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Ground Penetrating Radar investigation of the floor of Palazzo Vecchio's Great Hall

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***Abstract* – Ground Penetrating Radar is a powerful nondestructive investigation tool widely used in archaeology. This paper reports the radar investigation of the floor of Palazzo Vecchio's Great Hall. In 1555 Cosimo I dei Medici commissioned a monumental fountain that should be collocated in the Great Hall, but the historical sources state that it was never installed in its own collocation. The aim of this radar investigation is to find traces (e.g. a basement or water pipes) under the floor that could support the hypothesis of a temporary collocation of the fountain in the Great Hall. Although the radar detected some interesting features inside and under the floor, no clear evidences of the fountain have been found.**

I. INTRODUCTION

The Great Hall "Sala Grande", named also "Salone dei Cinquecento (Hall of five hundred) as it can hold up to 500 people, is the largest and most known room of "Palazzo Vecchio" (Old Palace), the City Hall of Florence. This impressive hall is 54 m long, 23 m wide, and 18 m high (see Fig. 1).

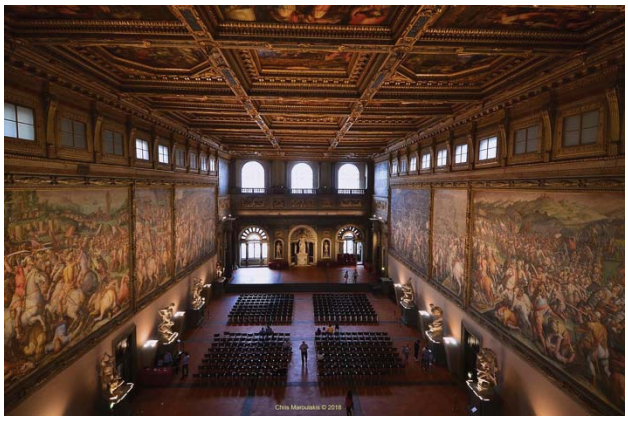

Fig. 1. The Great Hall as appears today

The hall was built between July 1495 and February 1496, by Simone del Pollaiolo and by Francesco di Domenico commissioned by Girolamo Savonarola, the monk who established a brief theocratic regime in Florence (1494-1498).

In 1555 the Florentine sculptor and architect Bartolomeo Ammannati (1511-1592) was commissioned by Cosimo I de 'Medici, Duke of Florence and Grand Duke of Tuscany to design and create a monumental fountain in the Great Hall known as Fountain of Juno [1]. The theme of the sculptural complex was the "Creation of water" and its aim was to celebrate Cosimo's good government. The original design included six statues of gods representing the Arno river, Ceres, Juno, Flora, Castalia and Temperance. The statues of the fountain carved between 1555 and 1561, were defined by Michelangelo a "beautiful fantasy" (see drawing by Giovanni Guerra in Fig. 2).

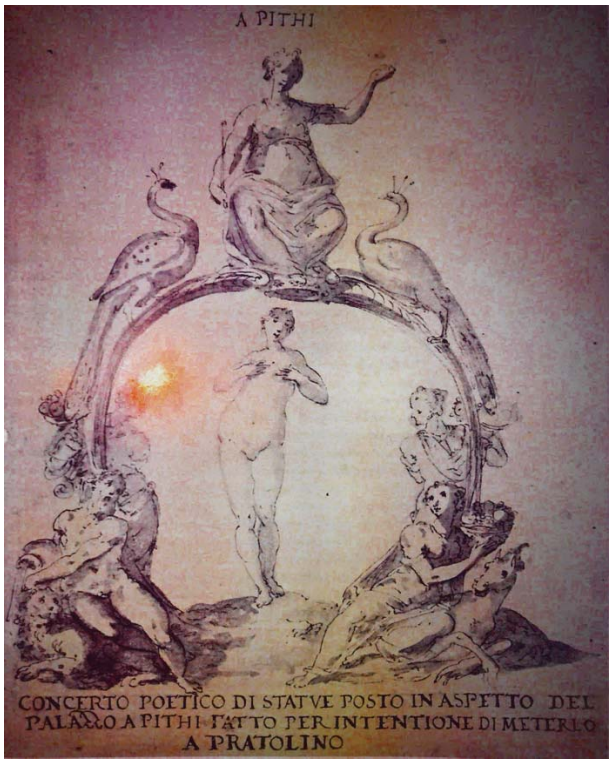

Fig. 2. Drawing of Ammannati fountain by Giovanni Guerra (1598 about)

Unfortunately, this artwork had a troubled life and it

seems that it never was installed on its own collocation in the Great Hall. It was collocated in the Pratolino Villa (on the hills near Florence) and later brought to the Boboli's Garden. Only recently (in 2011) the statues have been united in the courtyard of the Bargello museum (Fig. 3) [2].

Fig. 3. Reconstruction of Ammannati fountain at Bargello Museum, Florence, Italy

The current monumental appearance of the Great Hall (Fig. 1) is a design of Giorgio Vasari that was tasked, in the 1560s, with reconstruction and repainting the hall. Since he raised the roof of 8 m and changed radically the whole structure, today several open questions about the appearance of the Great Hall in the past are debated by scholars. One of these is whether some preliminary works were carried out in view of the installation of the fountain. Currently there is not any trace, but the radar investigation of the floor could give some clues.

It is not the first time that an extensive ground penetrating radar (GPR) campaign was performed in the hall. In 2003 one of the authors of this paper developed a specific no-contact radar that operated several months in the hall providing impressive images of the wall interior [4]. The aim was to gather clues about the possible location of remains of the legendary lost mural painting "Battle of Anghiari" that Leonardo da Vinci was commissioned to paint in one of the walls of the Great Hall. In one of the walls a discontinuity was detected, but no clear evidences of the lost painting were found. By the way some years after (in 2007) the Superintendence authorized an investigation partially destructive. Five holes were drilled in the east wall. While a discontinuity 15 cm in deep was found (according to the radar investigation), no traces of the lost fresco were found.

II. THE RADAR EQUIPMENT

The GPR equipment we used is a prototype (named ORFEUS) developed in the frame of an European Project aimed to reach the state-of art (of the year 2008) of Step frequency Continuous Wave (SFCW) technology [5],[6],[7]. The operative frequency range is 100 MHz – 1 GHz (so the bandwidth is 900 MHz), the dynamic range is about 100 dB, the unambiguous range is 60 m, the transmitted power is 0 dBm, the scan speed is up to 200 scan/s. Its antennas are two co-polarized loaded bowties. With respect to other commercial equipment this radar has a penetration capability 30 % larger and efficiency 20 dB better than stroboscopic pulse GPR [8]. Fig. 4 shows a picture of the equipment operating in the Great Hall.

Fig. 4. ORFEUS radar operating in the Great Hall

The acquired data have been managed with GRED software by IDS Georadar. The software geo-referenced the scans in an orthogonal grid in order to obtain image in the vertical plane (B-scan) and in the horizontal plane (C-scan).

III. EXPERIMENTAL RESULTS

The measurement campaign in the Great Hall of Palazzo Vecchio was carried out in a single day (12 June 2019). The Great Hall is at the second floor of Palazzo Vecchio, and the fountain should have been collocated on the South side of the hall. Therefore, we investigated an area of the floor 21 m wide and 16 m large located as shown in Fig. 5. The red lines in Figure 4 are the radar scans superimposed to the map of the second floor. The depth of the radar investigation has been evaluated assuming the speed of electromagnetic wave constant in the masonry and equal to 150 cm/ns. Since it is a rather rough assumption, the depth values we report in the following figures have to be considered indicative.

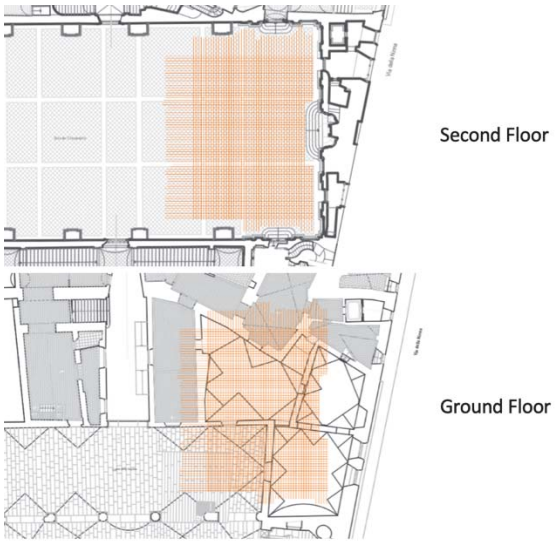

Fig. 5. Scan grid superimposed to the map of the second floor and the ground floor of Palazzo Vecchio

Fig. 6 shows the radar image (C-scan) at 0.11 m depth superimposed to the map of the second floor. The lines of "Serena" rock between the floor sections of "Cotto" bricks are clearly detected.

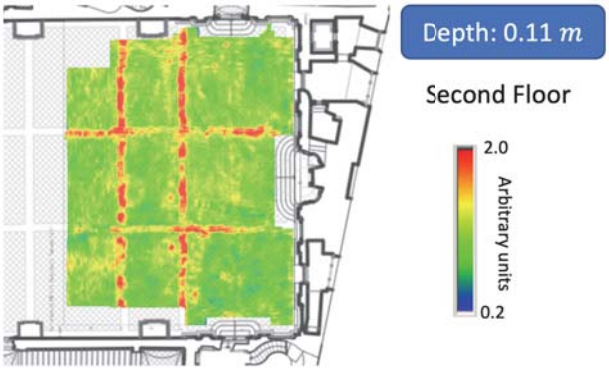

Fig. 6. C-scan at 0.11 m superimposed to the map of the second floor of Palazzo Vecchio

Fig. 7 shows the radar image (C-scan) at 0.23 m depth superimposed to the maps of the second floor and the ground floor. At this depth some interesting features are visible. In order to understand their meaning, it is useful to see the radar image 5 cm deeper (Fig. 8). In this we are able to recognize a long girder (we suppose, as it is not visible from ground floor) that cross the Great Hall and that rests on the walls of a room at ground floor.

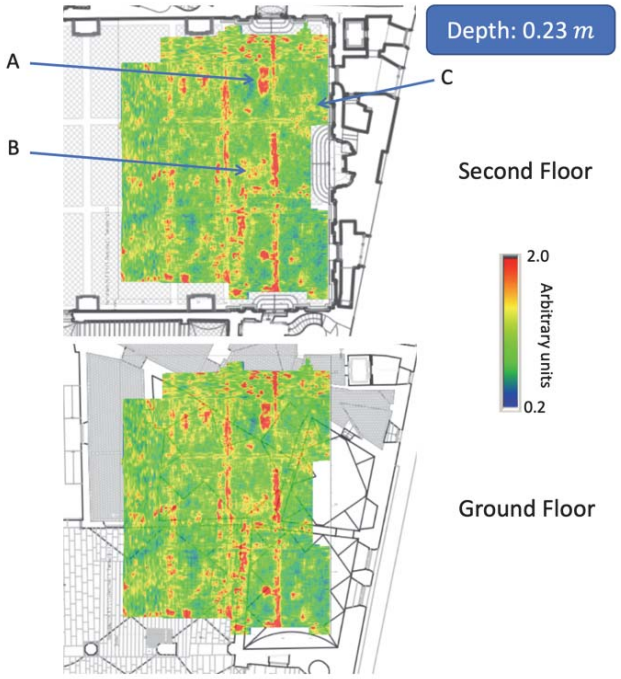

Fig. 7. C-scan at 0.23 m superimposed to the maps of the second floor and the ground floor

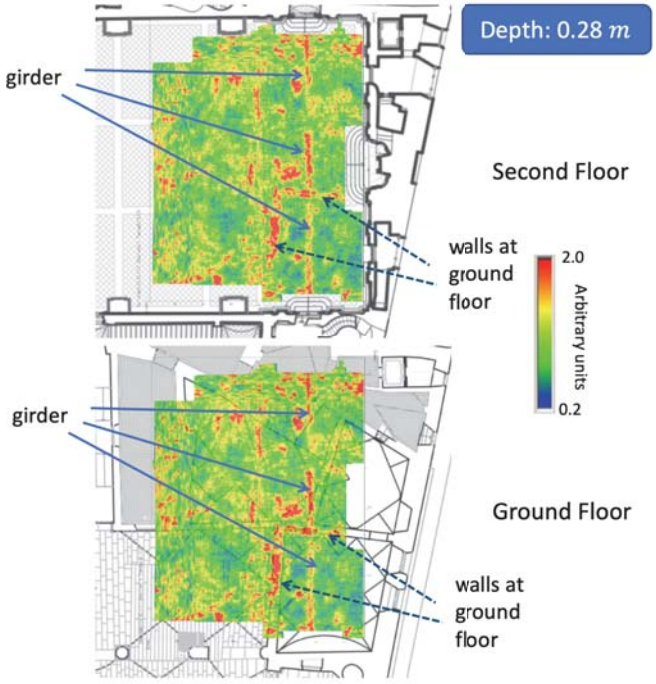

Fig. 8. C-scan at 0.28 m C-scan at 0.23 m superimposed to the maps of the second floor and the ground floor

Fig. 9 shows the radar image (C-scan) at 0.34 m depth superimposed to the maps of the second floor and the ground floor. At this depth the girder is less visible, while

the walls of the room at ground level are again evident (as well as in all the images at greater depth).

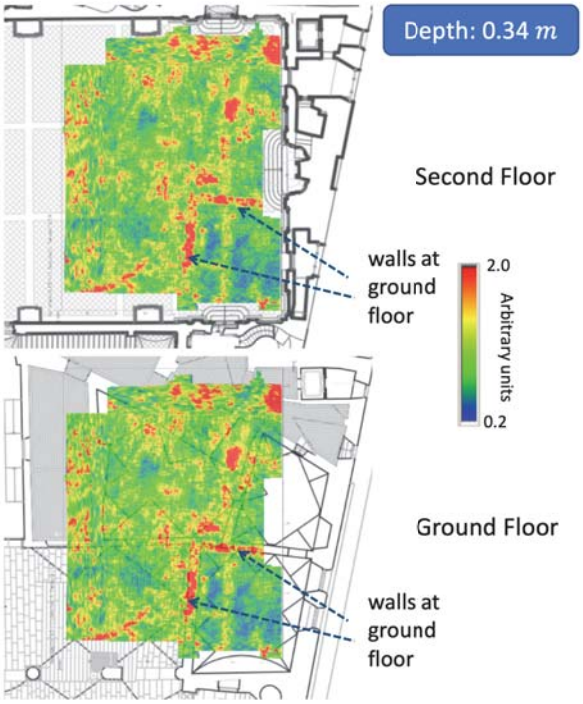

Fig. 9. C-scan at 0.34 m superimposed to the maps of the second floor and the ground floor

Fig. 10 shows the radar image (C-scan) at 0.39 m depth superimposed to the maps of the second floor and the ground floor. At this depth the ceilings of the vaults at ground level appear.

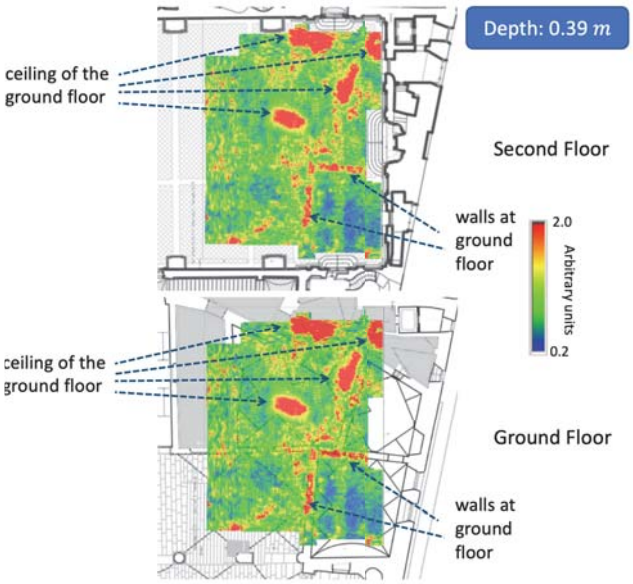

Fig. 10. C-scan at 0.39 m superimposed to the maps of the second floor and the ground floor

At greater depth it is possible to see also the sections of the vaults at ground level (see Fig. 11).

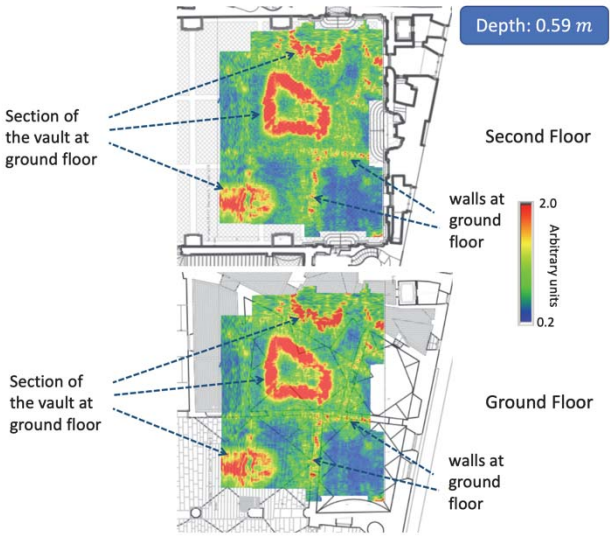

Fig. 11. C-scan at 0.59 m superimposed to the maps of the second floor and the ground floor

IV. DISCUSSION

On the basis of the experimental results shown above, the radar image that could provide clues about possible rests of a basement or water pipes is the C-scan at 0.23.m (Fig. 6). In this image we see three features (labeled with A, B, and C) not completely explainable. The A feature is a clear inhomogeneity of the floor, but it is too lateral for being the basement of a fountain that is supposed to be collocated at the center of the South side of the Great Hall [3]. The B feature is rather central, but it is too small and irregular for being the basement of the fountain. The C feature appears like a square tilted with respect to the Great Hall. We do not exclude that it could be the rest of the basement of a statue, but the fountain should not be tilted and should have five basements along a line. Finally, we do not notice any feature that can be associated to water pipes, although a fountain should necessarily have them.

V. CONCLUSION

Ground Penetrating radar has been demonstrated, once again, a powerful tool for investigating masonry. In effect large, flat, and dry masonry (like the floor of the Great Hall) is an almost ideal situation for this kind of investigation. In effect, the obtained images are rather impressive. The interior of the floor is clearly imaged and the structures of the floor below (walls, rooms, and vaults) are clearly detectable.

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