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GPR and ERT surveys at the Castle of Melfi (Potenza, Italy)

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***Abstract* – This paper presents some of the results of the GPR and ERT surveys conducted at the Castle of Melfi in order to document the presence of ancient buried structures. The fortress is made up of several buildings modified and added over time: the original core of the structure dates back to the Norman period and was probably built on a previous Byzantine castrum between the end of the 11th and the beginning of the 12th century; it was enlarged in the Frederick era and underwent further modifications in Angevin and Aragonese period. Integrated GPR and ERT investigations were conducted inside two courtyards of the westernmost part of the fortress, the *Cortile degli Armigeri* and the *Cortile del Mortorio*, and two isolated ERT profiles were also measured on the north-eastern sector of the external walls and in the underlying stretch of the moat.**

I. INTRODUCTION

The Castle of Melfi is made up of several buildings modified and added over a long period of time between the Norman age and the twentieth century. It is built on the north-western top of the hill on which Melfi stands dominating the entire ancient town with its imposing size [1]. The castle is surrounded by mighty walls with towers and equipped externally on the south and east sides by a large moat, which is absent on the west and north sides, where the hill drops sheer down towards the valley of the Melfia river. The original core of the structure dates back to the Norman period and was probably built on a previous Byzantine castrum, between the end of the 11th and the beginning of the 12th century. It was enlarged in the Frederick era, when the castle became the seat of the treasury and the royal archive, and also the summer residence of Emperor Frederick II, where he welcomed the most eminent personalities of the politics and culture of the time. In 1231, in fact, it was the place of promulgation of the Constitutions of Melfi, the legislative code of the Kingdom of Sicily. The Emperor, his notary Pier della Vigna, the philosopher and mathematician Michele Scoto and other important figures participated in the drafting of this code. In the Angevin period (13th century) the Norman-Swabian castle was considerably strengthened through the new project by the military architect Pierre d'Agincourt, carried out between 1277 and 1280. A new curtain wall marked by rectangular towers, the external walls and the large moat were built, so the castle took on its current appearance. At this time, the entrance to the fortress, preceded by a drawbridge, opened to the south-west, at the beginning of the moat, right where the city walls are joined to those of the castle. During the Aragonese government, the castle underwent further modifications and became the property of the noble families of the Acciaiuoli, then of the Marzano and subsequently of the Caracciolo. With the latter, in the fifteenth century, the transformation of the central nucleus of the castle into a baronial palace began, and it was then completed by the Doria family starting from the sixteenth century and for the following three centuries. In addition, the Doria family built the new monumental entrance that opens to the south towards the city: a three-arched stone bridge, once a drawbridge, crosses the wide moat and, through an ashlar portal in white stone, allows access to the Cortile Principale on which the Palazzo Doria and the 16th century noble chapel overlook.

The castle now houses the Museo Archeologico Nazionale del Vulture e Melfese "Massimo Pallottino". Following the restoration works promoted by the Direzione Regionale dei Musei della Basilicata, the Geophysics Lab and the Archaeological Mapping Lab of the Institute for Heritage Science of CNR performed geophysical investigations using the Ground Penetrating Radar (GPR) and Electrical Resistivity Tomography methods in the two Angevin courtyards located in the external part of the western sector of the castle (so-called Cortile degli Armigeri, on whose southern end there was the thirteenth-century entrance, and so-called Cortile del Mortorio) and in the north-eastern sector of the external walls and moat. The investigations were aimed at documenting the presence of any ancient buried structures and the depth and consistency of the base rock on which the fortress is built.

II GPR AND ERT MEASUREMENTS AND RESULTS

The GPR surveys were carried out in two areas called A and B (Fig. 1): the first concerns the westernmost sector (5 x 28 m) of the Cortile degli Armigeri, the other one the eastern portion (approx. 9 x 26 m) of the Cortile del Mortorio. The presence of obstacles on the ground prevented the entire surface of the two courtyards from being investigated with this method.

GPR measurements have been performed with an IDS Ris Hi-mode system equipped with the dual band antenna at a nominal central frequency of 200-600 MHz. A grid of 0.25 m spaced profiles was performed in the two investigated areas (a total of 321.7 sqm). Each B-scan has a time window of 80 ns (600 MHz antenna) and 120 ns (200 MHz antenna), discretized using 512 samples. The processing of the GPR data consisted of zero timing, background removal, declipping, Kirchoff migration and bandpass filter. This processing was implemented by means of the GPRSlice code [2]. An average electromagnetic (EM)-wave velocity equal to 0.085 m/ns has been evaluated from the shape of the diffraction hyperbolas. Afterward, horizontal depth-time slices were obtained using the processed data. Each slice was retrieved by averaging data within a time window Δt = 5 ns, which corresponds to a soil thickness of about 20 cm.

Fig. 1. Location of the investigated areas at the Castle of Melfi.

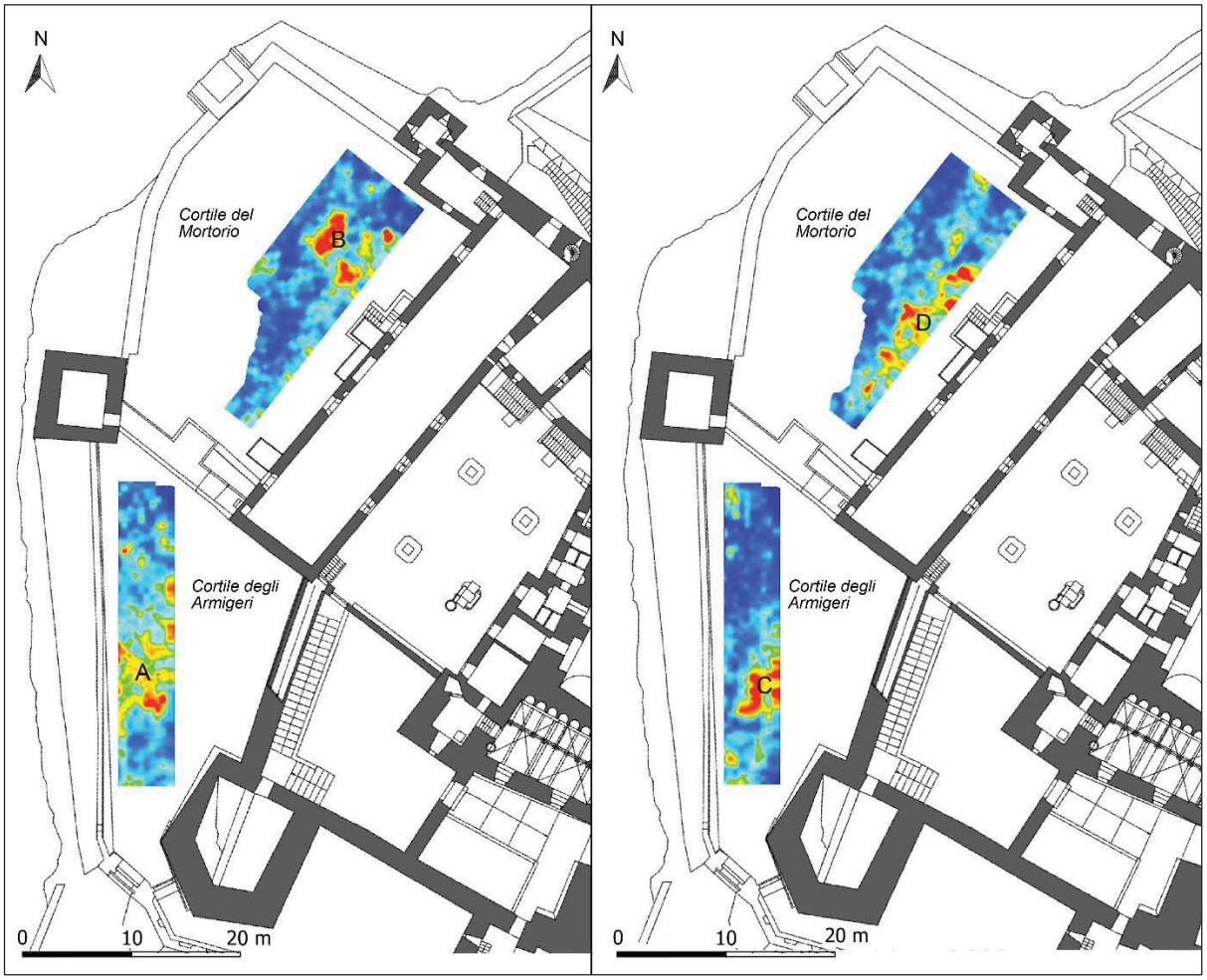

Fig. 2. 600 MHz antenna GPR slices at the depths of 0.5-0.7 m (left) and 1.6-1.8 (right) in Cortile degli Armigeri, and 0.8-1.0 m (left) and 2.2-2.3 (right) in Cortile del Mortorio.

In the *Cortile degli Armigeri* (area A), in the southern portion of the investigated area, various GPR anomalies related to wall structures were found, starting from 0.5-0.7 m (Fig. 2, A) and up to 1.2 m deep; other anomalies, perhaps referable to the same structures or to more ancient masonries, are found in the same area also between 1.6-1.8 m and 2.6-2.8 m of depth (Fig. 2, C), almost up to the rocky bank. The latter has been documented by geophysical prospecting about 2.6-3.0 m deep from the current level of the courtyard and with a slope to the west. In the *Cortile del Mortorio* (area B), some anomalies referable to wall structures are visible on a large part of the investigated surface already at a shallow depth (0.3-0.5 m), immediately below the sixteenth-century paving partially visible on the surface. More in depth, a concentration of anomalies probably attributable to wall structures in the northern part of the investigated area, between 0.6-0.8 m and 1.8-2.0 m of depth, can be seen (Fig. 2, B). Other interesting anomalies pertinent to buried structures are then noted in the eastern portion of the southern sector of the investigated area at a depth between 2.2-2.4 and 3.0 m (Fig. 2, D), probably in contact with the rocky bank, which in this portion of the courtyard appears to be 2.7-3.0 m deep.

Resistivity data were collected using a Syscal kid swich device (IRIS Instruments, France) supporting 24 electrodes with two reels of 55-m long connecting cable with 5 m maximum separation between electrodes. The investigations concerned two areas corresponding to the entire surfaces of the Cortile degli Armigeri (ERT-1; 433 sq m) and Cortile del Mortorio (ERT-2; 597 sq m) (Fig. 1). In order to investigate the whole courtyards special ERT arrays were used. The electrodes were distributed in such a way as to assume a snake shape [3, 4, 5, 6]. A dipole–dipole axial array was used. A roll-along acquisition mode considering several L shape profiles was used. In the dipole-dipole array the spacing between the current electrodes pair, C2-C1, is given as “a” which is the same as the distance between the potential electrodes pair P1-

P2. This array has another factor marked as “n”, which is the ratio of the distance between the C1 and P1 electrodes to the C2-C1 (or P1-P2) dipole separation “a”. In this array, the “a” spacing is initially kept fixed and the “n” factor is increased from 1 to 2 to 3 until up to about 6 in order to increase the depth of investigation. The measurements usually start with a spacing of 1a between C1 and C2 (electrodes of current) and also between P1 and P2 (electrodes of potential). The first sequence of measurements is made with a value of 1 for n factor, followed by n=2 while keeping the C1-C2 dipole pair spacing fixed at 1a. For successive measurements the n spacing factor is increased to a maximum value of about 6. To increase the depth of investigation, the spacing C1-C2 and P1-P2, is increased to 2a and another series of measurements with different values of n is made. The electrode initial separation for all arrays in x and y directions was 1 m. The dipole-dipole array is very sensitive to horizontal changes in resistivity and it is effective to map vertical structures as archaeological remains [3]. The investigated volumes were processed using the software ErtLab (http://www.geostudiastier.it) that makes use of Finite Elements algorithm. The smoothness constrain method was used [3] with 6 iterations and an RMS error of 5%. The true resistivity model computed has an investigation depth of 10 m, which guarantees that the inverted true resistivity model is deeper than the expected archaeological structures.

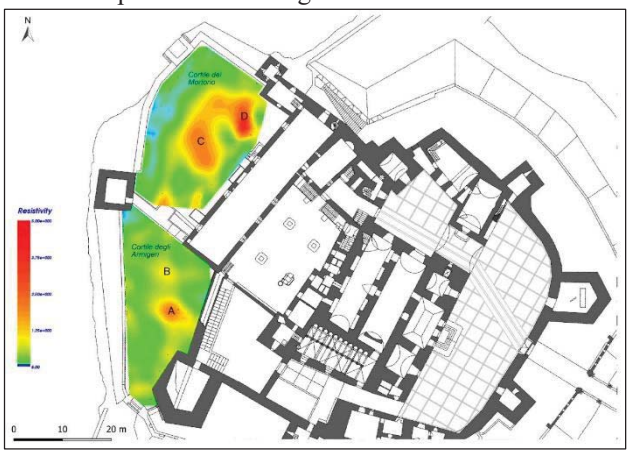

Fig. 3. ERT slices at the depths of 2 m (Cortile degli Armigeri) and 1 m (Cortile del Mortorio).

In the Cortile degli Armigeri (ERT-1), ERT measurements highlighted the presence of anomalies characterized by high resistivity values compatible with the presence of buried structures in the area immediately east of the area investigated with the georadar (Fig. 3, A-B); they are documented between 0.5 and 2.0 m deep and perhaps the southernmost anomaly (A) may be related to part of those highlighted by the georadar measurements. In the Cortile del Mortorio (ERT-2), ERT measurements documented anomalies with high resistivity values placed at depths between 0.5 and 3.0 m (Fig. 3, C-D), compatible with those highlighted by GPR and referable to possible buried wall structures. Furthermore, these ERT measurements have shown that the western part of the Cortile del Mortorio, beyond a wall recently brought to light by archaeological excavations and which delimits to the west the area A investigated with GPR, is free of anomalies referable to buried structures; on the other hand, anomalies with low resistivity values are noted, attributable to a not very compact filling soil.

Two single profiles, approx. 92 m, were finally measured at the top of the north-eastern sector of the external walls (ERT-3) and along the longitudinal axis of the underlying stretch of the moat (ERT-4) (Fig. 1). The first one documented, in the central part, at about 2.5 m deep, very high resistivity values (Fig. 4, A), higher than 11,500 ohm m compatible with the presence of a void in the rocky bank; in the remaining part of the profile there are anomalies referable to a rather fractured rocky bank, filled with very conductive materials. Finally, the ERT-4 profile showed that on the bottom of the moat there is a burial with a thickness varying between 1 and 3 m.

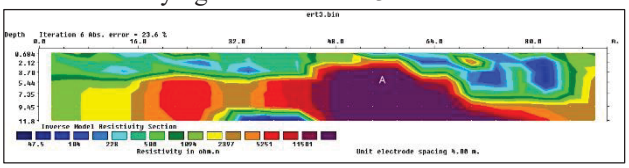

Fig. 4. ERT-3 profile.

III. CONCLUSIONS

This paper presents some of the results of the GPR and ERT prospecting conducted in the Castle of Melfi, while further results will be presented at the Conference. In particular, integrated GPR and ERT investigations were conducted inside two courtyards of the westernmost part of the fortress, the *Cortile degli Armigeri* and the *Cortile del Mortorio*. The geophysical prospecting revealed the presence of various anomalies referable to buried wall structures that can be referred to the medieval phases of the castle, the first nucleus of which dates back to the Norman period with subsequent Frederick, Angevin and Aragonese extensions. This approach revealed the effectiveness of the integrated methods to identify a series of anomalies that could be ascribed to anthropogenic features. Two isolated ERT profiles were also measured on the north-eastern sector of the outer walls and in the underlying stretch of the moat and they documented the depth and characteristics of the bedrock.

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