Precise mapping using ground-penetrating radar of a Roman villa at Thalerhof Airport, Graz, Austria: Verification and modification of an excavation-based model

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In the early 1930s, the remains of several buildings from the Roman era were found in the vicinity of Thalerhof Airport in Graz, Austria. Some years later (1937–1939) an archaeological excavation (Figure 1) in the area around the current airport found one of the largest Roman-aged villas of the eastern Alpine region. The excavation results were documented and a map of the buildings was drawn. However, during World War II, most of the documents were lost.

After the war, the ancient villa was once again discovered during construction of a new airstrip at Thalerhof. Unfortunately, the exact position of the villa was not documented during that postwar construction. Recently, it was decided to build an additional runway and extend the capacity of the airport. This runway needed to be parallel to the first, but built without interfering further with the remains of the Roman villa. Therefore, it was necessary to locate the Roman villa as precisely as possible using geophysics. Ground-penetrating radar (GPR) was the selected technique as it is a proven tool for high-resolution detection of (shallow) archaeological structures.

With the help of GPR, we expected to be able to determine the exact location of the Roman villa, verify or revise the drawings from the previous excavations that align the short side of the villa perfectly north-south, and verify the footprint of the structure as described by the excavation report.

Acquisition
At the insistence of the Austrian Federal Office for the Care of Monuments and based on recommendations of archaeologists, the investigation was focused on the southern part of the existing airstrip. The defined area of investigation is a quadrant aligned parallel to the existing airstrip with a side length of 105 m (Figures 2 and 6). As the area of investigation is on an active air field, it was necessary to perform all measurements outside the airport’s operating times. Therefore, all measurements needed to be taken between midnight and 5 a.m. We decided to divide the area of investigation into four small quadrants.

The GPR measurements were recorded using a GSSI SIR 3000 system with a monostatic 400-MHz antenna (mounted on a cart) over a span of seven nights during the summer of 2007. The profiles were recorded parallel to the x and y axis of the survey site with 50 scans/m, 512 samples/scan, and a recording time of 80 ns. The line spacing between each profile was 50 cm. These parameters were based on past archeological investigations carried out by Joanneum Research and are consistent with the recommendations by Jones (2008) for archeological prospection with GPR. To ensure positional accuracy of each individual profile and for maintaining straight profile lines, the antenna was moved along a strained tape measure. A detailed summary of the acquisition parameters for each quadrant is given in Table 1.

Processing
We recorded several test profiles at different locations around the survey site and processed them in the field using ReflexWin by Sandmeier Software. Because acquisition parameters greatly influence the final processed results, we felt it imperative to perform simple field processing to insure the parameters were the best possible. Additionally, after each night’s data acquisition, we processed at least two profiles as a quality control (QC) measure. These processing results were used for QC only and not included as part of the final processed sections.

One crucial step in the processing sequence is the determination of the velocity of the electromagnetic wave. In principle, it is possible to estimate the wave velocity based on measurements in the literature, but for achieving the best results it is advisable to analyze diffraction hyperbolas actually recorded at the investigation site. For this project, 20 single profiles were analyzed in detail. These analyses showed that the velocities of the electromagnetic wave were in the range of 0.06–0.12 m/ns. Based on these results, a mean velocity of 0.08 m/ns was used for migration and for time-to-depth conversion of the GPR data. Processing of individual profiles (principally for velocity analyses) was done with the ReflexWin software package.

Figure 1. Excavation by Schmid (1938). Copyright by Landesmuseum Joanneum.
The main objective of the GPR investigation was to generate high-quality time slices with sufficient resolution for an accurate interpretation by the archaeologist. For calculating and presentation of the time slices, we used GPR-SLICE (Geophysical Archaeometry Laboratory). The time slices for each quadrant were processed separately and later merged to provide a composite image.

The processing sequence used to calculate time slices included geometry definition, determination of the zero-point to locate the ground surface reflection, optimal
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gain parameters, dc notch filter, band-pass filtering, and migration.

Time slices of the processed data were produced to provide a horizon view of the subsurface. To get the optimum time/depth interval, it was necessary to run the calculation with a range of different parameters. Finally, a time interval of 2.66 ns (corresponding to 17 samples) was found to produce the best results. During the slice process, each radargram was resampled to a constant number of scans per line. The time slices were gridded to create pixel maps. For gridding, we chose inverse distance interpolation with a smoothing factor and a fine cell size. Figure 3 demonstrates the effect of an unmigrated (top) and migrated (bottom) data set (quadrant 2, 11–14 ns). The time slice from the migrated data provides better resolution but it also produces some artifacts on the right and the upper edge.

Figure 4 shows the results from the time-slice processing (unmigrated data) for 9–28 ns. These times correspond to a depth of 0.4–1.1 m. In each time slice, black and reddish colors indicate areas with high amplitudes (strong reflections). Grays indicate low amplitudes (weak reflections). The high-amplitude values are likely indicative of wall remnants.

Interpretation

A principal guide and basis for interpreting the GPR time slices were the excavation results from the 1930s by Grubinger (1946, 1959). Figure 5 shows the drawings of the excavation results. The total size of the Roman villa is approximately 180 × 60 m with about 70 rooms.

Parts of the middle section and the eastern wing of the villa were imaged on the GPR data. By overlaying the GPR images on the excavation drawings (Modrijan et al., 1968), it was possible to identify the overall structure and verify the size of the villa. Most importantly, from the airport construction perspective, we could determine the exact position of the villa. It was also possible to determine the alignment of the walls. In the previous drawings, the short side of the villa was always aligned perfectly north-south. The GPR results showed that the villa is slightly rotated counterclockwise (approximately 10°). The complete west wing of the villa is beneath the current airstrip (Figure 6).

The numbering system developed by Modrijan et al. was used to identify each room. GPR data appear to image parts of the middle section and the eastern wing of the villa. In various time slices, the wall remnants appear as high-amplitude anomalies. In the following sections, the middle section of the villa, the eastern wing of the villa, the southeastern parts, and the part north of the villa will be discussed separately.

Middle section. On the western margin of the time slices (middle section of the villa), five elements striking north-south are visible that correspond with the eastern wall elements of rooms 31, 26, 25, 19, and 21 on the excavation map (Figure 7). The eastern wall of room 26 is circular shaped and is interpreted as an apse. According to the excavation results, room 19 is interpreted as a praefurnium (heating room). East of rooms 25 and 19, two rectangular-shaped rooms (16, 18) can be seen in the time slices. The position of these rooms corresponds with the excavation results. Next to room 16 are two rooms (17a, 17b) that differ from the excavation reports. Additionally, it is necessary to move the eastern wall to the west by several meters. The northern wall element of this room can be prolonged to the east but runs out after a few meters.

By skipping through various time slices, it becomes clear...
that the basement of rooms 17a and 17b extend farther down than room 18. This leads to the interpretation that room 16 was built in a later construction phase and that initially rooms 25 and 17a were not connected. In previous maps, room 16 was always shown as rectangular. With the help of the GPR measurements, it is possible to detect an apse in the eastern part of this room.

In deeper time slices, another structure between rooms 16 and 18 is recognizable. This structure terminates at the prae-furnium (room 19) and is therefore interpreted as part of an underground heating system (green in Figure 7). This structure has a length of 53 m. Approximately in the middle of room 16 is a new wall element oriented north-south that was not mentioned in previous reports (room 79). With no wall structures present on the south side of this room, it seems to be open toward the south.

East wing. The entrance to the east wing of the villa is via the L-shaped room 12. The previous map shows no evidence for a connection between the eastern wing and the middle part of the villa. According to the GPR images, a direct co-
The basement of the connecting hallway can be seen best on deeper time slices. The size and shape of room 13 can be verified by the radar measurements. It is difficult to detect the wall elements of the large room number 11 with the GPR images. Particularly in the northern part of this room where only bits and pieces of the wall elements are detectable. On the other hand, it was possible to detect two construction phases on the western part of this room. It seems that room 11 was enlarged in a second construction phase, to form a small additional room. The basement of the second wall is at shallower depth than the first.

**Figure 5.** Map of the “Villa Thalerhof” based on the excavation results. The villa is approximately 180 m long and 60 m wide. (Modified after Modrijan et al., 1968.)

**Figure 6.** Map showing the location and orientation of the Roman villa determined with the help of GPR measurements. The complete west wing is beneath the current air strip. The GPR measurements reveal the structures of the east wing and to some degree the middle part of the villa.

**Figure 7.** Results of the interpretation of the GPR time slices. In the background, the eastern part of Figure 5 is shown. Red indicates interpreted walls and columns. Green indicates structures interpreted to be heating systems. Blue indicates shallow structures interpreted to be not of Roman age.
wall element. It is also hard to identify room 10, and the hallway of room 9 on the GPR images.

According to the excavation reports, there should be a foundation between rooms 6 and 9, which is not visible on the time slices. In the middle of room 9 is a small foundation at a depth of 0.6 m. Because of the depth of this foundation, it is assigned to the first construction phase. Because this foundation has a maximum thickness of only 0.3 m, it is interpreted as the substructure of an oven. Between rooms 9 and 13 it was possible to detect an additional room (81) that possesses a rectangular shape and a size of 8 × 2 m. All other rooms in the eastern wing are of a shape and size consistent with the excavation reports.

Southeastern section. The southeastern part of the villa is where the largest discrepancies occur between the original excavation map and the GPR survey. From the geophysical measurements, it is not possible to see any clear structures separating rooms 2, 3, and 4. In contrast to this, a secondary room can be interpreted inside room 4. This room has walls that appear to be up to 1 m thick. Inside this secondary room, at a depth of 0.65 m, are eight circular-shaped foundations with diameters of 1 m. These eight circular foundations are aligned in two rows with 4 m between foundations and 3 m from the nearest wall. At the moment this room is interpreted as a granary, but no hard data are available to confirm or refute this suggestion so its function is still speculative. East of this room, at approximately the same depth as the circular-shaped fundaments, another seven circular-shaped structures with diameters of 0.8 m and separated by a distance of 4 m can be seen. These are interpreted as foundations of columns that were holding a monopitch roof.

Outside the villa. North of the villa, structures are visible that appear to form a loop structure (blue in Figure 7). In the excavation reports, these elements were described as forming a triangular shaped room (76). No such wall elements are visible in the GPR images. The loop structure is at a shallow depth, implying this structure is more recent than the Roman occupation. During World War I, a detention camp was in this vicinity. Therefore, one possible explanation of this structure would be a road leading to the detention camp.

Conclusions

The aim of this project was to determine the location of the previously excavated Roman villa known to be beneath Thalerhof Airport. With the help of GPR images, we determined the exact position and orientation of the Roman villa. Furthermore, it was possible to verify the structure characteristics of the middle part and the east wing of the villa. In some parts of the villa, the GPR results resulted in modification of a previously drawn map. We could detect additional rooms in the south and southeast (granary), and we could show that the northern structures are almost certainly younger. By interpreting time slices at different depths, it was also possible to detect at least two stages of construction. In the middle part of the villa, a heating system could be detected that was not in the initial maps.

This project provided significant insights into aspects of this Roman-era villa that were missed during classical excavations, which further add to the value and significance of the GPR data. TLE

References

Grubinger, M., 1946, Frühömisches Grab in Abtissendorf bei Graz: Blatter für Heimatkunde, 82, 20–23.
Novo, A., Lorenzo, H., Rial, F. I., Solla, M., From pseudo-3D to full-resolution GPR imaging of a complex Roman site: Near Surface Geophysics, 2012, 10, 11–15

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