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GPR and ERT surveys in the “Giardino dell’Annunziata” in Cammarata (Sicily)

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***Abstract* – A recovery project has recently involved a garden sited in Cammarata (Southern Sicily), known as "Giardino dell'Annunziata" adjacent to the church of the same name (Chiesa dell'Annunziata). In this area, according to the scarce historical sources, there was a Benedictine convent, probably demolished in the eighteenth century. As a diagnostical support some geophysical surveys were carried out project in the garden. A 3D geoelectric survey and 36 Ground Penetrating Radar profiles were carried out which made it possible to reconstruct the corresponding 3D models of the subsoil. A large resistive anomaly has been detected, which has no match in the 3D GPR model. showing only minor surface anomalies. The anomalous area can be due to an original flow route of the river, but it cannot be excluded that it is caused by an artificial channel or even underground environments, subsequently filled with landfill material. Archaeological excavations are planned to better clarify the nature of the anomaly.**

INTRODUCTION

Cammarata, in Southern Sicily, is a town of medieval origin and its history is linked to the vicissitudes that marked Sicily from the Arabs onwards. The area under investigation is a garden known to the local community as the "Giardino dell’Annunziata" (Figure 1) as it is adjacent to the church of the same name (Chiesa dell’Annunziata, figure 2), and historical sources tell of the existence, between 1500 and 1700, of a Benedictine convent abandoned due to an unclear breakdown. It has been recently managed by the School Institute “Giovanni XXIII”, which has launched a project aimed at recovering from degradation. In this context, integrated geophysical investigations were carried out aimed at identifying the main anomalous structures of the subsoil and consequently clarifying the nature of the event which led to the destruction of the Benedictine convent and its abandonment in 1700.

Fig. 1. The “Giardino dell’Annunziata in Cammarata.

Fig. 3. Aerial view of the “Giardino dell’Annunziata, in Cammarata. The blackpointsindicate the ERT electrode positions. The red lines indicate the GPR profiles.

HISTORICAL FRAMEWORK

The town of Cammarata (Sicily) is located at 689 m a.s.l. above sea level on the slopes of Mount Cammarata (1578 m) and is a town of medieval origins, although archaeological remains have been found in the Cammarata area which testify that the area was also inhabited in Roman times.
The conquer of Cammarata by the Normans should have taken place in 1077 [1]. The existence of the inhabited center of Cammarata is supposed in the light of the chronicle of the Arab conquest of the territory around 840 [2].
The female Benedictine Monastery of the Annunziata, to which the Garden belonged, was located in the lower area of the town. The foundation of the monastery probably dates to the 15th century [3, 1]. The monastery building was abandoned in 1792, due to its poor static conditions, and at today there is no physical trace of the monastery building and we don't even know exactly what area it occupied.
From the first available aerial photo, from 1957, we can deduce that it extended to the north-east area where a small building is located today, that a small part fell within the area of the current garden (Figure 1).
A recent instrumental survey has allowed us to know more in detail the layout of the garden walls, which have a symmetrical configuration. We can see an apse located to the southwest of the perimeter, two wings similarly inclined on both sides with respect to the apse, and also two almost parallel wall fronts. This configuration is not typical in the gardens of Benedictine monasteries and could be of Arab origin.

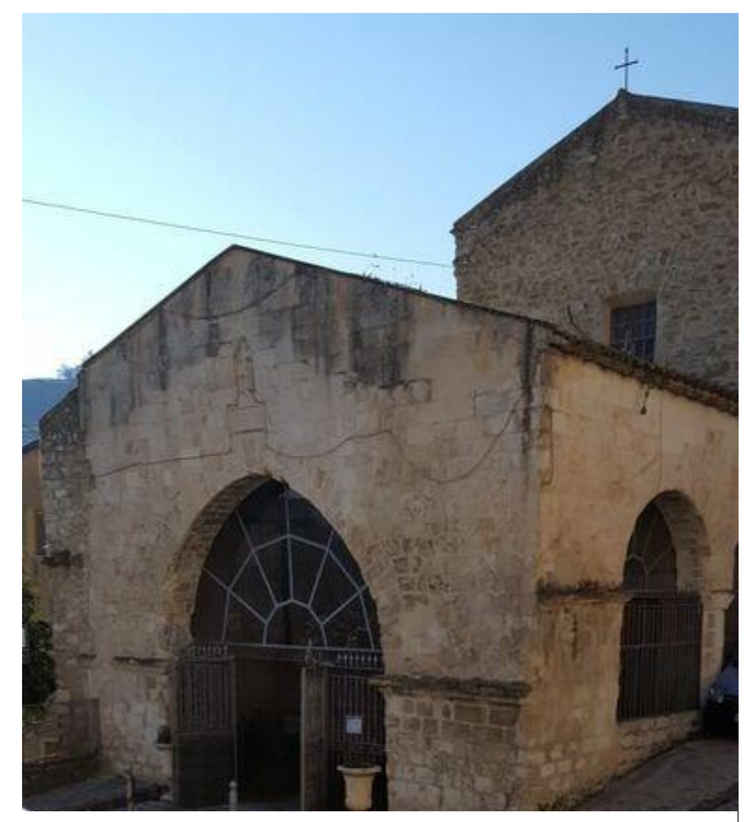

Fig. 2. The Church of the Annunziata in Cammarata.

GEOPHYSICAL SURVEYS

The geophysical investigations here presented were carried out on 23 May 2023, inside the Annunziata Garden (figure 3), with the aim of clarifying the geological asset of the subsoil and identifying buried archaeological structures in the area. 3D Electrical Resistivity and Ground Penetrating Radar (GPR) measurements [4-8] were carried out on an area of approximately 500 m^2.

3D Electrical Resistivity Tomography

240 electrodes were planted on the ground, with a minimum equidistance a = 1.5 m along the two perpendicular directions, forming a regular grid of 20 x 12 electrodes, with dimensions equal to 28.5 m x 16.5 m (Figure 1). The measurements were made by connecting 4 rows of 12 electrodes each time, using a dipole-dipole type electrode sequence with dipole lengths from a to $4a$ and dipole orders n from 1 to 10. In total, therefore, a total of 3500 measurements were performed (Figure 4,a). The apparent resistivity measurements were inverted using the RES3DINV software, obtaining an inverse 3D model with Abs. Error equal to 8.4% (figure 2, b). In it the electrical resistivity assumes values between 2 Ωm and 200 Ωm, with average values of about 30-40 Ωm, but with well-defined areas in which they exceed 60 Ωm. These high-resistive zones have been highlighted in the volume rendering by means of an isosurface (figure 4, b).

Ground Penetrating Radar

The georadar surveys (GPR) were carried out using the georadar instrumentation of IDS RIS MF HI-MOD model, with a double antenna at a frequency of 200 and 600 MHz.. In the investigation area, 36 profiles were acquired, with a regular grid and 1 meter interdistance (Figure 1). For GPR investigations, an acquisition range of 50 ns was used, for the 200 MHz antenna, and of 100 ns, for the 600 MHz antenna. The investigation depths were estimated considering a propagation speed of the electromagnetic waves average of 0.10 m/ns, for floor surveys, obtained from the slopes of the branches of the reflection hyperbolas present in the data. The 3D ground penetrating radar model (Figure 3) was elaborated through an interpolation algorithm implemented in Matlab, while the Voxler software (Golden Software LLC) was used for the 3D rendering.

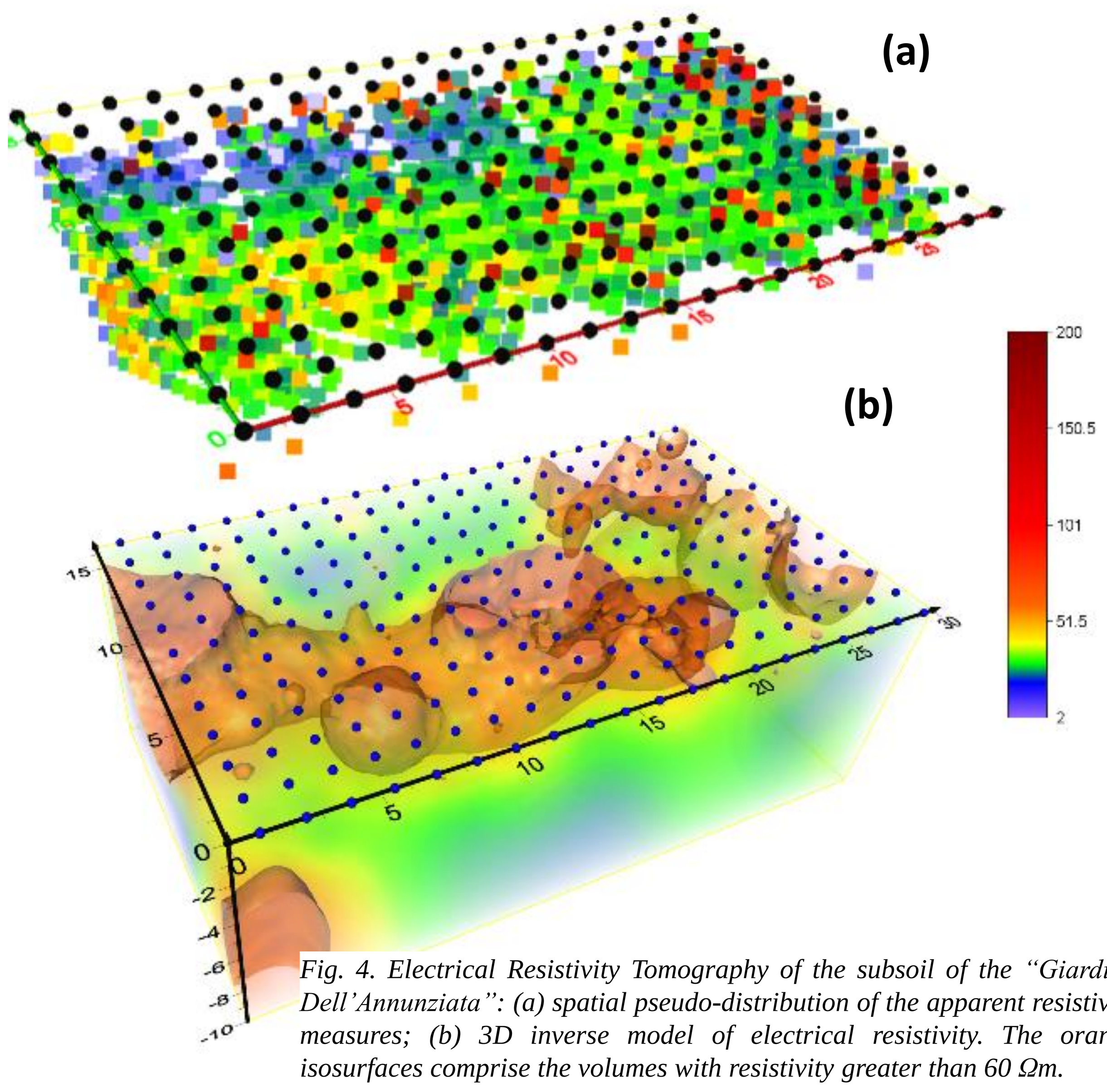

Fig. 4. Electrical Resistivity Tomography of the subsoil of the “Giardino Dell’Annunziata”: (a) spatial pseudo-distribution of the apparent resistivity measures; (b) 3D inverse model of electrical resistivity. The orange isosurfaces comprise the volumes with resistivity greater than 60 Ωm.

JOINT ANALYSIS AND INTERPRETATION

Observing the 3D ERT model (Figure 2, b) we note an elongated structure with a sub-parallel trend to the perimeter walls which deepens slightly as we proceed from the apse towards the north-west. This anomaly is characterized by resistivity values greater than 60 Ωm but in any case, not higher than 200 Ωm, therefore hardly compatible with voids, but rather with fillings of more porous and less cohesive material. At the center of the area there is also an approximately circular anomaly that descends from the surface into depth, intersecting the previously described elongated structure. The latter anomaly could be justified by the presence of a well, which was subsequently filled.
Indeed, the GPR model (Figure 3) does not show an anomaly in the area of high electrical resistivity, but shows substantially homogeneous data throughout the area, apart from some alignment that can be seen in the upper part of the model. this would lead to the exclusion of the presence of still empty natural or anthropic cavities in correspondence with the main resistivity anomaly, but it cannot be ruled out a priori that any paleo-riverbeds, artificial canals or even underground environments were subsequently filled with material having the same dielectric properties as the enclosing lithologies, albeit slightly higher resistivities. Subsequent archaeological excavations, in planning, will be able to better clarify the nature of the anomalies.

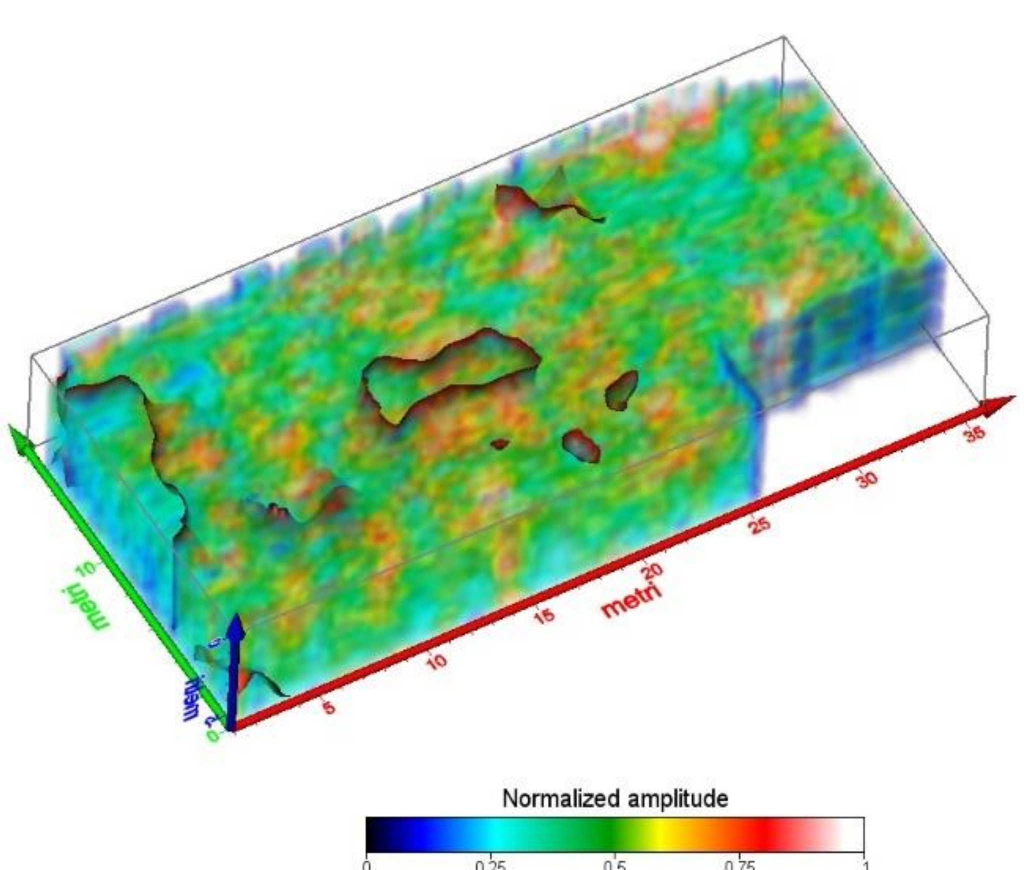

Fig. 5. Ground Penetrating Radar survey of the subsoil of the “Giardino Dell’Annunziata”: 3D GPR model.

ARCHAEOLOGICAL EXCAVATIONS

A preliminary exploratory excavation has begun in September 2023 aimed at ascertaining the origins of the geophysical anomalies. A 4m x 3m excavation was carried out in the area where the electrical resistivity anomaly is closest to the surface. At a depth of 1.3m, an anthropic structure was found, probably a defensive wall, of variable width with a complex structure because it presents several construction phases: a first phase (at the extreme south-west of the excavation), with a width of 1 .5m, with lightly worked stone elements of an average width of 0.5m on the outside and smaller than 0.2m on the inside. A few meters towards the NE the thickness of the wall increases because it incorporates erratic boulders into the core, presumably transported by the adjacent Turibolo stream. This thickness is believed to be constant throughout the garden. All the stone elements derive from the formation of the gray limestones with flint which constitute the nucleus of Monte Cammarata (Scillato Formation, Upper Lias). At the top of the wall, coins from the Frederick II period were found as well as abundant terracotta. All stratigraphic horizons were sampled in order to try to determine their age using radiocarbon dating.

Fig. 6. Aerial photo of the archaeological excavations.

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