2020 IMEKO TC-4 International Conference on
Metrology for Archaeology and Cultural Heritage
Trento, Italy, October 22-24, 2020

GPR prospecting for the search of St.Canio's lost bones (Acerenza, southern Italy)

De Giorgi Lara[1], Leucci Giovanni[1], Maurizio Lazzari[2], Raffaele Persico[3]

[1] *CNR ISPC – Prov.le Lecce-Monteroni c/o ecotekne, Lecce (LE)-Italy lara.degiorgi@cnr.it; giovanni.leucci@cnr.it*
[2] *CNR ISPC C/da S. Loja Zona industriale Tito Scalo (PZ)-Italy maurizio.lazzari@cnr.it*
[3] *Universitá della Calabria, via Pietro Bucci, Arcavacata di Rende, (CS)-Italy raffaele.persico@unical.it*

***Abstract* – In this paper the results of a GPR prospecting performed in the cathedral of Acerenza (Basilicata, southern Italy) are proposed. The investigation was aimed in particular to search, if any, traces of the tomb of St. Canio with his bones, protector of the town of Acerenza. Data processed with GPRslice code have been 3D shaped to define the position, depth and volume of the tomb. The results are also in agreement with the historical sources that indicate the probably burial place.**

I. INTRODUCTION

Investigation of monuments is a subject of increased interest for the knowledge, valorization and the preservation of the architectural works of art all over the world. Geophysical techniques, in particular, can provide images of the invisible parts of the monuments useful for achieving the identification and for some geometrical characterization of anomalies due to fractures, moisture or salts concentrations, traces of previous restoration works, but also tombs, crypts, previous foundations and possibly walled doors, walled windows or walled ciboria [1-8]. Ground penetrating radar (GPR) [9] is the most exploited technique in these cases, due to the high resolution, the shallow location of the anomalies looked for and the usually smooth surfaces to be investigated. Moreover, GPR does not require any knocking of electrodes or any glue for improving the electrical contacts, as instead the electrical resistivity does [10], and the monuments are often placed in urban contexts and/or are crossed by active electrical cables, which would degrade the results achievable with a magnetometer [10].
In this paper, we propose a GPR prospecting performed in the crypt and in the apsidal area of the cathedral of Acerenza (Basilicata, southern Italy). The main purpose was to find possible tombs, and in particular the tomb of St. Canio, the protector of Acerenza, that might be buried in this church.

II. METHODS

The investigations were carried in September 2019 with a Ris Hi-Mode system manufactured by IDSGeoradar and equipped with a dual antenna with central frequency at 200 and 600 MHz. Data along a conventional orthogonal grid of data were gathered in the crypt, whereas unconventional curved lines were followed in the apsidal area, due of course to the shape of the available room. This of course makes rigorously not correct the processing applied to the data, and in particular the evaluation of the propagation velocity [11] and the migration [12], that implicitly suppose a straight path of the instrument. However, the curvature rays of the observation lines were in any case quite larger than the internal wavelength, which made acceptable the distortion and valuable the better coverage achieved in this way. In the next section, a brief description of the monument is provided

II. STUDY AREA

The cathedral of Acerenza, in the Basilicata region, southern Italy, was built in 1080 by the archbishop Arnaldo, that, according to a reported tradition, found the remains of St. Canio, protector of Acerenza. In particular, the cathedral was built on the foundation of a previous paleo Christian basilica where, according to historical sources not fully certain, the relics of the Saint had been moved from Atella (the town where the Saint had died in the 3rd or 4th century, in the Campania region, also in southern Italy) in the year 799 under decision of the bishop Leone II .
The crypt (Fig. 1) was ended in 1524 and consists of a square room under the choir of the cathedral, divided into three naves thanks to four columns placed around the centre of the room. In the crypt there is also a marble sarcophagus that according to a first plan should have hosted the remains of the Saint, but that indeed contains objects for the cult. Uncertain historical sources also report about some further translations of the relics of this Saint

from the crypt to a place under the altar and viceversa, probably due to works done in the crypt during the centuries (but not all the times faithfully reported). So, the problem of the presence (or absence) of the body of the Saint under the crypt remains still nowadays unsolved, and in case it is still present, its location is not known.

Figure 1 - The cathedral of Acerenza (a) and the crypt (b).

III. GPR PROSPECTING AND RESULTS IN THE CRYPT

The data in the Ferrillo crypt have been gathered within a square area sized 6.9x6.9 m along an orthogonal grid where, whenever possible, the transect between any two adjacent lines was 30 cm. As said, the system gathered simultaneous data with an antenna at 600 MHz and an antenna at 200 MHz. Four no fly zones were present within the square because of the presence of four pillars. A map of the room was not available unfortunately, but the presence of the pillars at the centres of the no fly zones will allow the referencing of the data in case of localized excavations should be planned in the future.

The processing was performed with GPRSlice software [13]. 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 procedurewas 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 0.07 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. A way of obtaining visually useful maps for understanding the plan distribution of reflection amplitudes within specific time intervals is the creation of horizontal time slices. These are maps on which the reflection amplitudes have been projected at a specified time (or depth), with a selected time interval [10]. In a graphic method developed by [14], termed 'overlay analysis', the strongest and weakest reflectors at the depth of each slice are assigned specific colours. 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 seen and interpreted in a more easyily. 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. Moreover the highest amplitudes were rendered into an isosurface [10]. Three-dimensional amplitude isosurface rendering displays amplitudes of equal value in the GPR study volume. Shading is usually used to illuminate these surfaces, giving the appearance of real archaeological structures. In this case the threshold calibration is a very delicate task in order to obtain useful results. In order to define the depth of archaeological remains the electromagnetic (EM) wave velocity, using the characteristic hyperbolic shape of a reflection from a point source (diffraction hyperbola), was used. Fig. 2 shows the depth slice 4.8m-5.2m related to the 200MHz processed data. In the slices high-amplitude alignment is visible (dashed dark circle).

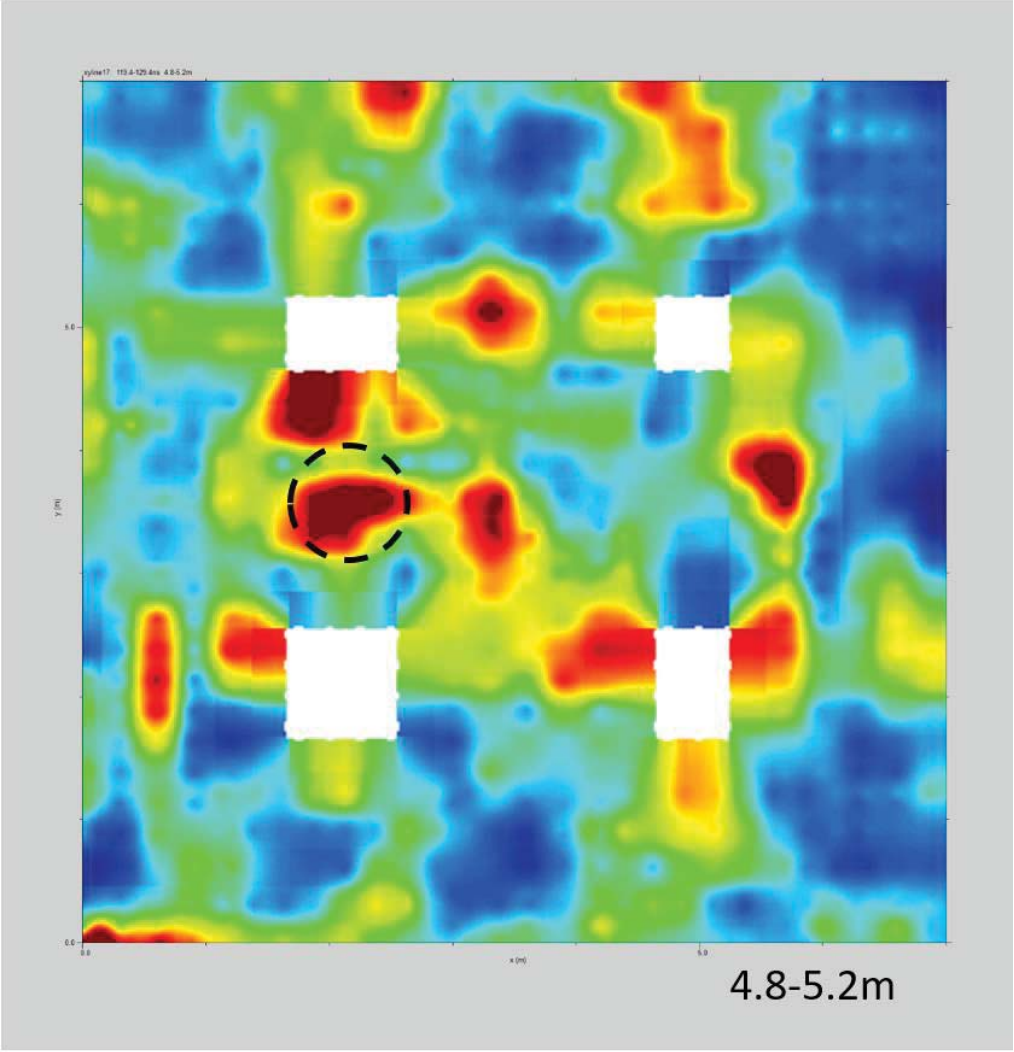

Figure 2 – depth slice

This anomaly was interpreted as due to an empty space.

CONCLUSIONS

In this paper we have presented the results of a gpr survey performed in the cathedral of Acerenza (Potenza, Italy). the aims of the survey were the assessment of the shallower underfloor layers in the church and possibly the identification of the tomb of St Canio, which historical fonts report to have been buried in this church, but without further details for the identification. the survey was performed both around the altar and in the crypt and, with regard to the crypt, the data were processed through gprslice commercial code. In particular, we have shown

that close to one of the columns there are the most meaningful anomalies. so, if an excavation were decided, we would suggest to try that are first of all. moreover, the excavation should probably go down at least for 3 m.

REFERENCES

[1] E. Utsi, The Shrine of Edward the Confessor: a Study in Multi-frequency Investigation, Near Surface Geophysics, vol. 10, n. 1, pp. 65-75, February 2012.

[2] R. Persico, S. D'Amico, L. Matera, E. Colica, C. De Giorgio, A. Alescio, C. Sammut, P. Galea, GPR Investigations at St John's Co-Cathedral in Valletta, , DOI 10.1002/nsg.12046, vol. 17, n. 3, pp. 213-229, 2019.

[3] F. Gabellone, G. Leucci, N. Masini, R. Persico, G. Quarta, F. Grasso, "Nondestructive Prospecting and virtual reconstruction of the chapel of the Holy Spirit in Lecce, Italy", Near Surface Geophysics, vol. 11, n. 2, pp. 231-238, April 2013.

[4] R. Persico, M. Ciminale, L. Matera, A new reconfigurable stepped frequency GPR system, possibilities and issues; applications to two different Cultural Heritage Resources, Near Surface Geophysics, vol. 12, n. 6, pp. 793-801 (doi: 10.3997/1873-0604.2014035), December 2014.

[5] I. Lubowiecka, P. Arias, B. Riveiro, M. Solla, Multidisciplinary approach to the assessment of historic structures based on the case of a masonry bridge in Galicia (Spain), Computers & Structures, vol. 89, n. 17-18, pp. 1615-1627, 2011.

[6] Persico R., D'Amico S., Leucci G., De Giorgi L., Lazzari M., Colica E. 2019 Innovative geophysical measurements on the cultural heritage in Malta: the case study of the S, Agata Tower. Geophysical Research Abstracts, Vol. 21, EGU2019-1861-1, 2019, EGU General Assembly 2019.

[7] Lazzari M., Leucci G., De Giorgi L. 2018, Geoarchaeological and GPR applications in a medieval tomb context to detect human remains. Geophysical Research Abstracts, Vol. 20, EGU2018-16405, 2018, EGU General Assembly 2018.

[8] Lazzari M., De Giorgi L., Ceraudo G., Persico R. 2018 - Geoprospecting survey in the archaeological site of Aquinum (Lazio, central Italy). Surveys in Geophysics, 39 (2018), 1167-1180.

[9] R. Pierri, G. Leone, F. Soldovieri, R. Persico, "Electromagnetic inversion for subsurface applications under the distorted Born approximation" Nuovo Cimento, vol. 24C, N. 2, pp 245-261, March-April 2001.

[10] G. Leucci, Nondestructive Testing for Archaeological and Cultural Heritage. A Practical Guide and New Perspectives, Springer, 2019.

[11] R. Persico G. Leucci, L. Matera, L. De Giorgi, F. Soldovieri, A. Cataldo, G. Cannazza, E. De Benedetto, Effect of the height of the observation line on the diffraction curve in GPR prospecting, Near Surface Geophysics, Vol. 13, n. 3, pp. 243-252, 2015.

[12] W. A. Schneider, Integral formulation for migration in two and three dimensions, Geophysics, vol. 43, n. 1, pp. 49-76, 1978.

[13] Goodman D. 2013. GPR Slice Version 7.0 Manual. http://www.gpr-survey.com (accessed June 2013).

[14] Goodman D, Steinberg J, Damiata B, Nishimure Y, Schneider K, Hiromichi H, Hisashi N. 2006. GPR overlay analysis for archaeological prospection. Proceedings of the 11th International Conference on Ground Penetrating Radar, Columbus, Ohio; CD-rom.