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INFRA CIVITATEM PRIWINAE

Geophysical Survey of the Early Medieval Centre of Mosapurc/Zalavár*

PETER MILO – BÉLA MIKLÓS SZŐKE – TOMÁŠ TENCER – ÁGNES RITOÓK – KATALIN GERGELY – MICHAL VÁGNER

One of the most attractive themes in archaeological research is the excavation of central places. These include early medieval centres which mirror the political and socio-economic relationships, reflecting the changes of their time. Zalavár-Vársziget is undoubtedly one of the most important fortified sites in Central Europe in the Early Middle Ages. Its short-lived existence from the 840s to the beginning of the 10th c. perfectly illustrates the rise and fall of Carolingian power in Pannonia. It was a place where important people of that time, including Pribina, Kocel, Methodius, and Arnulf, lived and worked. Its repeated occurrence in written historical sources also points to its significance. In these sources, it appears under various names, but especially as Mosaburg. Systematic archaeological excavation of the site has been conducted for approximately 70 years. Within the last decade, geophysical surveys followed field research. By comparing previous knowledge and new results from the geophysical prospection, we were able to, with the help of statistics and spatial analyses, evaluate the similarities and differences between the central area and its surroundings, identifying the basic characteristics of the individual parts of the site.

Keywords: Transdanubia, Early Medieval Period, fortified settlement, stronghold fortification, magnetometry, ground-penetrating radar survey.

INTRODUCTION

The power centre of Mosapurc/Zalavár is one of the key archaeological early medieval sites in the central Danubian region. It is situated in the western part of the Pannonian Basin at the south-western tip of Lake Balaton, in the marshy area of the Zala river on the sandy island called Vársziget (Castle island; Fig. 1; 2).

The earliest traces of settlement activity in Vársziget, come from the Late Stone Age. There is also evidence of the Middle Bronze Age and the Roman period occupation. In the Early Middle Ages, low elevated sandy islands (dunes) jutting out from the floodplain became the basis of the densely settled area. Despite this, there is no evidence of early medieval occupation in Vársziget. In the 9th c., Pribina (Priwina) built his Pannonian residence there. Vársziget became the central hub of settlement and gained historical significance. The site known from written historical sources as *civitas Priwinae*, *urbs paludarum*, *castrum Chezilonis*, *Mosapurc*, *Mosaburg*, became the administrative and economic centre of the easternmost march of the East Frankish Empire. Its significance is supported by numerous remains of stone and wooden, sacred and profane architecture, otherwise rare in this geographical region in the Early Middle Ages (*Sós 1963*; *Szőke 2010*). The site was inhabited even after the Magyars' conquest of the territory, although with lower intensity. In the 11th c., an administrative centre of the county was erected on the ruins of early medieval churches and palaces. Later on, the Benedictines built a monastery there which was converted into a fortress during the Turkish threat (*Ritoók 2015*). In Modern Times, the site was used mainly as pasture and a significant part was destroyed by the exploitation of building material from the ruins of the monastery and subsequent extraction of sand.

The site has been archaeologically examined since the end of the 19th c. up to the present day. Given the limited possibilities of archaeological excavation methods, such as high demands of time and resources, or the limited extent of the excavated area, it seems necessary to acquire new data by employing complementary methods. These include, among others, a geophysical survey which is capable of fast and precise identification of subsurface structures of archaeological origin. Being non-destructive, geophysical prospection leaves the examined feature intact for further investigation.

The aim of the following contribution is to present the results of geophysical measurements carried out on the site Vársziget in 2010 and 2015. The

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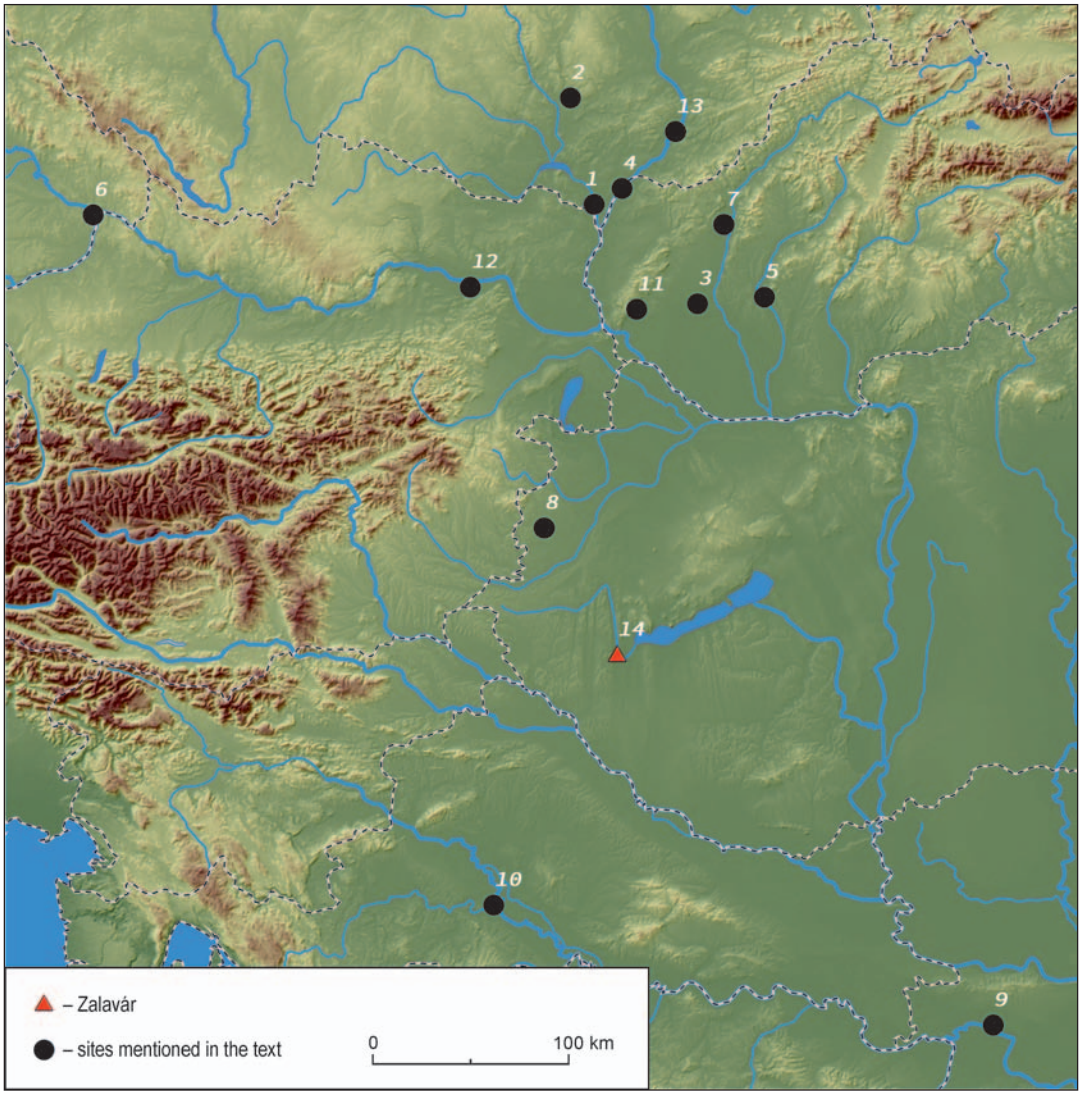

Fig. 1. Early medieval sites mentioned in the text. 1 – Břeclav-Pohansko; 2 – Brno-Staré Zámky; 3 – Majcichov; 4 – Mikulčice; 5 – Nitra; 6 – Passau; 7 – Pobedim; 8 – Savaria; 9 – Sirmium; 10 – Siscia; 11 – Svätý Jur-Neštich; 12 – Tulln; 13 – Uherské Hradiště; 14 – Zalavár-Vársziget.

magnetic survey concentrated on two parts of the site: the western section (main castle) and the north-eastern section (suburbium). The principal task was to detect areas with potential occurrence of features of archaeological origin. Ground-penetrating radar measurements examined nine smaller distinct are as with an aim to verify some of the results of the magnetic survey (Fig. 3).

SETTLEMENT ACTIVITIES FROM THE EARLY MIDDLE AGES TO MODERN TIMES

Since many variables influence the results of a geophysical survey and the identified structures are from different periods, this section presents a brief reconstruction of the development of settlement on the site, from the Early Middle Ages to Modern Times. Attention will mainly focus on the 9th c., when the settlement and construction activities peaked. We assume that most of the structures identified during the geophysical survey are related to this period. However, the site's history continued even after the demise of Zalavár as the centre of East Frankish power in Pannonia. Clear traces in the geophysical survey results have also been left by late medieval and modern anthropogenic activities that form a single heterogeneous whole, together with the earlier structures.

There are two main sources about the history of the castle island in Zalavár: written historical

Fig. 2. Zalavár-Vársziget and other sites of the early Middle Ages in the area.

sources and modern archaeological research. While the written sources have already been exploited in terms of the supply of new data, archaeological excavation continues to bring new evidence of human activities which left a trace. What is interesting and rare about Zalavár is that it is one of the very few early medieval sites in the central Danubian region where we can successfully compare both types of sources. In many aspects, they have complemented each other.

One of the essential written sources about the Pannonian region in the Early Middle Ages is the work *Conversio Bagoariorum et Carantanorum* (The Conversion of the Bavarians and the Carantanians) written at the beginning of the 870s probably by the Salzburg archbishop Adalwin (859–873) for king Louis the German. Some chapters of this document (cap. 10–14) deal with events related to the Pannonian domain of Pribina (Priwina) and his son Kocel (Chezil) on the western edge of Lake Balaton, on the lower course of the Zala river (*Lošek 1997*). Among the other written sources, we can mention *Annales Fuldenses* (*Rau 1975*), *Annales Iuvavenses maximi* (*Klebel 1921*) or the royal documents issued by Arnulf directly at Mosaburg (*Szőke 2018a*, 200). A detailed analysis of written sources relating to Mosaburg is presented in the latest publication by *B. M. Szőke* (*2021*).

Archaeological excavation at Zalavár-Vársziget started as early as the end of the 19th c. Flóris Rómer, who had visited the site several times from 1861, carried out small scale excavations in 1881, during

which he succeeded in uncovering one of the walls running in a north-south direction. Further digging was carried out in 1887 and 1891 by Viktor Récsey, but he did not make the results public. In autumn 1946, Aladár Radnóti and Sándor Soproni, who searched for continuity of Roman settlement, started the first systematically organised excavations at Mosaburg (*Szőke 2021*, 314–317). Based on the initial results of this research, an interdisciplinary working group (lead by Géza Fehér) was established in 1948, which gave an essential impulse for research into the Carolingian period in Hungary. Excavation work undertaken between 1951 and 1954 concentrated on the southern section of the castle island (*Fehér 1953*; *1954*). The premature death of Géza Fehér († 1955) put a temporary end to field work in Zalavár. It was resumed in the 1960s under the supervision of Ágnes Cs. Sós, who continued excavating in the southern part of the island, but she also led excavations in the direction towards the central area and to the northern course of the fortification (*Sós 1963*; *1973*; *1994*). Since 1994, research at Mosaburg has been led by Béla Miklós Szőke. He, together with Ágnes Ritoók, who is focusing on the Árpád period and the High Middle Ages, followed the course of the previous excavation and primarily focused on documenting larger continuous areas in the central part of the site (see details in the history of research *Ritoók 2002*; *Szőke 1976*, 69–71).

Systematic research on the Zalavár-Vársziget site uncovered a wide range of archaeological features and contexts. Written historical sources indicate that, apart from being the residence of Pribina and Kocel, Mosaburg was also a Pannonian palatium of king Arnulf and the Salzburg archbishop. Following the results of intensive excavations, it was possible to identify the five churches mentioned in *Conversio Bagoariorum et Carantanorum*. Based on the other excavated profane buildings and fortification systems, it was possible to detect and reconstruct the bishop's court and Arnulf's royal palace. As a result, in describing Mosaburg, we do not have to rely solely on period written source documents. The uncovered graves and the grave goods found in them, give us a picture of the community that lived at Mosaburg (*Szőke 2021*, 303–458).

To understand the origins and development of Mosaburg, we have to go back to the period when it was just an uninhabited elevation (island) surrounded by marshes. The birth of Mosaburg was the result of preceding events which had an impact both on the Vársziget region and its surroundings as well as the Carpathian Basin as a whole. During the rule of Charlemagne (742–814), the dynamically expanding reign of the Carolingians reached the Carpathian Basin. Between 791 and 811, numerous military campaigns and quiet diplomacy put an end to the Avar khaganate. A decision concerning the further political destiny of the Carpathian Basin was made in 811 at the imperial convention in Aachen when a compromise concerning peace between the Avars and the Slavs, whom the Avars had accused of attacking them, was reached. We are unaware of further details but the following events indirectly confirm that the agreement had not been violated. There is no later mention that fighting would continue anywhere between the Avars and the Slavs or the Avars and the Franks (*Deér 1965*, 778; *Steinhübel 2004*, 48–62; *Szőke 2018b*). At the same time, the new Carolingian province of Pannonia was officially established in the western part of the former Avar khaganate, subdivided into two administrative units. The territory between the Drava and the Sava with the centre in Siscia was called Pannonia inferior. Its administrator was directly subordinated to the duke of Friuli and spiritually, it fell under the Aquileia mission (*Wolfram 1995*, 225). The territory between the Drava and the Danube was Pannonia superior. Its worldly matters were subjected to the rule of the Bavarian prefect Gerold (III.) and spiritually, it fell under the Salzburg mission (*Reimitz 2001*). After the following turbulent period, marked mainly by the uprising of Liudewit and campaigns against it (819–822), and especially the occupation of the eastern part of the Sava and Drava crossroads, including the town Sirmium by the Bulgarians (828), Louis the Pious (Ludovicus Pius) decided to reorganise the eastern part of the empire. He was dividing up the larger territorial units into smaller ones, whereby he created a network of counties within the territory of Pannonia. As a result, Ratbod's county with its seat in Tulln and east of it, the Rihheri county with its seat in Savaria (first mention in writing in 844) were established within the province of Pannonia superior (*Szőke 2021*, 174–185). In Pannonia inferior, on the lower stream of the Zala river, a large area was given as a fief to the administration of Pribina (around 838–840). Pribina settled there and built a *munimen* (fortress/fortified residence) in the marshy woodland around the river. In 847 the East Frankish king Louis the German gave this land to Pribina into his personal possession (*Lošek 1997*, 122, 123; *Wolfram 1979*, 53). Pribina, and afterwards his son Kocel, significantly promoted the Christianisation of the region as confirmed by written reports of building more than 30 churches (*Szőke 2021*, 228–233).

Mosaburg has been developing rapidly since its foundation, thanks to intensive construction work. Based on the remains of the excavated fortification structures – including ditches and palisades with

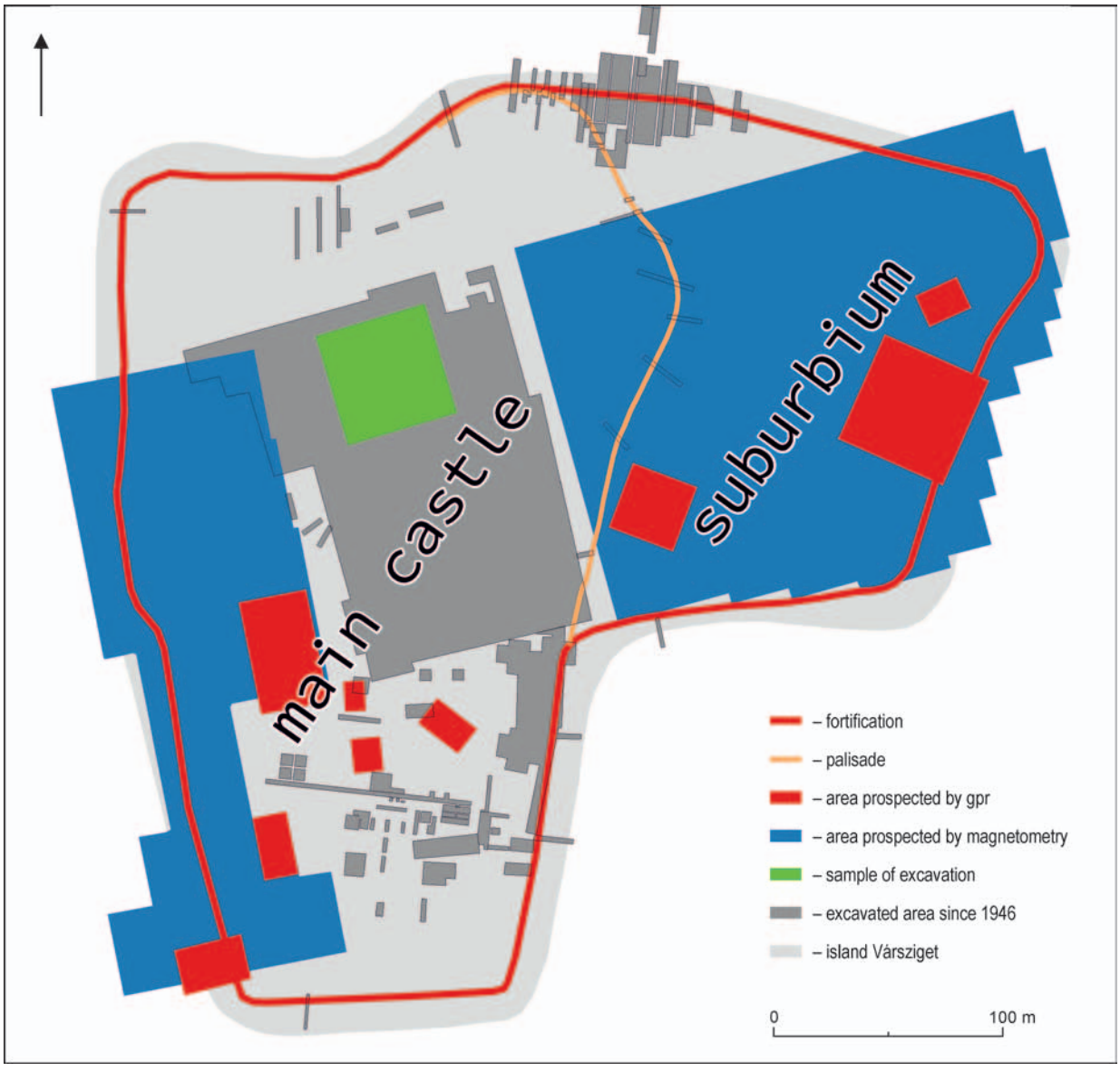

Fig. 3. Zalavár-Vársziget. Localisation of archaeological excavations and geophysical prospections.

various dating and the wall surrounding the entire site – we can divide the L-shaped castle elevation into three roughly equal sections: southern (3 ha), north-western (4 ha) and north-eastern (3.5 ha). Overall, we estimate the extent of the island at approximately 10.5 ha (Fig. 3).

The following overview of construction development on the site is based on the most recent research as well as observations and interpretations of find contexts according to B. M. Szőke and Á. Ritoók:

In the first construction phase (Fig. 4; Phase I – 840–850/855), the ditch separated the southern third of the island on which the residence of Pribina and later Kocel (*munimen Priwinae*, *castrum Chezilonis*) was erected. The residence was connected with the rest of the site only by a wooden bridge. There is only limited evidence of Pribina's residence as this part of the island was heavily destroyed in Modern Times by the quarrying of sand. Remains of the inhabited area have survived only along the margins of the pit. The archaeological excavation uncovered half-sunken huts and settlement pits, with evidence of intensive craftsmen's activities (*Gergely 2016*, 343–345). It is also in this area – *infra munimen Priwinae* – where we can locate Pribina's proprietary church built roughly ten years after the settlement of Mosaburg. The church was consecrated on 24 January 850 to the Blessed Virgin Mary by the Salzburg archbishop Liupram. For this occasion, all members of Pribina's family and his entourage and all the essential dignitaries and noblemen from the Eastern March, convened.

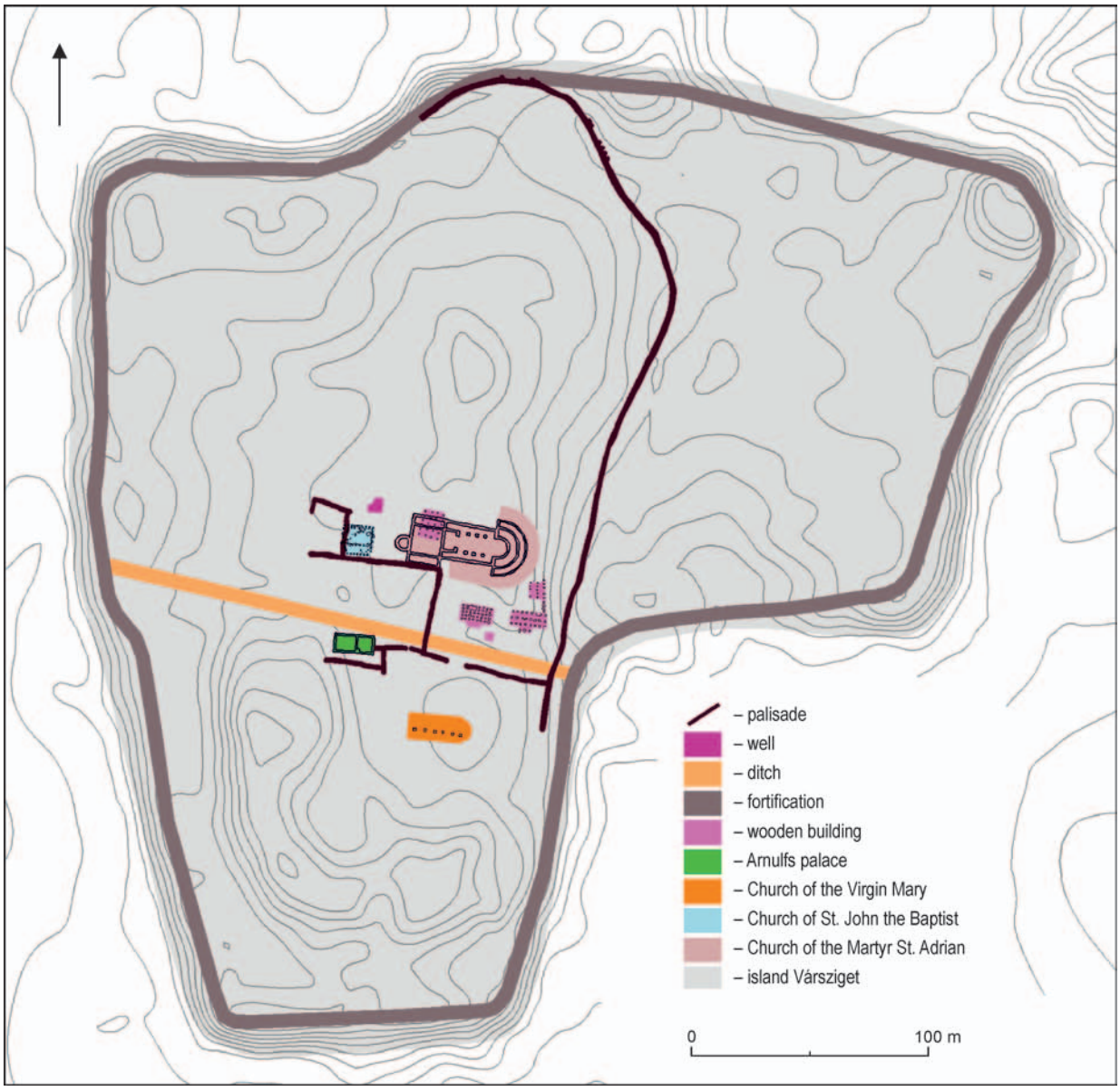

Fig. 4. Zalavár-Vársziget. Settlemet structures from Phase I (840–850/855), Phase II (850/855–870), Phase III (870/880–907) and Phase IV (10th c.).

In this respect, the plan of the church in the drawing of the Zalavár anti-Turkish fortress with a monastery made in 1569 by G. Turco is quite interesting. It is possible to imagine that Pribina's church survived the turbulent times of the 10th c. to be subsequently rebuilt to an unknown extent for the newly-established Benedictine monastery there. From the drawing we can merely identify its location. The original shape and dimensions are unknown, and we can only assume that it at least approximately, corresponded to its plan in the preserved drawing. There, the church is depicted as a three-nave structure with a semicircular apse and dimensions of ca. 26 × 12 m. There are no traces of the church or Pribina's palace that have survived. In the second half of the 19th c. the church was demolished with only the foundations left and the damage was completed by the quarrying of sand which followed after the extraction of building material from the ruins of the fortress, the monastery and Pribina's church. However, the appearance of the graves with rich grave goods in this area indicated its presence (*Szőke 2021*, 228–233).

The north-western part of the island had also been settled by that time. Most of the buildings were log houses, identified as amorphous pits and shallow depressions. They mainly served as dwellings and shelters for craftsmen's activities. However,

one building in this area was identified by the excavation team as in *eadem civitate* – the Church of St John the Baptist mentioned in *Conversio* (*Szőke 2021*, 339–354). Among the churches in Mosaburg this one was built as the first at the beginning of the 840s. It was a wooden structure of the hall type with dimensions of 12 × 8 m and a rectangular presbytery. From the south, the church is joined by an atrium with dimensions of 12 × 8 m which may have been a later addition built at the time of the replacement of the columns in the church hall. The Church of St John the Baptist is similar to the wooden churches from the 8th and 9th c. popular in the eastern part of the Frankish empire. A well lined with large basalt stones and built with special care, north of the church, was probably used as the source of water for baptisms. Another wooden structure situated east of the church *Ágnes Cs. Sós* (*1994*, 87) interpreted as a wooden church. The following examination brought a different interpretation. After a review and overall evaluation of the find context, *B. M. Szőke* (*2021*, 216, 458) interpreted the building as the wooden palace of the priest.

The hinterland of the site was inhabited at that time as well. In the immediate environs of Mosaburg, we are aware of settlements and two other churches from the Carolingian period. North-east of the Vársziget in the Récéskút location, excavations uncovered a stone-walled three-nave basilica and a sacred wooden building was documented to the south-east, in the Borjúállás site. According to *Conversio* the Church of St Mary was consecrated at the same time as the *Sandrata* and *Ermperhta foris civitatem* (outside the civitas) churches. Thus, these buildings may be identical to the two archaeologically localised churches within view from Mosaburg (*Szőke 2021*, 399–409).

In the next construction phase (Fig. 4; Phase II – 850/855-870), the ditch separating the southern part of the island was filled. The eastern and western sections of the island were divided by a palisade, resulting in the separation of the eastern third of the site from the rest of the island. There has been no excavation in the eastern section of the site so far, and its function, therefore, remains unknown. However, it is improbable that this area was densely populated at that time. The geophysical survey provided new data on this issue, which is discussed later in this contribution.

The most crucial building activities took place in the southern area of the north-western section of the island. The major role is played by the Salzburg archbishopric, which was in charge of missionary activities in this region. The result was the construction of a bishop's palatium (*Infra civitatem Priwinae*) with the most magnificent building in the whole of Mosaburg – the pilgrimage church of the Martyr St Adrian. It is the largest known church building in the eastern border region of the Carolingian empire. The concept of the three-nave building of the pilgrimage church with a crypt (*Umgangskrypta*), where the remains of Saint Adrian were kept, is unique for the eastern regions of the Frankish empire. The monumental dimensions of the structure (29.3 × 16.0–16.7 m) with a multi-storey interior and its artistic decoration with wall mural paintings and marble lining must have enchanted and deeply impressed the newly baptised inhabitants of Pannonia. The craftsmen involved in the construction of the church were sent directly by the Salzburg archbishop Liupram. They included a master who made the colourful glass panes for the windows, partly decorated with figurative motifs, and a master who cast what is to date the largest bell known to us from the Carolingian period. The heyday of St Adrian's as a pilgrimage and bishop's church was in the period of 860–875 (*Szőke 2021*, 354–398). Apart from the Church of St Adrian, the core of the bishop's residence consisted of two archaeologically confirmed wooden palaces situated south of the church. Written sources inform us that the archbishops Liupram and Adalwin spent the winter months several times at Mosaburg. It is also possible that Methodius may have used the bishop's residence during his stay (*Szőke 2010*, 49, 50)

The development of Mosaburg reached a peak from the end of the 870s when Arnulf, the grandson of Louis the German, became king of East Francia (Fig. 4; Phase III – 870/880–907). Arnulf, probably during the short reign of his father Karlmann (876–880), had extended the royal palatium at Mosaburg, which likely incorporated the stone palace uncovered during excavations in 2011 (*Szőke 2018a*, 200). The palace stood between the Church of the Virgin Mary in the south, and the churches of St John the Baptist and St Adrian in the north. Its orientation (east-west) is the same as the sacred buildings. The foundation stone wall was 70–80 cm wide, 60–70 cm deep, and the dimensions of the plan of the whole building were 17 × 8 m. An inner partition divided the building into two rooms – one smaller space and one larger hall. An anteroom (?) was situated on the southern side. The building was erected within a courtyard separated from the surroundings by a wooden palisade. The interpretation and dating of the building, as well as the entire complex, are not without complications. From the find context, its discoverers assume the palace was built for the East Frankish ruler Arnulf who visited Mosaburg several times and even stayed there for an extended period of time. Several documents

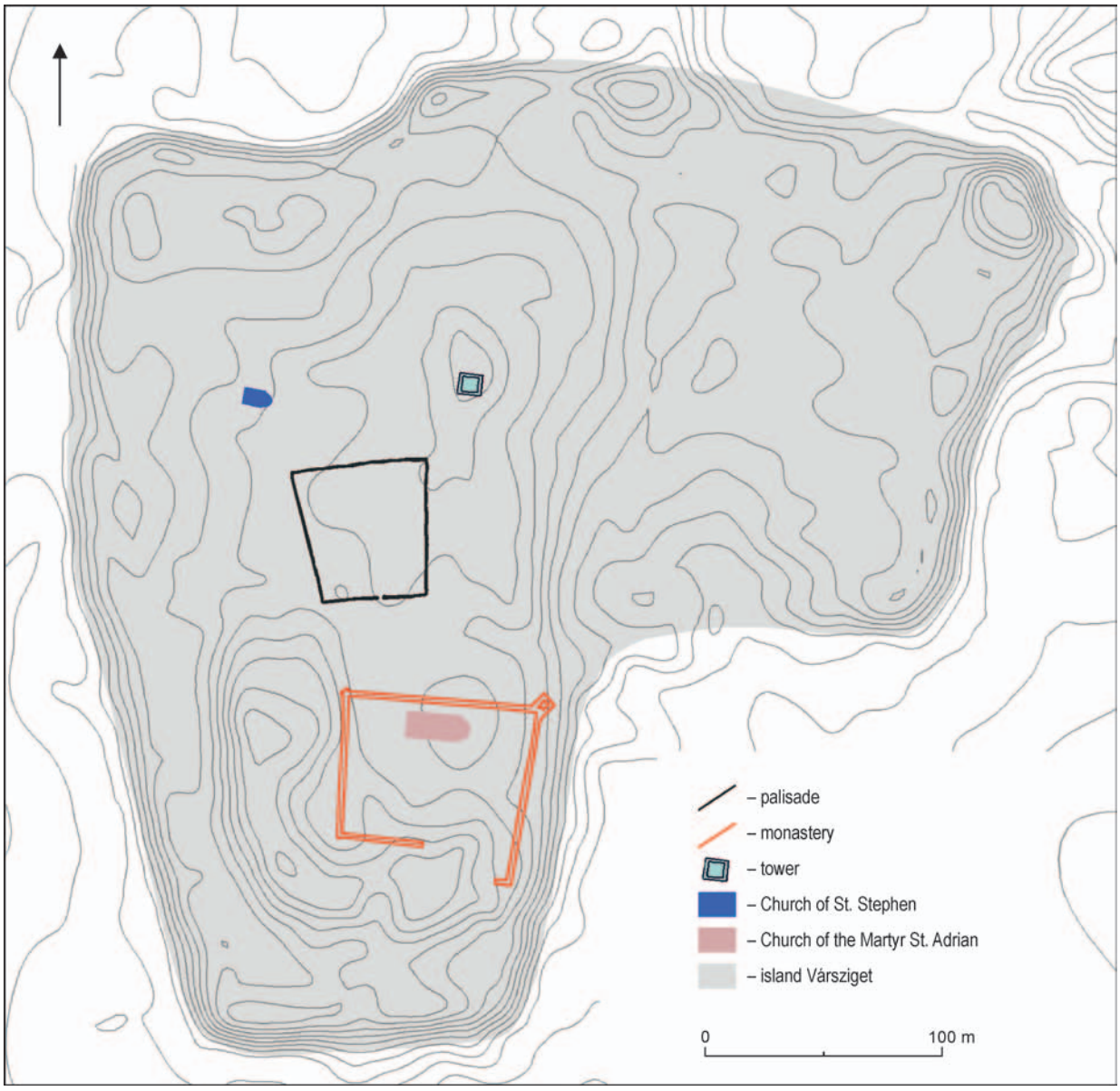

Fig. 5. Zalavár-Vársziget. Development of settlement in Phase V – 11th to 13th c.

from the years 888–890 have been preserved, which he had issued here, in the last of which Mosaburg is mentioned as *regia civitas Mosaburc* (*Szőke 2021*, 307–314).

The other discovered buildings were wooden. Excavation uncovers numerous smaller sunken features of various sizes and shapes throughout the whole area. Apart from dwellings, there is also evidence of features used for a variety of production and crafts activities, such as the processing of metal (iron, bronze and gold), bone and antler or beer brewing (*Gergely 2016*, 345). Their appearance indicates a high density of settlement within the whole area and its multi-functional use. Probably in Arnulf's time the wooden palaces standing on the southern side of the Church of St Adrian were demolished and the entire surrounding space was cleared for funerary purposes (*Szőke 2021*, 326–335).

In 896, Arnulf travelled to Rome, where he was crowned emperor. The administration of Mosaburg was entrusted to his confidant Braslav (*dux* Brazlav), who continued with the construction efforts. It may not have been until this period that the whole inhabited island was surrounded by fortification of earth and timber protected on the face with a stone wall. However, it was the time when the fate of Mosaburg as the centre of Carolingian power in Pannonia, and Carolingian Pannonia itself, was coming to an end. In July 907 the Bavarian army led by the margrave Liutpold suffered a catastrophic defeat

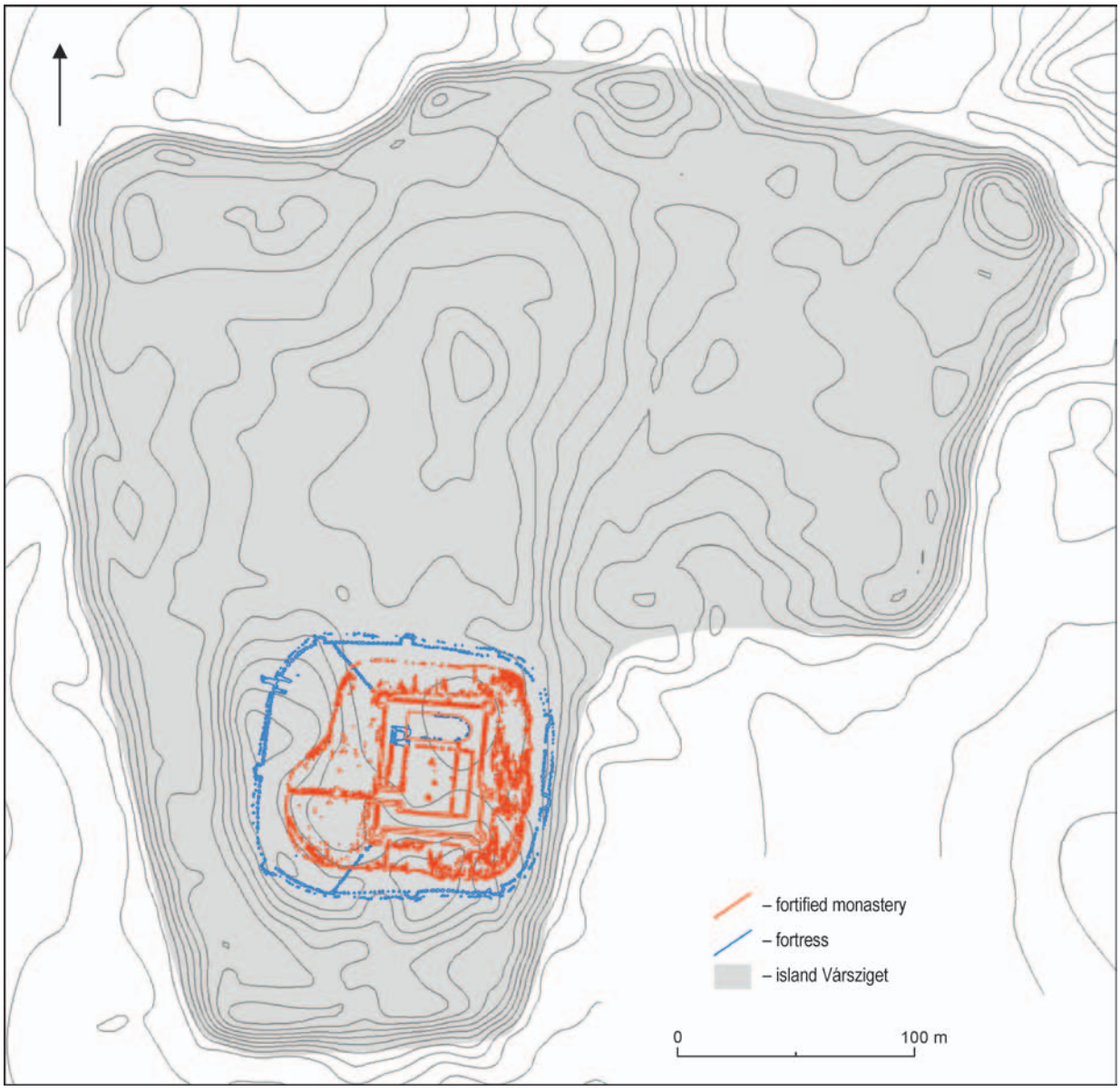

Fig. 6. Zalavár-Vársziget. Development of settlement in Phase VI – 15th to 17th c.

by the Magyars, which put an end to Mosaburg as an early medieval power centre and enabled the occupation of the whole of Pannonia by the Magyars (*Szőke 2021*, 295–301).

Although to a lesser extent, the site was inhabited even after the demise of the power centre (Fig. 4; Phase IV – 10th c.; details *Ritoók 2015*). Clusters of graves indicate a much less dense population during the 10th c. The Church of the Virgin Mary seems to be the only building to have survived that period in good condition. At the beginning of the 11th c., the church was renovated and in 1019 consecrated, and put under the protection of St Adrian (Fig. 5; Phase V – 11th–13th c.). The original Church of St Adrian was already in ruins by that time, and similar to the former Arnulf's palace, they were gradually disassembled and used as a building material. The new church was incorporated into a monastery complex built there by the Benedictines. The monastery was situated in the southern section of the island and covered an area of ca. 86 × 78 m. However, religious monks were not alone there as from the beginning of the 11th c. the site had to be shared by two institutions: the church and the county. The seat of the county occupied the central space of the island. It has been preserved in the form of a palisade trench surrounding an area of ca. 60 × 60 m. In the south-eastern section, the palisade trench broke through the foundation walls of the western part of the pilgrimage church of St Adrian from the 9th c.

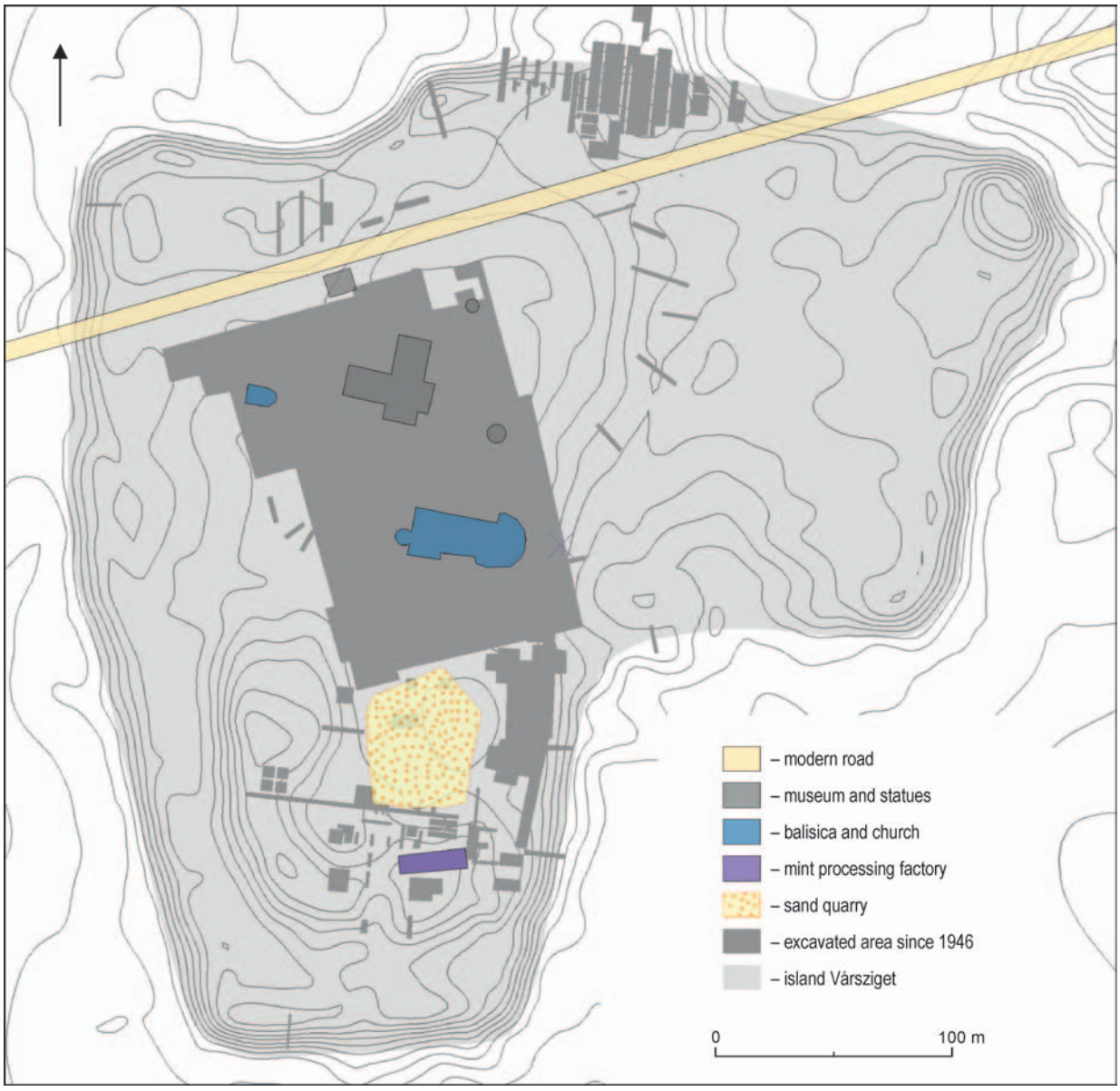

Fig. 7. Zalavár-Vársziget. Development of settlement in Phase VII – 19th to 21st c.

The residence of the county included a tower with a square-shaped base area sized 10 × 10 m situated ca. 40 m north-east of the countys centre. A cemetery was situated to the north-east of it. A church built there in the last third of the 11th c. became the religious place for the inhabitants serving in the seat of the county. By the end of the 13th c., the countys centre in Zalavár was closed down. The reason was a reorganisation of state administration and the changing climatic conditions.

From the 11th c., gradually increasing groundwater levels in the region to such an extent that rendered many roads impassable, making the settlement difficult to reach. The church, as well as the cemetery, were used only until the 13th c. However, the monastery was still in use and was fortified in the 15th c. (Fig. 6; Phase VI – 15th–17th c.). A resolution of the land assembly in 1575, obliged the monks to move to Vasvár due to the Turkish threat, and they did so in 1583. The abbot's residence was then transformed into a frontier fortress concentrating on defence against the Turks (Fig. 6). The 17th c. passed with sporadic Ottoman attacks and repelling them, and continual repair of the protective walls of the fortress. The fate of the building complex was sealed by an emperor's order to close it down. In August 1702, it was blown up using explosives (*Ritoók 2015*; *2018*).

In Modern Times, the site had been used mostly as pasture. In the 19th c. the intensive exploitation

of building material from the ruins of the monastery and a fortress, which is gradually changing for the extraction of sand, resulted in irreversible destruction of numerous monuments (Fig. 7; Phase VII – 19th–21st c.). In 1932 a mint-processing factory was built in the southern part of the island and was operated until 1948. The year 1948 marked the start of archaeological excavations on the site, which has continued with short intermissions until today. Since the 1990s, the place has been attracting ever-increasing throngs of tourists. A museum building focusing on the archaeological history of the site, the ethnography of the region and wildlife in the environs, was built in the northern part of the island. Other newly-erected features include memorials, a replica of the church of St Stephen from the end of the 11th c., a ground plan of the foundation walls of the basilica of St Adrian and a millennial building (*Ritoók 2018*). The central part of the site has been sown with grass. The southern section of the island as well as a segment north of road number 7512 running to Zalavár is covered with woods. The entire north-eastern area and the western edge of the site are being used for agriculture. Agricultural activities result in the slow destruction of the archaeological contexts, as proven by the ploughed-up settlement features and remains of the rampart visible on the surface (*Ritoók 2018*).

THE GEOPHYSICAL SURVEY AND ITS RESULTS

Method

The aim of the geophysical survey in Zalavár was to detect subsurface structures and to locate areas with potential occurrence of archaeological features and contexts. The main advantage of archaeogeophysical prospection is its non-destructive nature. It can be repeated without destroying the context, or various survey methods can be applied, depending on the circumstances or research questions. A combination of different methods where each examines different physical properties, may contribute to a better understanding of the site (*Campana/Piro 2009*; *Clark 1996*; *David/Linford/Linford 2008*; *Gaffney/Gater 2003*; *Scollar et al. 1990*; *Schmidt et al. 2016*). The two methods applied in Zalavár were magnetometry and a ground-penetrating radar survey.

Magnetometry is capable of investigating vast areas within a short time and identifying a wide range of archaeological features (*Aspinall/Gaffney/Schmidt 2008*; *Gaffney 2008*). Given the nature of settlement in Zalavár and a significant predominance of half-sunken settlement features in the form of simple pits, it is, at the same time, the ideal method for resolving the issues related to settlement activities (*Fassbinder 2017*; *Gaffney 2008*; *Milo 2014*; *Neubauer 2001*). In magnetic prospecting, we measure the intensity of the earth's magnetic field, which registers anomalies indicating the presence of subsurface structures of various nature. A key factor for identifying archaeological features is the distinguishability of the features against the surrounding environment. What is essential, is not the absolute magnetic values of the backfill, but the contrast between the feature backfill and its environs.

While prospecting the early medieval stronghold, positive results are to be expected in cases of structures that emerged due to thermoremanent magnetisation (*Le Borgne 1960*), such as fire pits, burned-out layers, destructions of daub, but also hoards or individual iron objects. Sunken features secondarily filled in with darker soils containing organic remains and magnetic minerals can also easily be detected (*Fassbinder 2015*; *Fassbinder/Stanjek 1993*). These include various settlement pits, trenches, sunken huts, and, in ideal cases, also post holes or larger remains of foundations of above-ground buildings. Remains of stone architecture and fortifications – ramparts, as well as the ditch – are usually successfully identified as well. However, the detection of graves can be difficult. In the area of Vársziget, due to the sandy deposits and complicated stratigraphy, it is a more than challenging task.

Another advantage of magnetic survey, is its ability to identify areas in which various specific activities used to be performed. For example, craftsmen's activities, leaving behind dispersed processed material or areas that served as waste dumps (*Gustavsen et al. 2018*). Traces of these specific activities are often situated immediately underneath the surface and can be easily overlooked during excavations. Magnetic surveying can therefore provide clues of their occurrence.

During the survey in Zalavár we used the Ferex (Förster) fluxgate gradiometer with four sensors. The magnetometer can record values of a change in magnetic field intensity with a precision of 0.2 nT/m. Measurement density was 0.25 × 0.5 m. The acquired data was processed in the Foerster Dataload (Förster) programme. Corrections of measurement errors (profile staggering) were made using the Magdatashift software (Masaryk University). The resulting magnetic map was processed in the Surfer (Golden software, inc.) programme.

Ground-penetrating radar (further referred to as GPR) survey was complementary to geomagnetic

prospection. The survey concentrated on the areas where the magnetometry detected structures. GPR belongs to the group of active geoelectric, resp. electromagnetic methods. It is based on the repeated transmitting of electromagnetic impulses (up to 100,000/s) at a high frequency (from 10 MHz to 4 GHz) into the investigated environment and on receiving their responses. It works on the principle of observing changes in physical values within the space of the measured environment, i.e. material differences in the substrate (permittivity) and resistivity of the individual layers (non-homogeneity; *Conyers 2004*; *2012*; *Conyers/Goodman 1997*; *Daniels 2004*; *Goodman 1994*; *Neubauer et al. 2020*; *Trinks et al. 2010*; *Vaughan 1986*).

GPR is one of the most frequently employed geophysical methods for identification of subsurface structures. In archaeology it has a wide range of applications, from detection of hollow spaces, such as crypts, etc., to the identification of the individual layers and backfills of settlement features. Together with the position of the feature, it can also estimate its depth. In the course of time, the GPR method proved itself to be best at detecting walled structures – either stone or brick. In Zalavár it offered the possibility of detecting potential remains of stone architecture or fortification systems.

During the survey we used the ground-penetrating radar X3M Ramac (Geoscience AB Malå) with two shielded antennae and the central frequency of 250 MHz and 500 MHz. Measurements were carried out in a raster of 0.10 × 0.25 m. The data was processed with the aid of the ArchaeoFusion (University of Arkansas), Easy 3D (Geoscience AB Malå) and GPR Slice (Geophysical Archaeometry Laboratory) software.

In the final phase, the results of the geophysical measurements were processed and further visualised in the GIS environment (ArcGIS; *Esri 2005*). The identified anomalies were interpreted as features with archaeological potential and transformed to digital vector format. Based on the physical properties of these anomalies, their shape, dimensions and the overall context or distribution in space, they were further classified as settlement pits, trenches, burnt features, fortifications, etc. In this way, we created a digital layer of interpreted archaeological features.

For this research, we also had a basic data set from earlier archaeological excavations available. The many years of archaeological research on the site, has created a considerable variety of documentation and digital data of various qualities. It was essential to create a unified digital vector layer of the examined features. However, comparison and analysis of all excavated areas were beyond the scope of our research. Due to time limitations, we decide to choose a representative area from the excavation. The selected area of 50 × 50 m is today situated underneath the building of the museum (Fig. 3).

In order to compare the results of archaeological excavation and geophysical prospecting, it was necessary to unify the level of interpretation of both methods. The polygons representing the archaeologically excavated or geophysically interpreted features were transformed into binary rasters with a cell dimension of 0.25 m. To minimise spatial inaccuracies arising during prospecting and the interpretation of the magnetic map, the polygons of the interpreted features were extended around the perimeter (buffer) by 0.5 m.

For every reported segment of the site, we calculated the percentage ratio between an area taken up by archaeological features and the area without features (empty areas) from these extended binary rasters. The tool used for comparing the characteristics of the settlement was density analysis (Kernel density). The chosen radius of 15 meters allows us to observe wider spatial relationships between features, and at the same time, the result should contain sufficient detail (*Esri 2020*; *Scianna/Villa 2011*). Due to their specific character, areas disturbed by recent interventions (a layer of destroyed building material, metal waste, past archaeological excavations, etc.) were eliminated from the analysis.

The areas surveyed by magnetometry are situated on both sides (west and east) of the archaeologically investigated ones. For the sake of objectivity, we analysed only those sections that lay inside the assumed fortified area. During the analysis, the north-eastern area of the magnetic survey was further divided into two parts – an area that covers the territory belonging to the central area (western section of the area) and an area interpreted as a suburb (eastern section of the area). In the 9th c., the palisade separated these two parts (Fig. 3).

Based on the created digital layers, it was possible to perform basic statistical analyses. The analyses aimed to evaluate the information value of the geophysical data, determine the density of occupancy in the area not previously excavated, and compare the density and characteristics of occupancy in the different parts of the hillfort.

Results

Due to vegetation and modern development (roads and buildings), we could not survey the site entirely. The prospection primarily concentrated on previously unexcavated parts. The magnetic survey

Fig. 8. Zalavár-Várossziget. Magnetic map of the surveyed area.

covered all accessible surfaces, especially the western peripheral section (2.1 ha) and the north-eastern precinct (3.7 ha). GPR investigated nine smaller distinct areas (together 0.7 ha), situated in various parts of the site (Fig. 3).

Soil conditions played an important role during the investigation in Zalavár. As far as detecting archaeological features is concerned, it should be stressed that in an environment of sand dunes, the possibility of their identification using magnetometry is problematic. Features sunken into sandy subsoil usually exhibit weak magnetic anomalies and low-contrast, the interpretation of which is often questionable (*Milo 2013*). This factor influenced the results of measurements in Zalavár as well. While the magnetic map shows a great number of anomalies, their shapes do not always correspond to the expected archaeological features. Despite these shortcomings the measurements can be considered informative and the data obtained, sufficiently credible to be used in interpretations related to the anthropogenic impact within the territory. In the investigated areas we can observe the dispersion and concentration of archaeological features and a difference in the magnetic values of the documented anomalies. The pedological composition on the site had no negative impact on the results of the GPR survey.

Within the analysis of the results of geophysical measurement, both investigated areas need to be described separately. The magnetic survey in the western part of the stronghold covered the peripheral area of the elevation on which the site is situated as well as a narrow band in the low-lying terrain outside the fortified area (Fig. 3). The remaining parts of the site within this space are inaccessible to magnetic surveying due to dense vegetation or are unsuitable because of recent

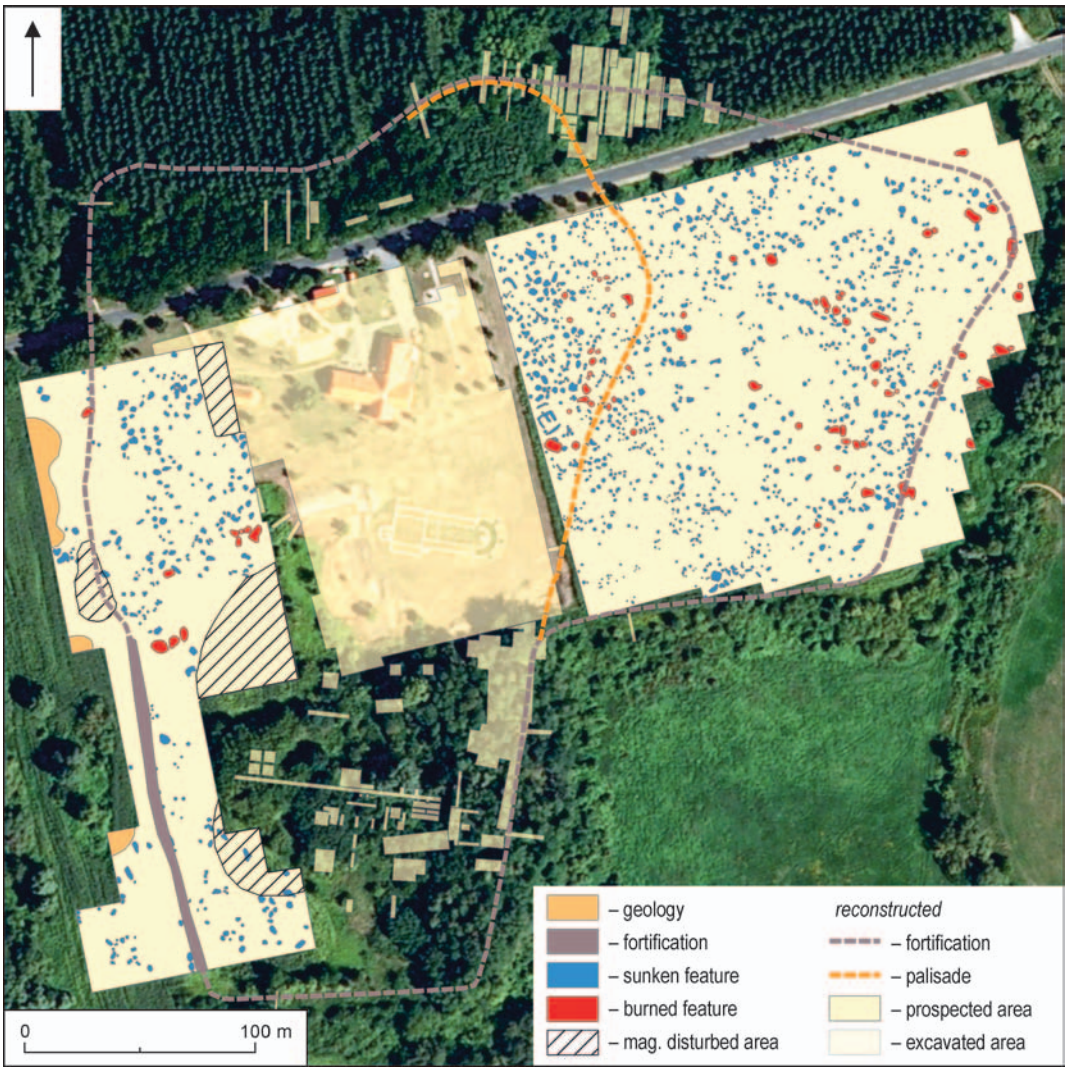

Fig. 9. Zalavár-Vársziget. Archaeological interpretation of the magnetic survey data.

magnetic disturbances. The resulting magnetic map shows that the identified anomalies are concentrated primarily in the eastern half of the examined area, i.e. inside the fortified area. However, not all recorded anomalies represent archaeological features. For example, a strong anomaly in the north-eastern corner of the area is caused by the building of the replica of the medieval church of St Stephen. Within 20 to 30 m from the building it is impossible to register any weaker anomalies of possible archaeological origin. Immediately beyond this limit, we observed a linear structure that was recognised as a furrow delineating a plot based on the cadastral map (Fig. 8; 9).

Some of the anomalies can be related to the small iron objects whose age and origin are questionable. The concentration of anomalies with high magnetic values at the western edge of the prospected area is related to the destroyed medieval monastery and a modern fortress. This is also indicated by the results of the GPR survey. From the characteristics of the GPR signal we can expect considerable non-homogeneities with different conductive properties. They are very likely caused by the accumulations of stones and fragments of brick. The GPR survey verified a linear anomaly from the magnetic survey, which probably represents a fragment of an outer wall from the anti-Turkish fortress (Fig. 8–10).

Interesting concentrations of anomalies with higher magnetic values with 10 to 30 nT were detected at the western edge of the investigated area. They are located outside the fortified settlement. We assume this area, situated in today's wetland, was also inaccessible and wet in the past. Verification of selected anomalies by pedological probes confirmed that the layers are of pedological-geological origin with high ferric minerals

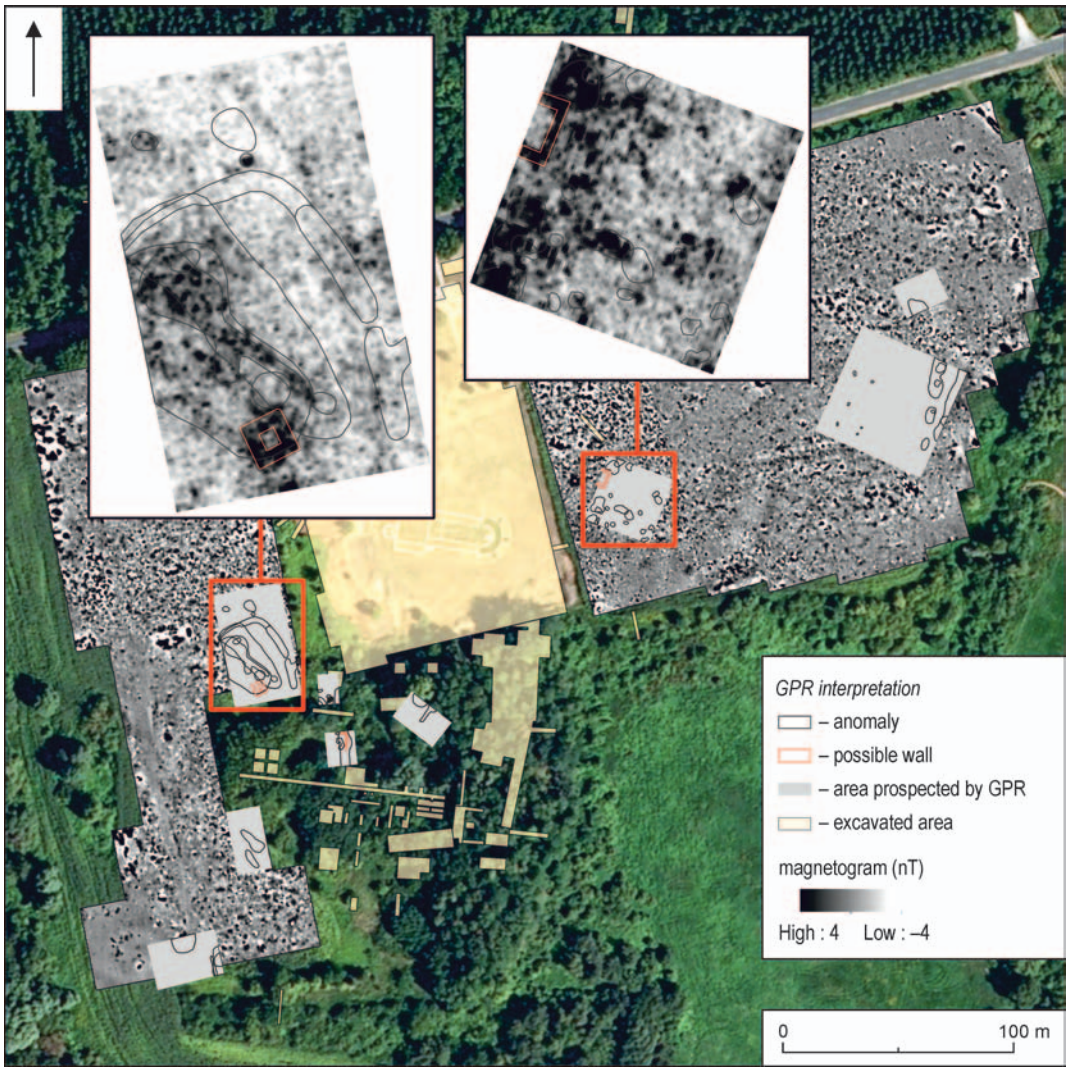

Fig. 10. Zalavár-Városziget. Selected results of the GPR survey.

content. Therefore, any connection between these structures with anthropogenic activities in the past can be ruled out.

An essential feature in the magnetogram is a ca. 4 m wide linear structure running through the prospected area in the NNW-SSE direction (Fig. 8; 9). In the magnetic data, it is clearly visible in the southern part. In the northern segment, numerous small anomalies overlay its course and it is impossible to follow it further. However, thanks to the evidence from aerial photos, we assume it continues in the NNW direction. The line separates the densely populated area in the east from the area with fewer archaeological features on the west. It has very low, sometimes zero to negative magnetic values. It most likely represents the remains of the ramparts of the defence system from the 9th c. The location of the anomaly on the edge of a sand dune also supported this interpretation. The construction elements of the rampart were not detected by magnetometry nor by GPR. The reason is a poor state of preservation of the fortification from which only the lowermost part survived intact.

However, detailed information on the construction of the Zalavár fortification comes from the archaeological excavation. Between 1951 and 1954 the rampart was investigated by test trenches in four sections (*Sós 1963*). The most important excavation took place in the 1970s on the northern edge of the island where the largest, over 50 m long section of the fortifications was uncovered (*Gergely 2016*). The rampart sat on a wooden grid construction. The core was made of two, sometimes three, rows of vertical embedded posts probably supporting a woven lattice of wattle and rammed earth. On the outside, the earth and timber rampart were protected by a ca. 1.5 m wide dry-stone wall. In some sections, the find contexts suggest the

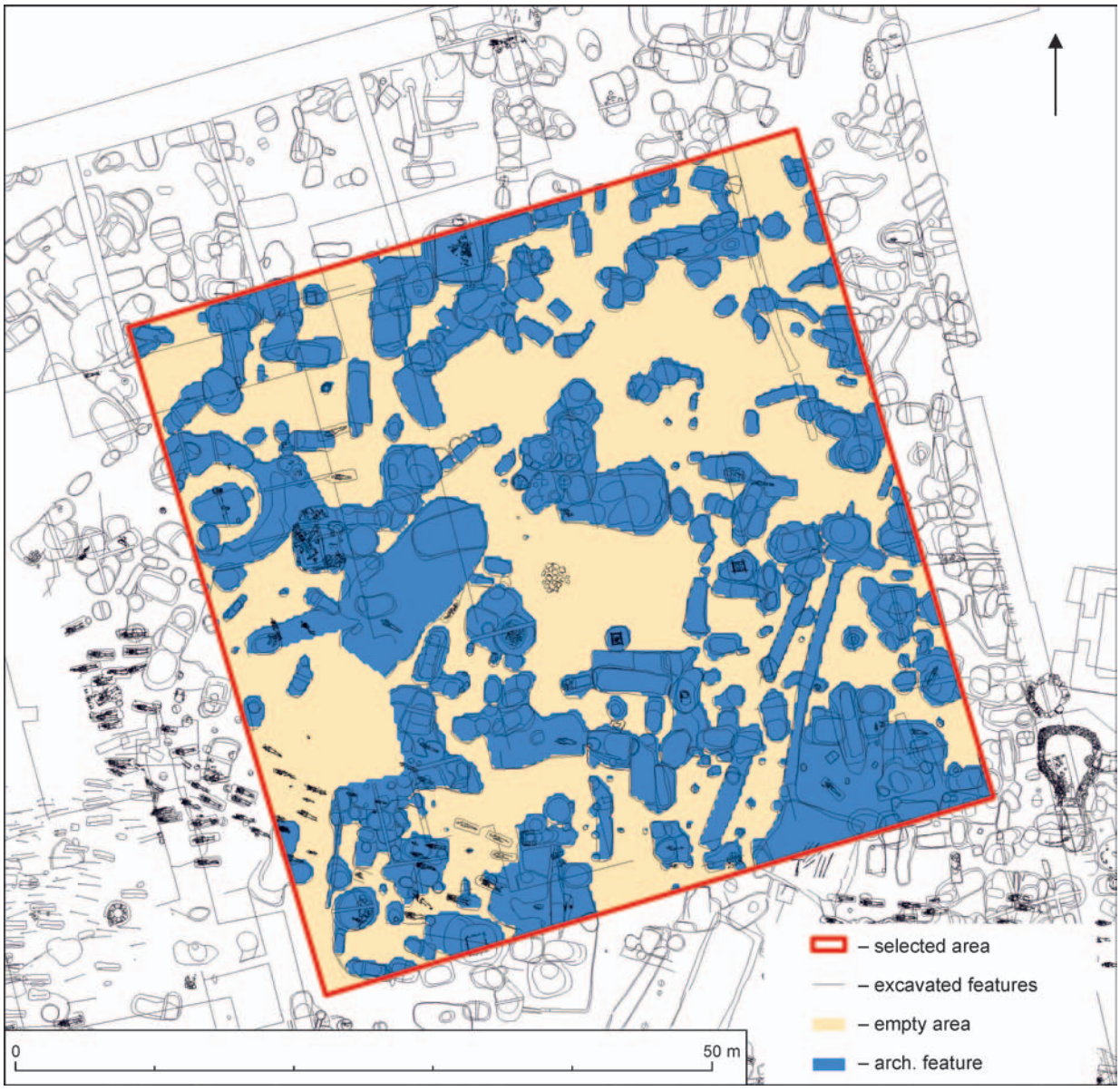

Fig. 11. Zalavár-Vársziget. Archaeologically excavated area of 50 × 50 m which was used to compare the quantity of excavated features with those detected by geophysical prospection.

presence of a stone wall, even on the inner side of the earth and timber rampart but it is not conclusive. The total width of the embankment was 5 to 10 m, which is more than the observation during magnetic survey. Therefore, it is most likely that geophysical prospection captured only the inner earth and timber part of the heavily destroyed ramparts. Neither excavation nor the geophysical prospection didn't bring evidence of the ditch system. Given the geographic settings of the site, surrounded by marshy terrain, there was probably no need to dig one.

The magnetic survey in the western section of the strongholds inner area detected numerous archaeological features. There were 289 anomalies recognised which we interpreted as settlement features (Fig. 8; 9). The majority of them are anomalies of a small dimension (1 to 10 m^2) with an irregular, oval to a circular shape. More detailed functional and chronological classification of these features is impossible. Weaker magnetic anomalies with 2 to 10 nT values probably represent the remains of dwellings and production buildings or various settlement pits. Slightly stronger anomalies with magnetic values of more than 10 nT could be fireplaces, ovens and various production or craftsmen's facilities or buildings with traces left by a fire. In the area outside the

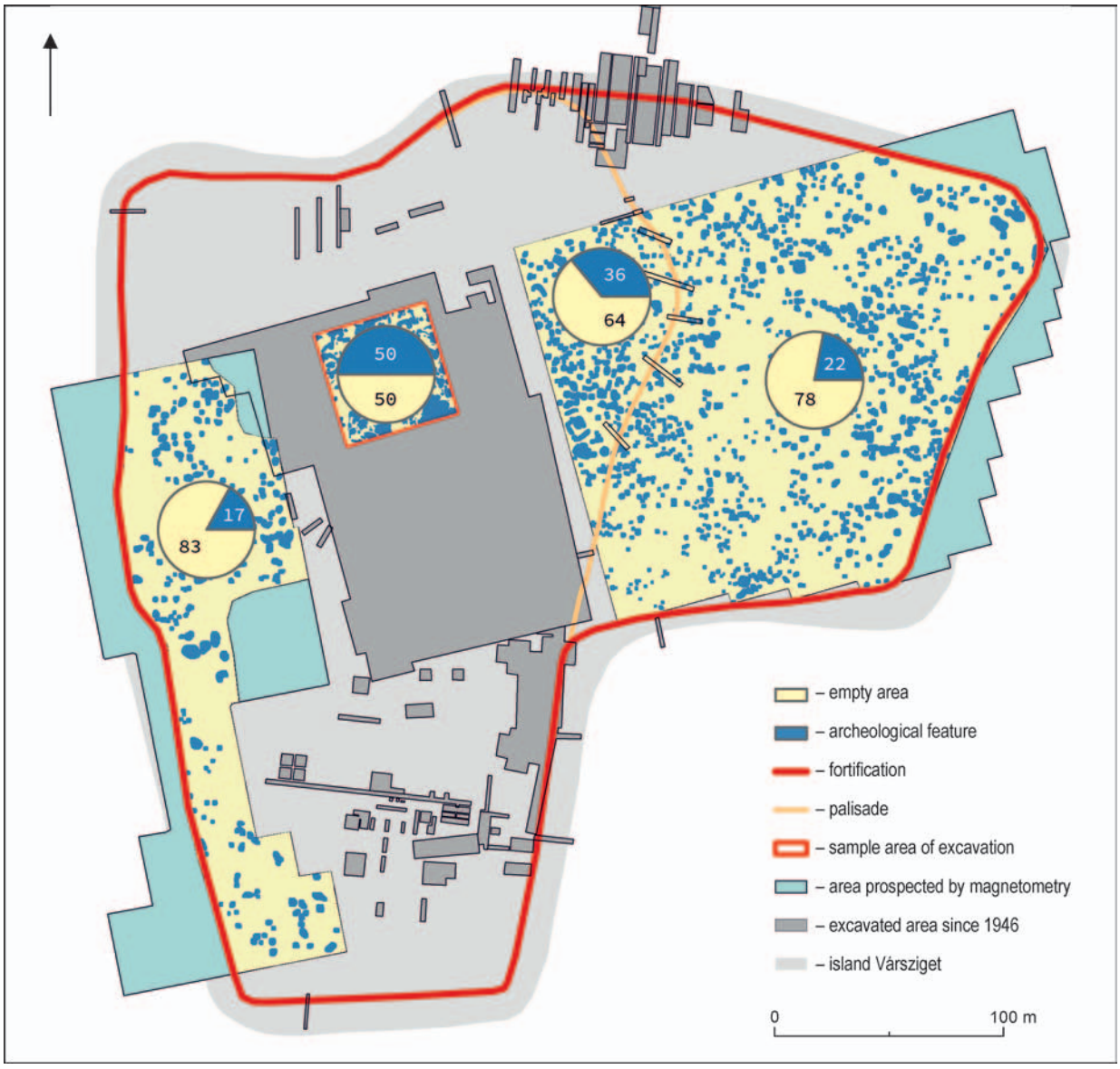

Fig. 12. Zalavár-Várszíget. The ratio of the inhabited area to the empty area in individual parts of the site.

fort, anthropogenic activities are minimal. Even here, however, it is possible to observe several potential objects of a settlement character. One smaller settlement unit consisting of about 15 buildings can be observed southwest of the fortified settlement.

In terms of the intensity of settlement activities in Zalavár the findings from the geophysical survey correspond to the results of archaeological research. In a selected segment of an excavated area of 50 × 50 m in the central part of the stronghold a total of 177 features of various shapes and functions were recognised (Fig. 11). A number of features are found in superpositions. They form complex features of enormous dimensions (up to 125 m^2). They are generally dated to the 9th c. The percentage ratio between an area taken up by archaeological features and the area without features is 50 : 50. After subtracting features smaller than 1 m^2 and recalculating the result per hectare, it represents ca. 500 features/ha. In the geophysically surveyed western edge of the main castle, after subtracting the areas outside the fortified settlement and an area which cannot be interpreted due to recent disturbance, the density of settlement features is 203 features/ha (Fig. 12; the density of features with a size above 1 m^2 is 175 features/ha).

While comparing the results of geophysical prospection and archaeological research, we

Tab. 1. Zalavár-Vársziget. Quantity of archaeological features, occupation density and the ratio of the inhabited area to the empty area in individual parts of the site.

ZALAVÁR	Features	Features over 1 m^2	Density features/1 ha	Density features over 1 m^2/1 ha	Ratio of inhabited/empty area
W area main castle GF (1.23 ha)	289	210	203	175	17 : 83
E area main castle GF (0.52 ha)	305	205	586	394	36 : 64
Main castle average GF	594	–	395	285	–
Suburb GF (2.77 ha)	990	686	357	248	22 : 78
Area main castle ARCHEO (0.25 ha)	177	125	708	500	50 : 50

analysed only objects with an area over 1 m^2. The main reason is that the size of the detected anomaly is closely related to the chosen configuration of the magnetometer or the density of the measured points. In our research, the spacing of the probes was 0.5 m, so the device could not effectively distinguish objects smaller than 1 m^2 (*David/Linford/Linford 2008*; *Fassbinder 2017*; *Gaffney/Gater 2003*). The ratio of areas taken up by features and empty areas (without the detected archaeological feature) is 17 : 83. It is questionable to what extent the statistics represent the actual situation and how successful the magnetic survey is in identifying individual archaeological objects. Assuming that the geophysically surveyed area was used in the past with the same intensity as the referential excavated area, we could state that the magnetic survey recorded ca. 35% of all the features present here. However, there are apparent limitations to geomagnetic prospection, such as an inability to detect superposition or identification of individual features within a large anomaly.

The southern part of the main castle was surveyed only to a limited extent. In this part archaeologists locate Pribina and Kocels residence (*Szőke 2020*). Today, the dense forest covered the entire area. However, it is assumed that younger activities (monastery, fortress) and modern sand exploitation considerably damaged the whole area. A spatially limited GPR survey was carried out in three locations and detected numerous non-homogeneities, which indicate the presence of destroyed sections from various materials (stone, bricks and mortar). However, regular structures in the form of walls and foundations of buildings were not detected. The results of the GPR survey supports evidence from excavations, which stated that parts of the buildings mentioned above no longer exist *in situ* (*Gergely 2016*).

The biggest challenge for geophysical survey in Zalavár was the north-eastern part of the island. This part has never been excavated, however, evidence from the archaeological fieldwalking suggests that area was inhabited in the 9th c. Although, we do not know to what extent and what are the characteristic features here. In this respect, the geophysical survey provides new data. In the 9th c., the palisade fortification split the area into two parts. The smaller western section was part of the main castle area. For the greater eastern part, we used the term suburb, although its real function is unknown (Fig. 3). Our aim was to discover whether these two parts of the stronghold will be expressed differently in geophysical data.

In the resulting data, we can observe a large number of magnetic contrasts (Fig. 8; 9). In some places, anomalies caused by the presence of high-magnetic objects dominate here. The bipolar anomalies are small iron objects of unknown origin and age. In most cases, such anomalies can be attributed to scattered recent waste, although some may represent an archaeological object.

The most important finding of the prospection was the determination of the characteristics and intensity of settlement. We interpret a total of 1295 anomalies as archaeological features in the prospected area (Tab. 1). Within the inner area of the main castle (inside the palisade), there were 305 anomalies (205 features with dimensions over 1 m^2). In the suburbium, we identified 990 features (686 with dimensions over 1 m^2). The inner area's density is 586 features/ha (394 features/ha for features larger than 1 m^2). Within the suburb area, it is 357 features/ha (248 features/ha for features with a size over 1 m^2). The percentage ratio of areas covered by detected features and empty spaces inside the palisade area is 36 : 64. In the area behind the palisade (suburbium) it is only 22 : 78. Although the suburb density of occupation is lower than in the main castle, we can describe it as densely populated (Fig. 12).

It is worth mentioning a comparison of settlement density in both geophysically examined areas within the inner castle. While settlement on the western edge exhibits low density (ca. 203 features/ha), on the eastern side it is relatively higher (586 features/

ha), which may indicate the different intensity of the settlement (Tab. 1). Based on this, the eastern part can be viewed as part of the central area, while the western part seems marginal. The average density of the geophysically recognized features in the inner castle (central area) is ca. 395 features/ha, or 285 features/ha for features larger than 1 m^2. In this regard, the overall population density of the main castle compared to the suburbs does not seem very different.

As mentioned previously, the eastern part of the site was free of disturbing elements, and conditions for the geophysical survey were very positive. It is not surprising then that the geophysical survey successfully identified a large number of anomalies. As mentioned above, the density of features per hectare of the excavated area in the central part of the stronghold is ca. 500 features/ha (for features with a size over 1 m^2). Alternatively, the area of features represents 50% of features in the total area. Suppose we assume that settlement density in the immediately adjoining geophysical survey area in the east is identical. In that case, we could state that the geophysical survey registered ca. 79% of the total number of features or 72% after recalculation on the area taken up by the features (Fig. 12).

The ratio of settlement intensity in the main castle (area inside the palisade) and the suburb in the north-eastern part of the stronghold is ca. 1.6 : 1. The geomagnetic survey results suggest archaeological features – mostly settlement pits of various types – dispersed almost throughout the prospected area. The majority of them are small features in size and an irregular, oval or circular plan. It is impossible to classify these features concerning their function and chronology, although they very likely represent settlement features, mainly from the Early Middle Ages. In some places we can observe concentrations of features with higher magnetic values (above 10 nT). In such cases, we consider them as areas where various craftsmen's activities were performed, such as iron and other metals or pottery processing. We have not been able to recognise any traces of planned settlement structures. Only some of the concentrations of features could indicate potential independent economic units or specific districts. In the magnetogram, we can also observe linear structures that might represent potential roads. However, it is more likely that they are structures of a pedological origin. We cannot say they layout the design of the built-up areas or that a significant number of features are related to them. Also, we did not detect any larger area without features that could be interpreted as a square or open area. The only areas without archaeological features are outside the fortified settlement and appear as uninhabited (Fig. 8; 9).

The ground-penetrating radar survey in the north-eastern part of the stronghold focused on areas where more pronounced anomalies were recorded during the magnetic survey (Fig. 3). Numerous detected non-homogeneities suggest the presence of archaeological features. The survey in the area in the southwestern part of the suburb in particular, confirmed multiple structures which corelate to anomalies from the magnetic survey. We can interpret them as fireplaces, ovens or production facilities. However, more detailed characteristics or dating of these features can only be provided by excavation. In the western section of the suburb the GPR survey has relatively poor results. This might be caused by the fact that potential features (settlement pits and shallow recesses) have identical material composition as their surroundings (features filled with soil without the presence of stone construction elements or their destruction). Several anomalies of uncertain characteristics might indicate the presence of archaeological features. Regarding the two most pronounced anomalies we can state that one has no parallel in the magnetic map while the other roughly overlaps a distinct feature which can be interpreted as a fireplace, an oven or a production facility. An exception is a conspicuous anomaly with a regular shape which, based on its characteristics, can be interpreted as part of the remains of a potential building with a stone or brick structure (Fig. 10). In all areas we detected traces of deep ploughing which provide evidence of considerable destruction of the site by agricultural activity.

An important issue for the geophysical survey was the detection of the fortification. It was surprising that the rampart did not appear in the geophysical data. There are possibly two reasons for that: a bad state of preservation and the fact that there is no evidence of fire. Today the remains of the ramparts are not visible. However, its presence is indicated by the topological map and by quite a sharp boundary between the inhabited area and its surroundings (Fig. 8; 9). This boundary is another important evidence in reconstructing its course. It can be identified in the northern and the eastern part of the magnetic map. The fortification in the south direction was impossible to identify due to the dense vegetation and inaccessible terrain. The situation in the southwestern corner of the investigated area is unclear. Isolated magnetic anomalies that occur there might indicate the presence of an archaeological feature. However, it is possible that due to the marshy terrain, the area was used in another way.

DISCUSION

When Pribina arrived in Lower Pannonia around 840, he chose the sandy elevation (island) originating from the Ice Age in the broad floodplain of the Zala river for his residence. Apart from the Zalavár castle island (Vársziget), there are several others (e.g. Récéskút and Borjúállás sziget) which emerged from the floodplain and were also inhabited in that period (Fig. 2). The physical-geographical conditions resemble in many respects the contemporary environment of the residences of the rulers in Moravia built on terrain elevations jutting out from the floodplain of the Morava river. There are also some other parallels to those sites that Mosaburg offers with regard to the characteristics of the built-up areas and fortifications.

Although the Vársziget site was inhabited for several centuries, most of the excavated features belong to the Early Middle Ages. Therefore, during the geophysical survey analysis and interpretation, we assume that identified archaeological structures are mostly related to the power centre Mosaburg. Based on written sources and archaeological research, we can provide reliable evidence of its existence from the 840s to the beginning of the 10th c. Though it is a relatively short period, the built-up areas in Mosaburg underwent turbulent development, evidence of which can be seen in frequent rebuilding and the high density of settlement activities. The geophysically recognised anomalies/features are not contemporary, but they express the intensity of settlement when Mosaburg was an important centre. We do not know the structure of the built-up areas within short time intervals in detail, but we can follow the trends by comparing the different parts of the site.

When looking for the sites within the territory of today's Hungary that could be compared with Mosaburg we face the problem of their virtual non-existence. There are some younger county centres such as Visegrád and Abaújvár, which have been studied archaeologically and using geophysical methods, or Borsod, where extensive archaeological excavations took place. The settlement in Visegrád has several evolutionary phases, from the Roman period to the 13th c. However, the intensity of the early medieval settlement does not come close to the one in Zalavár (*Buzás et al. 2017*). Abaújvár, as a county centre, was one of the most important castles in the Árpád period. The castle was built in the 11th c. on top of a settlement from the 3th–4th c. AD. In the area surrounded by ramparts, excavations confirmed sacred and profane architecture, but we have only incomplete information on the intensity of settlement (*Bakos et al. 2020*; *Wolf 2000*). In Borsod, another county centre from the 11th c., the density of confirmed settlement is also very low compared to Zalavár (*Wolf 2019*).

The significance of Zalavár can be best understood in its confrontation with the contemporary sites north of the Danube, i.e. the area where its founder Pribina comes from, thus, to the territory ruled by the Moravian dukes. In terms of the architecture on the site, the structure of the settlement, documented fortifications as well as the setting of the site in the landscape, the closest analogy to Zalavár can be seen in Mikulčice, which can be attributed with having central importance within Great Moravia. In historical sources it might stand for the mentioned *urbs antiqua Rastici* and *ineffabilis Rastici munitio* (*Poulík 1975*, 153–159), i.e. the old residence of Pribina's contemporary Rastislav and most probably even his predecessor and Pribina's arch-enemy Mojmír. In Moravia Mikulčice played a similar role to Mosapurc in Pannonia.

Excavations in Mikulčice confirmed 12 sacred buildings, one building interpreted as a ducal palace, burial grounds, dwellings, craftsmen's workshops, and a great number of settlement features of unknown function. The exceptionally rich inventory of finds (weapons, jewellery and objects of daily use) proves the special position of Mikulčice within the network of Great Moravian strongholds. The fortified settlement takes up a total area of 7.2 ha. The inner area of the stronghold is subdivided into the main castle with an area of 4.8 ha on the Valy location and the slightly lower lying part of Dolní Valy with an area of 2.4 ha. Both parts are surrounded by a 3 m high, 20 m wide and 1050 m long rampart. They are separated by a shallow terrain depression. To the north-west the stronghold is adjoined by a tongue-shaped fortified suburb situated on the Štěpnice location. The site surroundings are interwoven by multiple, today mostly vanished, river branches between which a dense network of settlements is concentrated with a dominance of above-ground buildings, a great number of production facilities as well as churches and adjoining cemeteries. The whole settlement agglomeration in Mikulčice extends over ca. 100 ha (*Poláček 2016*; *Poláček/Marek 2005*).

Since 2011, the geophysical surveys carried out in Mikulčice, depending on when the particular parts of the site were made accessible, have not been published in complete form. However, for illustration, we can mention that the picture obtained is similar to that from Mosaburg. Virtually everywhere throughout the whole prospected area in the main castle as well as the suburb, features of circular, oval to rectangular, square and irregular plan were identified. The majority of them are most likely vari-

ous pits of a settlement nature. In the case of smaller anomalies, we can also consider the presence of grave pits. From the archaeological excavation, and as it turned out, also from the geophysical research, Mikulčice and Zalavár are in many ways similar. In both cases, the main castle and the suburb are filled with archaeological features situated close to one another and often overlapping, resulting from a multi-phase settlement. Such intensive settlement activities have not been observed elsewhere in this period, which makes both sites exceptional.

Within the possibilities provided by the combination of geophysical and archaeological research, we can look at the results from Zalavár from the perspective of analyses carried out in Břeclav-Pohansko. Here, given the great size of the archaeologically examined area, it was possible to evaluate the effectiveness and informative value of the geophysical survey and comment on the structure of buildings on a considerable area of the fortified settlement. The central part of the site has 28 ha, of which 4.66 ha has been excavated (*Macháček 2010*). By comparing the magnetic survey results with excavations and a cartographic estimate at Pohansko, we claim that geophysical prospection has roughly 50% success in detecting features. However, this success varies depending on the type and size of features. The density of features per hectare of excavated area is nearly 641 features/ha. If we only considered features over 1 m^2 in size, the density is 188 features/ha. In the case of areas investigated by geophysics, the density is 95 features/ha. If we disregard areas that could not be interpreted due to recent interferences, the density of features reaches 105 features/ha (*Prišťáková/Milo 2021*). Despite the high density of settlement, compared to Zalavár where the density of features over 1 m^2 detected by geophysical survey is 285 features/ha in the main castle and 248 features/ha in the suburb, Pohansko is populated less intensively (the ratio being 1 : 2.7 in the main castle and 1 : 2.4 in the suburb). However, without a more detailed dating of the individual features, it is impossible to say what role is played by the duration of settlement on the site, which is longer in Zalavár.

At the same time, it has been shown that in Břeclav-Pohansko the area of the fortified settlement is built-up relatively evenly and in a planned manner. The concentrations of sunken huts in the geophysically examined areas support the observations from archaeological excavations where we also find that sunken huts are distributed evenly (*Macháček 2007*). By studying the configurations of the recognised features and the density analyses both in the geophysically prospected area and the excavated areas, we managed to define a system of roads and 12 courtyards. During the analysis and the interpretation of the results of geophysical prospecting, we assume that the recognised archaeological features are related to the period when Pohansko was an important central place in this region. Despite it being relatively short from the second half of the 9th c. to the beginning of the 10th c., the built-up areas did not go through significant changes. We understand, not all of the detected anomalies are contemporary, but we believe they express the appearance and intensity of structures and settlement on the site within this short period. Based on the above facts, we can state that the structure of the built-up areas within the central precinct at Pohansko had a system of its own to which there is no analogy in Great Moravia. This system of settlement was quite common in the Frankish Empire in the 9th c. The closest parallels can be found in South Germany where a number of important early medieval settlements, such as Kirchheim (*Geisler 1993*), Eschheim (*Gutsmiedl-Schümann/Pütz 2019*) and Lauchheim (*Stork 2001*) can be found. Characteristic for them is regularly built-up areas and the presence of farmsteads. Similar structures could be logically expected in Zalavár. However, their identification is considerably hampered by long-term settlement with multiple construction phases, which are difficult to distinguish by a non-destructive survey as well as excavation. From the results of our research, large-scale excavation in the suburb, where built-up areas did not go through such intensive changes and settlement is less dense, could shed more light on this issue.

There are several fortified settlements to compare with Mosaburg in the area north of the Danube. In two cases: Brno-Staré Zámky (*Milo et al. 2020a*) and Svätý Jur-Neštich (*Milo et al. 2020b*), we have been able to compare and combine the results of the geophysical survey and excavations. The documentation covered the course and characteristics of the ramparts and their destruction, as well as the distribution and density of archaeological features, which significantly contributed to better knowledge of these hillforts. However, in both cases it showed that while the acropolises of these hillforts exhibited intensive settlement, it was only sporadic in the suburbs, which is in stark contrast to what we can see in Zalavár.

The interpretation of the settlement structure is complicated also by two completely fortified settlements: Majcichov and Pobedim. Due to complex hydrological conditions and stratigraphy, an interpretation of the geophysical survey is challenging. In Majcichov there were only a few potential archaeological features identified within the ca. 6.6 ha inner area of the stronghold. The later inundation

layer overlaid the original settlement horizon and made the identification of the individual settlement features with magnetic survey impossible (*Ruttkay et al. 2006*). Settlement features were registered with certainty only in the slightly elevated fortified suburb. From archaeological test drilling it is evident that the inner area of the stronghold was inhabited as well, but the settlement characteristics and intensity are unknown.

The fortified settlement in Pobedim consists of two sections – an inner rampart running crosswise divides it into two parts: the main castle with an area of c 4.1 ha on the Hradištia location and the so-called suburb with an area of ca. 3.9 ha on the Podhradištia location. Another suburb with an area of ca. 2 ha was located to the north-west of the hillfort. The area of the whole hillfort was therefore approximately 10 ha. In the immediate surroundings, we know of other sites with characteristics of a settlement forming a dense network of open settlements in the hinterland of the fortified settlement. Excavations carried out by D. Bialeková between 1959 and 1975 brought extensive information on the structure of the early medieval and prehistoric settlement on the site (*Bialeková 1978*). The geophysical survey conveniently complemented information from the excavations. The great number of magnetic anomalies testifies to intensive settlement on the site, particularly in the main castle area. The features are distributed here throughout the whole area, whereby they often cluster into groups. The limiting factor is the presence of prehistoric settlement that we cannot distinguish from the early medieval one. On the Podhradištia location and in the newly localised suburb the number of registered archaeological features is lower. From their even distribution it can be assumed that the majority of them were contemporary with the hillfort. It seems that dwellings and other buildings stood in rows oriented in line with the course of the rampart. Settlement density of features over 1 m^2 reaches ca. 70 features/ha there. This is 3.5 times less than in the suburb in Zalavár, or 4.1 times less than in the main castle in Zalavár and 1.5 times less than in Břeclav-Pohansko. However, this estimate is purely theoretical as we do not know the dating of the detected anomalies and the total period during which the fortified settlement was in operation.

Since the geophysical survey was focused on open, accessible areas, it brought only a limited amount of new data related to fortification in Zalavár. As far as the fortification is concerned, Mosaburg is a typical example of the development of early medieval fortification techniques in the central Danube region. During most of its existence, the main fortification element was a simple palisade. Light fortification in the form of a palisade or free-standing poles interconnected by a wicker fence, uncovered in Mikulčice and Uherské Hradiště, is typical of the early phases of the oldest fortified settlements (*Procházka 2009*, 255; *Staňa 1972*, 113, 114). It was not until the second half of the 9th c. that more complicated types of fortification replaced them. Within the territorial core of Great Moravia, the most frequent construction type was a rampart with a stone apron at the front and a timber wall at the back, such as those investigated in Mikulčice (*Poláček 2016*), Břeclav-Pohansko (*Dresler 2011*), Staré Město (*Galuška 2008*) and on many other sites (see *Procházka 2009*, 257). The fortifications in Zalavár can be classified in the same category as these ramparts. Géza Fehér and Ágnes Cs. Sós dated the initial construction of the fortifications to the beginning of the 11th c., to the time of consolidation of the Hungarian kingdom by Stephen I (*Sós 1963*; *1973*). However, the recent research provides evidence that the construction of the fortifications began within the end of the 9th c. (*Gergely 2016*, 350; *Szőke 2014*, 36). Dendrochronological analyses are even more specific and date the construction of the rampart in between 880 and 890 (*Grynaeus 2015*). The fortification of Zalavár thus belongs among the above-mentioned Great Moravian fortifications not only in terms of construction but also due to the period of its foundation, which is characterized by the construction of fortifications across the whole of Central Europe.

The palisade dividing the main castle from the suburb in Zalavár was not visible in geophysical data. There is only a slight indication of a short segment, whose identification would be questionable without previous knowledge. However, the interface between the main castle and the suburb in the palisade area indicates a change in settlement intensity which is lower in the suburb. The absence of a perimeter fortification in the geophysical data in the suburb is surprising. Its course and appearance are partially known from excavations (*Gergely 2016*) and the terrain configuration. The position of the rampart is indicated by a relatively distinct boundary between the inhabited and the uninhabited area. However, the rampart is well visible in geophysical data and aerial photographs on the western side of the main castle. It exhibits very low positive, sometimes negative magnetic values. It is approximately 4 m wide. Although it is clearly visible, it is not possible to study the structural elements of the rampart. This finding is not unusual in any case. Similar results were received from magnetic surveys in other early medieval fortified settlements in the central Danube region. There are

a few exceptions, such as the hillfort in Majcichov. The magnetogram allows us to recognize in detail the ditch as well as the wooden chamber structure and the frontal stone apron of the rampart, but only in its eastern, northern and north-western part. The reason is a fire on these segments of the rampart. The southern and south-western part of the rampart did not burn down and can be observed in the magnetogram in the same way as in Zalavár, only in the form of a line with slightly increased magnetic values (*Henning/Milo 2005*, 143, 144, fig. 3; 6). Similar observations are known from Břeclav-Pohansko as well. In a few segments, we succeeded in detecting burnt wooden parts of the rampart's structure in detail, while elsewhere vast parts of the rampart exhibit only a small contrast (*Milo/Dresler/Macháček 2011*).

Although the geophysical survey in Zalavár did not bring any substantial findings concerning the fortification of the stronghold, from the results it follows that the investigated part of the rampart was not damaged by fire. This piece of evidence puts Mosaburg in contrast to the other significant centres in the areas north of the Danube, the ramparts of which bear clear signs of catastrophic destruction – e.g. Břeclav-Pohansko (*Dresler 2011*), Majcichov (*Ruttkay et al. 2006*) and Pobedim (*Bialeková 1978*). Overall, the cause of the demise of Mosaburg need not be different. Undoubtedly it was a change in the power-political map of Central Europe caused by the arrival of the Magyars to the Carpathian Basin and the related raids. It seems, however, that Mosaburg was not besieged, its inhabitants did not resist the attacking Magyars on the ramparts. However, in the apprehension of imminent danger, Mosaburg was abandoned without a fight.

CONCLUSION

Our knowledge of settlement in Zalavár-Vársziget has so far been based on historical written sources and data obtained from archaeological excavations. The recent geophysical survey complements the existing dataset. New evidence of settlement activities was gathered mainly in the area of the suburb. Due to dense vegetation and recent disturbance, the survey in the main castle area could only be done to a limited extent and remains a challenge for future projects in this area. An essential help in interpreting geophysical data was provided by former excavations, which enabled us to correlate these two sources of information.

The magnetic survey in the inner area of the main castle confirmed numerous archaeological features, which can be interpreted as settlement structures of various kinds – remains of residential and production buildings, ovens and different settlement pits. Regarding the intensity of settlement activities, the geophysical survey results correspond to the results from previous excavations and bring new findings. Above all, we were able to state that in the geophysically surveyed western edge of the main castle, the density of registered settlement features is lower than on the eastern edge. Certainly, geophysical prospecting did not manage to capture all the features. Nevertheless, the finding points to a fundamental trend in the use of the fortified settlement area for construction activities.

The greatest challenge for geophysical measurements in Zalavár was the problem of the appearance of the north-eastern part of the site. We described it as a suburb for the purposes of research, however, its detailed function is unknown. In general, it was assumed that this area was inhabited in the 9th c., but only little was known about its settlement characteristics or intensity. The geophysical survey proved that the settlement characteristics are similar to those in the main castle. The entire suburb is dotted with various settlement features, but settlement intensity is lower than in the main castle area. Despite this, we can consider the whole of this area to be inhabited entirely. Most of the detected structures could probably be considered features related to the settlement on the site in the period of early medieval Mosaburg.

The geophysical survey did not provide evidence of planned development. The main finding is evidence that the whole area of the hillfort was intensively used and densely built-up. We did not register any larger empty areas. The closest analogy to the Mosaburg in this respect is Mikulčice in Moravia. Further signs shared by both sites, such as sacred and profane stone architecture, a similar type of fortification and the setting of both centres in the landscape of a river floodplain, are additional factors that allow us to compare the two sites. There is no other hillfort from this period in the central Danube region where intensive settlement activities over such extensive areas could be observed. In the future, it will be necessary to verify the geophysical results – in this case magnetic survey by targeted excavations, extending them with additional data potentially brought by large-scale ground-penetrating radar and geoelectric resistivity measurement. It needs to be stressed that the outline of settlement and construction activities from the Early Middle Ages to Modern Times presented in the introductory section is not definitive. It will need to be reviewed in line with ongoing research.

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doc. Dr. phil. Peter Milo
Ústav archeologie a muzeologie
Filozofická fakulta
Masarykova univerzita Brno
Arna Nováka 1
CZ – 602 00 Brno
peter.milo@mail.muni.cz

Dr. Béla Miklós Szőke, DsC.
Eötvös Lorand Research Network
Tóth Kálmán 4
HU – 1097 Budapest
szoke.bela@abtk.hu

Mgr. Tomáš Tencer, PhD.
Ústav archeologie a muzeologie
Filozofická fakulta
Masarykova univerzita Brno
Arna Nováka 1
CZ – 602 00 Brno
tencer@mail.muni.cz

Ágnes Ritoók, PhD.
Hungarian National Museum
Múzeum körút 14–16
HU – 1088 Budapest
ritook.agnes@hnm.hu

Mgr. Katalin Gergely
Hungarian National Museum
Múzeum körút 14–16
HU – 1088 Budapest
gergely.katalin@hnm.hu

Mgr. Michal Vágner, PhD.
Ústav archeologie a muzeologie
Filozofická fakulta
Masarykova univerzita Brno
Arna Nováka 1
CZ – 602 00 Brno
vagnermichal@mail.muni.cz

Infra civitatem Priwinae

Geofyzikálny prieskum včasnostredovekého centra Mosapurc/Zalavár

Peter Milo – Béla Miklós Szőke – Tomáš Tencer – Ágnes Ritoók – Katlin Gergely – Michal Vágner

SÚHRN

Včasnostredoveké mocenské centrum Mosapurc/Zalavár patrí ku kľúčovým archeologickým lokalitám daného obdobia v strednom Podunajsku. Nachádza sa v západnej časti Panónskej nížiny, pri juhozápadnom cípe jazera Balaton, v zamokrenej oblasti, ktorej hlavným vodným tokom je rieka Zala (obr. 1). Z nivy rieky tu vystupujú nevýrazné piesočné ostrovčeky, ktoré sa v období raného stredoveku stali základom hustého osídlenia oblasti. Na jednej z najväčších takýchto pieskových vyvýšenín je situovaná lokalita s názvom Városziget (obr. 2). Ťažisko osídlenia a osobitný dejinný význam nadobúda v 9. stor., kedy tu zakladá svoje panónske sídlo Pribina. Lokalita, z historických prameňov známa ako *civitas Priwinae*, *urbs paludarum*, *castrum Chezilonis*, *Mosapurc*, *Mosaburg*, sa stáva správnym a hospodárskym centrom najvýchodnejšej marky Východofranskej ríše. Jej význam dnes dokazujú početné pozostatky murovaných a drevených, sakrálnych a profánnych architektúr, ktoré sú pre tento geografický priestor vo včasnom stredoveku výnimočné (*Sós 1963*; *Szőke 2010*). Poloha bola osídlená, aj keď už vo výrazne menšej miere, aj po obsadení oblasti Maďarmi. V 11. stor. tu na rozvalinách včasnostredovekých kostolov a palácov vzniká správne centrum župy a Benediktíni tu budujú kláštor, ktorý je neskôr v čase tureckého nebezpečenstva prebudovaný na pevnosť (*Ritoók 2015*). V novoveku bola poloha využívaná prevažne ako pasienok, podstatná časť však bola pri exploatácii stavebného materiálu z ruín kláštora a nasledovnej ťažbe piesku zničená.

Cieľom príspevku bolo predstaviť výsledky geofyzikálnych meraní, ktoré sa na lokalite uskutočnili v rokoch 2010 a 2015. Kvôli vegetácii a modernej zástavbe (cesty, budovy) nebola plocha hradiska preskúmaná celá (obr. 3). Magnetický prieskum sa sústredil na dve časti lokality: západnú časť hradiska (hlavný hrad – 2,1 ha) a severovýchodnú časť hradiska (suburbium – 3,7 ha). Jeho hlavnou úlohou bola detekcia areálov s potenciálnym výskytom archeologických objektov. Georadarové merania preskúmali deväť samostatných plôch menšieho rozsahu (spolu 0,7 ha), situovaných v rôznych častiach lokality. Ich hlavnou úlohou bolo overiť niektoré z výsledkov magnetických meraní. Keďže do geofyzikálnych dát vstupuje množstvo premenných a zaznamenané štruktúry pochádzajú z rôznych období, pokúsili sme sa stručne zrekonštruovať aj vývoj osídlenia lokality od včasného stredoveku po novovek (obr. 4–7). Hlavná pozornosť bola venovaná 9. stor., kedy tu sídelné a stavebné aktivity zaznamenávajú vrchol. Väčšina štruktúr lokalizovaných pri geofyzikálnom prieskume súvisí práve s touto dobou. Dejiny sa tu ale neprestali písať ani po zániku Zalaváru ako centra východofranskej moci v Panónii. Výraznú stopu vo výsledkoch geofyzikálnych meraní zanechali tiež vrcholnostredoveké a novoveké antropogénne aktivity, ktoré vytvárajú spolu so staršími štruktúrami jeden heterogénny celok.

Geofyzikálny prieskum vnútornej plochy hlavného hradu doložil početné archeologické objekty, ktoré môžeme interpretovať ako sídliskové štruktúry rôzneho charakteru – pozostatky obytných a hospodárskych stavieb, pece a rôzne sídliskové jamy (obr. 8–10). V otázke intenzity sídelných aktivít korešpondujú výsledky geofyzikálneho prieskumu s výsledkami doterajšieho archeologického bádania (obr. 11), prinášajú ale aj nové zistenia. Predovšetkým sme mohli konštatovať, že na geofyzikálne skúmanom západnom okraji hlavného hradu je hustota evidovaných sídliskových štruktúr nižšia, ako na východnom okraji (obr. 12; tabela 1). Je isté, že nie všetky objekty sa geofyzikálnou prospekciou podarilo zachytiť. Napriek tomu poukazuje dané zistenie na základný trend vo využívaní plochy hradiska pre stavebné aktivity.

Najväčšou výzvou geofyzikálnych meraní v Zalavári bola otázka vzhľadu severovýchodnej časti hradiska, ktorej bližšia funkcia nám bola neznáma, pracovne sme ju ale označili ako predhradie. Vo všeobecnosti sa predpokladalo, že tento areál bol v 9. stor. osídlený, nepoznali sme ale, aké charakteristické znaky tu osídlenie vykazuje, a aká je jeho intenzita. Geofyzikálny prieskum doložil, že charakter osídlenia je tu podobný tomu z hlavného hradu (obr. 8–12; tabela 1). Celé predhradie je pokryté rôznymi sídliskovými objektami. Intenzita osídlenia je tu menšia ako na ploche hlavného hradu. Aj tak ale môžeme celú túto plochu označiť za kompletne osídlenú a väčšinu z detegovaných štruktúr zrejme môžeme považovať za objekty súvisiace s osídlením polohy v období včasnostredovekého *Mosaburgu*.

Geofyzikálny prieskum nedoložil nikde plánovanú zástavbu. Hlavným zistením je doklad, že celá plocha hradiska bola intenzívne využívaná a husto zastavaná. Nikde neevidujeme väčšie prázdne plochy. Najbližšou analógiou v tomto smere je voči *Mosaburgu* hradisko v Mikulčiciach na Morave. Ďalšie znaky, ktoré obe lokality spájajú, ako napríklad prítomnosť sakrálnej

a profánnej murovanej architektúry, podobný typ dokumentovaných fortifikácií, ako aj zasadenie oboch centier do krajiny riečnej nivy, sú iba ďalším z faktorov, ktoré nám umožňujú obe lokality medzi sebou porovnávať. Na žiadnom inom hradisku z tohto obdobia v strednom Podunajsku také intenzívne sídelné aktivity na tak rozsiahlych plochách pozorované neboli. V budúcnosti však bude potrebné výsledky geofyzikálneho – v tomto prípade hlavne magnetického – prieskumu verifikovať cieleným archeologickým výskumom, ako aj rozšíriť o nové poznatky, ktoré by mohli priniesť veľkoplošné georadarové a geoelektrické odporové merania. Návrh vývoja osídlenia a stavebných aktivít na lokalite od včasného stredoveku do novoveku, prezentovaný v úvodnej časti štúdie, nie je s istotou konečný a v priebehu ďalšieho výskumu ho bude nutné revidovať.