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Burial Crypt Identification Beneath the Trabzon St. Anna Church Using Ground Penetrating Radar (GPR) Survey

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ABSTRACT

Located in the Ortahisar district of Trabzon, Saint Anna (Küçük Ayvasıl) Church is recognized as the city's most ancient standing church. The absence of a construction inscription precludes precise dating, yet its three-aisled basilica layout has led scholars to propose an Early Byzantine period origin. The church possesses a restoration inscription on the south side of its entrance, comprising six lines detailing its renovation during the joint reign of Emperors Basil I, Leo VI, and Alexander in AD 884–885. This modestly sized structure represents a noteworthy example of basilica architecture, preserved through successive restorations. The reuse of stone artifacts on the façades and the remnants of wall paintings within the church underscore its historical significance. The possible presence of an inaccessible crypt beneath the church further enhances its uniqueness, suggesting it may have served as a special burial site for prominent figures of the Empire of Trebizond. This study focuses on the GPR application for a better understanding of the Church of Saint Anna (Trabzon). The UtilityScan system with 350HS digital shielded antenna was utilized to verify the existence of a burial chamber (crypt) situated on the lower floor of the church in 2022. Survey were carried out to scan depths of 5 m and 8 m below the church floor. Two-dimensional radar data were taken along profiles with 0.25 m intervals. Additional profiles were also made perpendicular to the previous lines. Then, three-dimensional sections for different depth slices were created. The results suggest the presence of a buried chamber below the analyzed church floor.

Yer Radarı (GPR) Kullanılarak Trabzon St. Anna Kilisesi'ndeki Kripta'nın Belirlenmesi

Makale Bilgisi

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ÖZET

Trabzon'un Ortahisar ilçesinde bulunan Aziz Anna (Küçük Ayvasıl) Kilisesi, Trabzon'un ayakta kalan en eski kilisesidir. Bu mütevazı yapının üzerinde inşa kitabesi bulunmadığından, kesin inşa tarihini belirlemek mümkün değildir. Üç nefli bazilikal plan düzenine sahip olması, araştırmacıların yapının Erken Bizans döneminde inşa edildiğini öne sürmelerine yol açmıştır. Kilisede onarım kitabesi mevcuttur. Giriş kapısının güney tarafında, altı satırlık yazıtta İmparator I. Basil, İmparator VI. Leo ve İmparator Aleksandr'ın ortak hükümdarlık döneminde, MS 884-885 yıllarında restore edildiği yazmaktadır. Günümüze kadar çeşitli onarımlarla ayakta kalabilen bu yapı, küçük boyutuna rağmen bazilika planının önemli bir örneğini temsil etmektedir. Cephelerde taş eserlerin yeniden kullanımı ve içerideki duvar resimlerinin kalıntıları, yapının tarihî önemini vurgulamaktadır. Kilisenin altında, doğrudan erişilemeyen bir kriptanın varlığı, Trabzon İmparatorluğu'nun önde gelen figürlerinin burada gömülmüş olabileceği olasılığıyla onu özel bir mezar yapısı haline getirmektedir. Bu çalışma, Trabzon'daki Saint Anna Kilisesi'nin apsis kısmı altında var olduğu ileri sürülen kripta bölümünün tespiti amacıyla yapılan GPR (Yer Radarı) uygulamasına odaklanmaktadır. 2022 yılında kilisenin alt katında yer alan bir mezar odasının (kript) varlığını doğrulamak amacıyla 350HS dijital korumalı antene sahip UtilityScan sistemi kullanılmıştır. Kilise zemininden 5 m ve 8 m derinliklere kadar olan alanları taramak için ölçümler yapılmıştır. 0,25 m aralıklarla profiller boyunca iki boyutlu radar verileri alınmış ve önceki hatlara dik ek profiller de oluşturulmuştur. Ardından, farklı derinlik dilimlerine ait üç boyutlu kesitler hazırlanmıştır. Sonuçlar, analiz edilen kilise zemininin altında gömülü bir odanın varlığına işaret etmektedir.

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1. INTRODUCTION

1.1. St. Anna Church

St. Anna (Küçük Ayvasıl) Church, located in the Ortahisar district, is the oldest surviving church in Trabzon (Map 1).

Map 1.

Location map of Study Area (Google Earth)

It is not possible to determine the exact construction date since there is no construction inscription. The three-nave basilical layout of this modest building has led scholars to hypothesize that it was constructed in the Early Byzantine period.

Above the door on the south side of the church, a spolia sarcophagus features a six-line repair inscription, indicating the alterations and renovations the church underwent over time. The inscription reveals that the building was restored during the joint reign of Emperor Basil I, Emperor Leo VI, and Emperor Alexander in the years 884-885 AD (Ballance, 1960; Brayer and Winfield, 1985; Easmond, 2016).

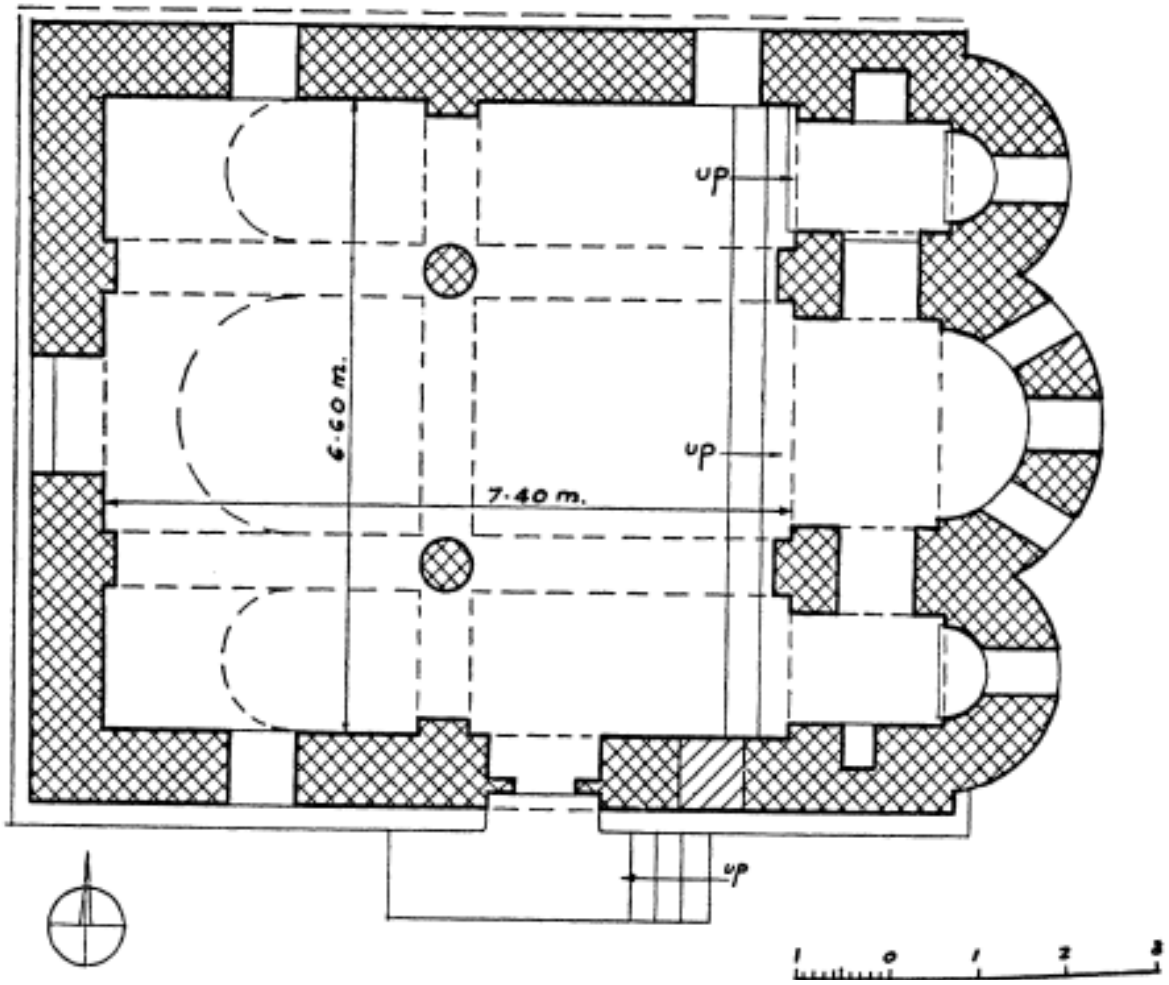
Another inscription within the structure is the inscription block, which was originally situated on the stairs in front of the entrance on the south facade until the 1950s. This block was later relocated to the apse of Trabzon Hagia Sophia. This fragment, believed to be an altarpiece, features a three-line inscription. Although it lacks a specific date, the inscription, which is possibly a votive dedication by Priest Gregorios, is thought to date from the 10th century or even earlier, based on its writing style (Brayer and Winfield, 1985).

The church is constructed in a three-aisled basilica plan with three apses, using well-cut stone, rubble stone, and brick materials, oriented in the east-west direction. The building, which lacks a

narthex, is entered through two doors: one on the west side and the other in the center of the southern facade. Two rows of columns divide the naos into three aisles (Plan 1)**.**

Plan 1

St. Anna Church Plan (Ballance, 1985)



Each aisle features a round-sectioned column and a T-shaped pier. The upper cover of the naos is a barrel vault. The central aisle is wider and longer compared to the side aisles.

On the south and north walls of the naos, there are four semi-circular arched windows. Two of these windows are positioned at a lower level to open to the side aisles, while the other two, at an upper level, open to the central aisle. The main apse forming the eastern facade of the structure features three semi-circular arched windows, with each side apse having one such window opening. The original stone window grilles on these windows on the eastern facade are still visible, characterized by stacked circular openings.

The wall paintings, executed in the fresco technique, reveal traces of three different layers, although they have suffered considerable damage. As part of the restoration carried out between 2021 and 2022, the interior wall paintings of the structure were meticulously cleaned and preserved. Among the wall paintings identified from multiple periods, full-length portraits of two individuals who died in 1411 and 1413, as well as depictions of Saint Leontios and the Prophet Daniel, can be observed on the west wall. On the north wall, there are figures of Mary with the infant Jesus, Saint Michael, and John the Baptist. The south wall features scenes depicting the Descent from the Cross, the meeting of Anna and Elizabeth, and the Threnos scene with a sea monster are depicted (Figure 1).

Figure 1

Fragment of the wall painting in the St. Anna Church (DOKA archive, 2022)

The main apse wall features a compositional arrangement with a two-part burial scene. In the semi-dome of the apse, there is a scene of Mary seated on a throne with the infant Jesus, flanked by a male and female figure on each side. Millet says that he noticed these figures during his visit and that these people were apostles in the place where the two archangels should be (Millet, 1936). Below this scene, there is a crowded composition: Mary is seated on a throne, surrounded by twelve apostles arranged in groups of six on each side. Above Mary, Jesus is depicted seated within an aura carried by four angels. The sections between the apse wall windows portray full-length figures of Church Fathers.

Milet (1936) dates the frescoes in the church to the 12th century, while Rice (1985) places them in the 13th to 14th centuries. Researchers suggest that the church served as one of Trabzon's most significant burial structures in the late 14th century and early 15th century (Brayer and Winfield, 1985; Milet, 1936; Rice, 1985). Besides the elaborate wall paintings, the stone artifacts, repurposed and placed as decorative elements, adorn the southern entrance.

Used as a church until the population exchange in 1923, the building remained empty for a while after the population exchange and was later reused as a family residence. The state treasury originally owned the property but later relinquished and transferred it to the Trabzon Museum Directorate. The building, which underwent restoration work between 2021 and 2022, is scheduled to be completed and opened to visitors as a monument museum in 2023 (Ballance, 1960).

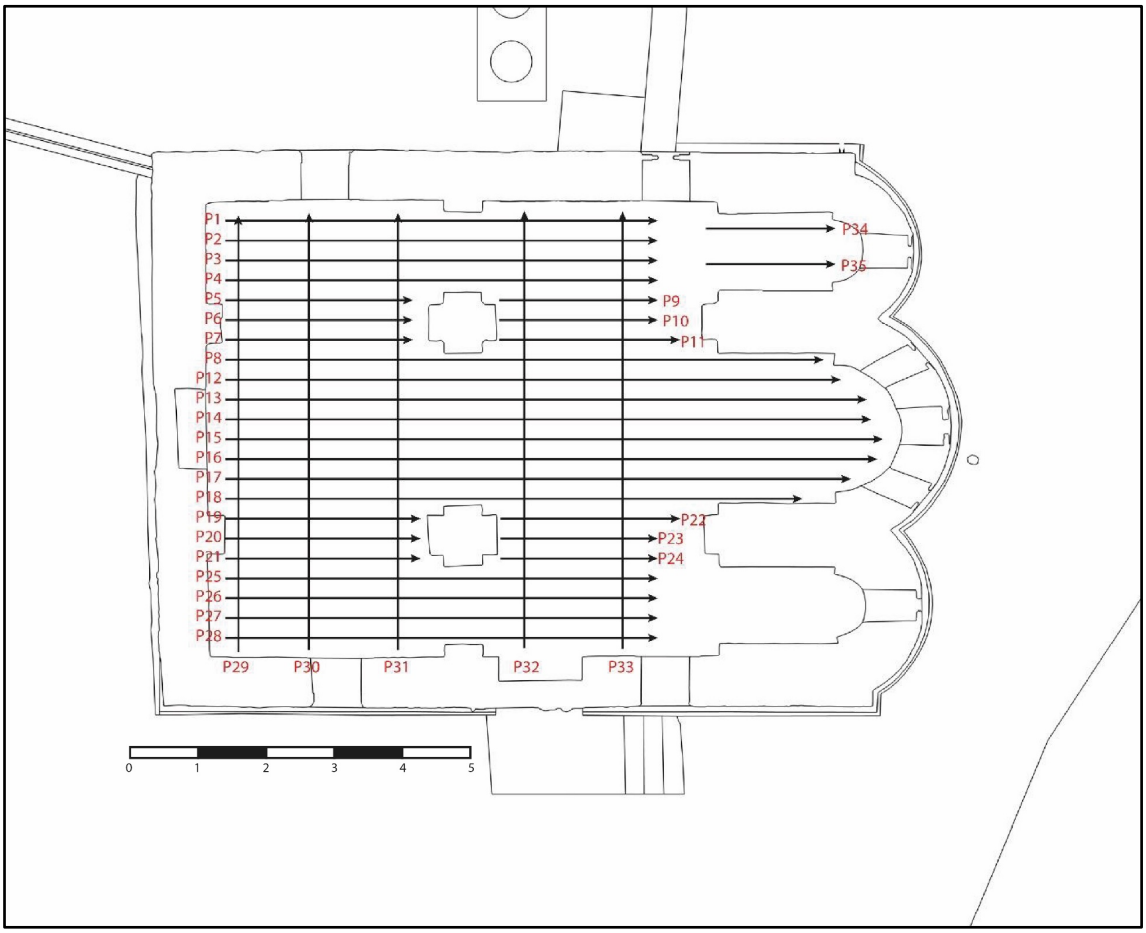
Many travelers and researchers who have visited Trabzon since the 19th century, as well as those who have examined the church with its richly frescoed interior, have noted that it is a uniquely distinct structure due to its architectural plan and decorative features. Furthermore, these sources draw attention to the existence of a burial chamber (crypt) situated on the lower floor of the church (Brayer and Winfield, 1985).

1.2. Ground penetrating radar (GPR) studies

On January 20-21, 2022, a Ground Penetrating Radar (GPR) survey was carried out to investigate the potential existence of a crypt beneath St. Anna Church. The study utilized the GSSI UtilityScan system equipped with a 350HS digital shielded antenna. Surveys were conducted at depths of 5 and 8 meters, collecting two-dimensional radar data at 0.25-meter intervals in multiple directions (Plan 2).

Plan 2

GPR profiles are overlaid on the ground floor plan. The numbers (P1 through P33) indicate the order of the data, while the arrows denote the starting and ending locations of the survey. For a more detailed explanation, please refer to Table 2.



This data was used to create three-dimensional depth slices, enabling a detailed examination of the subsurface features of the church, with the aim of identifying any hidden structures, such as a burial chamber.

2. Data and Methodology

GPR is an active geophysical technique that transmits electromagnetic pulses into the subsurface using surface antennas and measures the time delay between the transmission and reception of these pulses (Conyers, 2013; Conyers and Goodman, 1997; Yiğit et al., 2018). The method relies on the reflection of high-frequency electromagnetic (EM) waves, which are recorded based on subsurface features, such as fractures. Numerous studies in archaeogeophysics have demonstrated that GPR enables a detailed assessment of the characteristics of archaeological sites (Vaughan, 1986; Conyers and Goodman, 1997; Conyers, 2013; Goodman et al., 2006; Yiğit et al., 2018).

Taking into account the moisture content and surface conditions, researchers applied the GPR technique to generate cross-sections of the subsurface. The application of GPR in archaeological mapping and interpretation has evolved from a primarily exploratory approach, which relied on two-dimensional reflection profiles, to a method that frequently employs three-dimensional mapping and computer-generated visualization for studying larger subsurface areas (Conyers 2013; Goodman and Piro 2013; Conyers 2015). In most archaeological surveys, detection is the primary objective of GPR investigations (Jol, 2009), as it enables the identification of buried structural features (Leucci et al., 2021; Yiğit et al., 2018).

At the St. Anna (Küçük Ayvasıl) Church, located in the Çarşı neighborhood of the Ortahisar district in Trabzon, GPR was utilized during the ongoing restoration works to detect a potential space or chamber beneath the structure. For this study, the GSSI 350HS digital shielded antenna was selected, as detailed in Table 1.

Table 1

Antenna Specifications

Antenna Central Frequency (MHz)	**Vertical resolution (Meter)**	**Penetration Depth (Meter)**	**Vertical Sampling**	**Scan Density (Scans/Meter)**	**Antennae Separation (Meter)**
350	0,004	0.00-10.00	512	0,02	0.3

The 350HS antenna, equipped with advanced HyperStacking (HS) technology, provides superior depth penetration and resolution compared to traditional Equivalent Time Sampling (ETS) methods (Feigin and Cist, 2016), allowing data collection from depths of up to 8 meters with a central frequency of 350 MHz.

3. GPR Survey and Data Processing

The survey was conducted using a 350 HS (Hyper Stacking) antenna, collecting radar data along parallel lines at 0.25-meter intervals from P1 to P28, and exploring to a depth of 5.00 meters on the floor, as illustrated in Plan 2 and Table 2.

Table 2.

350HS digital antenna survey data

Depth	**Number of Profile**	**Survey Data Length (meter)**
0.00-5.00	28	148
0.00-8.00	35	182

Total	63	330

Additionally, we extended the lines perpendicular to the previous lines in order to reach a depth of 8 meters in the profiles from p29 to p35 (Plan 2).

Figure 2 illustrates the GPR profile survey labeled as P33, including its survey direction, marked with dashed lines, while the arrow indicates the start and end points. The data processing sequence involved static correction, energy gain, background removal, band-pass filtering, and f-k filtering (Yiğit, 2016). These steps were applied to the raw GPR data to generate two-dimensional depth sections (radargrams) and slice maps from 28 profiles.

During data processing, velocity analysis was performed using the hyperbola-fitting method. This technique is commonly used in GPR surveys to estimate the velocity of electromagnetic waves by fitting hyperbolic reflections, typically produced by point-like or small buried objects, to a mathematical model (Jol, 2009; Conyers, 2013). By adjusting the hyperbola to match the observed reflections in the radargrams, the velocity of wave propagation through the subsurface was determined to be approximately 0.089 m/ns.

Figure 2.

GPR survey on the church floor for the P33 profile.

The estimated velocity was then used to calculate the dielectric constant (or relative permittivity) of the soil, which affects how electromagnetic waves propagate through different materials. The dielectric constant in this case was determined to be approximately 11.36. Higher dielectric constants are generally associated with moisture-rich or conductive soils, as they tend to slow down the

propagation of electromagnetic waves (Daniels, 2004; Leucci, 2018). This suggests that the surveyed area contains a significant amount of moisture, which is typical for such environments.

Figure 3 presents sample 2-dimensional vertical radargrams showing high amplitudes, along with contour maps created for depths of 0.50 m, 2.70 m, 3.05 m, and 4.05 m. Dashed lines indicate high amplitudes observed on contour maps and vertical radargrams. Sample vertical radargrams were selected from the survey results obtained for the 5.00 m depth scan (P2, P12, P16, P18). Additionally, 2-dimensional depth sections obtained from profile survey (P29-P33), which were conducted perpendicular to the profile survey shown in Plan 2, are observed anomaly effects for the 8.00-meter depth scan (Fig. 4).

Figure 3.

Depth slices with 5.00-meter vertical radargrams which high amplitude anomalies are shown with black dashed lines. (a) 0.50 m depth slice with P2 radargram. (b) 2.70 m depth slice with P12 radargram. (c) 3.05 m depth slice with P16 radargram. (d) 4.05 m depth slice with P18 radargram.

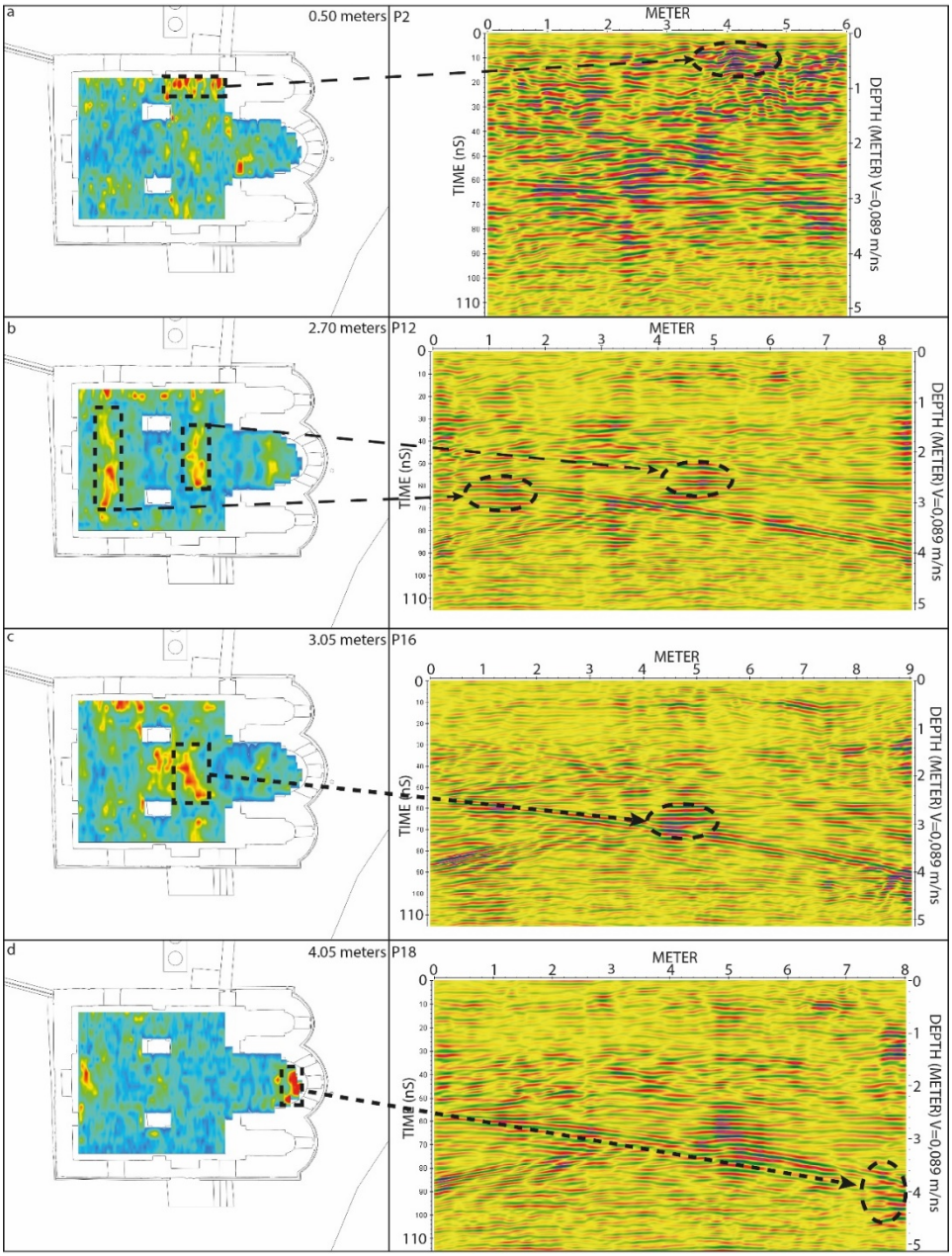
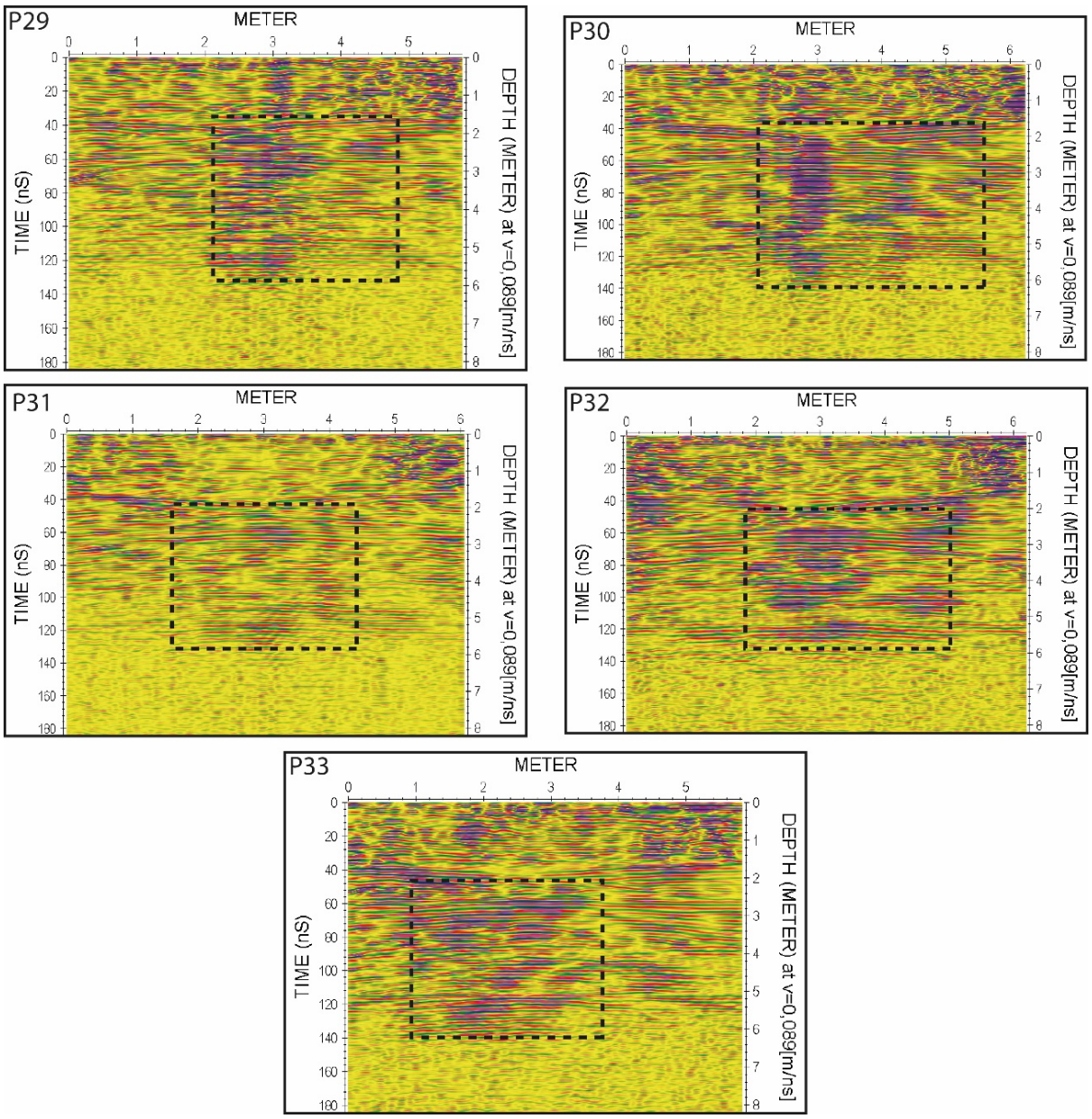


Figure 4.

8.00-meter radargrams for P29-P33 profiles. High Amplitude anomalies are shown with black dashed lines.



4. Results and Discussion

St. Anna (Küçük Ayvasıl) Church is the oldest church in Trabzon. The structure, which has survived the present day through various repairs, is a small-sized yet essential example of a basilica plan. B The reuse of stone artifacts on the facades and the remnants of wall paintings inside highlight its historical significance. The existence of a crypt beneath the church, though inaccessible, makes it a unique funerary structure where prominent figures from the Trabzon Empire were likely buried.

Examples of structures with a crypt in the lower part are rare in Byzantine architecture. The Odalar Mosque (12th century) includes a crypt-tomb chamber in its lower section (whether the lower level was originally designed as a tomb chamber is a subject of debate). The Palace of Bogdan (14th century) also features a crypt. Additionally, in Halki, only depicted in illustrations, the Savior Church, and in Greece's Hasios Loukas, a beautiful crypt is located beneath the Catholicon (main church) (Ousterhout, 2016). In this context, the existence of the chamber-crypt in the lower part of St. Anne Church and whether it was

originally designed from the beginning is debated. Ballance (1985) claims that the crypt was present from the outset.

GPR results from the study at St. Anna Church identified several subsurface anomalies that suggest the presence of a chamber beneath the building. At a depth of 0.55 meters, high-amplitude reflections, indicated by dashed lines, are interpreted as potential access stairs to the underground chamber (Fig. 3a). Anomalies suggesting possible remnants of walls are anticipated at a depth of 2.70 meters below the church floor level. Anomaly effects observed at depth of 3.05 meters and in the vertical sections obtained at 8.00 meters are considered indicative of an underground chamber. At a depth of approximately 4.05 meters from the working surface, void anomalies are observed beneath the apse and aligned under the door area (Fig. 3d). Anomalies resembling an underground chamber, with a height of 4 meters and a length of 3 meters, have been detected, starting at a depth of approximately 2 meters and extending to 6 meters below the survey surface. (Fig. 4). The GPR data supports the hypothesis of a large underground chamber, possibly the crypt, under the church. The high-amplitude reflections at shallow depths suggest the presence of stairs leading to the chamber, and further excavation is recommended to confirm this feature and better understand the chronological development of the crypt.

5. CONCLUSIONS

The GPR survey at St. Anna (Küçük Ayvasıl) Church has provided critical insights into the subsurface features of this important Byzantine structure. The identification of a significant underground space, likely a crypt, suggests the church's function as a funerary site for notable figures of the period. High-amplitude reflections indicate the possible presence of stairs, supporting the hypothesis of an extensive burial chamber.

This study demonstrates the effectiveness of GPR as a non-invasive tool for archaeological exploration, particularly in heritage contexts where excavation is limited. Further excavations are recommended to verify the existence of the crypt and to clarify its historical development, contributing to broader understandings of Byzantine architectural and burial practices. The use of modern geophysical methods alongside traditional archaeology offers valuable opportunities for preserving and interpreting cultural heritage sites.

Ethical Statement

This article has not been previously published elsewhere.

Ethics Committee Approval

No need for ethics committee approval.

Author Contributions

Research Design (CRediT 1) Author 1 (%35) – Author 2 (%35) – Author 3 (%30)

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Writing the Article (CRediT 12-13) Author 1 (%30) – Author 2 (%35) – Author 3 (%35)

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