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

Raffaele Martorana1, Patrizia Capizzi2, Calogero Giambrone2, Valeria Genco2, Lisa Simonello2
1 Dipartimento di Scienze della Terra e del Mare, Università degli Studi di Palermo, 90123, Palermo, Italy, raffaele.martorana@unipa.it (R.M.), patrizia.capizzi@unipa.it (P.C.)
2 I.L.S.S. Archimede, Cammarata (AG), Italy, g.giambrone59@gmail.com (C.G.) valeriagenda@gmail.com (V.G.)

Abstract – A recovery project has recently involved a garden situated 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 diagnostic support some geophysical surveys were carried out in the garden. A 3D geoelectric survey and 3D Ground Penetrating Radar profiles were carried out which made it possible to reconstruct the corresponding 3D models of the subsurface. A large resistivity 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 vicinities 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 us the existence of a Benedictine convent abandoned due to an unclear breakdown. It has been recently managed by the School Institute “Giambone XXIII”, which has launched a project aimed at recovering the garden. In this context, integrated geophysical investigations were carried out and it was possible to determine the main characteristics of the subsurface and consequently clarifying the nature of the event which led to the destruction of the Benedictine convent and its abandonment in 1700.

HISTORICAL FRAMEWORK
The town of Cammarata (Sicily) is located at 69 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 certify that the area was also inhabited in Roman times. The conquest of Cammarata by the Normans should have taken place in 1077 [1]. The existence of the inhabited center of Cammarata is supported in the light of the chronicles 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, 4]. 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 do not 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 garden (Figure 2). 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 present: two wings similarly inclined on both sides with respect to the same, and two almost parallel wall fronts. This configuration is not typical in the gardens of Benedictine monasteries and could be of Arab origin.

GEOPHYSICAL SURVEYS
The geophysical investigations have been performed in 23 May 2023, inside the Annunziata Garden (figure 3), with the aim of clarifying the geological asset of the subsurface and identifying buried archaeological structures in the area. 3D Electrical Resistivity and Ground Penetrating Radar (GPR) measurements [4-6] were carried out on an area of approximately 500 m².

3D Electrical Resistivity Tomography
240 electrodes were placed on the ground, with a maximum equivalence of 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 4). The measurements were made by connecting 4 rows of 12 electrodes each time, using a dipole-dipole type electrode sequence with dipole length from 4 to 4c and dipole order from 1 to 10. In total, there were 3,500 measurements were performed (Figure 4a). The apparent resistivity measurements were inverted using the RES2DINV software, obtaining an inverse 3D model with Abs. Error equal to 3.5% (figure 2, b). In it the electrical resistivity assumes values between 2.4 and 200 mΩm, with average values of about 30-40 mΩm, but with well-defined areas in which they exceed 60 mΩm. These high-contrast areas have been highlighted in the volume rendering by means of an isosurface (Figure 4b).

Ground Penetrating Radar
The ground-penetrating GPR surveys (Figure 5) were carried out using the georadar instrumentation of IDS RIS MF-HMM model, with a double antenna at a frequency of 200 and 600 MHz. In the investigated area, 36 profiles were acquired with a regular grid and 1 meter simmetry (Figure 1a), and with an investigation depth of 0.6 meters. A GPR investigation, acquisition range of 50 m was used, for the 200 MHz antenna, and of 100 m, for the 600 MHz antenna. The investigation depth was estimated considering a propagation speed of the electromagnetic wave from the slope of the branches of the reflection hyperboloids present in the data. 3D GPR, ground-penetrating radar model (Figure 3) was elaborated through an interpolation algorithm implemented in Matlab, while the Visor software (Golden Software LLC) was used for the 3D rendering.

JOINT ANALYSIS AND INTERPRETATION
Observing the 3D GPR model (Figure 3), we can see an elongated structure with a sub-parallel tendency to the perimeter walls which descends slightly as we proceed from the apse towards the north-west. This anomaly is characterized by resistivity values greater than 60 mΩm but in any case, not higher than 200 mΩm, therefore hardly correlated with voids, but rather may be the result of a greater porosity and lack 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 any anomaly in the area of high electrical resistivity, but shows substantially homogenous data throughout the area, apart from some segment that can be seen in the upper part of the model. This would lead to the exclusion of the presence of still liquid or archaeological carving in correspondence with the main resistivity anomaly, but it cannot be ruled out a priori a pond or ancient riverbeds, artificial canals or even underground environments were subsequently filled with material having the same dielectric properties as the underlying dolomites, albeit slightly higher resistivities. Subsequent archaeological excavations, in planning, will be able to better clarify the nature of the anomalies.

ARCHAEOLOGICAL EXCAVATIONS
A preliminary exploration excavation has begun in September 2023 aimed at ascertaining the origins of the geophysical anomalies. A 3 x 3 m excavation was carried out in the area where the electrical resistivity anomaly is closest to the surface. At a depth of 1 m, 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 1.5 m, with lightly worked stone elements of an average width of 0.5 m from the outside and smaller than 0.2 m on the inside. A few meters towards the NE the thickness of the wall increases because it incorporates eratic boulders into the core, presumably transported by the adjacent Taburlo stream. This thickness is believed to be constant throughout the garden. All the stone elements derive from the formation of the gray limoniteey with flint which constitute the nucleus of Monte Cammarata (Sciattlo Formation, Upper Liassic). At the top of the wall, comes from the Frederico II period and were found as well as abundant terracotta. All stratigraphic horizons were sampled in order to try to determine their age using radiocarbon dating.