

# Geophysical surveys for the study and reconstruction of the sixteenth-century fortifications of Lecce.

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**Abstract – Within the project for the restoration of the northern section of the sixteenth-century city walls of Lecce, a team of researchers of CNR-IBAM carried out in 2014 and 2015 geophysical surveys aimed at the study and the reconstruction of the moat outside the fortifications. The use of GPR method allowed to detect anomalies related to the main ditch outside the city walls and to characterize the rocky bank in which it was excavated; at the time of the surveys, this ditch was still buried and the results of the geophysical measurements directed the works for its excavation. As well as investigations have allowed to identify also other possible ditches or quarries and more ancient structures, which subsequent archaeological excavations have dated at the Medieval and Roman periods. Moreover, geophysical surveys highlighted the presence of modern walls, corresponding with the foundations of the stadium built in the 1920s close to the city walls.**

## I. INTRODUCTION

In 2014 and in 2015 integrated geophysical surveys were carried out outside the northern section of the sixteenth-century city walls of Lecce by a team of researchers of the Laboratory of Geophysical applied to the Archaeological and Monumental Heritage and the Laboratory of Ancient Topography, Archaeology and Remote Sensing of CNR-IBAM in Lecce. The investigations were carried out in cooperation with the chair of the Medieval Archaeology of the University of Salento, responsible for archaeological excavations aimed at studying the ancient remains inside and outside the sixteenth-century city walls. The investigations were performed during the massive restoration works promoted by the Municipality of Lecce and aimed at enhancement of value of this section of the city walls, including the reconstruction of the original aspect of the fortifications and the external moat.

The main goal of the geophysical surveys was to identify the large moat outside the city walls, excavated in the rocky bank (quite close to the surface) and filled with soil probably in the 18<sup>th</sup> century or at the beginning

of the 19<sup>th</sup> century. In particular, the geophysical measurements were based on Ground-penetrating Radar (GPR) and Electrical Resistivity Tomography (ERT) techniques; in this paper, the main results of GPR prospecting are presented.

Geophysical survey allowed the researchers to determine the direction, width and depth of the sixteenth-century moat. So, the excavation activities in the area immediately outside the fortifications were performed according to the results of the geophysical prospecting, which highlighted also other anomalies related to more ancient remains identified during the archaeological excavations as a Medieval ditch and a Roman road. At the same time, geophysical surveys have highlighted numerous anomalies related to the recent history of the investigated area, where in 1920s a stadium was built. Lastly, the investigations were also very important since they allowed not only to direct the archaeological excavations, but also because they allowed to formulate some hypotheses on the ancient topography of the not excavated area.

## II. STUDY AREA AND METHODOLOGY

The study area is located at the northern end of the city walls of Lecce built in sixteenth-century partially retracing the previous fortifications of the Messapian and Medieval periods (Fig. 1). These works were encouraged by the Emperor Charles V and executed by architect Gian Giacomo dell'Acaya, starting from 1542. This intervention also included the adaptation of the northern end of the defensive system; in fact, this sector was perhaps initially constituted by a lance-shaped bastion, then replaced by a more effective polyorcetic solution consisting of an advanced defensive-work with double bastions tenaille-shaped (nowadays called bastions of S. Francis) [1]. The imposing defensive system was completed by a deep moat, which had lost all trace due to a subsequent filling.

Therefore, the main goal of the geophysical investigations, in line with the project of recovery and valorisation of the city walls, was to identify the main moat of this sector of the defensive system and possible

other anomalies that could contribute to increase the knowledge of the ancient topography of the area and its transformations over the centuries. At this regard and in order to correctly interpret the data obtained from geophysical surveys, historical maps and historical aerial photographs have been collected and studied.

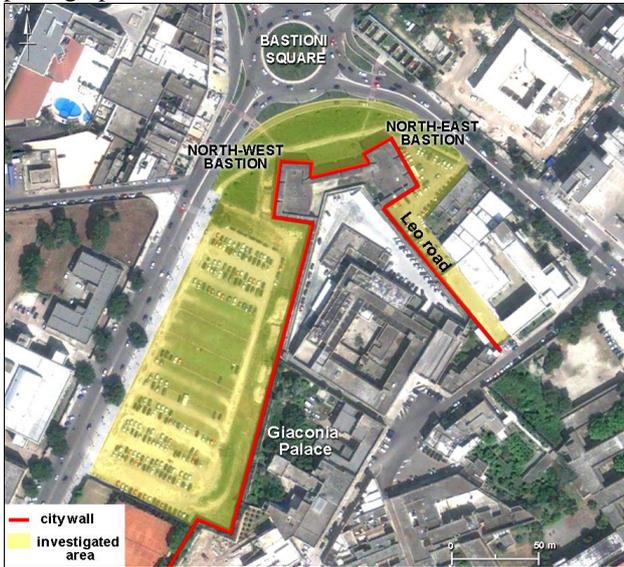


Fig. 1. Lecce, the northern side of the sixteenth-century city walls with the Bastion of St. Francis. In yellow the investigated area.

The aim was to reconstruct the recent history of the investigated area and to document the presence of modern structures nowadays demolished (at this regard see also the previous researches carried out in Lecce [2, 3]). Specifically, while in the “Pianta della città di Lecce” drawn by Michele Astuti in 1882 the area immediately outside the city walls appeared as an open space, in an aerial photo of 1947 it was partially occupied by modern edifices. In particular, two buildings were immediately to the north of the double bastions and the structures of the “Campo polisportivo Achille Starace”, built in 1924, were in the area immediately to the west of this stretch of city walls. These structures were used until 1967; after they were progressively abandoned and finally dismantled to use the area, in the last decades, as a parking.

The investigated area involved a stretch of about 500 m of the city walls and a surface of approximately 1.8 hectares, which was entirely covered by the GPR measurements. Profiles and time slices were positioned using a DGPS system and georeferenced on the large-scale archaeological map of Lecce.

## II. GEOPHYSICAL PROSPECTION

Geophysical survey was performed in five areas using Ground-penetrating Radar (GPR) technique. A Ris Hi mod georadar system with a dual band 600MHz-200MHz antennae was used. The GPR data have been gathered

with transect between with a variable distance (0.5m and 2.0m; Fig. 2) between any two adjacent measurement line, and the data have been processed by making use of the GPRSLICE code [4]. Particularly, the processing has consisted in zero timing, background removal, gain variable vs. the depth and Kirchhoff migration [5]. The dielectric constant has been retrieved from the diffraction hyperbolas [5]. The analysis of the GPR data pointed out: the presence of an interface, denominated “base rock”, located between 3.0 m and 4.0 m in depth; the presence of a numerous anomalies that represent a cut in the bedrock; such anomalies are due to the probable presence of the limit of the moat outside the city walls; other reflection events could be related to the probable presence of archaeological structures.

In Figures 3, 5 and 7, the horizontal slices at the respective estimated depths of 129-144 cm (Fig. 3), 147-162 cm (Fig. 5), and 135-170 cm (Fig. 7) are represented. They show the most interesting results among those gathered in the investigated areas.

## III. RESULTS

Geophysical investigations have allowed us to identify numerous anomalies, some closely linked to the sixteenth-century defensive system, while others are likely to be linked to more ancient structures. Very important are also the data relating to the characterization of the bedrock on which the walls were built, especially in the areas outside the two bastions and south of the north-western one; in particular, these measurements highlighted that the surface of the rocky bank was irregular and partially integrated by the foundations of the walls.



Fig. 2. Lecce, the northern side of the sixteenth-century city walls; in red the GPR profiles performed.

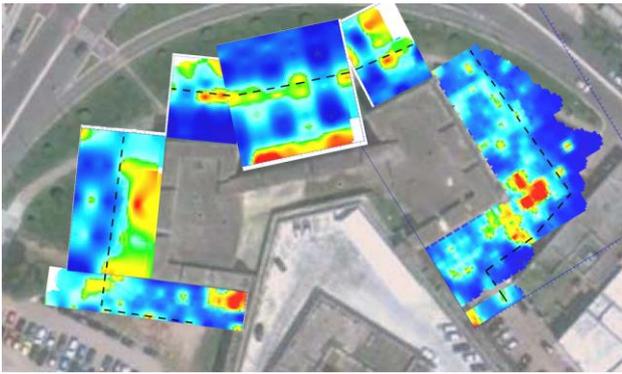


Fig. 3. Lecce, area of St. Francis Bastions: GPR time slices (129-144 cm depth; 200MHz) georeferenced on 2010 Google Earth satellite image.

#### A. The sixteenth-century moat

The geophysical surveys clearly documented the sixteenth-century moat that was excavated immediately outside the city walls, along the whole investigated stretch. The major anomalies related to the moat surrounding the fortifications have been highlighted thanks to the GPR profiles, which were carried out along the entire perimeter of the city walls and with an orientation orthogonal to the fortifications. The measurements documented a moat between 6-8 and 10-15 m large, and between 4.50 and 6 m deep, excavated in the bedrock and characterized by vertical faces (Figs. 3-4); it was filled with soil and blocks. It is interesting to highlight that along L. Leo road, in the stretch south of the north-eastern bastion, the moat has quite the same width of the modern road; so, the modern buildings that flanked the eastern side of the road are built immediately to the east of the edge of the moat.

Moreover, four GPR profiles measured in the area north of the bastions of St. Francis, beyond the moat, have highlighted other anomalies maybe linked to an additional moat (as frequent in the sixteenth-century fortifications systems); this area is under Bastioni Square and was not excavated.

#### B. Other archaeological remains

A series of other interesting anomalies were documented by GPR surveys a short distance from the western sector of city walls, in correspondence with Giaconia Palace. These are roughly parallel to the city walls, well visible in particular with the 600MHz antenna, at a depth of between 1.25 and 1.60 m (Fig. 5). The anomalies were hypothetically attributed to an ancient structure about 6-7 m wide; subsequent archaeological excavations have clarified that this evidence was a Roman road, glareata style and contained between two side walls built with large blocks. This road was immediately out of the city of Lupiae (about the urban layout of Lecce in the Roman period see [6, 7, 8])

and a long stretch of about 70 m was brought to light.

In the same area, some GPR profiles (Fig. 6) documented anomalies linked to another moat cut in the bedrock, located a few meters to the west of the sixteenth-century moat; subsequent archaeological excavations have clarified that this evidence was a Medieval moat, which was 4-5 m large, and partially cut the Roman road. It had a direction NNW-SSE quite divergent by the Roman road and the sixteenth-century city walls, and at its northern end it turned in east direction; two stretches, respectively 85 m (NNW-SSE orientation) and 25 m (E-W orientation) were brought to light.

Lastly, again in this area west of the city walls, some GPR profiles have also highlighted other anomalies more to west of the Medieval moat, in a not excavated area; they may be linked to another moat (pertaining to the sixteenth-century fortification system?) or ancient quarrying activities for the extraction of construction stone materials.

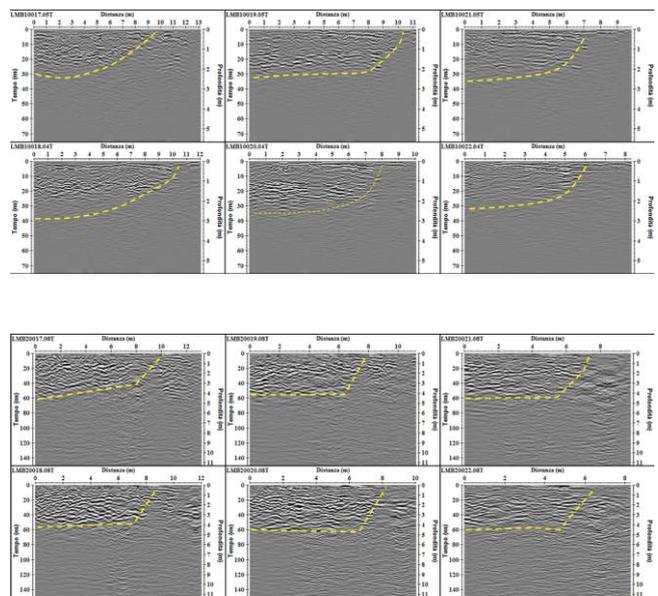


Fig. 4. Lecce, area of St. Francis Bastions: GPR profiles (600MHz antenna above, 200MHz antenna below).

#### C. Modern structures

Lastly, in the western investigated area, GPR surveys documented also some structures, built in the 1920s using calcareous blocks and pertaining to the “Campo polisportivo Achille Starace”; in particular, a stretch of the eastern stand of the stadium (fig. 7, A) and the building of the dressing room (fig. 7, B) were identified. These structures were abandoned in 1967 and after demolished.

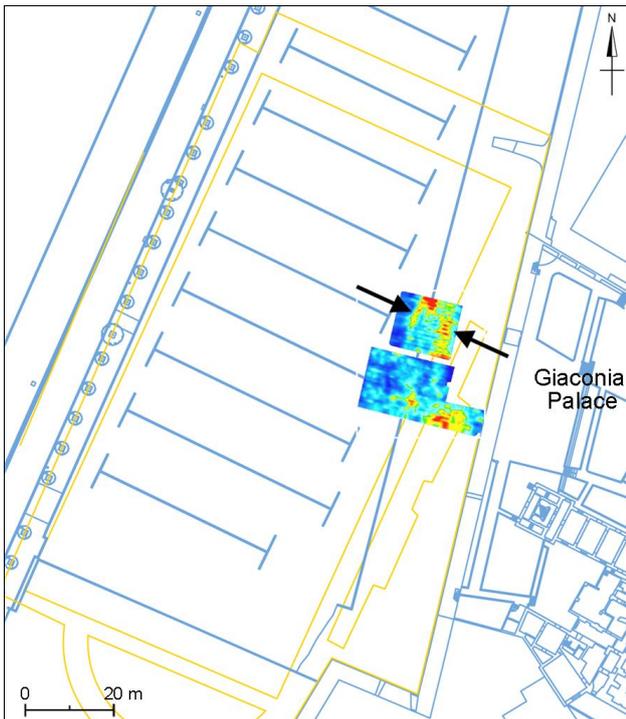


Fig. 5. Lecce, sixteenth-century city fortifications: GPR time slices (147-162 cm depth; 600MHz antenna) georeferenced in large scale map of Lecce. In yellow the layout of the "Campo Polisportivo Achille Starace".

#### IV. CONCLUSIONS

The investigations presented in this paper highlight the importance of non-invasive geophysical systems for the research on cultural heritage. Geophysical prospecting, in fact, was able to identify numerous anomalies in the area of the northern city walls of Lecce, which were very useful to direct the archaeological excavations. In particular, the geophysical investigations have identified (i) the sixteenth-century moat outside the city walls, and the presence of (ii) a further moat and (iii) a road, which subsequent archaeological excavations dated respectively to the Medieval and Roman periods. Even some demolished structures of the stadium built in 1920s were identified. The use of GPR method also documented the characteristics of the bedrock, highlighting that its surface is irregular and a lot of geophysical anomalies detected are related to human activities.

For the interpretation of GPR measurements it was very important the positioning by DGPS system and the georeferencing of profiles and time slices on the large-scale archaeological map of Lecce. Even important for the geophysical data interpretation was the study of the historical maps and documents of the 19<sup>th</sup> century and first-half of 20<sup>th</sup> century. In fact, only the managing of all data collected and available allows the understanding of the relations between the documented evidence and the correctly interpretation of the collected the anomalies. About the last matter, obviously very important was the

verify through archaeological excavations, which allow for a precise interpretation and dating.

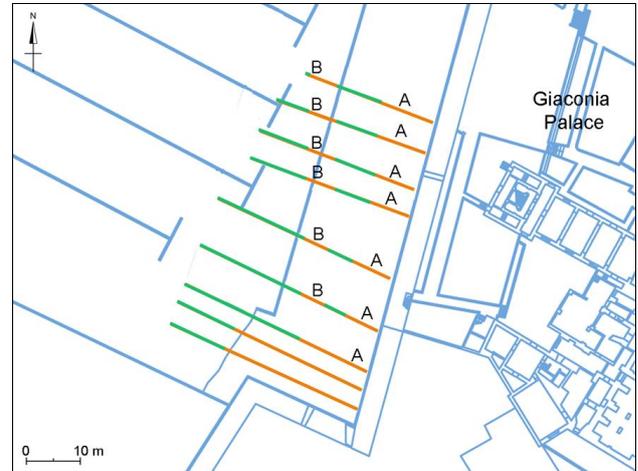


Fig. 6. Lecce, sixteenth-century city fortifications. Schematic georeferencing of GPR profiles: A, sixteenth-century moat; B, Medieval moat. In green the bedrock.

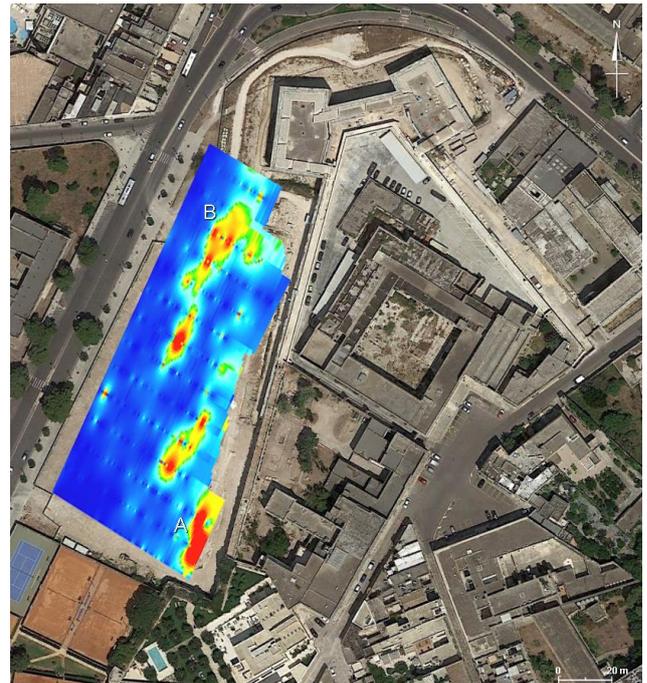


Fig. 7. Lecce, sixteenth-century city fortifications. GPR time slices (135-170 cm depth; 200MHz antenna) georeferenced on 2015 Google Earth satellite image. A, anomalies related to the stands of old stadium; B, anomalies probably of the building of changing room near the stadium.

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