MEDIEVAL PHASES OF SETTLEMENT AT BENABBIO CASTLE, APENNINE MOUNTAINS, ITALY: EVIDENCE FROM GROUND PENETRATING RADAR SURVEY

Monica Bini[a*], Antonio Fornaciari[b], Adriano Ribolini[a], Alessandro Bianchi[c], Simone Sartini[c], Francesco Coschino[d]

[a] Dipartimento di Scienze della Terra, Università di Pisa, Italy
[b] Dipartimento di Archeologia e Storia delle Arti, Sezione di Archeologia Medievale, Università di Siena, Italy
[c] SO.GE.T. snc, Lucca, Italy
[d] Dipartimento di Oncologia, dei Trapianti e delle Nuove Tecnologie in Medicina, Divisione di Paleopatologia, Università di Pisa, Italy

Abstract

The lack of written sources for many of the medieval castles in the northern Apennines (Italy) makes it difficult to completely establish the most ancient historical phases of these settlements. The church of San Michele belongs to an abandoned fortified settlement of the Castle of Benabbio, in the mountains surrounding Lucca. Thanks to an epigraph still visible on the façade, the church foundation is dated back to 1218 AD. However, several archaeological findings at the settlement seem to suggest stages of encastlement that are older than the church foundation.
A Ground-Penetrating Radar (GPR) survey has been carried out in the inner part of the church in order to identify the presence of pre-1218 AD buried structures. A 0.5 m grid was used to acquire GPR data over the entire pavement of the church, using an antenna of 200 MHz of nominal peak frequency. A standard sequence of raw data processing was adopted, and the interpretation was performed both on vertical radar profiles and time-slices.
The distribution of areas of high backscattered electromagnetic energy shows regular patterns with orthogonal alignments archaeologically compatible with buried stone walls. In the western sector of the church, the subsurface structures are consistent with the wall remains of a building which, due to its size and shape, is unlikely to have been used for religious activities. This building can be related to an 11th-12th century encastlement of the site.The other structures detected by GPR prospection can be referred to the construction of the 13th century Romanesque church, while its Renaissance enlargement may have taken place in the late 15th century. During this last phase, a hypogean room was excavated near the altar and probably used as crypt/ossuary.
The results of this multidisciplinary work have supported some archaeological hypotheses concerning the architectural history of the church, dating back to the 11th-12th century, when the first stone structures of the Benabbio castle were erected.

1. Introduction

The study of medieval castles in Apennine Tuscany has greatly developed in the last twenty years as a result of historical and archaeological research (Wickham, 1990; 1997). Several excavations and surveys have revealed the importance of such research for the reconstruction of ancient medieval landscapes (Ciampoltrini et al., 1998; Giovannetti, 1998; Quirós Castillo, 1999a; 1999b; 2004; Francovich and Ginatempo, 2000; Vannini, 2002; 2009; Gattiglia and Milanese, 2009). However, evidence of settlement phases in this part of the Apennines before the 11^{th} -12^{th} centuries is limited to the sites of Gorfigliano Castle (Quirós Castillo, 2004) and Terrazzana Castle (Quirós Castillo, 1999a). The lack of written sources for most of the Northern Apennine castles makes the study of the material remains necessary for establishing the historical phases of the sites. A non-invasive geophysical approach, i.e. Ground Penetrating Radar, is useful for obtaining results on the possibility of finding pre-existent structures, otherwise invisible, and for planning the archaeological excavation agenda. Our research focuses on an abandoned fortified settlement in northern Tuscany, the Castle of Benabbio (Fig. 1). Only one of the buildings located in the castle can be accurately dated: the church of San Michele. As a matter of fact, an epigraph still visible on the façade dates the building of the Romanesque church back to 1218 AD. Ground Penetrating Radar prospection, assisted by archaeological interpretation, could attest the existence of remains older than the church construction, shifting further back in time the history of this settlement.

2. Archaeological background

Benabbio Castle is located in the Lima Valley, to the west of the Apennine chain, on a narrow hilltop around 600 m above sea level. The small village of Benabbio, still populated, lies on the south-western side of the hill, at an altitude between 400 and 500 m above sea level (Fig. 1). The area is geologically characterised by outcrops of sandstone rocks and by several landslides which skirt the western part of the castle walls. The remains of the enclosure run for about 400 m, surrounding an area of more than 6000 m^2 (Fig. 2). The church of San Michele, the only surviving building, is located in the middle of the castle and dates back to the first half of the 13^{th} century. It is an imposing religious building, 9.5 m wide, with an important lengthwise development of 24 m and valuable walls of rough stone squares. The eastern wall surface in ‘bozzette’ is not only one of the most important elements of the building, but also part of the surrounding walls of the castle. An inscription on the façade reports the likely date of construction: “Anno Domini MCCXVIII”. The inside of the church (Fig. 3a) is very interesting for its flooring made of ancient cobble flagstone, dating back to the year 1400. A late 15th century extension at the back of the church is also visible (Fig. 3b). Many works carried out on the church of San Michele are attested by written documents of the years 1494-1495, found in the Benabbio Parish Archives. These documents confirm the dating provided by archaeological observations of structural typologies (Laganà, 2007).

On this basis, in 2007, new investigations in the area occupied by the remains of the castle were initiated and conducted from an unusual perspective, which consisted of examining the spaces reserved to the dead first and the settlement area afterwards. Individuals buried in the medieval cemetery near the church were exhumed together with the people who had died in the village during the cholera epidemic of the year 1855, and had been buried in the same place (Fornaciari, 2007; 2008; 2009). To date, 41 individuals have been brought to light (Figs. 2, 3c and 3d).

Furthermore, the excavations also brought to light many well preserved traces of medieval buildings, leading to the decision to examine the settlement in its entirety. The excavations performed alongside the eastern walls of the castle revealed the presence of 14th century stone buildings used as habitations until the end of the 15th century (Fornaciari, 2007; 2008).

Finally, the excavation campaigns of July-August 2009 attested the presence of a large rectangular structure (about 7.5 x 11 m) with 0.7-0.8 m thick stone walls in front of the church (Fig. 2). The building is probably contemporary to the church and both constructions lean against the eastern curtain of the castle. Another stone wall, 0.6 m wide, is located west of the church, surrounding the area of the churchyard.

On the one hand, the fieldwork has cast light on the last years of life of the permanent settlement, abandoned before the 16th century; on the other hand, there are less evident traces of the early stages of encastlement, probably due to the initiatives of an important local lord family of the 11th-12th century.

In this context, the construction of the church is an important *terminus ad quem*, the ultimate goal representing a novelty in the history of the settlement; however, the events prior to its construction are still unknown.

At this stage of archaeological research, it is impossible to determine when the hilltop of Benabbio was first occupied by a settlement. The oldest documents mentioning the village of "Menabla" date back to 983 AD, but no reference is made to high ground settlements (Fornaciari, 2009). In southern Tuscany, the occupation of a hilltop location generally took place long before the development of a castle (Francovich, 2004). In the Lucchese territory, the two sites of Terrazzana and Gorfigliano show traces of hut villages prior to their transformation in stone castles (Quirós Castillo, 1999a; 2004). There was certainly an important increase in population at the castle of Benabbio between the 12th and the 13th century, as suggested by the size of the San Michele church and the extension of the enclosure.

Our study takes place within this archaeological framework and is aimed at obtaining new knowledge about the early stages of settlement of the castle. A non-invasive Ground-Penetrating Radar (GPR) survey has been carried out in the inner area of the church in order to identify the potential presence of buried structures referable to settlement phases antecedent to the year 1218 AD.

3. Method

Ground-Penetrating Radar (GPR) is a fast and cost-effective electromagnetic (EM) method providing relevant information on the shallow subsurface. Since it is based on the propagation and reflection of EM waves, it is sensitive to variations of the EM parameters in the subsoil, especially the dielectric constant and electric conductivity (Davis and Annan, 1989). The lower the frequency of EM waves propagating into the subsurface, the greater their penetration. The latter varies from a few meters in conductive materials to 50 m for low conductivity (less than 1 mS/m) media (Davis and Annan, 1989; Smith and Jol, 1995; Annan, 2009). The capability to resolve targets vertically (vertical resolution) increases with the antenna frequency up to centimetre values. Lateral resolution depends on the geometry of acquisition (step size, i.e. the distance between each point where a measurement is made along a GPR profile) and can reach a sub-centimetric resolution.

The Nyquist sampling interval, i.e. one-quarter of the wavelength in the ground, is the base value to which the step size of the acquisition refers in order to avoid spatial aliasing effects (Davis and Annan, 1989; Annan, 2009).

Despite its relatively low penetration depth (especially with high frequency antennae and in moderately conductive environments), unsuitable for many geological aims, the GPR's high resolution (lateral and vertical) makes this technique successful in studies of shallow surfaces, such as for archaeological applications (Basile et al., 2000; Leckebush, 2003; Grasmueck et al., 2004; Leucci, 2006; Orlando, 2007; Campana et al., 2009; Soldovieri and Orlando, 2009).

Moreover, further significant advantages are reached by adopting a grid of radar profiles, allowing a 3D visualisation of the subsurface, and facilitating the interpretation of geometric structures, such as archaeological remains (Malagodi et al., 1996; Nuzzo et al., 2002). However, recording a full-resolution 3D data set requires a very dense data acquisition grid on the measuring surface above the volume to be imaged, with strong topographic control at centimetric resolution. Finally, 'time slice' (or depth slice) maps can be used to display the plan pattern of radar data at variable depths, as well as the volumetric representation of particular details (Goodman et al., 1995).

In this study, the GPR survey has been performed using the Radar System device of IDS Company © (www.ids-spa.it), equipped with an antenna of 200 MHz of nominal peak frequency and HH-polarised. The transmission and reception antennae are separated at a distance of 0.19 m and oriented in broadside mode. The data were acquired in continuous mode, controlling the step size by means of an odometer wheel. In vertical direction, the subsurface was explored for 128 ns (range), taking 512 samples per scan, while horizontally the radar source was triggered every 2.4 cm.

A 0.5 m grid was used to cover almost the entire pavement of the church of San Michele, with the exception of limited sectors reserved to the scaffolds that had been erected for restoration works.

The processing sequence applied to the raw data of the radar is summarised below:
- time-zero correction shifting the first arrivals by a constant;

- running average filter in order to filter the DC component (Dewow filter);
- linear and smoothed gain with window-length of 71 ns (5 m depth);
- subtracting the mean trace in order to filter out the continuous flat reflections caused by the breakthrough among the shielded antennae and by multiple reflections between the antenna and the ground surface (Daniels, 2004);
- vertical band-pass filter;
- determination of EM wave velocity for depth conversion using the method of hyperbolic shape of a reflection from a point source (diffraction hyperbola).

After the above-mentioned processing sequence, the areas of high back-scattered energy corresponding to reflections of EM waves (anomalies in the following) were interpreted and compared with the archaeological data, already available thanks to the previous excavation campaigns in the area surrounding the church.

4. Results

Spectral analysis was performed of the collected field data. This analysis provides a peak frequency of about 180 MHz and a frequency band from 150 to 1900 MHz (Fig. 4). From the collected radar profiles, a signal penetration depth of about 3-3.5 m could be inferred.

Data interpretations were first undertaken analysing the energy attribute as time-slices (C-scan), extracted from the 3D volume of data. In this analysis, the vertical and lateral continuity of anomalies improved, with energy stacking on a time-window of 0.1 m, chosen as function of the thickness of the expected archaeological structures. Finally, selected anomalies evident on the C-scans were analysed by means of vertical radar profiles (B-scans).

4.1. Sector 1

The distribution of radar anomalies shows a regular pattern, with orthogonal alignments and areas of high back-scattered energy of lenticular form in plan (Fig. 5).

At -0.9 m depth, two orthogonal directions are clearly visible (A, B), more or less corresponding to the x = 5 m and y = 4.5 m coordinates. Moreover, a lenticular shaped anomaly with a long axis elongated in the x direction for 1.8 m and a width of 0.8 m is identified (C). In correspondence with the NW corner of the pavement, an anomaly is visible at -0.9 m depth (D), very close to the peripheral wall of the church.

At -1.2 m depth, A and B are visible only in the central-northern part of the time-slice, with a width variable between 0.5 and 0.8 m, while C disappears. D assumes an elongated shape in the y direction, orthogonal to the B anomaly.

At -1.3 m depth, A and D assume a more regular shape, with a maximum width of 0.9 m and 0.6 m, respectively, and B becomes highly discontinuous.

Looking at the B scans, a vertical continuity up to 1.5 m can be observed for the A (L21, L28), B (T14, T08, T03) and D anomalies (L28) (Fig. 6).

B-scan L21 shows how the C anomaly is determined by a slightly concave reflector 1.8 m long with a maximum depth of 0.9 m, standing below a convex reflector visible at 0.4-0.5 m in depth. The C anomaly is cross-cut perpendicularly to its long axis by T08. This allows the observation of the shape of the same reflectors (concave/convex) at comparable depths.

Gently sloping reflectors visible at a depth below 2 metres and starting from both sides of the section (Fig. 6) can be attributed to air wave reflections from standing walls. This effect is often visible in other B-scans in our survey.

4.2. Sector 2

Anomalies aligned in directions x and y are also observed in sector 2, together with areas of high back-scattered energy of irregular shape in plan (Fig. 7).

The most evident alignments (E, F) cover the entire extension of the church pavements. As regards the F anomaly, a width >0.3 m could only be estimated because a step in the floor determined the lack of a line of acquisition in the y direction. E tends to be invisible below 0.9 m, while F can still be observed up to maximum signal penetration depth.

At 0.5 m depth, the lens-shaped anomalies H and G show their potential alignment in the y direction.

Looking at the B scan (Fig. 8), F and G show vertical continuity up to 1.1 m depth, with clear hyperbolic reflections, while E seems to stop at 0.9 m depth. H is consistent with a clear hyperbola at 0.4 m in depth, showing reflections up to 0.6 m.

4.3. Sector 3

I and L represent the most important areas of back-scattered energy at -0.4 m depth, and are mutually perpendicular, being oriented parallel to the x and y directions, respectively (Fig. 9). At 1.1 m in depth, M becomes more evident, assuming a clear x parallel direction. In total, these anomalies encompass an area (N) that is transparent to electromagnetic signals, i.e. without any reflections. This area is limited by the F anomaly in sector 2 (Figs. 7 and 8).

The B-scan T02 crosses I and M showing corresponding reflections, extended up to 1.5 m in depth, with widths of 0.6 m and 0.4 m, respectively. Moreover, the lack of a reflection area extended from 4.5 to 7 m in the x direction corresponds to N. Similarly, the N area is consistent with the homogeneous portion of B scan L22 between 0 and 0.8 m in the x direction (Fig. 10). Finally, L22 shows the reflections corresponding to the M anomaly, visible up to 1.2 m in depth.

5. Discussion

5.1. Sector 1

Most of the anomalies present in sector 1 are archaeologically compatible with some of the walls enclosing rooms that were present before the construction of the 13th century church.

The orthogonal disposition of some of the structures supports the hypothesis of a possible connection between the parts. Furthermore, the depth of the foundations and levelling of the wall tops suggests that they coexisted in at least one of the phases of the history of the site. In particular, anomaly D, part of anomaly B, and part of anomaly A identify the perimeter of a large 3 x 5 m rectangular space. This room exploits a part of the pre-existing walls of the castle as its north-eastern perimeter. The remaining parts of anomalies A and B identify segments of wall structures which can be related to the room described before. In this case, it would be possible to reconstruct at least three other areas, two of which probably corresponding to closed rooms and another one, probably open, situated to the west of anomaly B. Anomaly C, compatible with a pit filled up with highly reflecting material, was probably connected with a working site – during one of its phases – to be related (due to its nature and height) to the construction of the 13th century church. Hollows of this type were often found during the archaeological excavations near the working sites; moreover, in this case, the depth of the hollow suggests a possible relation with the building of the church.

5.2. Sector 2

The most evident anomalies in this sector are those of E and F. The F anomalies are consistent with a stone wall, which can most likely be identified with the rear wall of the medieval church. In fact, in both the perimeter walls and in connection with the anomalies, there is a clear discrepancy in the façade of the walls (Fig. 3b). The E anomalies identify another stone structure, which, owing to the shallow depth of the foundations, could be interpreted as a stone step or balustrade separating the presbytery from the rest of the medieval church nave.

Anomalies G and H are more difficult to understand, as they are located near two existing pilasters, constructed in the 18th century. These anomalies could represent the remains of structures related to the pilasters.

5.3. Sector 3

This sector, probably dating back to the late 15th century, is the most recent in the church. Anomalies I, L and M identify walls bordering a buried hypogean room, apparently L-shaped (N). Making a rough estimate, the room may have had a surface of about 6 m^2.

The depth of the room could not be clearly detected by the antenna that was used, but appeared to be larger than 1 m. These sizes are consistent with similar hypogean rooms used as ossuaries or crypts, documented in Modern Age churches.

The presence of the room is supported by a lacuna in the floor tiles of the presbytery, in front of the high altar. This lacuna, currently closed by lime, probably represented the access point to the room.

6. Conclusions

In the present study, GPR and archaeological data have been integrated for the purpose of identifying structures located under the floor of the San Michele church, dating back to the year 1218 AD. The results of the GPR survey have revealed several reflections of electromagnetic waves, whose patterns are consistent with different buried structures that can be ascribed to three different phases of settlement history (Fig. 11):

1) the most ancient structures, located in sector 1 (Fig. 11a), describe the remains of a building which, due to its size and shape, is unlikely to have been used for religious activities. This building can be related to the early encastlement of the site, as it certainly belongs to a period antecedent to the time when the church was built. The topographic location, close to a cliff-face, seems to suggest the search for a defence position. Furthermore, the structure makes it possible to hypothesise the existence of an 11th-12th century castle with a different organisation of the spaces.

The complete absence of written sources makes it particularly difficult to extend the chronology of the fortified site.

2) two structures located in sector 2 have been related to the Romanesque church of the 13th century (Fig. 11b). The eastern structure can certainly be identified as the original ‘end-wall’ of the medieval church. The western structure can be recognised as a division element between the presbytery and the rest of the church.

3) the structures located in sector 3 (Fig. 11c), consistent with a hypogean room, probably used as crypt/ossuary, are the most recent, and they can be linked to the Renaissance enlargement of the late 15th century church.

This multidisciplinary work has supported some archaeological hypotheses concerning the architectural history of the church, suggesting unknown elements of habitation at the site, and has allowed the planning of new guidelines for future archaeological surveys.

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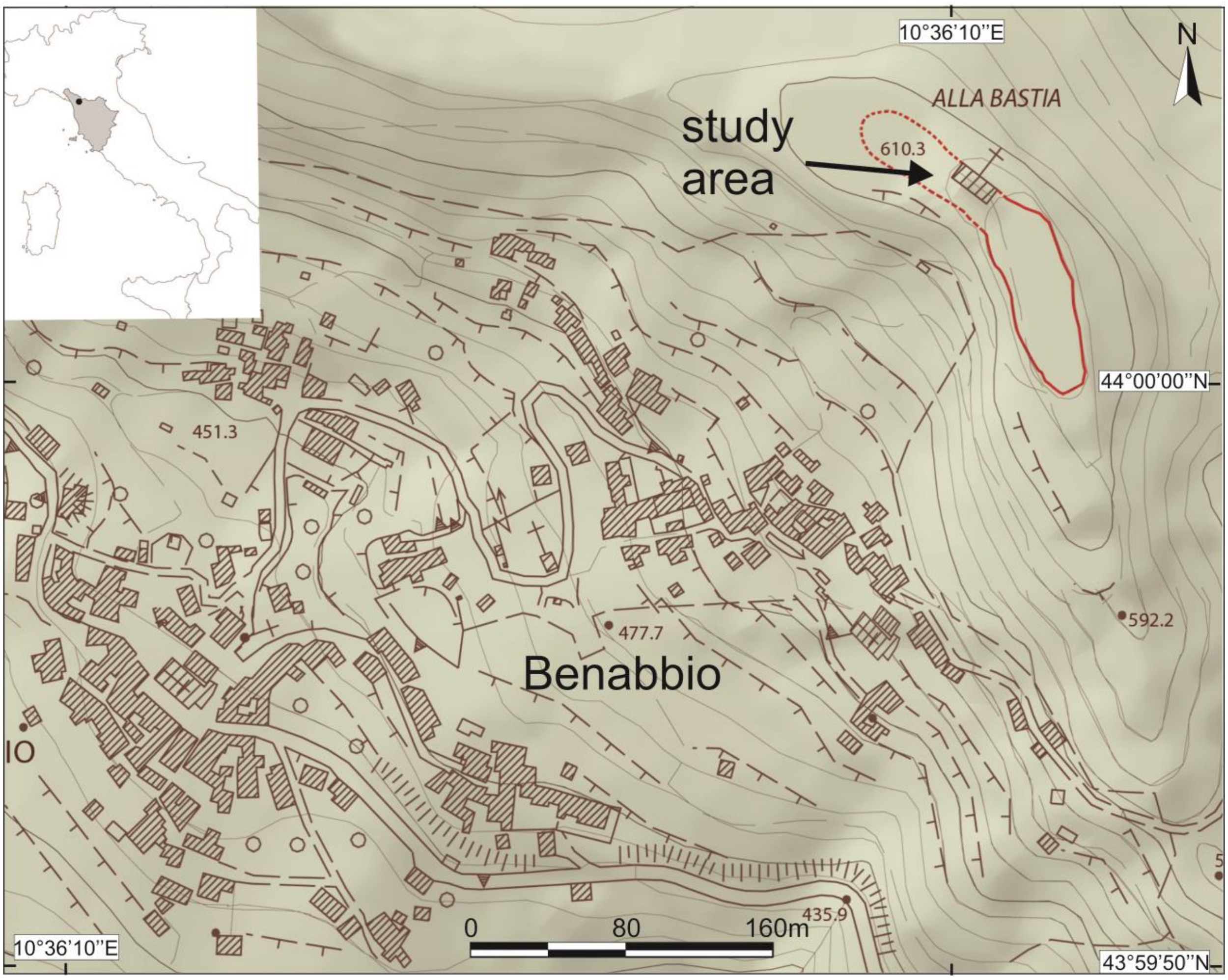

Fig. 1 – Geographical map of the Benabbio area with the indication of the Benabbio Castle (study area).

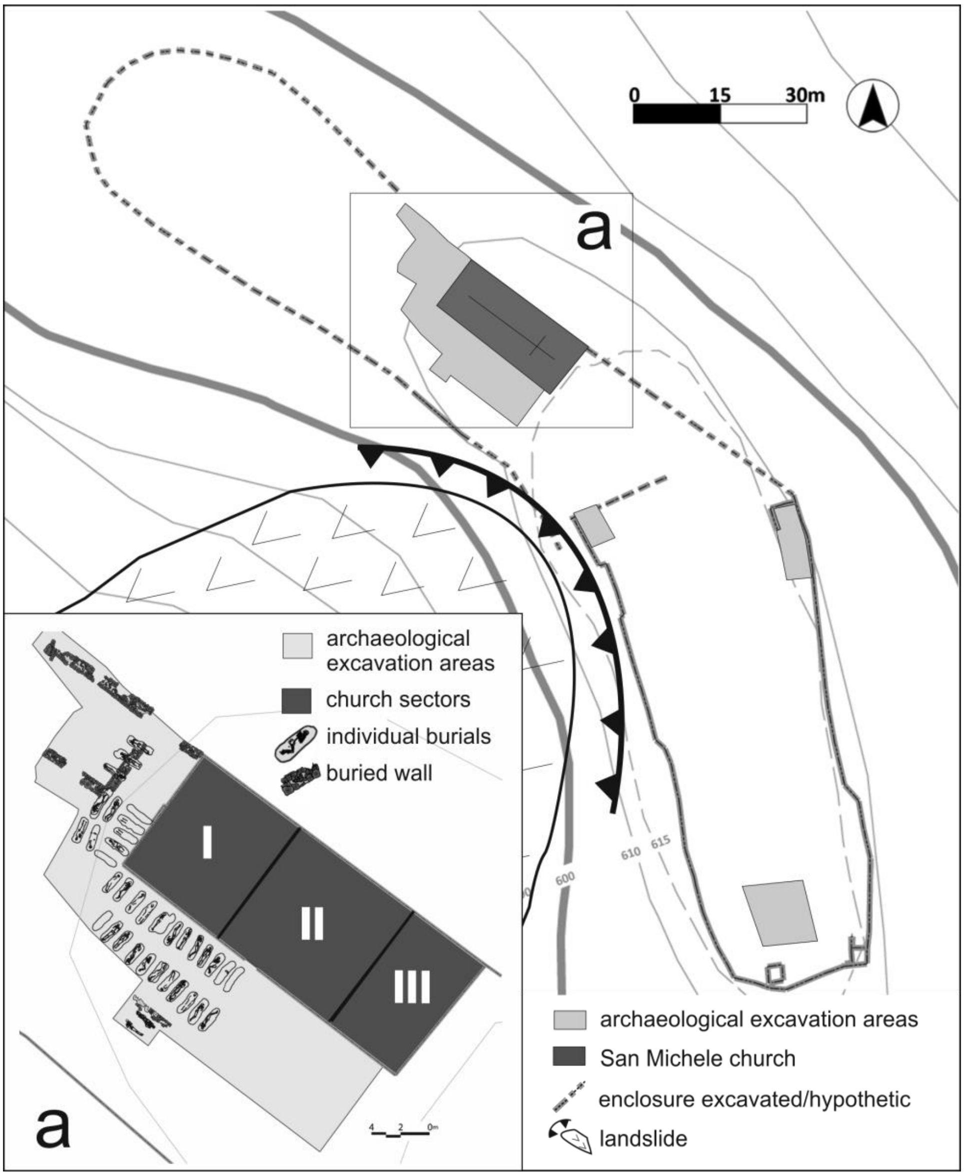

Fig. 2 – The encastlement area of Benabbio. A detail of the San Michele church is reported in the enlargement (a) with the main archaeological findings.

Fig. 3 – The interior of San Michele church (a); the south-west wall of San Michele church: the marking indicates the late 15th century extension (b); the archaeological area near the San Michele church in zenithal view, showing the 19th century cholera cemetery (c); two burials of the 1855 cholera pandemic (d).

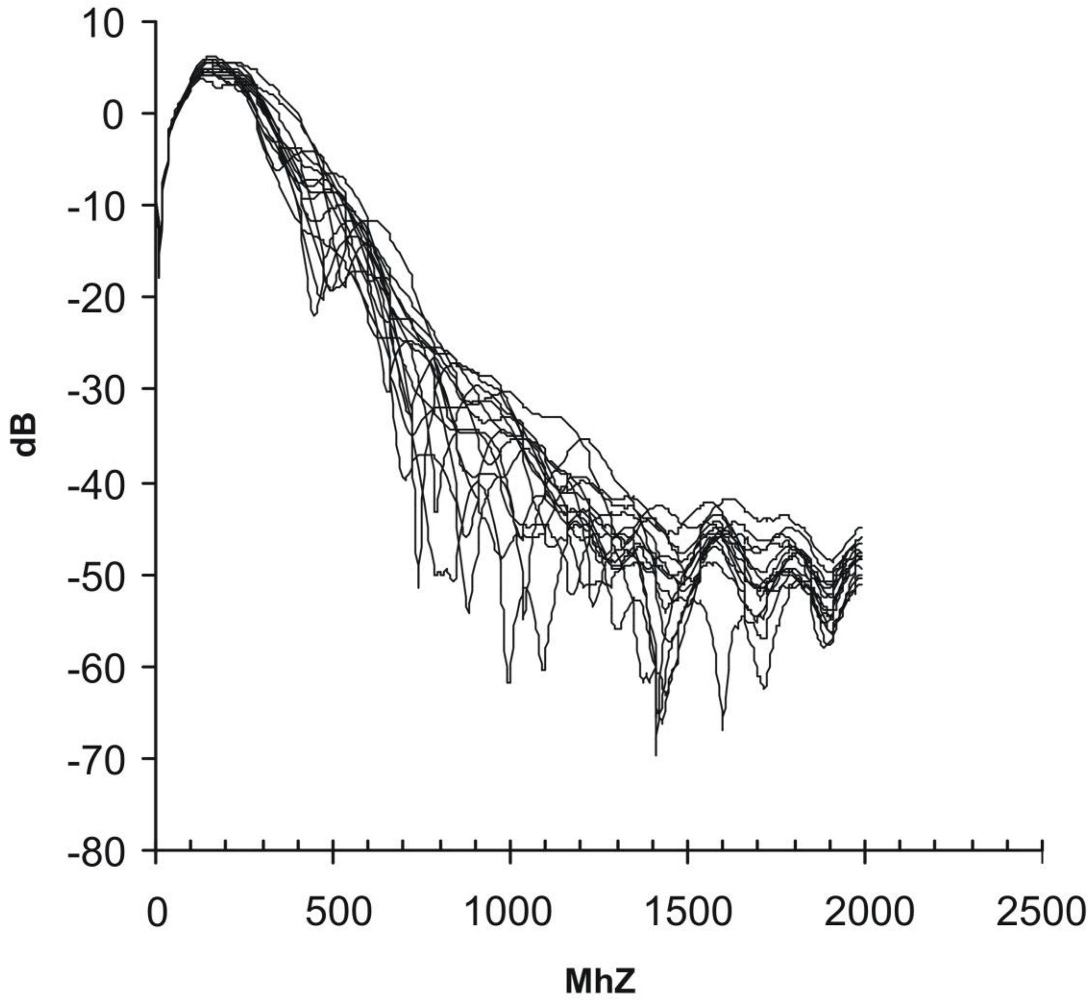

Fig. 4 – Average trace spectrum of the radar signal received by the 200 MHz antenna.

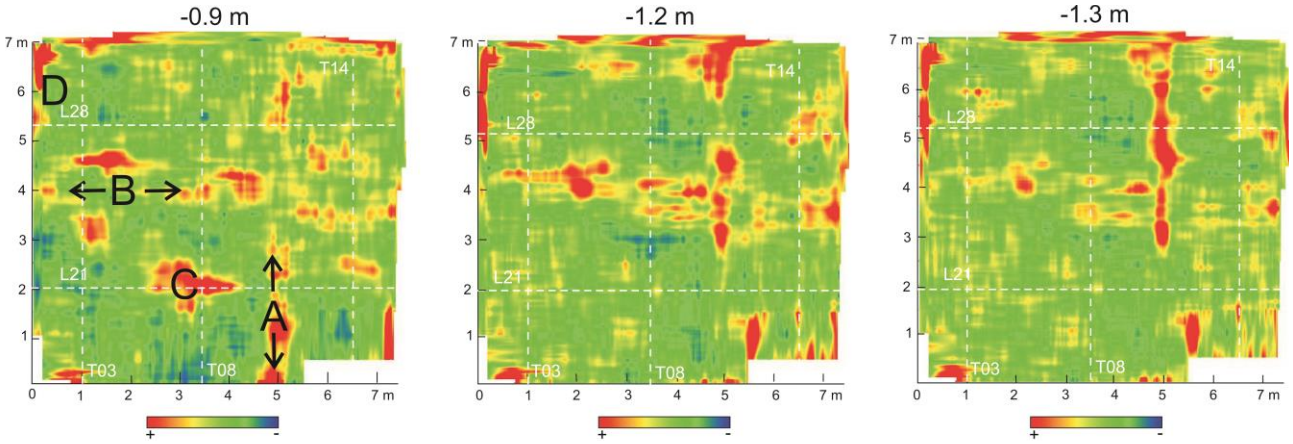

Fig. 5 – Time-slices (C-scan) of sector 1 at 0.9 m, 1.1 m, 1.3 m depth. Letters indicate anomalies discussed in the text.

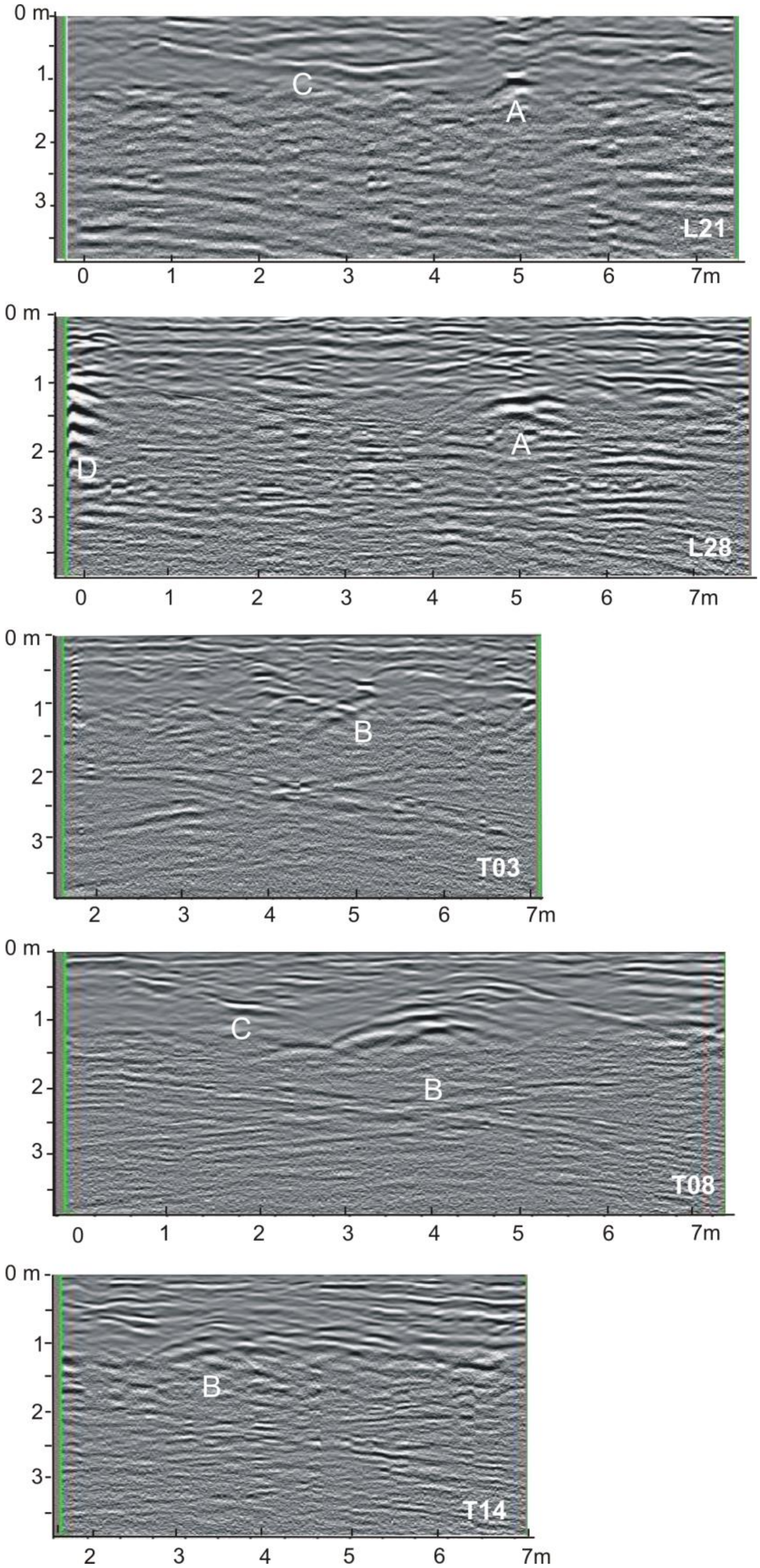

Fig. 6 – Selected vertical radar profiles (B-scans) in sector 1. The letters indicate anomalies discussed in the text, the code indicates the number of the profile. For profile location, see Figure 5.

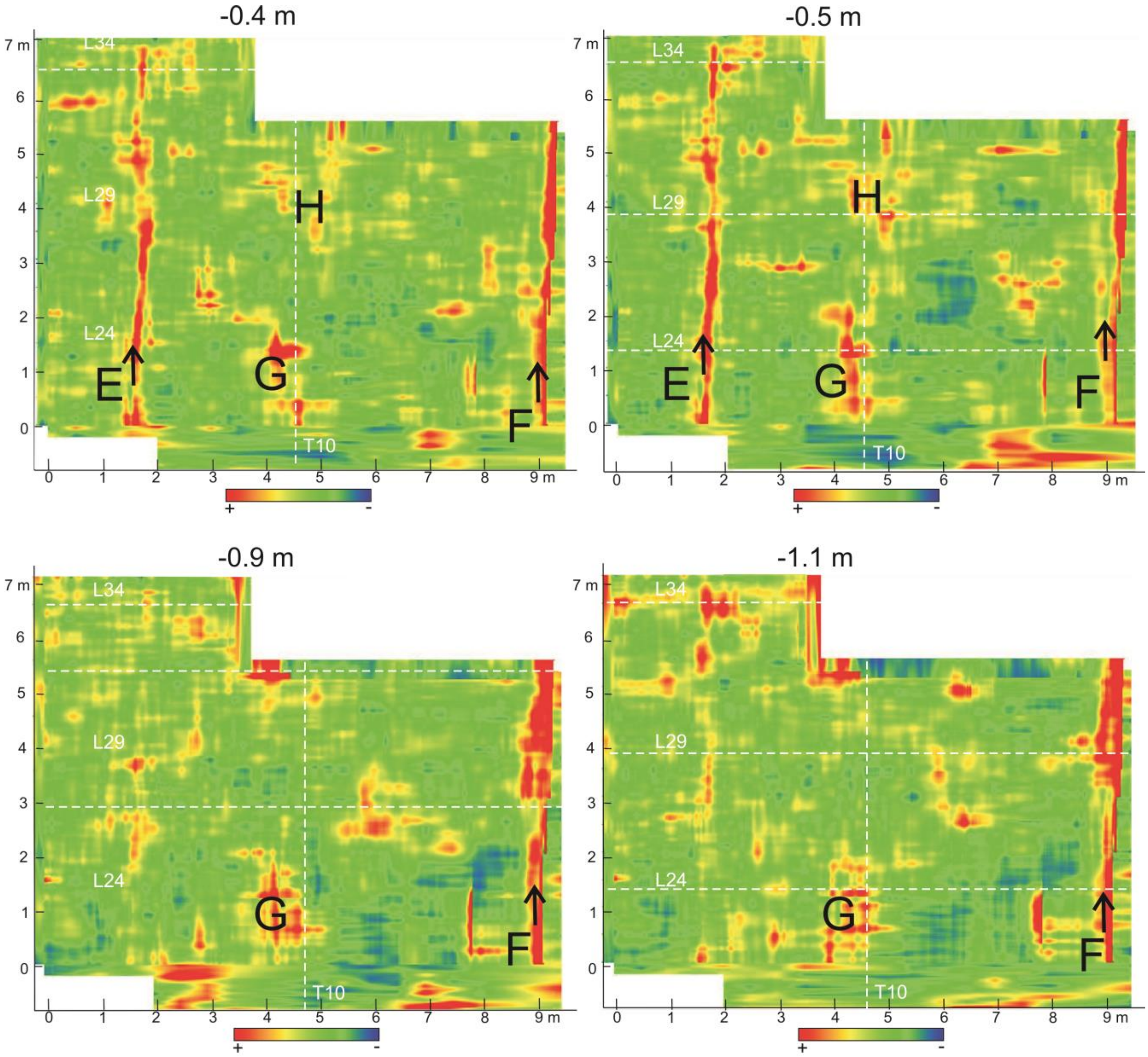

Fig. 7 – Time-slices (C-scan) of sector 2 at 0.4 m, 0.5 m, 0.9 m and 1.1 m depth. Letters indicate anomalies discussed in the text.

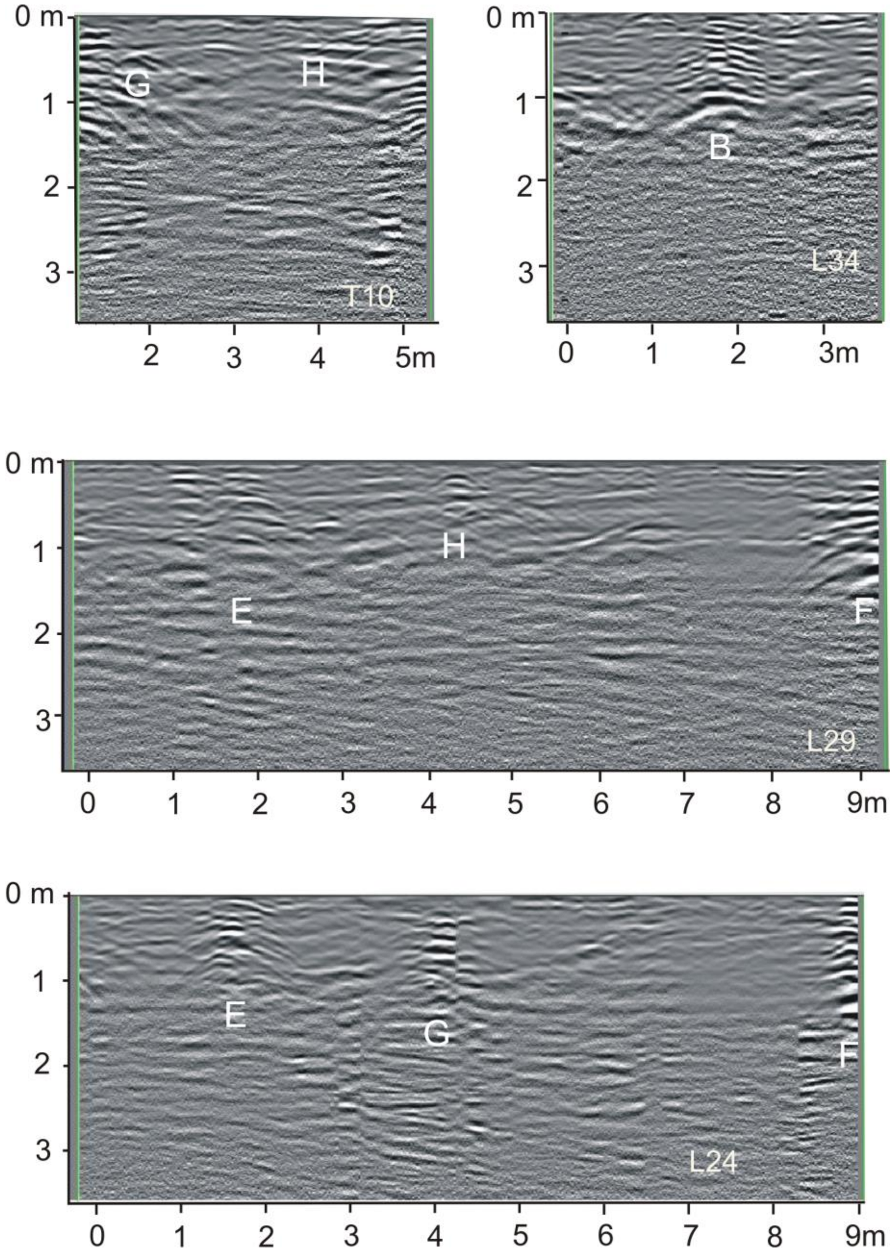

Fig. 8 – Selected vertical radar profiles (B-scans) in sector 2. The letters indicate anomalies discussed in the text, the code indicates the number of the profile. For profile location, see Figure 7.

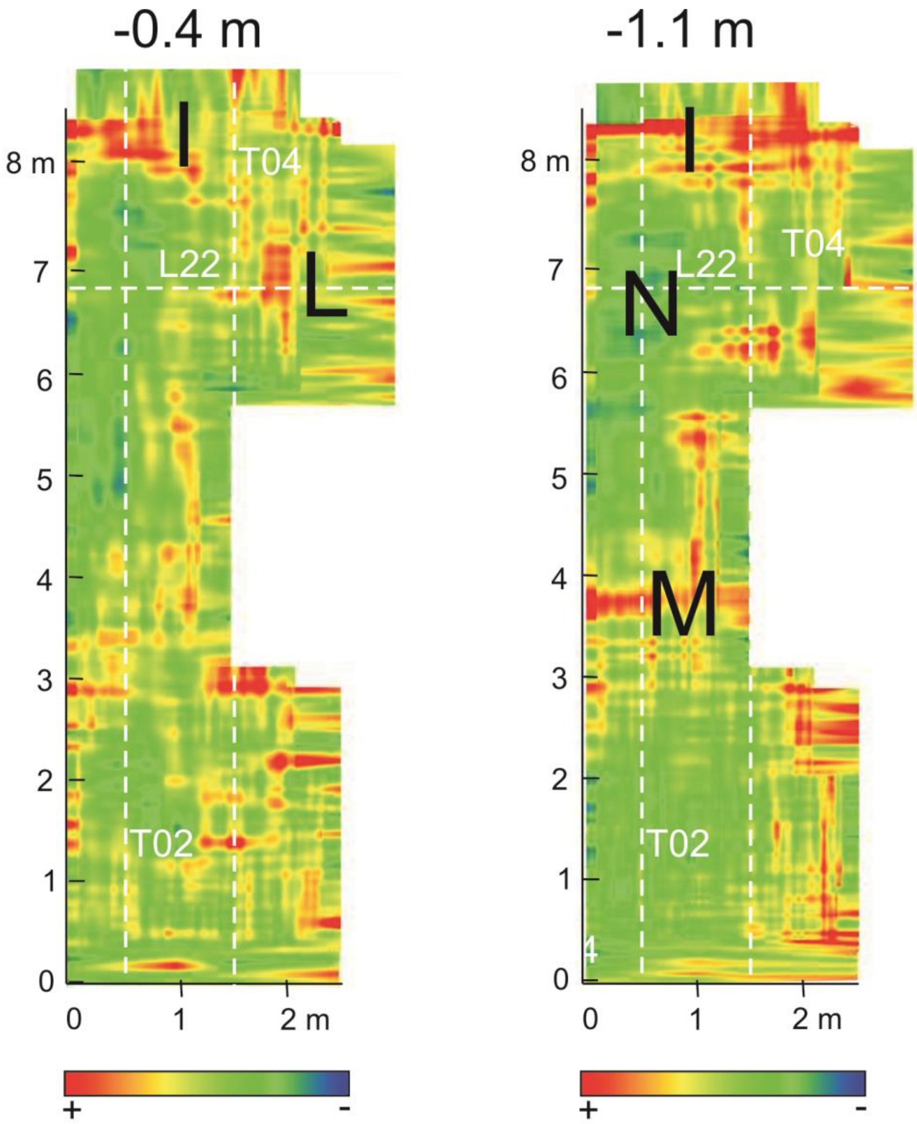

Fig. 9 – Time-slices (C-scan) of sector 3 at 0.4 m and 1.1 m depth. Letters indicate anomalies discussed in the text.

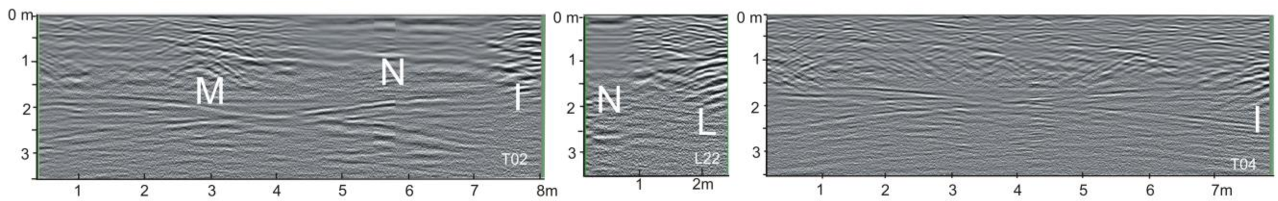

Fig. 10 – Selected vertical radar profiles (B-scans) in sector 3. The letters indicate anomalies discussed in the text, the code indicates the number of the profile. For profile location, see Figure 9.

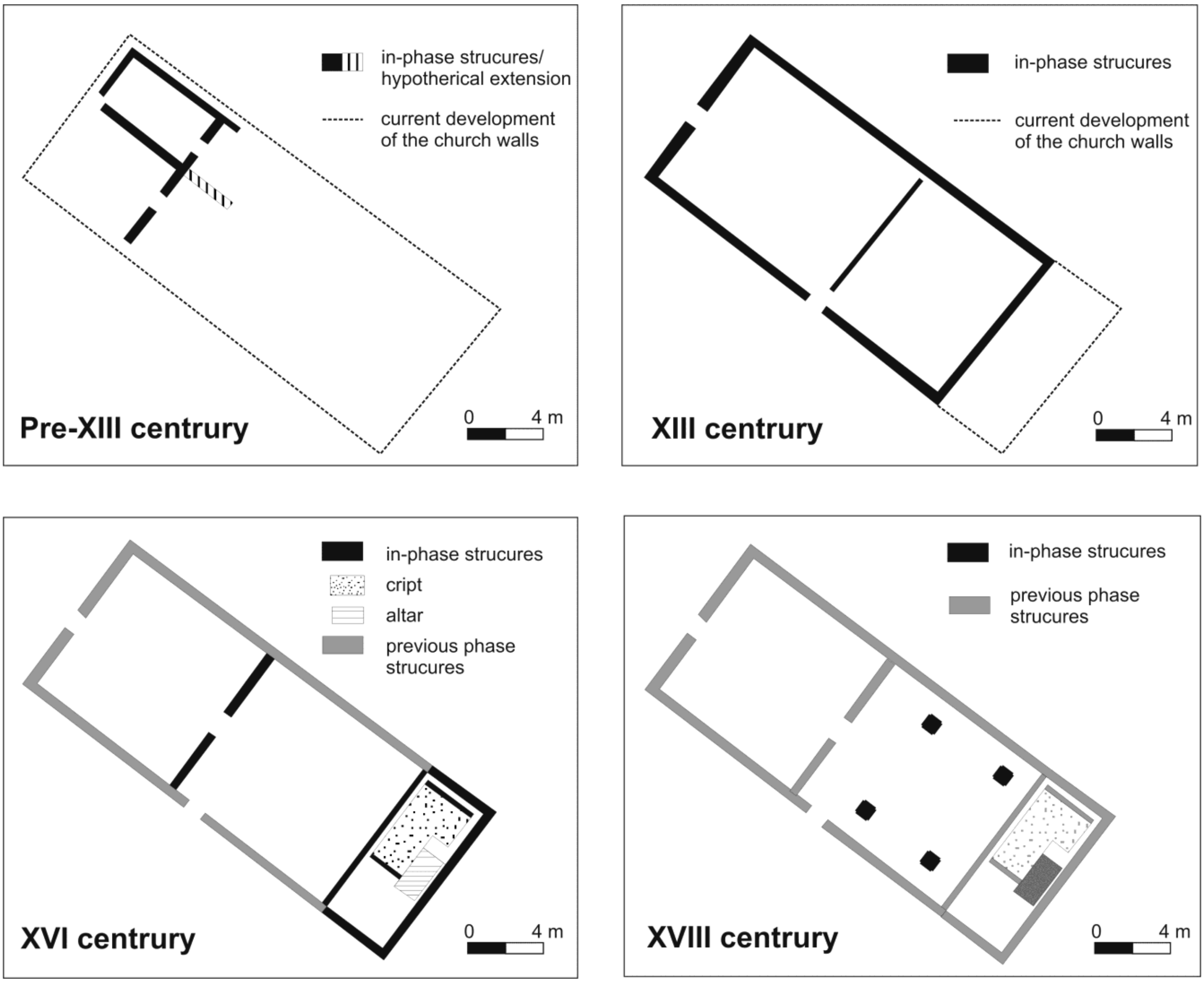

Fig. 11 – Reconstruction of the structures evolution in the area of the present day San Michele church. ‘In-phase structures’ refers to structures from this building phase. For the location of the GPR surveyed sectors, see Figure 1a.