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First conclusions about results of GPR investigations in the Church of the Assumption of the Blessed Virgin Mary in Kłodzko, Poland

Anatolii Chernov[1], Dariusz Dziubacki[2], Martina Cogoni[3], Alexandru Bădescu[4]

[1]Institute of Geology, Department of Geophysics, Taras Shevchenko National University of Kyiv, Kyiv, Ukraine
[2]Faculty of Geology, Geophysics and Environmental Protection, Department of Geophysics, AGH University of Science and Technology, Krakow, Poland
[3]Department of Civil Engineering, Environmental Engineering and Architecture, University of Cagliari, Cagliari, Italy
[4]Faculty of Geology and Geophysics, Department of Geophysics, University of Bucharest, Bucharest, Romania

Correspondence to: Chernov Anatolii (achernovp@gmail.com)

Abstract. The article shows results of the GPR investigation in the Church of the Assumption of the Blessed Virgin Mary (XIV–XVI AD). Due to the wars in the 20th century, the majority of the documents connected with the church's history was lost. For this reason under the floor of the catholic temple, the unknown structures might still exist. To verify the presence of underground structures such as crypts and tombs, a GPR survey was carried out in chapels and aisles with 500 and 800 MHz GPR shielded antennas. During the investigation, numerous anomalies were detected. It was concluded that anomalies under the chapels were caused by the presence of the crypt beneath the floor. The presented work shows first results of GPR surveys in the church in Kłodzko.

1. Introduction

Significant progress in archaeology was possible due to GPR surveys. Even though it is a method developed and widely used in the scientific fields, such as geology, environmental studies and engineering, it offers a good image of what could lie underground, for instance: caves, tombs and buried objects. The concept of the GPR is well known. An electromagnetic pulse is directed to the ground. Heterogeneities cause reflections that are detected by a receiver (Annan and Cosway, 1992).

The GPR investigation presented in this paper took place in the Church of the Assumption of the Blessed Virgin Mary in Kłodzko. It is a town in the south-western part of Poland. The first information about sacral building in this region comes from the 12th century. The current catholic temple was constructed from the 14th to the 16th century. Its founder was Ernest of Pardubitz, the first Archbishop of Prague. In the beginning, it was a Joannites property, but soon it moved under the Jesuites management. Nowadays the church is administered by the Jesuits order (www.klodzko.pl – Religious monuments, 2017).

Mortuary chambers which are situated on the territory of the church are as follows: remains of Ernest of Pardubitz (the first Archbishop of Prague); Dead People's Chapel immediately adjacent to the north aisle (the remains of Count Montani of Oldrzychowice) – surveyed site; the Main Altar of 1727–1729; The Altar of the Assumption of the Blessed Virgin Mary (1725); Chapel of St. Jacob (also a surveyed site) (www.klodzko.pl – Religious monuments, 2017) and (Parafia Rzymskokatolicka WNMP, 2017).

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Most of the documents connected with the church, like parish chronicles, were burned during the Second World War. Therefore, the main sources of information were church's sketches presented in Fig. 1, Fig. 3 and a few websites. General knowledge about the temple's underground is still poor. The aim of the presented work is to verify the presence of structures under the church's floor.

2. Acquisition and processing

Surveys were conducted in aisles and chapels. Radargrams were recorded with GPRs 500 MHz and 800 MHz shielded antennas. Velocity for the surrounding medium was established as 0.1 m/ns (based on similar investigations (Panisova et al., 2016) and processing approach (Persico, 2014, pp. 13–16)) . Localization of the profiles in aisles is shown in Fig. 1 (profiles from 500 MHz antenna), in Dead People's Chapel in the Fig. 3 (a), (b) (profiles recorded with 500 MHz (a) and 800 MHz (b) antenna). Figure 3 (c) shows profiles from the Chapel of St. Jacob recorded with 800 MHz antenna. The chapels' floors were covered by a regular grid of profiles. Anomalies which were detected on radargrams are shown with green ovals on the ground floor plans (Fig.1, Fig.3). The processing sequence for recorded radargrams includes routine steps (Karczewski et al., 2011).

3. Analysis and interpretation

3.1. Aisles

Several clear hyperbolic anomalies were indicated along the aisles at a depth of 50–75 ns (3–4 m) with both 500 and 800 MHz antennas. The shape of the reflector resembles a curve of 15 m radius circle according to the evaluation of the angle between branches of hyperbolic anomalies (e.g. PR 8 on Fig. 2). Shallow anomalies (2–20 ns) along the PR 8 profile (on the distance 2–5 m, 14–18 m, 22–24 m) are marked in the Fig. 1. These anomalies are probably caused by the foundations of the pillars (Daniels, 2004, p.356). Shallow anomalies and strong reflections at a distance 31.8–36.2 m are connected with elements of central heating system under the floor. According to the comparison of the data obtained along and across aisles and information about the setting of the former church, (www.klodzko.pl – Religious monuments, 2017), it is possible that reflections from 50 to 75 ns might be caused by a presence of foundation remains of a previous sacral building. Despite the fact that antennas were shielded these anomalies might be reflections from the ceiling of the church (vaults of the naves) (Daniels, 2004, pp. 335–339). Analysis of the velocity of the hyperbolic reflections gave values from the 0.25 m/ns to 0.30 m/ns. The shape of the reflections indicates the presence of diffraction.

3.2. Dead People's Chapel

Radargrams registered with the 500 MHz antenna show hyperbolic anomaly at six ns (0.3 m). The anomaly is visible clearly on radargram from the PPR 14 profile (Fig.4 (a)). There is also another reflection visible at the 26–32 ns (1.2–1.6 m). Radargram from 800 MHz antenna shows also clear anomaly at 50 ns (2.5 m), which is worse visible on the data from 500

MHz antenna. Figure 4 (c) shows radargram obtained along the P 9 profile which is perpendicular to the P 1 (Fig.4 (b)). The deepest reflection at time 50 ns is still visible. Reflection at 26 ns continues from the beginning to the end of the profile with changing depth.

The hyperbolic anomaly at six ns is interpreted as a reflection from the ceiling (vault) of the crypt. It is the most probable interpretation of this anomaly. Such objects as crypts or tombs are common in the middle–aged catholic temples. In this church, there are more crypts which are marked on the ground floor plan, e.g. crypt under the PPR 19 and the PPR 20 profiles on Fig. 3 (b) (probably Count Montani's crypt). However, this crypt considered to be new, because there is no sign of it on the church sketches (Fig. 3 (a), (b)). The shape of the anomaly suggests that the entrance to it may be under the altar, on the outer side of the wall. The shape of this reflection also suggests that it might be connected with already known crypt which is justified because in Fig. 4 (c) this reflection appears on different times. The shape of the anomaly from 26 ns may be classified by velocity pull-up (Conyers, 2014, pp. 31–35) and can be interpreted as a coffin in the crypt, or crypt's floor. The deepest anomaly from 50 ns could be defined as multiple reflections from the ceiling of the chapel. Another variant is that these might be remains of the previous church.

Probable dimensions of the discovered crypt are 3 m in width and 1.8–2.5 m in height. The velocity of the electromagnetic wave in the crypt (0.3 m/ns) which is three times higher than the velocity in the ground, so the height of the discovered crypt is around 0.6–1.5 and that crypt is most probably filled with air.

3.3. Chaple of St. Jacob

The hyperbolic anomaly at four ns (0.2 m) is visible on the radargrams from this chapel (Fig. 5 (a), (b)). The difference between similar anomalies (six ns from Dead People's Chapel) is that directly under the main reflection there are many smaller disturbances. Like in the previous Dead People's Chapel, reflections at 50 ns are visible.

The main hyperbolic reflection at a depth of four ns (0.18 m) is interpreted as a vault of the crypt (Fig. 5 (a), (b)). The changes in the shape of the anomaly are associated with the direction of profiles. Vault can be described as a barrel vault or pointed barrel vault (Imposa and Grassi., 2015 ; Barilaro et al., 2007). In that case, on profiles crossing perpendicularly to its stretch a hyperbolic anomaly was detected (Fig. 5 (a)). Radargrams collected parallel to the stretch of the vault showed flat reflections (Fig. 5 (b)), because the shape of the crypt's ceiling was lateral under them.

Probable size of the crypt is 2 m in width. The crypt is also a newly discovered underground object. Because of the shape and location of the anomaly, expected entrance to the tomb is outside the chapel.

4. Conclusions

As a result of the investigation carried out in the church in Kłodzko, locations of two previously unknown crypts were indicated just beneath chapel's floor. Their position suggests that entrance to the crypts may be outside the church. The complexity of the radargram image from the Dead People's Chapel gives reasons to expect potential connections between the newly discovered crypt and already known one.

The majority of the radargrams recorder along profiles in aisles and chapels include hyperbolic anomalies at a depth 50–75 ns (2.5–3.8 m). They are probably the effect of electromagnetic wave diffraction. In that case two explanations are proposed. The first is that their origin is probably connected with remains of previous church, second, that these are the diffraction points on the ceiling of the catholic temple.

This research might be helpful for future investigations, especially archeological excavations and restoration works.

It should be mentioned that our results were compared with similar surveys that had been conducted in the Church of St. George (Panisova et al., 2016): researchers evaluated the same velocity for the underground medium as we did – 0.1 m/ns. The depth of the upper part of the crypts was ten ns (our 4–6 ns) and 20–24 ns (our 26 ns) to the lower part.

Considering that GPR surveying resolution is evaluated as 1/4 of the electromagnetic wavelength, it was concluded that better vertical resolution could be obtained with 800 MHz than 500 MHz antenna.

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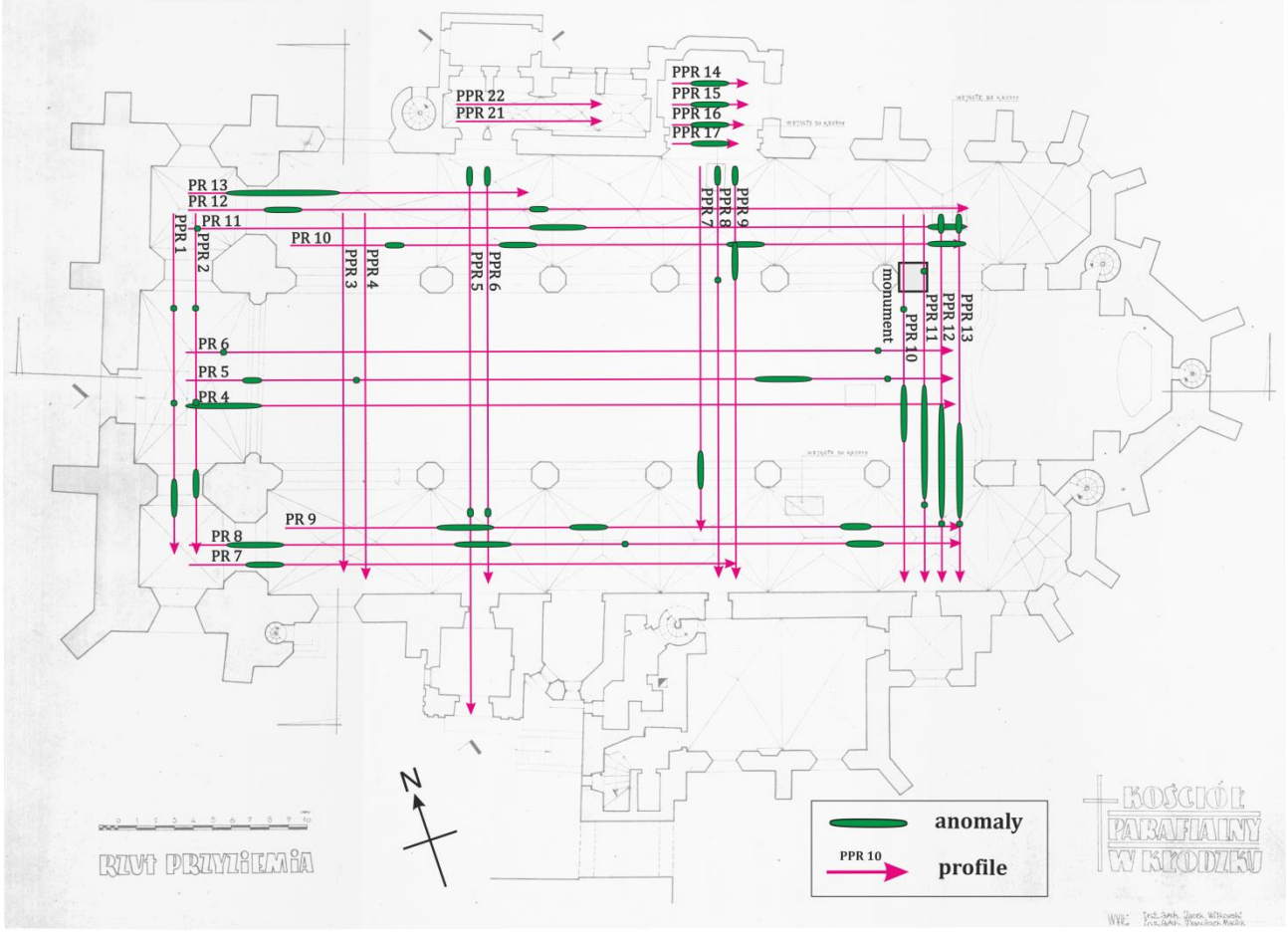

Figure 1. Ground floor plan of the Church with profiles (red) and anomalies (green) set by 500 MHz antenna. Visualization thanks to the Department of Geophysics, AGH University of Science and Technology.

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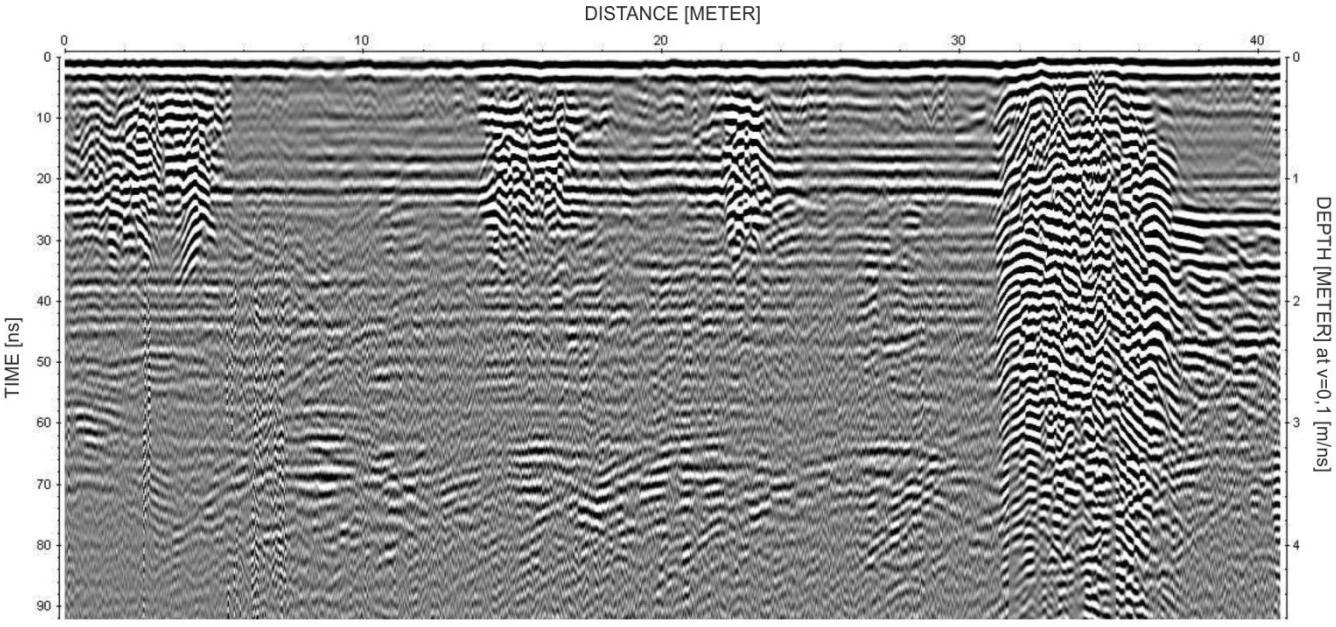

Figure 2. Profile PR8, antenna 500 MHz

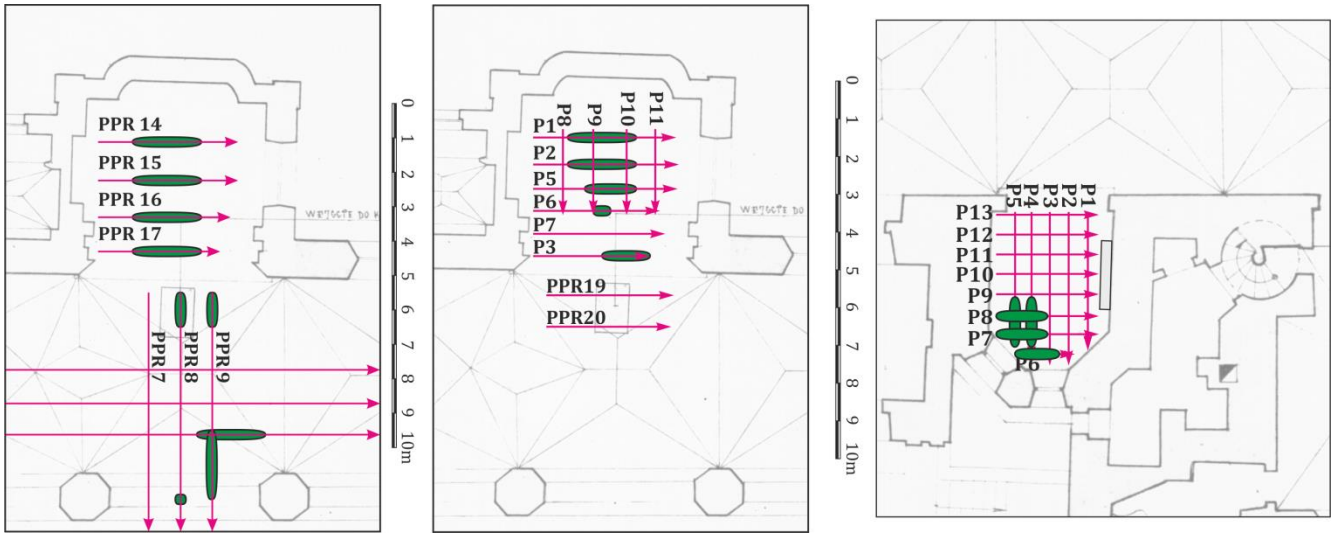

Figure 3. (a) Ground floor plan of the Dead's People Chapel with profiles set by 500 MHz antenna.(PPR 14, PPR 15, PPR 16, PPR 17). (b) Ground floor plan of the Dead's People Chapel with profiles set by 800 MHz antenna. (P1, P2, P3, P5, P6, P7, P8m P9, P10, P11). (c) Ground floor plan of the Chapel of St. Jacob with profiles set by 800 MHz antenna. (P1 – P5 & P6 – P13). Visualization thanks to the Department of Geophysics, AGH University of Science and Technology.

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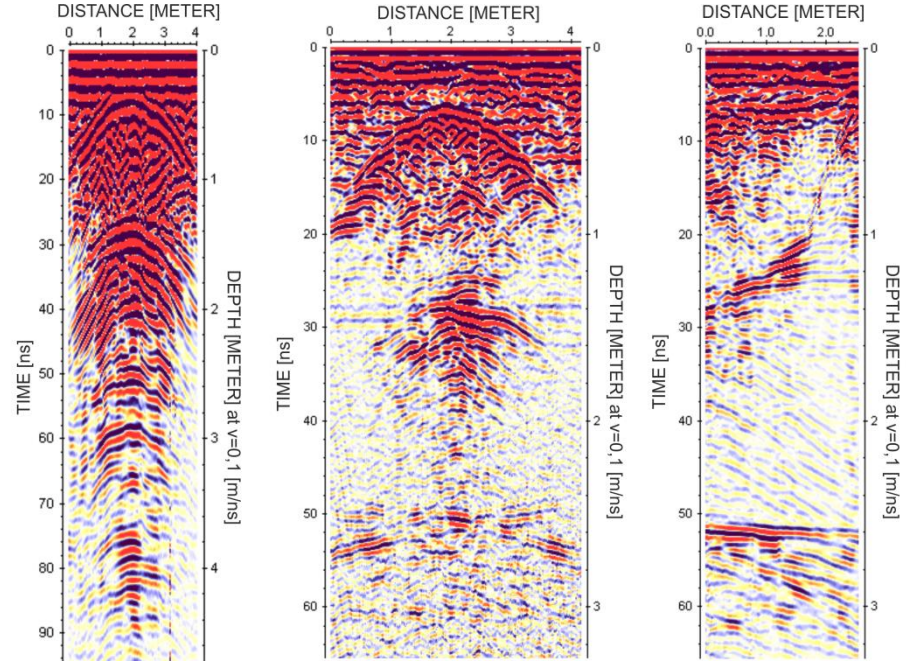

Figure 4. (a) Profile PPR 14, 500 MHz antenna, (b) Profile P. 1., antenna 800 MHz, (c) Profile P. 9., (perpendicular to the previous one) antenna 800 MHz

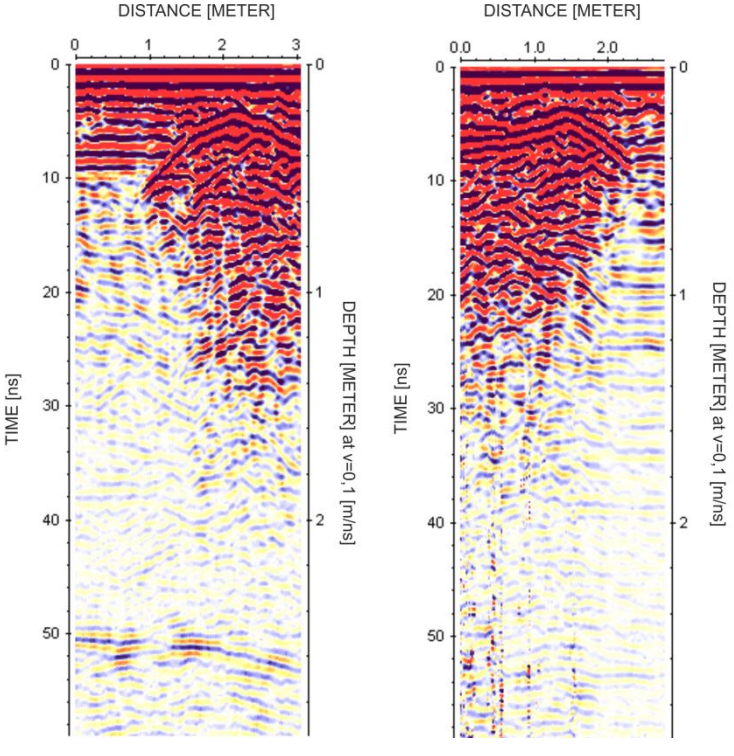

Figure 5. (a) Profile P5, antenna 800 MHz, (b) Profile P8, antenna 800 MHz