2022 IMEKO TC-4 International Conference on
Metrology for Archaeology and Cultural Heritage
University of Calabria, Italy, October 19-21, 2022

Non-destructive diagnosis at the Brancacci Chapel, Church of Santa Maria del Carmine (Florence)

Leucci[1*] G., De Giorgi[1] L., Ferrari[1] I., Giuri[1] F., Longhitano[2] L., Felici[3] A., Cristiano[4] R.

[1]*Institute of Heritage Sciences, National Research Council, 73100 Lecce*
[2]*PhD student University of Catania, lucrezia.longhitano@phd.unict.it*
[3]*SABAP di Firenze, alberto.felici@beniculturali.it*
[4]*Institute of Heritage Sciences, National Research Council, 50019 Sesto Fiorentino (FI), cristiano.riminesi@cnr.it*
[*]*corresponding author, giovanni.leucci@cnr.it*

***Abstract* – The Basilica of Santa Maria del Carmine in Florence, in the Oltrarno area, was built in 1268 (pre-Renaissance low medieval context), consecrated in 1422. Due to a devastating fire in 1771 of the interior of the original church, very little remained, between the parts that managed to save including the Corsini and Brancacci chapels. The architect Giuseppe Ruggeri was responsible for the reconstruction of the church, which was completed in 1782 (with the exception of the gabled façade which remained unfinished, as it can still be seen today (in fact it has bricks and exposed stone elements). Geophysical investigations were undertaken into the Brancacci chapel in order to have information on the wall structure that contains the wall paintings by Masaccio, Masolino and Filippino Lippi, to understand the stratigraphy of the mortars and formulate some hypotheses on the causes of their detachment.. The results are interesting.**

I. INTRODUCTION

Inside the church of Santa Maria del Carmine the Brancacci Chapel (Fig. 1) islocated to the south-west, to the left of the transept. It was miraculously saved from the devastating fire of 1771 together with the Corsini Chapel (opposite side of the transept). Historically framing the chapel, it belonged to the Florentine Brancacci family (to which it owes its name) from the second half of the 1300s until 1780. , then passing to the Riccardi family. Felice Brancacci, who was the patron saint of the chapel from 1422 until about 1436, and a leading exponent of the Florentine nobility, following his return from the role of ambassador to Cairo, commissioned the pictorial apparatus that characterizes and makes the chapel famous.

The paintings were the work of the important Renaissance artist Masaccio (Tommaso di Mone Cassai; Castel San Giovanni, 1401 - Rome, 1428) and by Masolino da Panicale (Tommaso di Cristoforo Fini; Panicale, 1383 - Florence, 1440), completed by Filippino Lippi (Prato, 1457 - Florence, 1504). The decorative apparatus was built starting in 1422 and ending in 1475.

The cycle represented concerns the stories of the life of Saint Peter, drawing the events from the Gospels, the Acts of the Apostles and the Golden Legend and two moments taken from Genesis. The importance and fame of the Brancacci Chapel are largely due to the presence of Masaccio who, although a young painter who died at the age of twenty-seven, was the architect of a new vision in the field of painting at the beginning of the fifteenth century (Fig. 2).

On the walls of the Brancacci Chapel, Masaccio collaborated on an equal footing with Masolino, an older painter than himself, starting from the end of 1424. The cycle remained unfinished and was completed fifty years later by Filippino Lippi, who also had the task of compensating some faces that had been erased to obscure the memory of Felice Brancacci's client. For a long time, due to the conditions of the pictorial surface, blackened by the smoke of the candles, it was difficult to attribute the scenes to each of the two artists. With the important twentieth-century restoration, which made the situation more legible, it was possible to make the attributions more solid. To support the thesis that Masolino and Masaccio worked simultaneously in this chapel, there is the extraordinary perspective unity of the scenes in this cycle: not only does each panel have its own vanishing point and it is towards this that all the lines of depth converge, but the individual vanishing points of the scenes on the opposite walls fit together perfectly. In other words, the perspective layout of two scenes viewed from the front, if reversed, can be superimposed. On the back wall, on the other hand, the vanishing point is external to the scenes and matches the geometric centre of the wall.

Fig. 1. The Brancacci chapel

Fig. 2. The wall paintings with indication of the areas investigated with the GPR

Nowadays, non-destructive geophysical techniques for monitoring the state of conservation are of great help to conservators to determine intervention strategies and the most appropriate conservation solutions. These techniques provide a reliable means of assessing damage to cultural properties without compromising their structural condition. Among these, the use of ground-penetrating radar (GPR) has become increasingly extensive in recent decades due to its non-invasive effect [1]. The GPR is a rapid data acquisition technique that offers observable results in high-resolution imaging [1, 2], supplies information on monumental structures with acceptable limits of uncertainty, and helps identify hidden targets in the subsoil, for example, voids or cavities such as tombs or crypts [1,2,3] and walls or buried structures that are entirely invisible on the surface [1, 2, 3]. The GPR has also been used to assess the state of conservation of wooden structures and columns [3] and to identify fractures in walls and cavities [1, 4, 5]. In the case of frescoes, the GPR provides essential information to define the textural and structural conditions and alterations of the walls [5, 6] which support the painting [7]. Interesting examples of GPR applications for walls and frescos hidden are also shown in [5].

The aim of this research was to estimate the state of conservation of the wall structure that contains the frescoes by Masaccio and Masolino and the state of conservation of the paintings by means of 3-D analysis at different depths of the vertical surfaces investigated. The results obtained are helpful to determine the degree of lack of adhesion of the layers beneath the painting in order to plan its restoration in situ.

II. THE GPR SURVEY

The GPR is based on the emission, transmission, reflection and reception of high frequencies (between about 10 and 2600 MHz) electromagnetic (EM) waves propagating within the substrate or through the examined structures. The intensity of the reflections of the EM waves depends on the contrast of the EM impedance between layers (or targets), the way the incident wave is polarized and the incidence angle. The velocity of EM waves in the medium mainly depends on the electrical permittivity of the materials and in turn, on the water content (humidity) of the soil: the higher the humidity in the soil, the lower the velocity of GPR waves. The change in conductivity (σ) affects the absorption of the radar signal whilst the variation in relative permittivity (ε_r) determines variations in the velocity of the medium [1]. The reflection occurs whenever there is a contrast in the dielectric properties of the surveyed structure due to buried discontinuities.

The GPR system is generally composed of a control unit, a transmitting and receiving antenna, and a computer. The central unit produces short electromagnetic pulses (from about 1 to 60 ns) [1] that are radiated to the ground through the transmitting antenna and then recorded back to the receiving antenna. The data acquisition was performed using the impulse GPR system Ris Hi-mod (IDS) equipped with a monostatic shielded antenna of 900 MHz and 2000 MHz nominal frequency. The chose these frequencies is related to the fact that it is known that smaller objects can be detected by higher frequency signals whereas big objects require low frequencies. Moreover, the higher the frequency of the antenna used, the higher the vertical resolution and the lower the investigation depth. The choice allows obtaining a good compromise between resolution and depth of investigation. In order to protect the frescoes from any damage that might be caused when passing the antenna (Fig. 3), GPR data were acquired keeping the antenna about 1cm away from the wall. An orthogonal grid with 0.1 m spacing was designed, acquiring scans in both X (horizontal) and Y (vertical) directions. Close parallel profiles allowed the assembling of a 3D GPR volume, which was then sliced into GPR time slices and GPR iso amplitude surface.

Fig. 3. The GPR data acquisition

The quality of the raw data did not require advanced processing techniques. However, appropriate processing has been performed for easier interpretation using the REFLEXW software [3]. The following data processing has been performed:

(i) amplitude normalization, consisting of the declipping of saturated (and thus clipped) traces using a polynomial interpolation procedure [1];

(ii) background removal, whereby the filter is a simple arithmetic process that sums all the amplitudes of reflections that were recorded at the same time along with a profile and divide by the number of traces summed the resulting composite digital wave, which is an average of all background noise, is then subtracted from the data set;

(iii) Kirchhoff two-dimensional velocity migration [1], which is a time migration of a two-dimensional profile based on a two-dimensional velocity distribution is performed. The goal of the migration is to trace back the reflection and diffraction energy to their 'source'. The Kirchhoff twodimensional velocity migration is done in the x–t range, this means that a weighted summation for each point of the profile over a calculated hyperbola of pre-set bandwidth is performed. The bandwidth means the number of traces (parameter summation width) over which summation takes place. Some processed GPR profiles related to the second floor right side and to 2000MHz antenna are shown in Fig. 4.

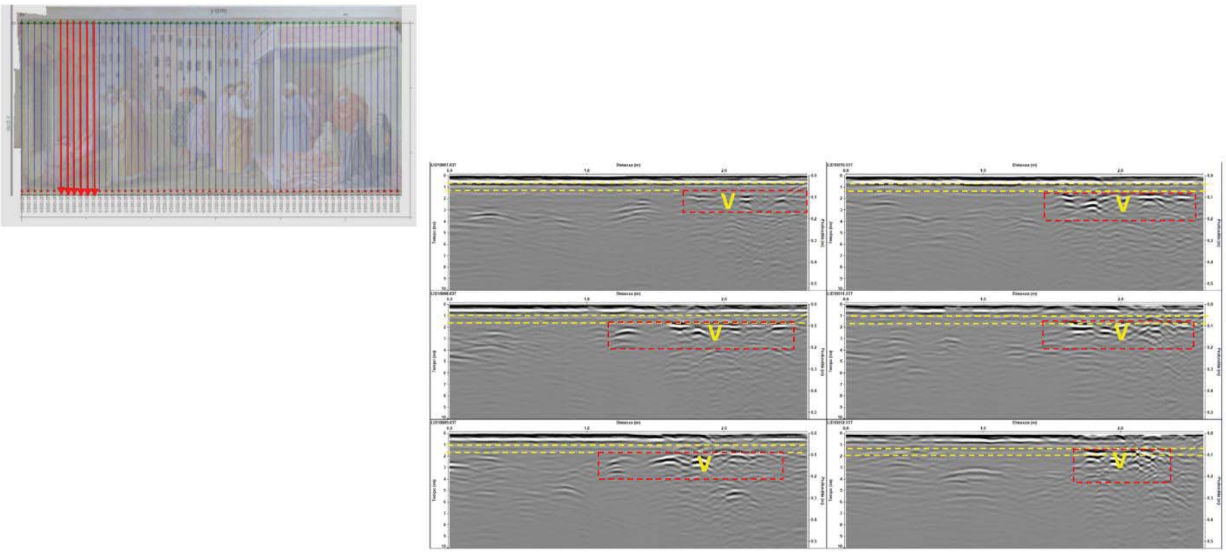

Fig. 4. Some processed GPR profiles were acquired on the second floor right side of the chapel

A close examination of the data showed the presence of numerous reflection hyperbolae from a point source. This allows us to estimate the EM wave velocity propagation [1]. It ranging from 0.09 m/ns to 0.12 m/ns. A general characteristic of the surveyed area shows a good penetration of the electromagnetic energy that allow to have information on the first 0.4m in depth. This is a result of the physical characteristics of the shallow subsurface, which is characterized by material that is slightly dissipating to electromagnetic energy. In the radar sections a series of two (yellow dashed lines) horizontal reflection event are identifiable at the time ranging from about 1 ns to about 1.8 ns (from 0.04 m to 0.08 m in depth). They could be related to two different layers of the plaster.

Other reflection events labelled V are visible. They have a hyperbolic shape that could be related to void spaces. The arrangement of the profiles in a grid has allowed us to correlate, spatially, the important reflections within two-dimensional reflection profiles (standard radar sections). A way to obtain visually useful maps for understanding the plan distribution of reflection amplitudes within specific time intervals is the creation of horizontal time slices. The area related to these reflections is located where the painting surface present a huge deformation respect of its vertical profile. Fig. 5 highlights the deformation of the masonry that correspond with the detected anomalies.

Fig. 5. Raking light image of the scene of the Miracle

Time slices examine only reflection amplitude changes (or energy changes if the square value is used instead of the absolute value) within specific time intervals, and thus within consecutive soil layers of nearly constant thickness. Each time slice is, therefore, roughly comparable to a standard archaeological excavation level [1, 2, 3]. Areas of low reflection amplitude (or energy) indicate uniform matrix materials or quite homogeneous soils, whereas those of high amplitude denote zones of high electrical subsurface properties contrast, such as buried archaeological features, voids or important stratigraphical changes.

In the present work, the time slice technique has been used to display the energy variations within the 0.0m-0.089m in depth, where the majority of anomalies (of hyperbolic shape) were observed in all acquired radar sections (Fig. 6).

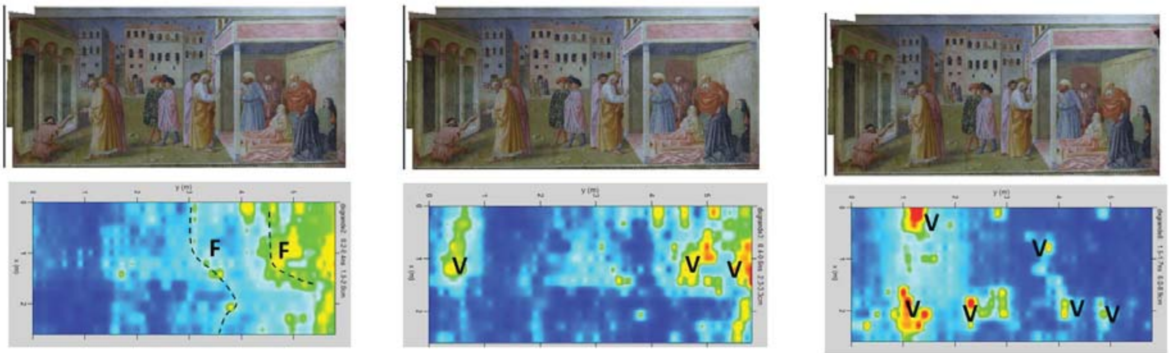

Fig. 6. The time slices

One high-amplitude anomaly (V in Fig. 6) is visible. The irregular shape and the size of the high-amplitude anomaly suggest that it is related to the presence of voids. Other relatively low-amplitude anomalies (F in Fig. 6) are visible. They could be related to the fractures.

III. CONCLUSIONS

The results obtained in this work show that GPR is a useful method to understand the anomalies in the masonry of wall painting, in particular, the high-frequency inspection allows to locate the mortar detachments and to estimate the state of adhesion of the mortar layers. By means of accurate and reliable pseudo3-D data analyses at different depths, we can identify the size and geometry of the detachment zones, and determine the degree of alteration of the support walls. The thickness of the different layers that make up the support of the painting was identified according to the difference in time (ns) measured between pulses, whose peaks appear, although with variations, every 0.8 ns, which indicates that there are three layers of approximately 4 cm each.

REFERENCES

[1] Leucci G., 2019, Nondestructive Testing for Archaeology and Cultural Heritage: A practical guide and new perspective. Springer editore pp 217, ISBN 978-3-030-01898-6

[2] Giannino F., Leucci G., 2021. Electromagnetic Methods in Geophysics: Applications in GeoRadar, FDEM, TDEM, and AEM. Wiley, pp 352, ISBN: 978-1-119-77098-5.

[3] Leucci G., 2020, Advances in Geophysical Methods Applied to Forensic Investigations: New Developments in Acquisition and Data Analysis Methodologies. Springer editore, pp 200, ISBN 978-3-030-46241-3

[4] M. Cozzolino , E. Di Giovanni , P. Mauriello , S. Piro , D Zamuer , in: Geophysical Methods for Cultural

Heritage Management, Springer, 2018, p. 211

[5] Ortega-Ramírez J., Bano M., Lelo de Larrea-López L., Robles-Camacho J., Ávi- la-Luna P., Villa-Alvarado L.A., GPR measurements to identify cracks and textural arrangements in the altar Wall of the 16th-century Santa María Huiramangaro Church, Michoacán, Mexico, Near Surf. Geophys. 17 (2019) 247–261

[6] De Giorgi L., Lazzari M., Leucci G., Persico R., 2020. Geomorphological and non-destructive GPR survey for the conservation of frescos in the rupestrian churches of Matera (Basilicata, southern Italy) Archaeological Prospection, DOI: 10.1002/arp.1795

[7] Ortega-Ramirez J., Bano M., Villa-Alvarado L.A., GPR for detecting cracks and voids in a historical mural, before restoration, on the altar Wall of a XVII cen- tury church, in: Mexico City. 18th International Conference on Ground Pene- trating Radar; Society of Exploration Geophysicists, 2020, pp. 22–25