2019 IMEKO TC-4 International Conference on
Metrology for Archaeology and Cultural Heritage
Florence, Italy, December 4-6, 2019

# Matera European Capital of Culture 2019: NDT surveys in cave churches

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

[1] *IBAM-CNR - Istituto per i Beni Archeologici e Monumentali, Consiglio Nazionale delle Ricerche, Lecce, Italy, giovanni.leucci@cnr.it*

***Abstract* – Non-destructive surveys were carried out in the cave churches of Matera. Aim of surveys was to understand the conservation degree of the frescoes conserved in the churches. The investigations highlighted the presence of many structural problems related to fractures and wet.**

## I. INTRODUCTION

The rock churches of the territory of Matera, founded mainly in the early Middle Ages, are buildings carved into the rock. Initially born as religious structures, over time they have undergone various transformations of use, becoming homes or shelters for animals. They are an important testimony to the presence of communities of Benedictine, Longobard and Byzantine monks. Some churches, moreover, despite the substantial Latin setting, have Byzantine elements, or vice versa, architecturally Greek churches have liturgical spaces of the Latin type. The rock churches often contain frescoes and sculptural elements, which, in addition to the decorative function, led to contemplation and prayer. In the Middle Ages small communities of lay people and monks immigrated from the areas of Cappadocia [1], Armenia, Syria and Asia Minor, after having lost the possibilities of worship, took refuge in these caves which became places of prayer decorated with Byzantine frescoes, enriching art and the entire area's eastern culture.

Non-destructive (NDT) surveys by using ground penetrating radar (GPR) method were performed in five cave churches with the aim of identifying the state of preservation of the frescoes present in the churches (voids, fractures, humidity, etc.).

## II. GEOPHYSICAL INVESTIGATIONS

The georadar investigations were performed in 2018 using the Ris Hi Mod (IDS) georadar equipped with the 2000 MHz. In all surveys the GPR data acquisition were performed along contiguous parallel profiles 1 cm wide, 512 samples per trace. The data were processed by background removal, bandpass filtering and migration [2,3]. Here only the results related to the "Madonna delle tre Porte"are shown (Fig1).

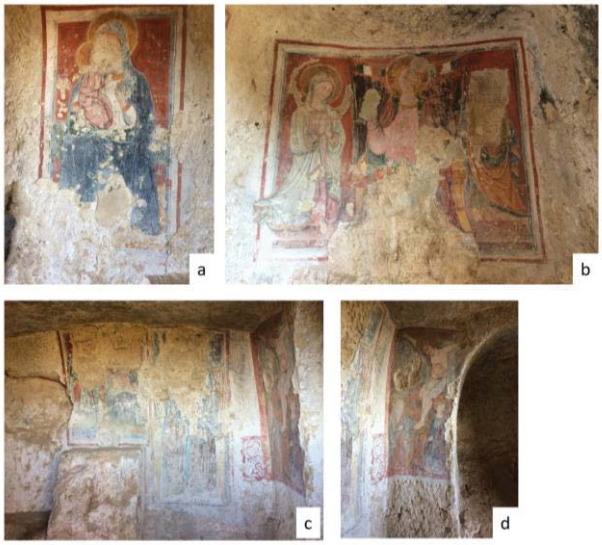


*Fig. 1. The Madonna delle tre Porte church: the surveyed frescoes.*

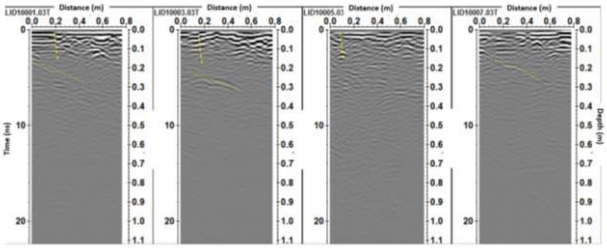

*Fig. 2. The Madonna delle tre Porte church: the processed radar sections.*

## III. RESULTS AND DISCUSSION

The GPR results highlighted a series of anomalies regarding various defect below the frescoes (Figs. 2), which correspond to fractures (yellow dashed lines).

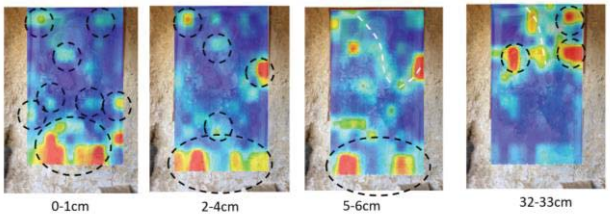


*Fig. 3. GPR time slice overlapped to the frescoes photos*

The planimetry of the profiles, acquired at a distance of 0.01m from each other, allowed the anomalies present on each single radar section to be spatially correlated, using the analysis of the amplitude of the events reflected within assigned time intervals (time slices). The type of analysis applied to the area under study has given satisfactory results. Amplitude slices were constructed at time intervals of 2ns; each slice corresponds to a soil thickness of about 0.01m.

The blue color indicates the weak amplitude of the reflected signal (subsoil consisting of substantially homogeneous material); the colors from light blue to the most intense red indicate variations in amplitudes of the reflected signal and therefore the presence of significant electromagnetic discontinuities. The variations in amplitude (and therefore in color) in the same slice are an indication of horizontal variations in the electromagnetic characteristics of the materials investigated. In Fig. 3 the most significant depth slices superimposed on the fresco photo are shown. In this last figure it is possible to notice a state of diffuse degradation (inside of the black dotted circles) and a series of fractures (white dashed lines).

Very interesting is the analysis of the amplitude spectrum of electromagnetic waves at data acquisition frequencies. The type of analysis is related to the greater and / or less absorption of electromagnetic energy by the materials investigated. In this case the blue color indicates weak amplitude and therefore greater absorption of energy (index of more conductive materials and consequently with a relatively high volumetric content in water); the colors from light blue to the most intense red indicate greater amplitudes of the energy and therefore less absorption. Fig. 4 shows the slices related to the 2GHz amplitude spectrum superimposed on the fresco photo. It is possible to identify an extended area (within the dashed yellow line) in which the electromagnetic energy is strongly attenuated very probably due to a high degree of humidity present in the material investigated at the time of measurement.

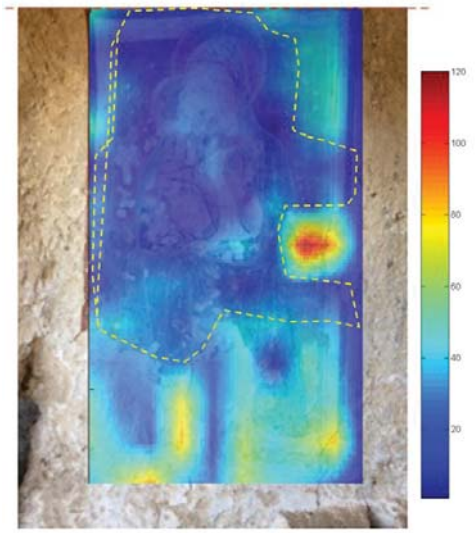


*Fig. 4. The electromagnetic spectral amplitude at 2GHz*

## IV. CONCLUSIONS

The application of the high resolution pulse electromagnetic methodology has contribute to understand the state of conservation of the investigated frescoes investigated. The structural aspects (i.e. fractures, volumetric water content) were provided which are improved the knowledge useful for the possible restoration. The geophysical survey has highlighted the presence of a series of superficial anomalies (dashed black circles) probably related to a state of advanced degradation (probable presence of aggregation of salts). The structures investigated present a series of karst discontinuities (empty fractures). Fractures (indicated by dashed white lines probably develop to the depth of the investigation).

## REFERENCES

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[3] G. Leucci, “Nondestructive Testing for Archaeology and Cultural Heritage: A practical guide and new perspective”, Springer, Berlin, Germany, 2019.