

The Roman *villa* in Oberlienz-Lesendorf, Austria. GPR Survey and Archaeological Interpretation

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Abstract

In 2007, the remains of an extended Roman *villa rustica*, only partially known from old excavations, were detected through high-resolution GPR measurements at Oberlienz-Lesendorf (Austria). The archaeological prospection was conducted by the Vienna Institute for Archaeological Science (VIAS) in collaboration with the Department of Archaeologies of Innsbruck University and ZAMG Archeo Prospections. Despite the important discovery, the Roman *villa* in Oberlienz-Lesendorf was not further investigated in the years that followed the GPR survey. In this article the main steps of the GPR survey are described. Attention is focused on the GIS-based archaeological interpretation of the data through the 3D approach. An optimised workflow, based on the efficient integration of ArcGIS with 3D modelling software (3D Studio Max and MeshLab), has been developed. The process, which included the necessary comparisons with a few Roman villas in Austria and Germany (Bavaria), resulted in a semi-reconstructive 3D digital model of the Roman *villa*. The work, focused on methodological aspects, was conducted by the first author in close and interdisciplinary collaboration with the team of the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology (LBI ArchPro) as part of her dissertation at the University of Vienna, which was concluded in 2017.

Keywords

GPR, 3D GIS, archaeological interpretation, virtual archaeology, 3D modelling, Roman villas

Zusammenfassung – Die römische Villa in Oberlienz-Lesendorf, Österreich. GPR-Survey und archäologische Interpretation

Im Jahre 2007 wurden die Überreste einer ausgedehnten römischen *villa rustica*, die nur teilweise aus alten Ausgrabungen bekannt war, durch hochauflösende GPR-Messungen in Oberlienz-Lesendorf (Österreich) entdeckt. Die archäologische Prospektion wurde vom Vienna Institute for Archaeological Science (VIAS) in Zusammenarbeit mit dem Institut für Archäologien der Universität Innsbruck

und ZAMG Archeo Prospections durchgeführt. Trotz der bedeutenden Entdeckung wurde die römische Villa in Oberlienz-Lesendorf in den Jahren nach der GPR-Prospektion nicht weiter untersucht. In diesem Artikel sollen die wichtigsten Aspekte der GPR-Prospektion beschrieben werden. Die GIS-basierte 3D-Interpretation der GPR-Daten bildet dabei den Hauptschwerpunkt. Es wird die Entwicklung eines optimierten Arbeitsablaufs auf der Grundlage einer effizienten Integration der GIS-Software ArcGIS mit der 3D-Modellierungssoftware (3D Studio Max und MeshLab) gezeigt. Die 3D-Kartierung der archäologischen Strukturen wurde in der 3D-Umgebung von ESRI ArcGIS 10.2 umgesetzt. Um den Interpretationsprozess zu verbessern, wurde eine Geodatenbank mit 2D und 3D *feature classes* mit vordefinierten Feldern und Domänen (Liste gültiger Werte) entworfen und als ESRI *file geodatabase* implementiert. Ein Vergleich mit römischen Villen aus *Noricum* stellte einen weiteren notwendigen Schritt der Interpretation dar. Die 3D-Interpretation der GPR-Daten wurde von der Erstautorin in enger interdisziplinärer Zusammenarbeit mit dem Ludwig Boltzmann Institut für Archäologische Prospektion and Virtuelle Archäologie (LBI ArchPro) im Rahmen ihrer Dissertation, die im Jahr 2017 an der Universität Wien abgeschlossen wurde, durchgeführt.

Schlüsselbegriffe

GPR, 3D GIS, archäologische Interpretation, virtuelle Archäologie, 3D Modellierung, römische Villen

1. Introduction

Non-invasive archaeological investigation by means of geophysical measurements has become a routine method for detecting buried structures. The main advantage in using non-destructive methods is the possibility to collect information about the subsoil in a relatively cost-efficient way, which facilitates better archaeological excavation planning. If excavations cannot be undertaken, the detailed

information from high-resolution geophysical surveys allows interpretative archaeological mapping of the buried remains and helps with their preservation.

Among geophysical methods, high-resolution ground penetrating radar (GPR) measurements allow detailed three-dimensional investigation of the subsoil. The method¹ is based on the propagation and reflection of electromagnetic waves in the subsurface, typically of frequencies ranging between 200 and 1000 MHz, and is particularly suitable for detecting stone structures, walls, floors and compacted layers or pits, postholes and cavities. If the propagation velocity of the electromagnetic wave is known, the depth of the targets can be estimated based on the time delay of the reflected signal. In Roman sites, the GPR method is typically applied to investigate stone walls, floors, hypocausts and debris layers that are detectable due to the differences in their electrical properties compared to the surrounding medium: in the processed data (see section 4) walls are normally detectable as linear features of high-amplitude reflection, and floors, hypocausts and debris layers as areas of high-amplitude reflection. In the case of a quite well-preserved hypocaust, the acquisition of high-resolution GPR data can result in the punctual detection of the individual pillars.²

Despite the sophisticated technology, the archaeological interpretation of geophysical data remains a complicated task, requiring interdisciplinary knowledge and appropriate tools. The interpretation process is not a linear nor a totally objective process: depending on the background knowledge about the archaeological site (previous excavations, reports etc.), the available tools (software) for the digital mapping and the archaeological background of the interpreter, both the interpretation process and the result (interpretation model) can vary.

In this article we describe the complex process of the archaeological interpretation of GPR data collected a few years ago at the site of the Roman *villa* in Oberlienz-Lesendordf (East Tyrol, Austria). The aim of the GPR prospection was to ‘relocate’ archaeological structures which had been partially investigated in the past and collect more specific information about the site.

Before discussing the specific topic, a short overview of Roman villas in Austria and its neighbouring regions investigated through geophysical methods will be presented.

2. Geophysical Prospections at Roman Villas (Austria and Bavaria)

During the last two decades an increasing number of Roman sites in Austria have been systematically investigated through geophysical methods,³ often by integrating the GPR survey with other geophysical survey techniques such as magnetic⁴ and resistivity measurements.⁵

Attention has often been paid to rural settlements, as in the region of Lake Neusiedl,⁶ which was part of the Roman province *Pannonia*, and in the Salzburg region, the former northwestern *Noricum*. In the latter region, a series of Roman villas have been systematically investigated since the beginning of the 2000s⁷ within cooperation projects involving the Salzburg Museum and archaeological prospection teams.⁸ In the ‘Bavarian’ part of *Noricum* (Germany), a series of Roman rural settlements has been systematically prospected using geophysical methods during the years 2011–2016 as part of a dissertation project at the Ludwig Maximilian University of Munich (LMU), with the support of the Bavarian State Office for Monument Preservation (BLfD);⁹ the surveys provided significant new insights into the organisation and structure of Roman estates west of *Iuvavum*-Salzburg.

Near the Roman town *Flavia Solva*, in southeastern *Noricum* (nowadays the Styria region), geophysical surveys (magnetic and resistivity) conducted in 2007 by the Austrian Archaeological Institute (OeAI) of the Austrian Academy of Sciences (OeAW) contributed to the archaeological investigation of Roman villas by preliminarily detecting subsurface features and thus directing the excavation trenches.¹⁰ More recently, in the above-mentioned region of Lake Neusiedl, the OeAI has re-investigated, by means of geophysical methods, the well-known Roman *villa* of

3 E.g. NEUBAUER et al. 2002. – NEUBAUER et al. 2009. – KASTLER 2015. – DONEUS et al. 2018.

4 The magnetic method, more specifically the gradiometric method, is based on the recording of spatial variations of the Earth’s magnetic field and is usually applied for a preliminary cost-efficient prospection over large areas, before investigating selected areas by means of GPR.

5 While magnetometry investigates magnetic properties, resistivity and GPR measurements mainly investigate electrical properties. The integration of the methods is therefore useful in order to acquire more comprehensive information about the subsurface features.

6 See KASTLER 2015. – DAIM, DONEUS 2018. – DONEUS et al. 2018.

7 See KASTLER 2010. – TRAXLER 2014. – KASTLER 2015. – LANG, TRAXLER, KASTLER 2017. – LÖCKER et al. 2021.

8 ArcheoProspections ZAMG, Vienna, Austria; Posselt and Zickgraf Prospections, Marburg, Germany.

9 KÜHNE, LINCK, FASSBINDER 2013. – LAMBERS 2017.

10 GROH, LINDINGER, SEDLMAYER 2007. – GROH et al. 2008.

1 DAVIS, ANNAN 1989. – CONYERS 2004. – DANIELS 2007.

2 E.g. NEUBAUER et al. 2012. – KÜHNE, LINCK, FASSBINDER 2013.

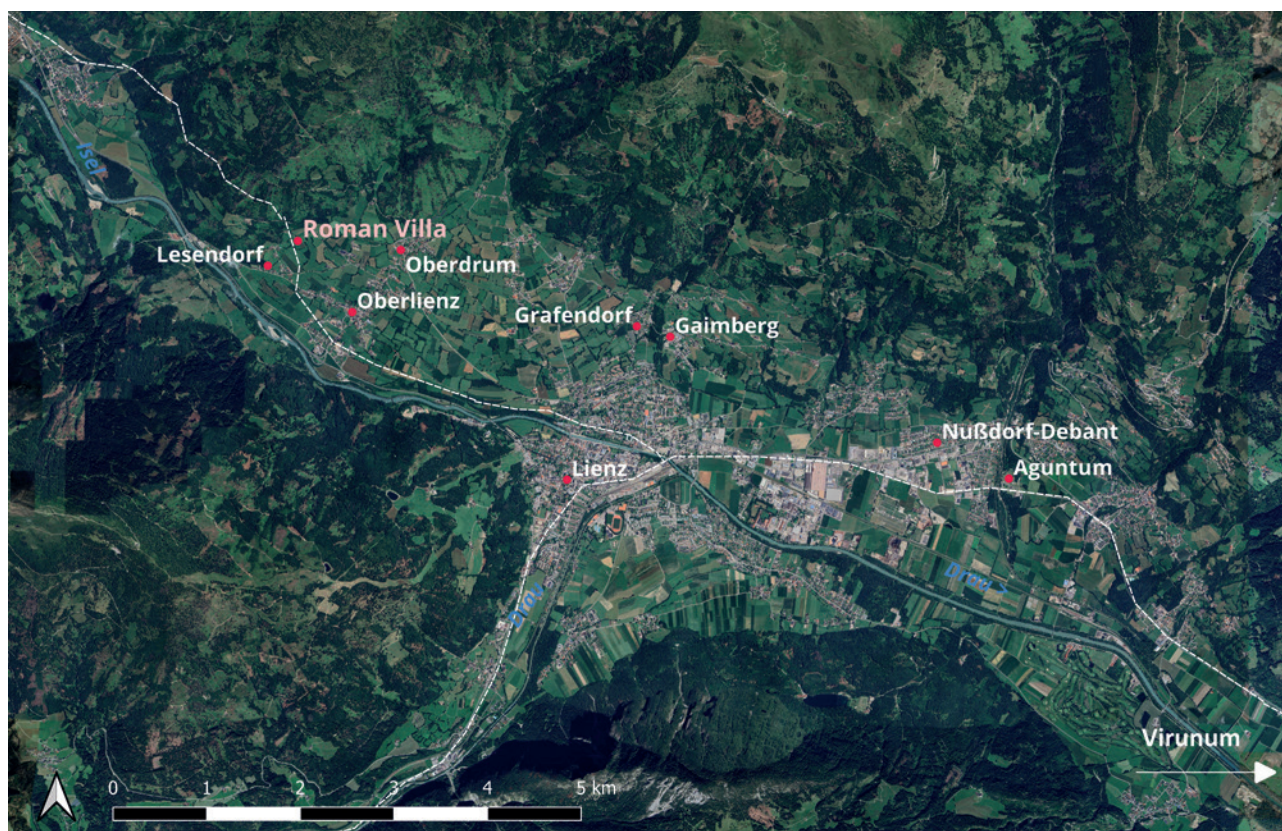


Fig. 1. The 'Lienzer Becken' at the end of the Isel valley. Dashed lines indicate the presumed Roman street system. The ancient roads in the area have not been specifically investigated so far, and their precise location is unknown (Graphics: V. Poscetti).

Bruckneudorf (Burgenland),¹¹ resulting in a reassessment of the entire *villa* complex.¹²

The Roman villas investigated through geophysics in Austria and Bavaria often consist of areas that have already been partially investigated through excavations in the past,¹³ typically between the end of the 19th century and the middle of the 20th century;¹⁴ these areas were usually reburied, often without recording the precise location. Geophysical surveys thus play a key role in allowing us to correctly locate the 'lost' buried structures and to detect 'new' remains, thanks to the possibility to investigate

archaeologically, by means of continuously developing geophysical methods, larger areas compared to those investigated in the past.

3. The Study Area

3.1. The Isel Valley and the Ancient Road System

The study area is located in East Tyrol (*Osttirol*) at the exit of the Isel valley and the transition to the basin known as the Lienzer Becken (Fig. 1). The Isel River rises at the Umbral glacier in the eastern Alps (Umbalkees) at about 2500 m above sea level and ends 4.7 km from the site in the Drau River, an important tributary of the Danube. The site is located on the western side of a large alluvial fan at the foot of the Schleinitz Mountain. For many centuries, the sunny slopes in this area, characterised by brown earth and black earth soils,¹⁵ have offered an ideal location for farming, as shown by dense land divisions and terracing. While the flat land at the Drau-Isel confluence is mostly covered by the urban area of Lienz, small villages characterise the sloping

¹¹ The *villa* of Bruckneudorf (Burgenland) was systematically investigated by the OeAI through archaeological excavations, which took place (with interruptions) from 1931 to 2003. Nowadays the site is being newly investigated by means of geophysics within the research project 'Settlement Archaeology on the Amber Road: The Villa of Bruckneudorf and the Village of the Boii'.

¹² GROH, SEDLMAYER 2022.

¹³ See the *villa* of Bruckneudorf (Burgenland) mentioned above.

¹⁴ Among the *villa* complexes reinvestigated by means of geophysical methods, see also the *villa rustica* in Pfaffing (*Noricum*) in GASSNER, PLOYER 2017, and the *villae rusticae* in 'Bavarian *Noricum*' in KÜHNE, LINCK, FASSBINDER 2013.

¹⁵ See the CORINE Land Cover map: COPERNICUS LAND MONITORING SERVICE 2020.

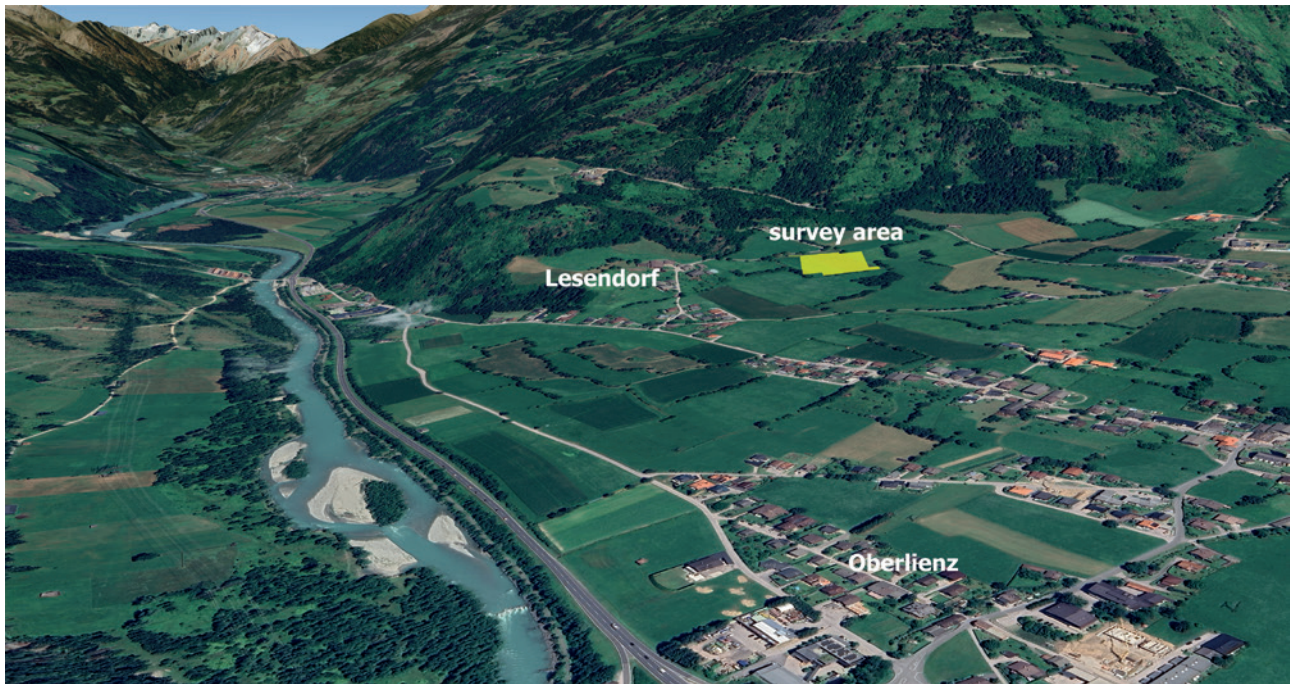


Fig. 2. GPR survey area (in yellow) in Oberlienz-Lesendorf (Graphics: V. Poscetti).

areas on the alluvial fan. The cultivated areas extend from an altitude of about 650 m near the Isel River up to about 1000 m to 1200 m in the upper part of the alluvial fan and the river terraces near Lienz.

In Roman times this area was part of the province *Noricum*, the former Celtic *Regnum Noricum*, which was progressively annexed to the Roman Empire between the end of the 1st century BC and the first half of the 1st century AD. A widely accepted opinion¹⁶ is that the *Regnum Noricum* became a Roman *procuratorial* province under Claudius (AD 41–54), when C. Baebius Atticus is attested as procurator in an honorific inscription.¹⁷ According to ancient sources (Plinius, nat. hist. III 146), five Celtic *oppida* in *Noricum* became *municipia Claudia*, confirming the fact that important administrative changes occurred in this province in the Claudian period.

Without going into details of all the historical aspects that are beyond the scope of this article, we would like to focus on *Aguntum*, one of the five *municipia* mentioned in the sources, which is located 7.5 km southeast of the study area. The remains of the Roman town *Aguntum*¹⁸ are located in

Dölsach-Stribach, c. 4.5 km east of the city of Lienz. Among the visible structures of the Roman town are an impressive gate in the partially preserved city wall,¹⁹ the remains of public buildings, a *macellum*²⁰ and a luxurious house known as ‘the Atrium’.²¹

The Roman *municipium* (*Municipium Claudium Aguntum*) was located in a strategic position near the Drau-Isel confluence and connected to other notable towns like *Virunum* (near Klagenfurt), the capital of *Noricum*, through the west-east main road running through the Drau valley (Fig. 1, dashed line). North of the Drau, the ancient road²² ran roughly along the same route as the modern road. Near the modern town of Lienz, the road branched off. One stretch ran to the east, to *Aguntum* and *Virunum*; the other stretch bent north into the Isel valley. Stephan Karwiese suggests that, based on the topography, the ancient road went up the mountain just north of Lesendorf and then down again into the Isel valley, thereby avoiding the difficult passage along the mountain river in its very narrow valley.²³

¹⁶ ALFÖLDY 1974. – FISCHER 2002. – ŠAŠEL KOS 2010.

¹⁷ ŠAŠEL KOS 2010, 213.

¹⁸ E.g. ALZINGER, TEMPORINI 1977. – ALZINGER 1985. – WALDE 2002. – TSCHURTSCHENTHALER 2007. – WALDE, GRABHERR 2007.

¹⁹ AUER 2008.

²⁰ AUER 2025.

²¹ TSCHURTSCHENTHALER 2002.

²² KARWIESE 1975, 16–18. – HÖCK 2005, 64–66.

²³ KARWIESE 1975, 17, 51.

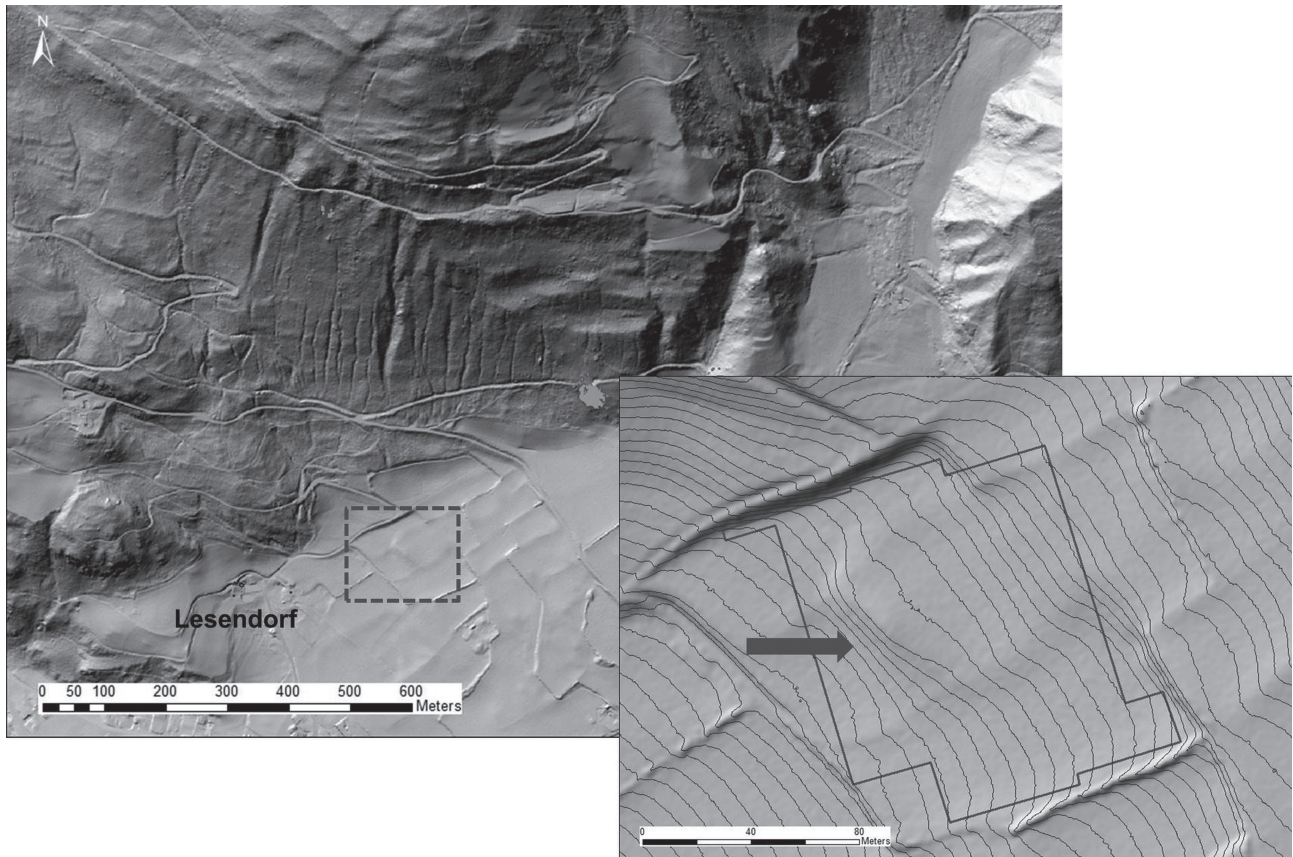


Fig. 3. – Left: The area of interest (dashed line) in the digital terrain model (DTM) (1 m resolution; DTM: Amt der Tiroler Landesregierung). – Right: The survey area in detail. The arrow points out the particular morphology relating to the terracing wall of the Roman *villa* (Graphics: V. Poscetti).

3.2. Archaeological Evidence

Besides the well-known archaeological structures of *Aguntum*, only few Roman remains have so far been attested between *Aguntum* and Oberlienz-Lesendorf (Fig. 1):

In Nußdorf-Debant, about 2 km west of *Aguntum*, the remains of a suburban *villa*, known since the 18th century, were reinvestigated through geophysical prospection²⁴ and excavations.²⁵

Numerous Roman remains which probably belonged to Roman villas²⁶ are known in the Lienzer Becken on the sunny slopes north of the Isel and the Drau, for example at Gaimberg-Grafendorf.

A Roman inscription located in the church of Oberlienz-Oberdrum mentions a mayor of *Aguntum*, clearly attesting to the Romanisation of the area (ILLPRON 1051²⁷).

At the end of the 20th century, excavations unearthed foundations of early Christian buildings with spolia from a Roman grave construction at the churches of Oberlienz²⁸ and Oberlienz-Oberdrum.²⁹

In this reasonably incomplete archaeological context, the discovery of the *villa rustica* complex in Oberlienz-Lesendorf plays a vital role in the interpretation and reconstruction of the archaeological landscape around Roman *Aguntum*.

3.3. The Survey Area in Oberlienz-Lesendorf

Located c. 500 m northwest of the present-day village of Oberlienz in the district of Lienz, the survey area in Lesendorf (Fig. 2) is a sloping portion of land, just exceeding 1 ha and lying on the western slopes of the alluvial cone of Schleinitz, about 7.5 km west of the Roman town of *Aguntum*. The area was partially investigated at the beginning of

²⁴ MÜLLER 2007.

²⁵ MÜLLER, SCHAFFENRATH 2007. – MÜLLER 2008b.

²⁶ HÖCK 2005, 71–74.

²⁷ HAINZMANN, SCHUBERT 1986–1987.

²⁸ SYDOW 1988, 166–172.

²⁹ SYDOW 1995, 393.

Oberlienz-Lesendorf

Archaeological Prospections 2007–2008



Fig. 4. GPR prospection areas superimposed on the aerial image (Aerial image: © Land Tirol).

the 20th century through excavations that discovered the foundations of a Roman building containing hypocausts and mosaic floors.³⁰ Back then, the scholars interpreted the excavated remains as part of a Roman *villa*, but no indication about the presence of other buildings at the site was found in the old report.

The area of the *villa* has traditionally been called *Schlossacker*, probably referencing the presence of the ancient remains.³¹ First excavations were undertaken by order of Prof. Franz von Wieser (1848–1923), director of the prehistoric section of the *Tiroler Landesmuseum Ferdinandeum* in Innsbruck and conservator of the Imperial-Royal Central Commission for the research and preservation of art and historical monuments. Parts of the foundations of the *villa*, hypocausts and mosaic floors were discovered. Unfortunately, these old excavations were not published. The information about this research comes indirectly from the report by two other scholars who investigated the site a few

years later.³² Despite the lack of scientifically documented excavations, the report provides useful information about the buried remains. In particular, the scholars refer to the discovery of a large building, about 30 m long, unearthed for a height of about 0.60 m, equipped with vaulted hypocausts and channels. Floor slabs, pieces of marble, bricks, pottery, pieces of glass and iron objects, mostly belonging to the Roman period, were also discovered during these excavations.

A variety of finds such as tiles, bricks, fragments of oil lamps, pottery including fragments of *terra sigillata* and local pottery, and a gold *fibula*, which is now missing, have been collected at the site over the past century. Most of these finds have been discovered by local people during agricultural works, and no systematic collection was performed. Based on the few documented finds, it has been argued that the *villa* was used over a period of at least 300 years, between the 1st and 4th centuries AD.³³

³⁰ MEYER, UNTERFORCHER 1908, 108–109.

³¹ MÜLLER 2010.

³² MEYER, UNTERFORCHER 1908, 108.

³³ STADLER 1998. – HÖCK 2005, 81.

Nowadays, no traces of old excavations are visible; nevertheless, in the western part of the survey area, the morphology clearly indicates the presence of buried remains (Fig. 3, detail). This area was selected as the location for first GPR measurements.

4. The GPR Surveys

4.1. Data Acquisition and First Processing

The first GPR survey, covering an area of 1250 m² (Fig. 4), was conducted in the summer of 2007.³⁴ These test measurements were produced using a single 500 MHz GPR antenna (PulseEKKO PRO) with a grid spacing of 25 cm × 5 cm. The foundations of a large building were detected, presumably the same building which had been partially excavated in the past. A larger area (12850 m²) was investigated one year later (Fig. 4),³⁵ using two PulseEKKO PRO systems with 500 MHz antennas and the same spatial resolution. The data was collected over eight adjacent areas, resulting in eight datasets that were merged during data processing.

The data processing was executed using the software AP-Mag (ZAMG Archeo Prospections). First, several pre-processing steps were applied to the GPR data: the removal of a constant shift, defining time zero, a band-pass filter with a range of 250–1000 MHz and an average trace removal filter. Afterwards, depth slices of 10 cm were extracted. The depth slices were produced by summing the absolute amplitude values of the reflected waves within a specific time range, which is defined by the desired depth, using an absolute mean velocity taking account of the distance between the transmitting and receiving antennas. For the time-to-depth conversion, a mean wave velocity in the ground of 10 cm/ns was applied, based on the hyperbola fitting. Interpretation of the data could be improved by determining the precise distribution of the velocity in the ground;³⁶ however, calculation of the mean velocity, as mentioned above, represents a practical method, allowing the data to be analysed in terms of penetration depth and depth of the targets, albeit with some approximation.

The data processing resulted in the production of five series of amplitude maps, each of them corresponding to a specific depth slice thickness (0.10 m, 0.20 m, 0.30 m, 0.40 m, 0.50 m). The single amplitude maps have been georeferenced based on geodetically surveyed control points. In figures 5a–7a the most significant 0.50 m depth slices are shown. Despite the sloping terrain, the first data

processing did not include any topographic correction of the GPR data.

Only small amounts of instrumental noise can be noted in the data, yielding good-quality data that enabled the detection of fine structures and sub-20 cm horizontal mapping accuracy. The soil, developed on parent sand and gravel, allowed for good signal penetration. The archaeological structures are readily visible in the GPR data, starting from about 0.50 m below the surface (Fig. 5a) down to about 2 m (Fig. 7a), where the foundations of the Roman structures seem to be located.

4.2. The Initial GIS-Based Archaeological Interpretation (2009)

The initial interpretation of the data (Figs. 5b–7b) was conducted in 2009 by Wolfgang Neubauer (University of Vienna) in cooperation with Florian M. Müller (University of Innsbruck) applying ESRI ArcGIS. The interpretative mapping was based on the visual inspection of 0.50 m depth slices, as shown in figures 5–7. The 0.20 m depth slices were also analysed in order to detect small details (thin features) more effectively. The global interpretation of the complex is shown in Figure 8. In the following paragraphs, we summarise the results of this initial work.

A group of buildings (Fig. 8/A–D) with variable dimensions surround a large courtyard of about 40 m × 40 m. Most of the detected structures are located in the depth range of 0.50 m to 1.50 m (Figs. 5a–b and 6a–b), where main walls, internal partition walls and floor layers are best detectable. In the shallowest depth levels (depth range 0.50 m to 1.00 m), in the northern part of Building A, traces of an extensive excavation have been detected (Fig. 5b, disturbance); these are most likely related to the old archaeological dig from the beginning of the 20th century.

Among the three main building blocks (A, B and C), buildings A and C have been interpreted as the remains of two main houses. Building A, about 45 m long by 12 m wide and located in the western part of the survey area, has several rooms of different sizes, ranging from around 10 m² to 20 m². The building is supported to the west by a massive terracing wall. A reflective compacted layer of about 3 m width along the eastern side of the building is interpreted as the remains of a *porticus* protruding into the big courtyard (Figs. 6a–b). On the western side of the building, a linear anomaly of approximately 20 m in length (running parallel to the main axis of the building) has been detected about 5 m from the terracing wall, and this is interpreted as the remains of a second *porticus* (Fig. 5b); however, the slightly different orientation of this anomaly to the main axis of the building could suggest the alternative

³⁴ MÜLLER 2008a.

³⁵ MÜLLER 2009.

³⁶ CONYERS 2004, 12–13. – LECKEBUSCH 2007. – VERDONK 2012, 198.

Oberlienz-Lesendorf

Archaeological Prospection 2008



Oberlienz-Lesendorf

Archaeological Interpretation



Fig. 5. – a. GPR depth-slice 0.50–1.00 m (Background: aerial image from © Land Tirol). – b. Archaeological interpretation (2009) of the GPR data in the 0.50–1.00 m depth range (Graphics: W. Neubauer, V. Poscetti).

Oberlienz-Lesendorf Archaeological Prospection 2008



Oberlienz-Lesendorf Archaeological Interpretation



Fig. 6. – a. GPR depth-slice 1.00–1.50 m (Background: aerial image from © Land Tirol). – b. Archaeological interpretation (2009) of the GPR data in the 1.00–1.50 m depth range (Graphics: W. Neubauer, V. Poscetti).

Oberlienz-Lesendorf Archaeological Prospection 2008



Oberlienz-Lesendorf Archaeological Interpretation



Fig. 7. – a. GPR depth-slice 1.50–2.00 m (Background: aerial image from © Land Tirol). – b. Archaeological interpretation (2009) of the GPR data in the 1.50–2.00 m depth range (Graphics: W. Neubauer, V. Poscetti).

Oberlienz-Lesendorf

Archaeological Interpretation 2009

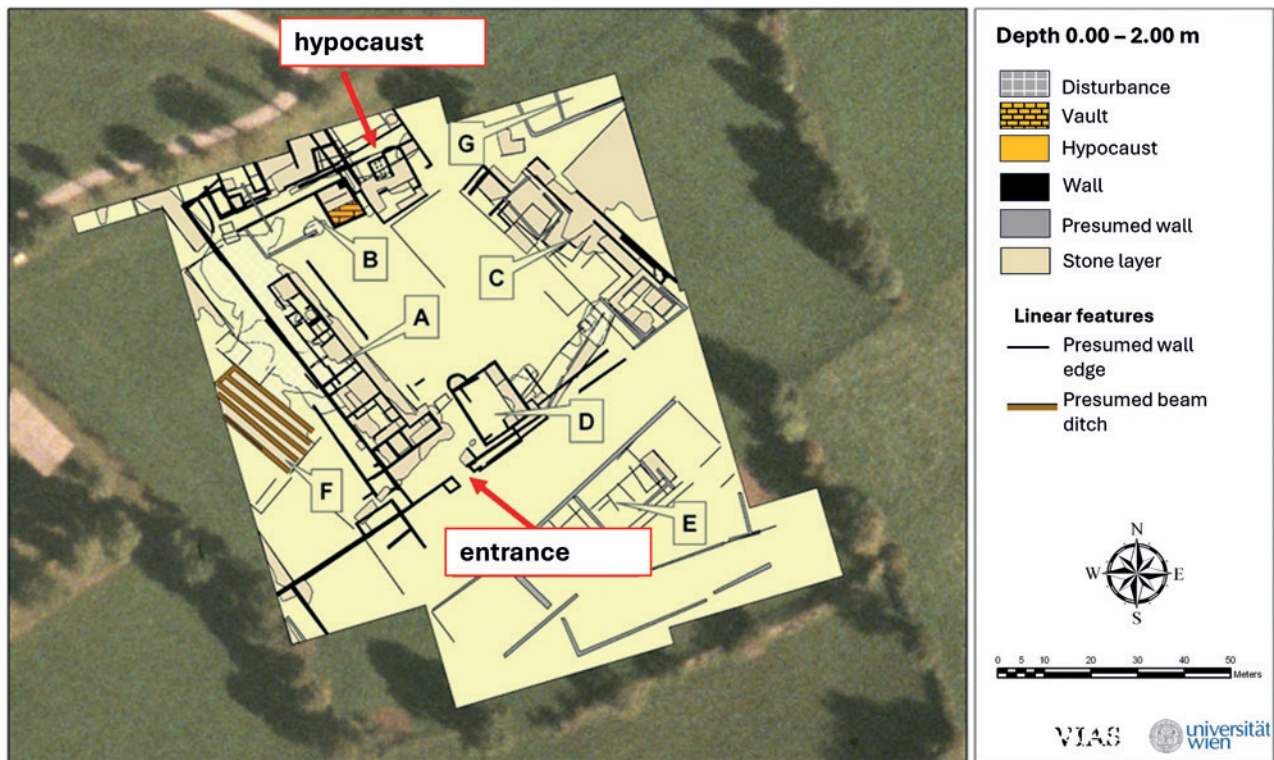


Fig. 8. Global interpretation with mapping of all structures detected through GPR (Graphics by W. Neubauer with additional annotations).

hypothesis of a structure from a different phase. Building C, in the eastern part of the *villa*, is poorly preserved. The observable layout of debris layers (Figs. 5a and 6a) and linear features (presumed wall edges) suggests the remains of a winged *porticus villa* (*Porticus Villa mit Eckrisaliten*³⁷) with two protruding rooms of c. 10 m × 10 m each in the northern and southern parts of the block (Figs. 5b and 6b; see also the semi-reconstructive map in Fig. 14).

In the northern part of the prospected area, Building complex B (Fig. 8/B) shows many intersecting structures with slightly different orientations that are probably from different phases. The remains of a bath with hypocaust (Fig. 8) were clearly detected in the range of 1.00 m to 1.20 m (Fig. 9). A thick reflective layer west of the bath is probably related to a room with a vaulted cellar (maybe a kitchen) (Fig. 8, vault). Building complex B was supposed to be the ancillary part of the *villa*. Building D, about 10 m × 10 m and located in the central part of the prospected area, has an apse in the northwestern corner. The function of this building

has not been defined in the initial interpretation. A plausible interpretation will be given in section 7.3.

The enclosure wall of the *villa* is partially visible as a strong linear anomaly oriented northeast/southwest in the southern part of the complex. It extends beyond the investigated area, indicating that the *villa* covered at least 1 hectare. The detected wall has a gap corresponding with a squared structure, interpretable as a tower, indicating this point as a probable entrance (Fig. 8).

On the borders of the survey area, outside the main complex of the *villa* (southern and northeastern part of the survey area), a series of linear features with high reflection amplitude are visible in the GPR data (Fig. 8/E, G), but interpreting these as building remains of the *villa* is difficult due to the limited investigation area. An unusual area (Fig. 8/F and Fig. 5a) in the western part of the site measuring about 24 m × 9 m, shows a series of parallel bands (c. 2 m in width) of high reflectivity. These anomalies have been interpreted as the foundations of a typical historical timber hayloft.

5. Topographic Correction and Improved Data Analysis

To improve the interpretation of the GPR dataset, we applied a topographic correction, which was not included in

³⁷ See TRAXLER, KASTLER 2010.

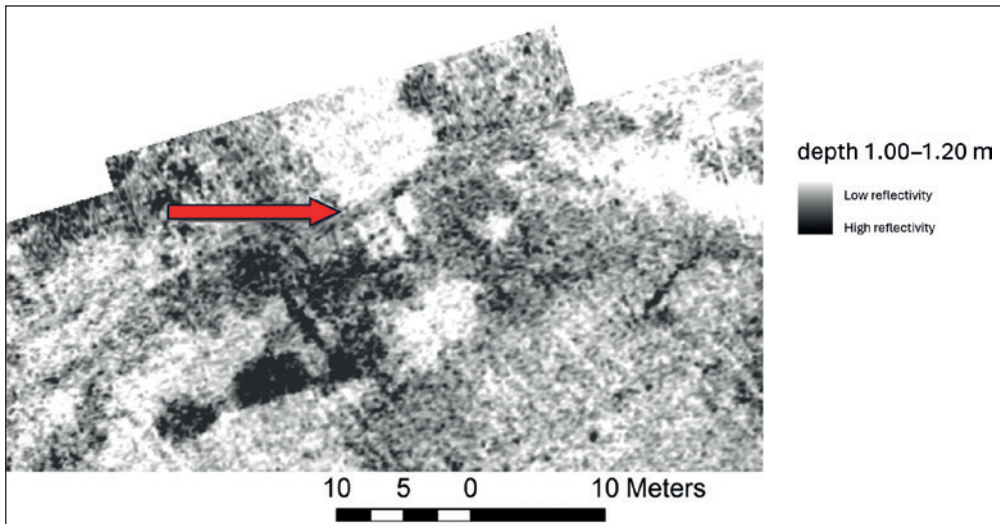


Fig. 9. Detail of Area B in the *villa* complex with the remains of the bath with hypocaust; depth range 1.00–1.20 m (Graphics: V. Poscetti).

the initial data processing (section 4). For the topographic correction, the digital terrain model (DTM) available with a resolution of 1 m from the *Landesamt der Tiroler Landesregierung* was used. Figure 10 shows the sequence of depth slices with topographic correction.

For the first data analysis of the datasets in ESRI ArcGIS 10.2, depth slice animations have been applied.³⁸ In this specific case, both topographically corrected and non-corrected data are loaded into two raster catalogues within a file geodatabase and visualised in ArcMap. An optional property of an ArcGIS raster catalogue is using image time in the form of a calendar date, commonly applied to observe changes in a sequence of conventional aerial imagery. By enabling time in the raster layers, the sequence of GPR amplitude maps within the raster catalogues can be displayed dynamically and interactively by operating the ‘time slider tool’. In the case of GPR depth slices, the sequence of raster images does not show changes in time but rather changes in depth, i.e. the main changes in the archaeological stratification. The temporal attribute stored in the raster catalogue is thus used as a spatial component representing the depth used for the animated visualisations. The use of raster catalogues and respective animations within ArcMap facilitates efficient visual inspection of the data and allows a rapid comparison between the two different datasets.

In the western part of the survey area, where the terrain slopes dramatically, the topographically corrected data provides an improved depiction of Building A, making it

easier to distinguish between floor levels and foundations (Fig. 11). Hypocausts that remained unnoticed in the initial interpretation (section 4.2) have shown up (Fig. 11a). The detection of hypocausts entirely agrees with the old report,³⁹ in which the authors mentioned the discovery of the foundations of a large building provided with mosaic floors and hypocausts. It now seems apparent that they were referring to Building A. The traces of a large excavation trench detected by the GPR in this area further confirm that fact. In other parts of the investigated area, where the topography is flatter, the topographically corrected data do not provide essential additional information. Only in the bath are we also able to identify a few hypocaust pillars that remained undocumented in the first interpretation (in addition to the hypocaust pillars that were also initially mapped).

The detection of an individual hypocaust’s pillars in the GPR data mainly depends on the high resolution of the GPR survey; since the last 10–15 years, multichannel GPR systems have allowed rapid data collection with centimetric spatial resolution (e.g. 0.08 m × 0.04 m), enabling the detection of hypocaust pillars in Roman sites with unprecedented detail.⁴⁰ Even though the GPR survey in Oberlienz-Lesenddorf was conducted in a ‘traditional way’ using single antenna systems, the spatial resolution applied enabled satisfactory detection of pillars.⁴¹

³⁹ MEYER, UNTERFORCHER 1908, 108–109.

⁴⁰ E.g. NEUBAUER et al. 2012.

⁴¹ For a similar application, see, for example, KÜHNE, LINCK, FASSBINDER 2013.

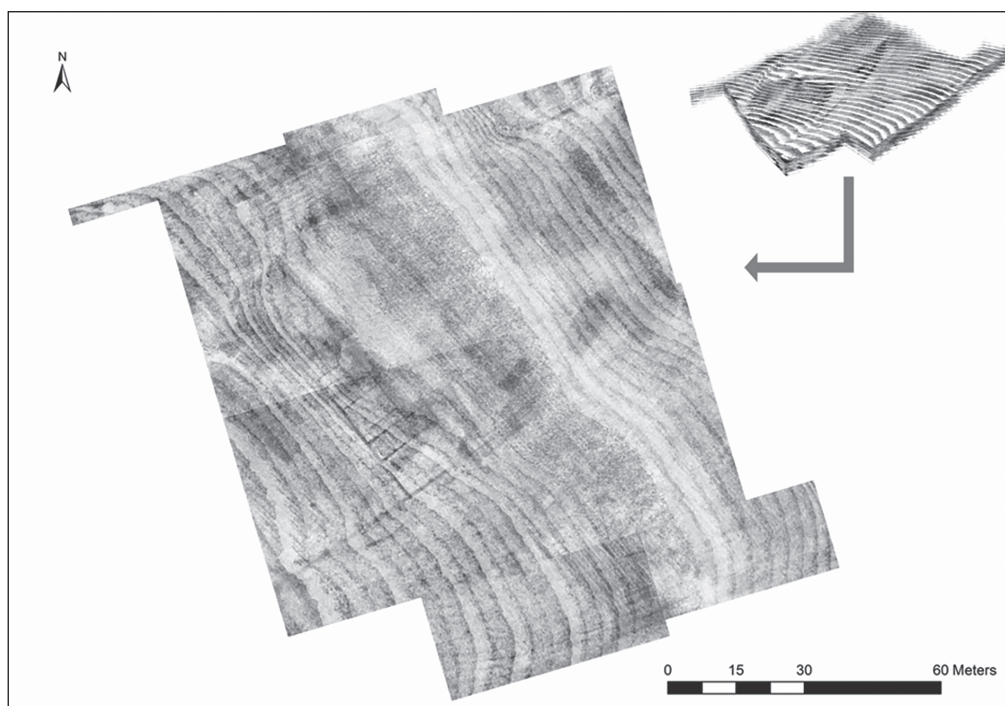


Fig. 10. GPR data with topographic correction. The map shows the data displayed in ArcMap; for each layer a transparency of 70 % has been applied. The main structures of the western building are relatively visible. Other structures are more difficult to detect due to the superimposing of layers. The subsurface structures can nevertheless easily be detected by applying a layer animation. – Above right: The images are displayed in ArcScene with the appropriate base height for each layer (Graphics: V. Poscetti).

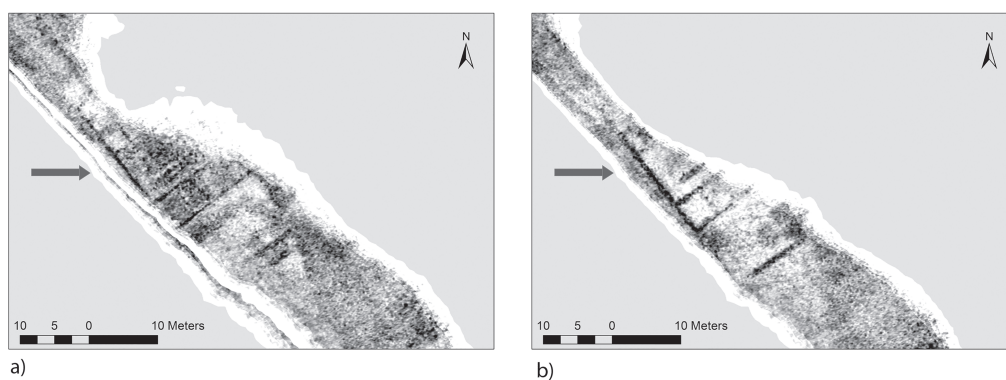


Fig. 11. Area of Building A: the topographically corrected data are visualized in ArcScene. The hypocaust level (a) and the foundation level (b) are easily distinguishable (Graphics: V. Poscetti).

6. The GIS-Based 3D Archaeological Interpretation

6.1. The Interpretative Mapping Approach

The conventional GIS-based archaeological interpretation of geophysical data as first outlined by Neubauer⁴² and applied for the initial interpretation of the GPR data from Oberlienz-Lesendorf is conducted in a 2D mapping environment

(e.g. ArcMap) by mapping all the relevant features detected in the data with lines and/or polygons. In particular, for GPR data,⁴³ the interpretative mapping is conducted on different layers, based on the visual inspection of a series of 2D amplitude maps that are imported into a GIS project in the form of stacks of geo-referenced raster images (geoTIFF). To achieve

⁴² NEUBAUER 2001, 160–176.

⁴³ NEUBAUER et al. 2002.

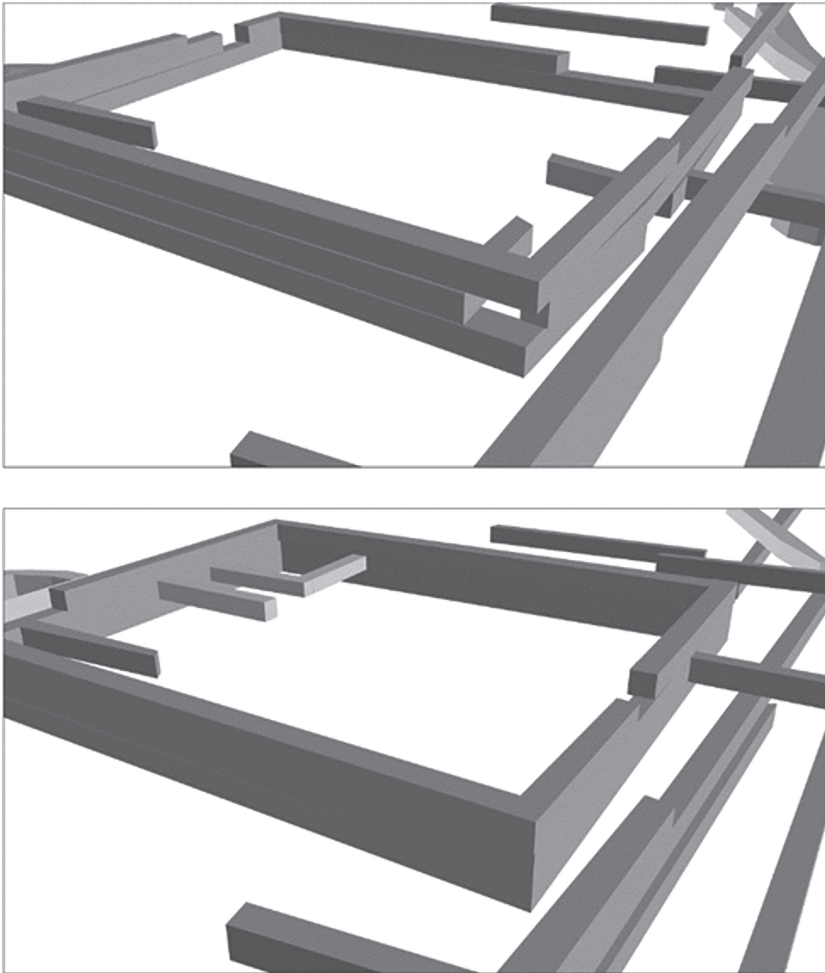


Fig. 12. – Above: Building D of the *villa* in the initial interpretation (2009). – Below: Improved 2.5D model after graphic corrections. Images with a vertical exaggeration of 1.5 (Graphics: V. Poscetti).

a 3D visualisation, in the form of a 2.5D model of the buried remains, the polygons are extruded vertically in the ESRI ArcGIS 3D environment ArcScene, which is usually only used as a display environment. In general, no reconstructive hypotheses are included in the GIS-based interpretative mapping. Also, in those cases where the applications are specifically focused on the 3D interpretation,⁴⁴ the interpretative mapping is confined to the visualisation of the detected anomalies and does not include the virtual reconstruction of building complexes, which is generally considered a separate process.⁴⁵ In our approach we have combined the two processes by developing an efficient workflow for the editing and integration of 3D models within the GIS environment.

⁴⁴ LECKEBUSCH, WEIBEL, BÜHLER 2008. – VERDONCK 2012. – VERDONCK 2016.

⁴⁵ NEUBAUER et al. 2014.

The ESRI ArcGIS 3D environment becomes the fundamental visualisation and editing environment in which 3D polygons and 3D objects, known as multipatch features, are used to represent, investigate and document the 3D archaeological structures more comprehensively and intuitively.

6.2. The 3D Interpretative Mapping Process in ArcScene

The new interpretative mapping in ArcScene is derived from the visual inspection of both topographically corrected and non-topographically corrected data added to the ArcScene project on individual layers, for each of which an appropriate attribute representing the base height of the GPR depth slice is set. Integrative use of non-topographically corrected data is required to provide an overall view of the subsurface features. Layer animations were applied to the series of raster images to dynamically analyse the GPR data, similar to the preliminary data analysis in ArcMap.

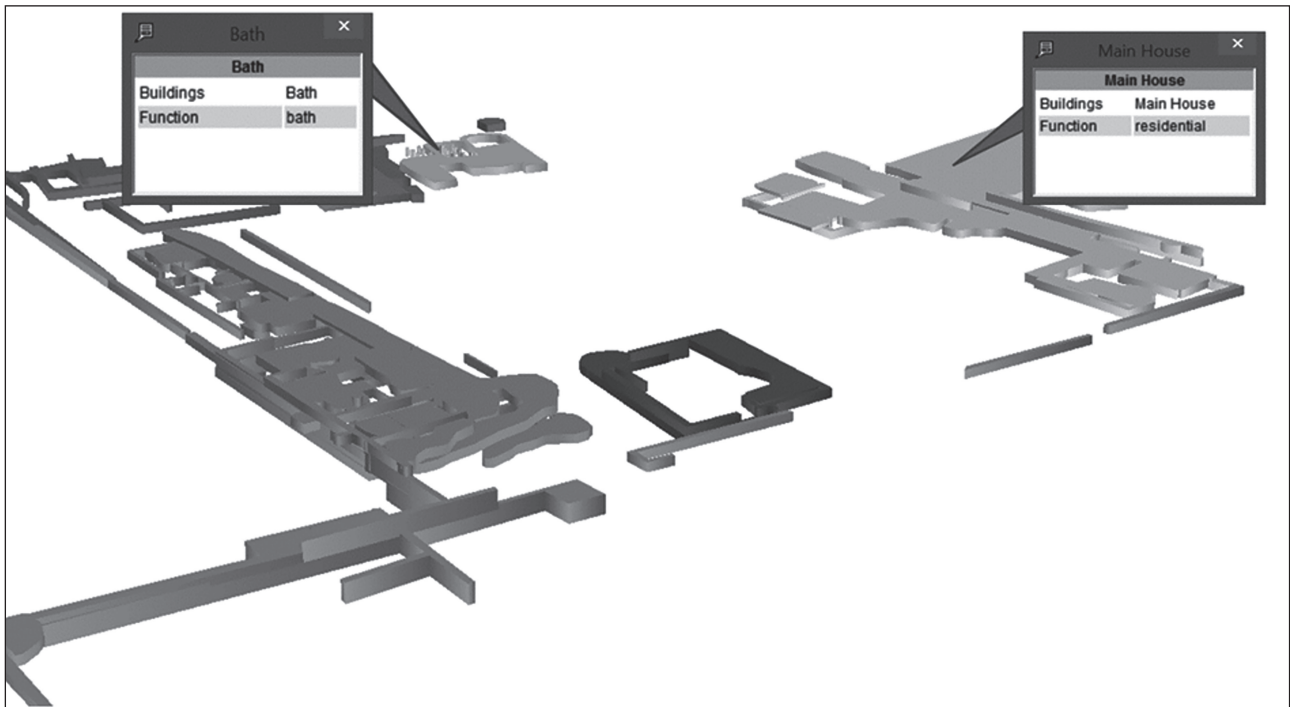


Fig. 13. True 3D model after conversion of the extruded polygons into multipatch features (MP). In this case every building is represented by one MP feature. The model can be explored interactively by means of HTML popups (Graphics: V. Poscetti).

To perform an efficient mapping in the 3D GIS environment, an ESRI file geodatabase including features classes with predefined fields and domains has been used. The available data from the initial interpretation in 2009 were amalgamated into the new ArcGIS project and modified to fit with the new approach. In a first step, the initial data, which were stored as 2D polygonal features in different shapefiles, are converted into 3D polygons. The conversion into 3D polygons allows for more flexibility in the representation of the 3D subsurface structures, as it allows for the extrusion of the vertices of the features in the z-direction. The polygonal data were then imported into the structured file geodatabase and edited in accordance with the new GPR data analysis.

In the initial data interpretation, the features were exclusively classified by typology. To improve the classification, new attributable information like the preservation height (extrusion), function and relative chronology (phase) were added to the database's predefined fields and domains. Compared to the initial mapping in 2009, which had exclusively focused on a primary level of classification distinguishing between walls, pillars, stone layers, etc., the improved classification of the buried features allowed thematic maps to be created at a hierarchical set of classification levels for the interpretative mapping process. The hierarchy that was developed ranged from the basic interpretation of individual anomalies to individual archaeological structures,

rooms and buildings right up to the global level relating to the function of the different buildings.

Graphical errors like misalignments and redundant polygons in the initial interpretation were corrected in ArcScene using the 3D editing tool. In the new concept, a single structure like a wall is typically represented by only one polygon, which is drawn at the base of the wall and extruded to match its estimated preservation height, independent of the thickness of the depth slices. This represents a more intuitive way of mapping the features, resulting in a cleaner and more readable 3D visualisation of the buried structures (Fig. 12).

Finally, extruded polygons were converted into 3D multipatch features utilising the 'layer 3D to feature class' geoprocessing tool to create a true 3D model of the buried remains of the Roman *villa* (Fig. 13). While it seems that there is no visual difference when using these 3D objects compared to the extruded 2.5D models, we nevertheless create multipatch features for the following reasons:

- To achieve a simplified 3D model in ArcGIS in which each building is represented by one 3D object instead of a set of 2D extruded polygons. This allows for a practical and intuitive interactive investigation of the interpretative model.
- So that we have the possibility to integrate reconstructive 3D models (untextured and textured) created in other 3D environments (e.g. 3D Studio Max).

7. Comparisons and Reinterpretation

7.1. General Layout and Residential Buildings

Beside the technical aspects described above, the reinterpretation of the GPR data from Oberlienz has also required more in-depth comparisons with other case studies of Roman villas in *Noricum*⁴⁶ and the neighbouring regions.

The general layout of the *villa* in Oberlienz-Lesendorf can be reinterpreted as a so-called *Streubauhof*⁴⁷ in which the main house and ancillary buildings are, more or less, spread irregularly about the farmyard, as known in most parts of *Noricum*⁴⁸ as well as in the neighbouring province *Raetia*.⁴⁹

A crucial aspect of our case study is represented by the remains of the two buildings (A, C), both interpreted as ‘main house’ in the initial interpretation, located on the western and eastern sides of the courtyard, respectively (see Fig. 8/A, C). Due to the limits of the prospection area and the presence of destruction layers from old excavations, the archaeological interpretation of both buildings, in terms of comparative examples, is difficult.

Looking at Building A, it has already been observed, based on the dimensions and the presence of excavation traces in the area, that the detected remains very probably correspond to the building excavated in the past (see 4.2). Moreover, the reinterpretation of the data, based on topographic correction (Figs. 10–11), further supports the hypothesis due to the hypocausts detected within the building, which were also documented in the old reports, as well as mosaic pavements. Unfortunately, we do not have the excavation plan from that period to directly compare our digital interpretive mapping with the excavated remains; however, all the elements considered above (i.e. the general layout, dimensions, hypocausts and the destruction layer from the excavations) make the correspondence quite certain. On the other hand, both the detected hypocausts and the mosaics documented in the old report, make the residential function of the building quite evident.

Despite the readable function, the specific layout of building A, in terms of its architectural typology, is not entirely apparent: assuming an elongated building about 40 m long and 12 m wide with a *porticus* to the eastern side, as supposed in the initial interpretation (see section 4.2 and Fig. 6b), no directly comparable examples

have been found within the limits of our research. Only a few examples from *Noricum* partially recall the interpreted layout of Building A. These are the main building in the *villa* in Baar-Unterbaar (Bavaria),⁵⁰ with rooms arranged along a 46 metre-long and 3.5 metre-wide corridor, and three buildings with an elongated rectangular floorplan and rooms of variable dimensions, also in northwestern *Noricum*.⁵¹ However, the latter three examples refer to buildings of smaller dimensions, without a *porticus*, and their identification as the main building is presented by the authors as uncertain.

On the other hand, an alternative hypothesis for Building A, designating it as a larger compact building block (by imagining a possible extension to the southwest), for which we could maybe find more comparisons, is unlikely due to the presence of the terracing wall, presumably defining the limit of the building on the western side. Moreover, no structures clearly assignable to Building A have been detected west of it, except for a few linear features, initially interpreted as a second *porticus* (see section 4.2), but more likely representing structures from different phases and/or with a different function (canals?).

The southeastern corner of Building A seems to have a small protruding wing attached, suggesting the hypothesis of a similar structure on the opposite corner,⁵² within the detected ‘destruction area’, and thus probably not preserved. A hypothetical partial reconstruction of Building A’s floorplan is shown in Figure 14.

The layout of Building C, on the other side of the *villa* complex, is, apparently, even more difficult to understand due to the bad state of conservation and the limits of the prospection area; however, the shape and dimensions of the highly reflective layers, very probably from stone and/or debris layers of the building, allow its interpretation (see also section 4.2) as a ‘typical’ winged main house, the so-called *Porticus Villa mit Eckrisaliten* known from many examples in *Noricum*⁵³ and *Raetia*.⁵⁴

Specifically referring to *Noricum*, three different types of winged buildings have been observed.⁵⁵ The first type relates to portico villas with a compacted architecture (block-like) and corner rooms (*turmartige Risaliten*) aligned with the façade *porticus* or slightly protruding. This type of

46 See TRAXLER, KASTLER 2010 for a systematic classification of Roman villas in northwestern *Noricum*.

47 REUTTI 1995. – LENZ 1998. – TRAXLER, KASTLER 2010.

48 E.g. TRAXLER, KASTLER 2010, 233. – KASTLER 2015. – LAMBERS 2017.

49 E.g. FISCHER 1990. – CZYSZ et al. 1995. – SORGE 1999.

50 KAINRATH 1998.

51 TRAXLER, KASTLER 2010, 242 and Fig. 7/10–12.

52 Regarding main-houses with lateral wings, see later in the text.

53 TRAXLER, KASTLER 2010, 234–239. – GASSNER, PLOYER 2017. – LAMBERS 2017.

54 CZYSZ et al. 1995.

55 TRAXLER, KASTLER 2010, 234–239.

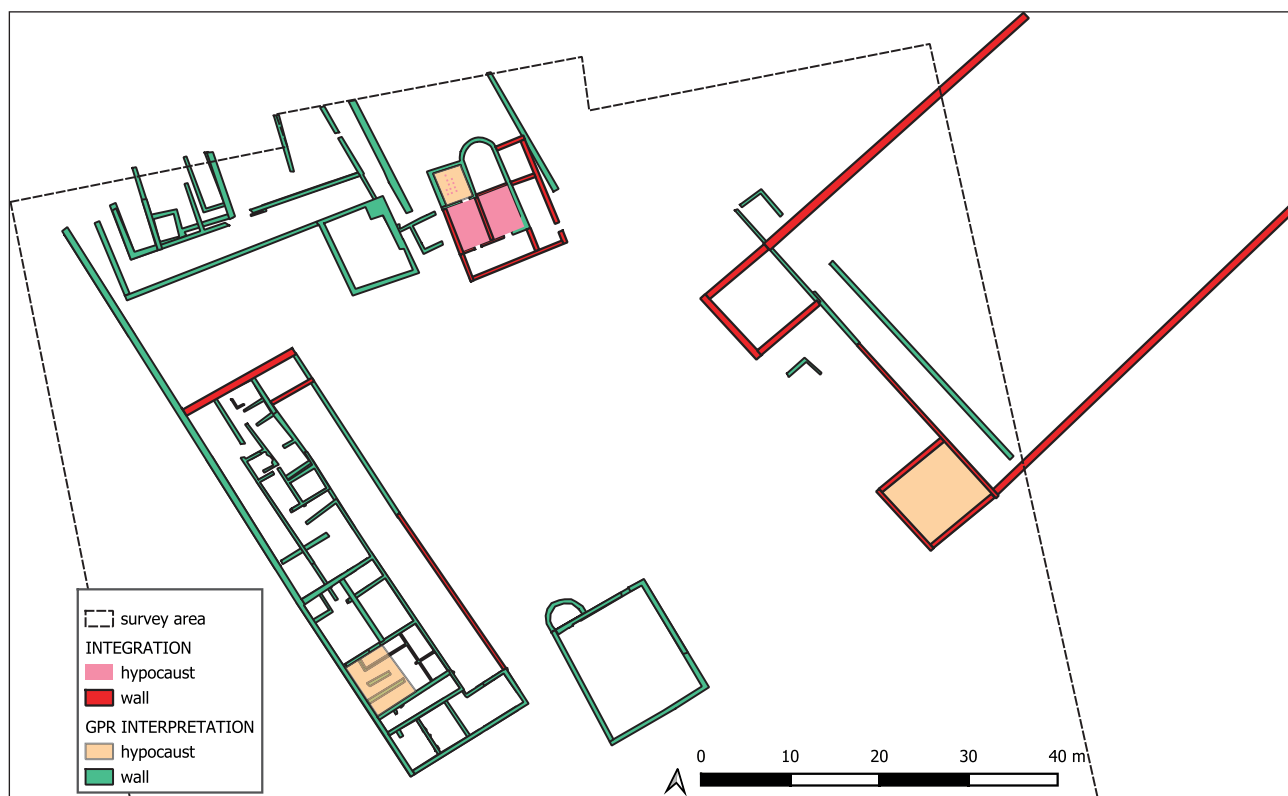


Fig. 14. Semi-reconstructive interpretation model of the *villa* complex (Graphics: V. Poscetti).

building generally has a squared open or roofed courtyard (hall). Some examples⁵⁶ were documented in Holzhausen, Lederau, and Goldegg. The second type consists of buildings with a rectangular shape and protruding wings like the *villa* in Salzburg-Liefering⁵⁷ and that in Pfaffing-Haushamer Feld.⁵⁸ The third type also shows protruding wings but has a more open layout.⁵⁹

More recently,⁶⁰ a reinterpretation, based on both old excavation data and new prospection data, of a series of Roman villas in the Bavarian part of former *Noricum* has provided new insights into the specific topic: within a wide heterogeneity of building typology, a predominant layout has nevertheless been identified for the main houses, i.e. an elongated rectangular building, normally with hypocausts within the lateral wings, with a tripartite layout behind the building's front, including internal courtyards.

Based on all the considerations above, the layout of Building C has been reinterpreted in a semi-reconstructive way (Fig. 14):

The large and strongly reflective layer behind the supposed building's front (see above, Figs. 5a–b) indicates the probable extension of the house in the northeast direction, in the unexplored area; considering the massive reflective layer, a collapsed roof from a roofed courtyard could be supposed. The hypothesis of a roofed courtyard has been presumed for the Lederau *villa*,⁶¹ even though this is not the only possibility. Moreover, we may suppose that the strongly reflective layer within the southeastern corner room of Building C could relate, at least partially, to the remains of a hypocaust, even though individual pillars are not detectable in the GPR data.

Without further investigations, we cannot say if the house had a squared or an elongated shape. Assuming the possible presence of a roofed courtyard, the first hypothesis would possibly be more likely;⁶² in the case of an open courtyard, both solutions could be presumed.

⁵⁶ TRAXLER, KASTLER 2010, Fig. 3.

⁵⁷ TRAXLER, KASTLER 2010, Fig. 4.4.

⁵⁸ GASSNER, PLOYER 2017.

⁵⁹ TRAXLER, KASTLER 2010, Fig. 6.

⁶⁰ LAMBERS 2017.

⁶¹ See TRAXLER, KASTLER 2010, 234 and Fig. 3/2 (Lederau).

⁶² See TRAXLER, KASTLER 2010, 234.

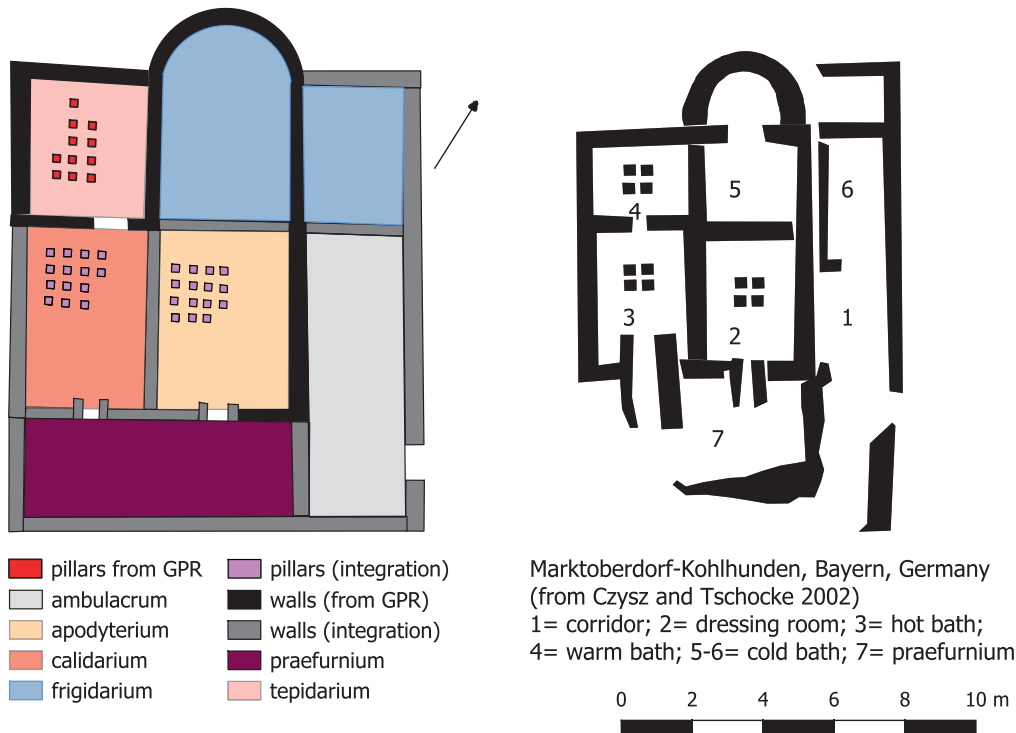


Fig. 15. – Left: Interpretative planimetric reconstruction of the bath in Oberlienz-Lesendorf. – Right: The excavated remains of the bath of the Roman *villa* in Marktoberdorf-Kohlhunden, Bavaria, Germany (from CZYSZ, TSCHOCKE 2002, slightly modified; graphics: V. Poscetti).

7.2. Two Main Houses in the *villa* Complex

The presence of two main houses within a *villa rustica* has been documented, in *Noricum*, in the northwestern area, in particular in Pfongau II,⁶³ Glas,⁶⁴ Liefering⁶⁵ und Kerath.⁶⁶ In the Bavarian part of the province a series of rural complexes with two residential buildings have also been identified.⁶⁷ Generally, one of the two buildings is larger and is assigned, assuming contemporaneity, to the owner, the smaller one being assigned to the manager (*vilicus*). Besides the size, additional factors, typically including a better location (higher) on the ground, can identify the building as the owner's house. Further hypotheses to explicate the presence of two 'main houses' within a *villa* relate to a possible 'communal property' of the Roman *fundi*⁶⁸ or to the possible use of one of the two buildings as a *taberna* or *mansion*.⁶⁹ However, at the current state of the research,⁷⁰ the contemporary use

of two main buildings within the *villae rusticae* in western *Noricum* has still not been verified through excavations. Alternatively, the two main houses can be interpreted as buildings from different phases of the rural complex.

As mentioned above, similar hypotheses can be proposed for the two main buildings in Oberlienz-Lesendorf. Considering the long life of the *villa*, between the 1st and the 4th century AD (see above, section 3.3), we can assume that the two main houses were not built at the same time; on the other hand, we can suppose that at some point between the 1st and the 4th century AD, both buildings were in use simultaneously. In other words, even assuming the non-contemporaneity of the two main houses, their contemporary use by the owner and the manager, respectively, cannot be excluded. Unfortunately, at the current state of the research, we do not have any direct information about the archaeological stratigraphy at the site which could clarify the dating and phasing of the remains. Lacking excavation controls, the hypotheses mentioned above cannot be verified.

7.3. Bathhouse and Ancillary Buildings

On the remains of the bath in Building complex B (see Fig. 8), the following observations can be made:

The bath has a slightly different orientation compared to the adjacent structures. This seems to indicate that it was

⁶³ KASTLER et al. 2010.

⁶⁴ WERNER, ZICKGRAF 2014.

⁶⁵ HELL 1968. – TRAXLER, KASTLER 2010, 234.

⁶⁶ RIES 2015.

⁶⁷ KÜHNE, LINCK, FASSBINDER 2013. – LAMBERS 2017.

⁶⁸ KASTLER et al. 2010, 99.

⁶⁹ HELL 1968, 345.

⁷⁰ LAMBERS 2017.

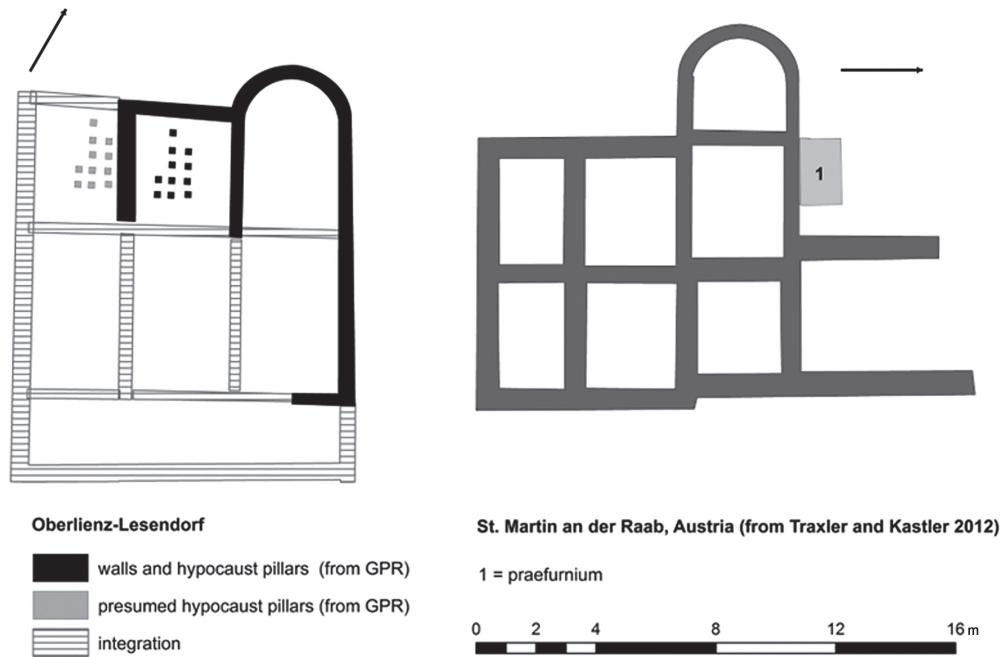


Fig. 16. – Left: Alternative interpretative planimetric reconstruction of the bathhouse in Oberlienz-Lesendorf. – Right: The bath of the Roman *villa* in St. Martin an der Raab, Austria (from TRAXLER, KASTLER 2012; graphics: V. Poscetti).

an independent block (sc. block type) as known from many other examples.⁷¹

Only an apsed room and a rectangular room of the bath are clearly visible in the GPR data; the latter room has hypocaust pillars. Traditionally, in Roman baths we expect to have at least three rooms (*apodyterium*, *tepidarium*, *caldarium*) with a hypocaust and one room for the cold bath (*frigidarium*). Probably, most of the partition walls and pillars of the bath are not preserved or cannot be detected by the GPR.

Comparing this specific case with the similarly designed excavated bath at Marktoberdorf-Kohlhunden⁷² in Bavaria allows for a plausible reconstruction, as shown in Figure 14 and, in more detail, in Figure 15. However, by considering the high variability of the layout of baths in the Roman *villae*,⁷³ alternative hypotheses can be put forward. In Figure 16 we propose an alternative reconstruction of the bath's ground plan, considering that a few hypocaust pillars seem to be detected west of the well-detected rectangular room in the latest data analysis. The latter interpretative

reconstruction is based on the comparison with the bath in the Roman *villa* in St. Martin an der Raab⁷⁴ (Burgenland, former *Pannonia*).

For the presumed kitchen with vaulted cellar near the bath (see section 4.2 and Fig. 8), it is difficult to find analogies. Kitchens, like any other ancillary structures, are among those buildings that are more difficult to detect and interpret because of their uncharacteristic structure (generally a simple squared building) and a location often far away from the main buildings.

Among the structures detected in the northern part of the survey area, most of them are also very difficult to interpret due to the probable stratification of different phases and the limits of the prospection area. Even though it is quite impossible to define the stratigraphic sequence based exclusively on GPR data, we have tried a speculative 'phasing map', mainly based on the different orientation and/or 'illogically' intersecting walls (Fig. 17).

Finally, we presume a multiphase building with different functions like a secondary house and/or a bath for Building D (see Figs. 8 and 18). According to the initial archaeological interpretation, this building probably had an apsed room.

⁷¹ E.g. TRAXLER, KASTLER 2010, Fig. 8. – TRAXLER, KASTLER 2012.

⁷² CZYSZ, TSCHOCKE 2002.

⁷³ See TRAXLER, KASTLER 2012.

⁷⁴ POCHMARSKI 2011. – LAMM, MARKO 2012, Fig. 3/3.7.



Fig. 17. 'Phasing map' of wall structures in the northern area; the classification by phases, indicated by different colours, does not correspond to a specific chronology; in fact, it would be very arduous to reconstruct even a mere relative chronology if working only with GPR data (Graphics: V. Poscetti).

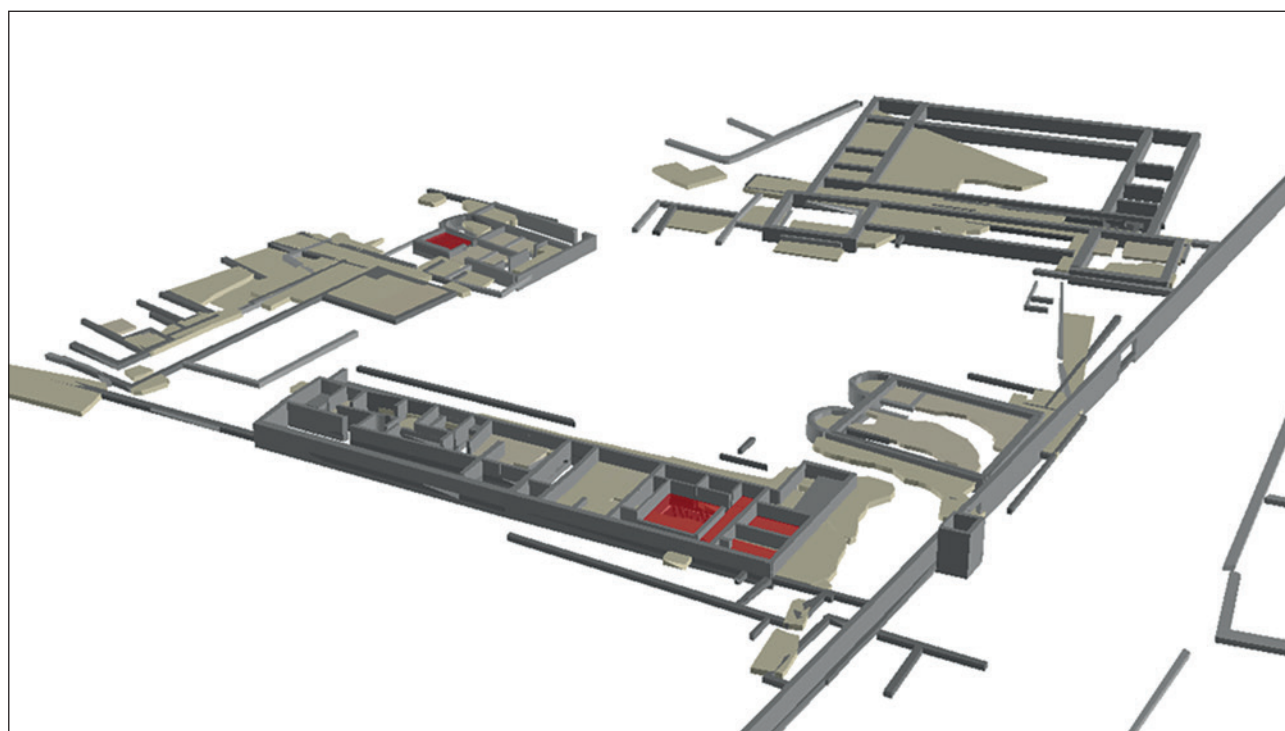


Fig. 18. 3D visualization of the Roman *villa* in Oberlienz-Lesendorf with buildings partially 'reconstructed' (Graphics: V. Poscetti).

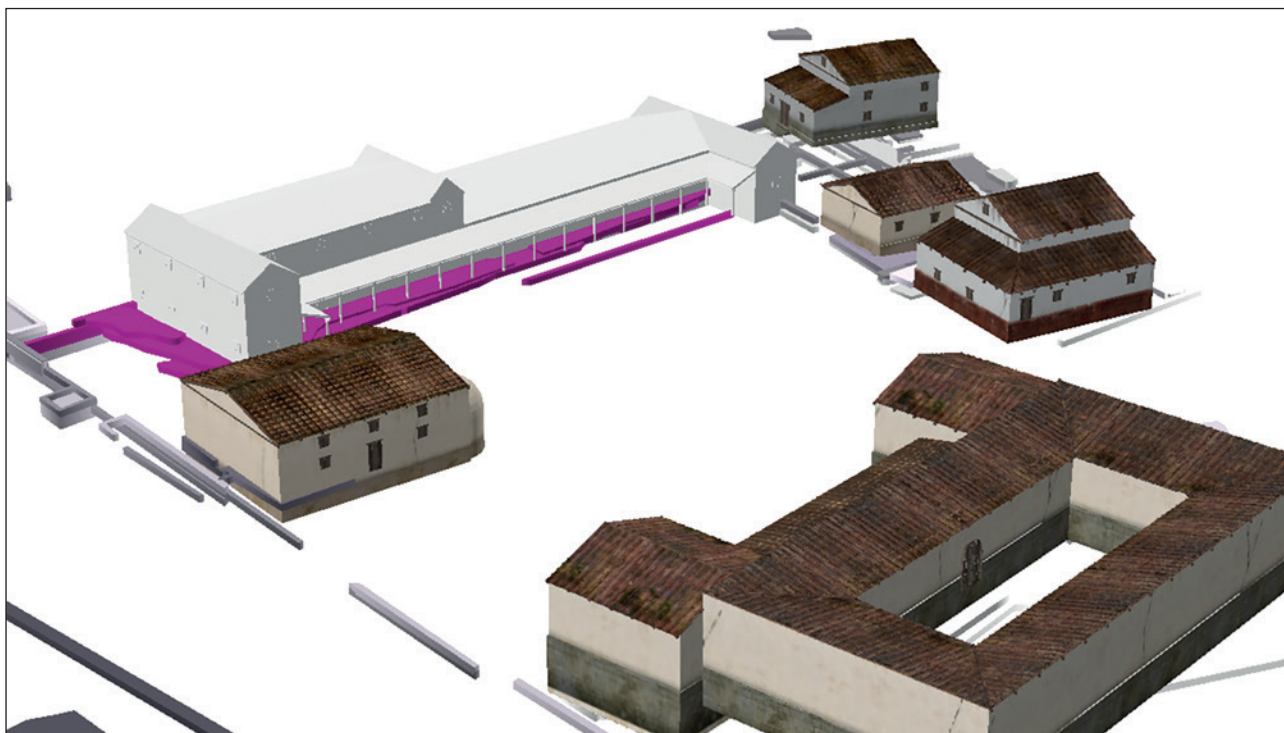


Fig. 19. Textured and untextured 3D models combined with the GIS-based interpretation in ArcScene (Graphics: V. Poscetti).

Based on the new GPR data analysis, we can suppose at least another apsed room, as apparently indicated by the presence of approximately semicircular-shaped anomalies similar to those observed by the first interpreter. The possible interpretation as a multiphase building, which can only be confirmed through excavation, is mainly based on the comparison with the station/*villa* at Sontheim an der Brenz, Kr. Heidenheim in Baden-Württemberg, Germany,⁷⁵ where a simple timber-framed rectangular structure on stone foundations was first transformed into an imposing residence with apsed rooms and later into a bath. Another interesting comparison can be made with the *villa* in Baar-Unterbaar in Bavaria (see above, section 7.1),⁷⁶ in which a squared building located immediately next to the main house was planned as a secondary residence for the manager.

Based on all the considerations above, a partial 'reconstruction' of the main buildings of the *villa* has been made in ArcScene (Fig. 18).

8. Advanced 3D Modelling

To achieve an interpretative 3D model suitable for future virtual reconstructions of the complex, both DTM and GPR

interpretations have been exported from ArcScene 10 as 3D files (VRML format) that allow georeferenced data to be retained. All of these datasets have been imported into the 3D Studio Max modelling software, where the data can be more efficiently modified in terms of 3D models. The processes to generate virtual reconstructions in the 3D Studio Max environment usually include the following steps:

- The DTM of the *villa*'s environment is edited to erase modern anthropological and topographic traces. Although this process is not as precise as we would like, it generates a more plausible model of the ancient surface where the complex was once erected.
- A volumetric interpretative reconstruction of the archaeological remains is created based on GPR interpretations.
- Semi-realistic textured models are created based on comparisons with scientific reconstructions of similar complexes within the Roman Empire.
- When all the models and reconstructions have been checked and accepted, different outputs like static images and short animations are created.

The textured 3D models created in 3D Studio Max are then exported as OBJ files, converted into COLLADA files and imported into ArcGIS multipatch feature classes utilising the 3D editing tool. Before importing them again into ArcScene, the geometry of the objects had to be simplified

⁷⁵ NUBER, SEITZ 1993.

⁷⁶ KAINRATH 1998.

by reducing the number of vertices due to the large memory footprint of the textured 3D models. This was performed by remeshing the 3D models in MeshLab. Due to the limitations of ArcGIS 10.2 in managing huge textured 3D models within a single multipatch feature class, the 3D models (e.g. the two main houses) have been stored in separate multipatch feature classes within the file geodatabase. The 3D GIS interpretation model, including interpretive textured models, is shown in Figure 19.

9. Conclusions

The GPR-based discovery of the Roman *villa rustica* in Oberlienz-Lesendorf, which was previously only partially known from old excavations, plays a vital role in the archaeological interpretation of the Roman period in East Tyrol. Despite the limitations of the GPR survey in terms of the dimensions of the prospection area and the state of preservation of the remains, the archaeological interpretation of the GPR data enabled us to identify a quite ‘typical’ *villa* complex, known as a *Streubauhof*. Even though the general layout of the complex has been quite apparent since the initial interpretation of the GPR data, the interpretation of the individual buildings, in terms of typology, required a more in-depth analysis of other case studies within the former *Noricum*.

The ever-increasing number of investigated villas in *Noricum* and in the adjacent Roman provinces, makes the interpretive process even more exciting, albeit more time-consuming due to the possibility to compare a large amount of archaeological data. Villas that have been investigated within *Noricum* mainly lie in its northwestern, central and southeastern parts. The GIS-based archaeological interpretation of the Oberlienz-Lesendorf *villa* contributes to the archaeological mapping of the Roman rural landscape in southwestern *Noricum*, which has still not been widely investigated.

From a technical point of view, the use of ArcGIS 10.2 represented a powerful and efficient tool for the 3D interpretative mapping of the archaeological features. This software is now outdated, with ArcGIS Pro being the updated and improved version of the software. However, from a methodological point of view, the GIS-based interpretation of the GPR data we performed has still proven to be a very good method, permitting us to efficiently retrieve and re-elaborate the interpretation data, including in a different environment such as the open-source QGIS.

To date, the archaeological site in Oberlienz-Lesendorf is still unexcavated, and no traces of the archaeological remains are visible in the available aerial images (from the *Landesamt der Tiroler Landesregierung*). More areas should be archaeologically investigated around the site in

the future to facilitate an improved interpretation of the whole design of the *villa rustica*, which was only partially investigated by GPR.

The possible detection of field borders, channels and other structures like *horrea* and tombs could permit a more comprehensive interpretation of the *villa* and its contemporary rural environment, also including the diachronic evolution of the complex.

At the current state of the research, neither the landscape of the Roman villas in the Lienzer Becken nor the Roman streets have yet been sufficiently investigated. A cost-effective extensive survey in the area employing non-invasive methods like remote sensing and geophysical methods could provide useful information about the presence of other *villae* in the area and clarify the ancient road system.

We think that a future interdisciplinary project in the area of Oberlienz and adjacent regions, also involving geo-archaeological and environmental research, could significantly boost the existing archaeological knowledge, while simultaneously improving the environmental and cultural management of the site.

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