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ZBORNÍK SLOVENSKÉHO NÁRODNÉHO MÚZEA

ARCHEOLÓGIA 25
ROČNÍK CIX – 2015

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ZBORNÍK SLOVENSKÉHO NÁRODNÉHO MÚZEA CIX – 2015 ARCHEOLÓGIA 25

OBSAH / INHALT

INTERPRETATION OF GEOPHYSICAL SURVEY OF AN EARTHEN MOUND FOR ARCHAEOLOGICAL PURPOSES, MOST PRI BRATISLAVE

IGOR MURÍN

Keywords: *Applied geophysics, non-destructive, ERT, GPR, magnetometry*

Abstract: *Geophysics, as a non-destructive and rapid survey technique, helps archaeologists save the time and labour by identifying and targeting potential archaeological features and revealing additional information about archaeological sites. Its application is very useful in present times with increased land development and agricultural activities.*
The aim of this paper is an archaeo-geophysical investigation of the site with a built earthen mound to clarify its history. The site of the geophysical survey is situated west of Most pri Bratislave village. To date, detailed topographic survey and applied geophysical methods including electrical resistivity tomography (ERT), ground penetrating radar (GPR) and magnetometry were applied. The results reveal information about the structure, construction and later use of this mound.

Introduction and purpose

This work is part of a project to test different geophysical methods and evaluate their success and suitability for further use in investigation of built earthen mounds. Such archaeological sites are undergoing changes as they are often located on agricultural land or in the area of urban development and can be in danger of disturbance. For this reason it is important to use a rapid method for their identification and initial description.

For this purpose in 2013 two campaigns of the geophysical survey were applied on the site with an earthen mound (Fig. 1), located west of village "Most pri Bratislave" (Fig. 2), 3 km east of Bratislava city, in the western part of an intermountain depression in the Danube basin called "Podunajská nížina". It is situated on the biggest river island in Europe "Žitný ostrov" (Rye island), on the right side of the Little Danube river. The sediments are composed mainly of Quaternary sediments (river Danube sand and gravel settled in fluvial or lacustrine conditions) and Late Tertiary (marine and lacustrine sand, fine sand). Beneath this, a system of aquifers and aquitards exist.

Fig. 1 The earthen mound, Most pri Bratislave.
Obr. 1 Zemný násyp, Most pri Bratislave.

Fig. 2 Google earth image (18.08.2013) with the site location, Most pri Bratislave.
Obr. 2 Snímka z " Google earth" (18.08.2013) s lokalizáciou miesta výskumu, Most pri Bratislave.

Topographic survey by GPS and a number of geophysical surveys were completed at the site in April and November 2013 using electrical resistivity tomography (ERT), ground penetrating radar (GPR) and magnetometry. The results from these surveys have revealed some information about the structure, construction and later use of this mound.

The mound is currently 22-25 m in diameter and 3.5 m high, covered by trees and other vegetation. There are many signs of disturbance: digs and redeposit of soil on the surface of the mound. A development site is located near the burial mound.

According to local legend, knights in rich armour, who died in a battle against the Tatars, are buried below the mound (locally called "Turkish Hill"). Trees were planted at this place and crosses were erected. Fires used to be made on the top of the hill on All Saints Day as a part of local tradition (www.mostpribratislave.sk).

There are two possible origins of this object: it might be a burial mound based on the nearby excavated burial mounds from the hallstatt period in Nové Košariská, located 5 km south, by Ms. M. Pichlerová (1969) and the existence of many other burial mounds in the vicinity or a mound with fortification on top called a "motte".

History of the village

The village itself is first mentioned in documents in 1238 as Prückel, a privileged village and royal property. The name Prückel comes from the name Bruck an der Donau, (Bridge over the Danube). The village was so-called because the Little Danube river often flooded the surroundings and bridges were needed to access the village. By the end of the medieval period the village went through turbulent times: plaque epidemics, Ottomans attacks and with anti-Habsburg rebellions times remained turbulent until the 18th century. All these destroyed much of the village and greatly decimated its population (www.mostpribratislave.sk). The earthen mound might have been built as a motte during this period of time.
Burial mounds, Hallstatt period

During the early Iron Age in central Europe there was a huge economic boom, as iron became part of daily use. This advanced lifestyle had given rise to an important culture called Hallstatt (8th to 5th centuries BC). It is characterised by construction of very rich graves under burial mounds. The mound of the interest could also have originated from this period.

Based on excavated burial mounds in Nové Košariská [Table 1] and the neighbouring Austrian and Hungarian territory two basic classes of burials have been identified: smaller burial mounds without a built in chamber and large mounds with a wooden burial chamber. From the excavated evidence at Nové Košariská two basic procedures for building burial mounds have been distinguished. One procedure was to take the building material from a wide area of land surrounding the mound. In the second procedure, the material was exploited from the circular ditch around the mound. These mounds are usually found in groups (up to 10), but can also occur isolated (Pichlerová 1969).

Tumulus	diameter (m)	hight (m)	cubature (m^3)	slope	
I	19,7	3,3	360	21°	
II	17	3,1	300	22°	ditch
III	33,4	5,1	1500	19°	chamber, ditch
IV	31,6	4,1	1100	17°	chamber
VI	40	6,6	2700	20°	chamber

Table 1 Excavated burial mounds in Nové Košariská with parameters by Ms. M. Pichlerová (*1969*).
Tabuľka 1 Vybrané parametre z preskúmaného mohylníku v Nových Košariskách M. Pichlerovou (1969).

Materials and Methods

Geophysical survey methods have become an important part of archaeological investigation. These methods are non-invasive techniques with the advantage of rapid data accusation on the site. The geophysical results depend on the contrast between the physical properties of the archaeological materials and the surrounding media where they are located. Each method has its own strengths and limitations, therefore a combination of techniques measuring different physical properties is desirable. (Barton et al. 2009)

Electric resistivity methods give an image of the differentiation of the subsurface area depending on the measured values of the earth's electric resistivity (Mareš a kol. 1990). The electrical properties depend of the humidity and mineral composition of the soil, these differences are recorded as anomalies with higher or lower electrical resistivity (Clark 1989). A common method used in archaeology is electric resistivity tomography (ERT), a measurement of resistivity in different depths along a line. Results of ERT survey are profiles, vertical sections of electric resistivity values.

Ground penetrating radar is a survey method transmitting electromagnetic (EM) radiation into the ground where it is reflected from subsurface structures with different electromagnetic properties (Daniels 2004). The GPR data are sequences of recorded amplitudes and time delay of reflected EM radiation from subsurface usually along a line in a form of radargrams. (Conyers 2011) These profiles need to be processed to improve the quality of the image and to obtain information about the shape and depth of the features of interest (Daniels 2004; Murin 2015).

Magnetometry is the most widely used geophysical method in archaeology. It is a rapid technique able to locate quite subtle archaeological features (Linford 2006; Gaffney 2009). It is based on different magnetic properties of archaeological features and surrounding subsoil area. Magnetic field of archaeological objects appears as a variation (magnetic anomaly) of the earth's magnetic field caused by a content of magnetic minerals in objects. It is also affected by their shape, size, position, and depths (Mareš a kol. 1990).

Methodology

The geophysical survey commenced in April 2013 on a survey area of approximately 55x55m in size using ERT, GPR surveys and magnetometry was carried out along two 55 m long profiles. The first profile-1 is orientated south-north and the second profile-2 east-west. They intersect in the middle on the top of the mound. Magnetic survey with a caesium magnetometer TM–4 (GTL Armidale, Australia) was carried out on 3 parallel lines with a 1 m separation along the profiles (Fig. 3). ERT measurements were recorded along both profiles with an ARES GF instrument with 1m spacing between the electrodes (Fig. 4) and GPR survey was conducted with GSSI SIR3000 system with a 400 MHz antenna (Fig. 5). In November 2013, based on results from previous surveys, an additional GPR survey with 100 MHz antenna was conducted along the profile-1.

A detailed topographical survey on a grid of approximately 1 x 1 m over the whole area was recorded using dual frequency Trimble GPS. Surfer (Golden Software, USA) was used to create a topographical map and a digital terrain model (DTM) of the site.

The magnetic data were processed in Magit and Magsys software (GTL Armidale, Australia) with low-pass and high-pass median filter to remove impulse noise, the time-variation of earth's magnetic field and some geological anomalies. Surfer from Golden software was used for the final visualization of results.

ERT was carried out with an electrode spacing of 1 m using a Wenner configuration. The position of each electrode of the profile was recorded using the GPS. Obtained 2D resistivity model sections from the inversion apparent resistivity pseudo-section data were done using the Res2Dinv program (Geotomo software).

GPR data were processed using Reflex-Win v. 7 (Sandmeier software) applying the following steps: substraction of mean trace, time-zero correction, bypass filter, gain correction, background removal and migration. For topographic correction the topography was extracted from the DTM. For time-depth conversion the wave propagation velocity was estimated by fitting diffraction hyperbola to average values 0,09 m/ns.

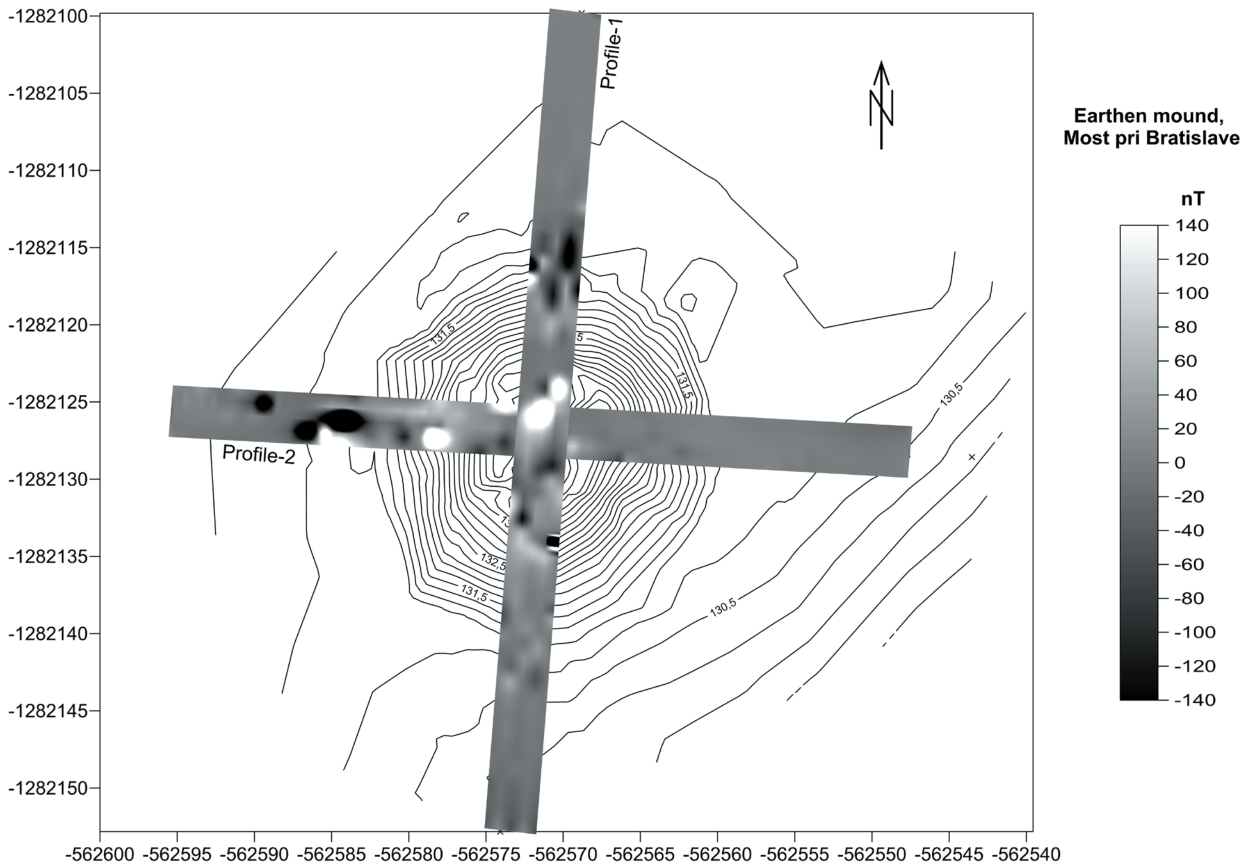

Fig. 3 Topographic map of the site with magnetic survey results.
Obr. 3 Topgrafická mapa lokality s výsledkami magnetického merania.

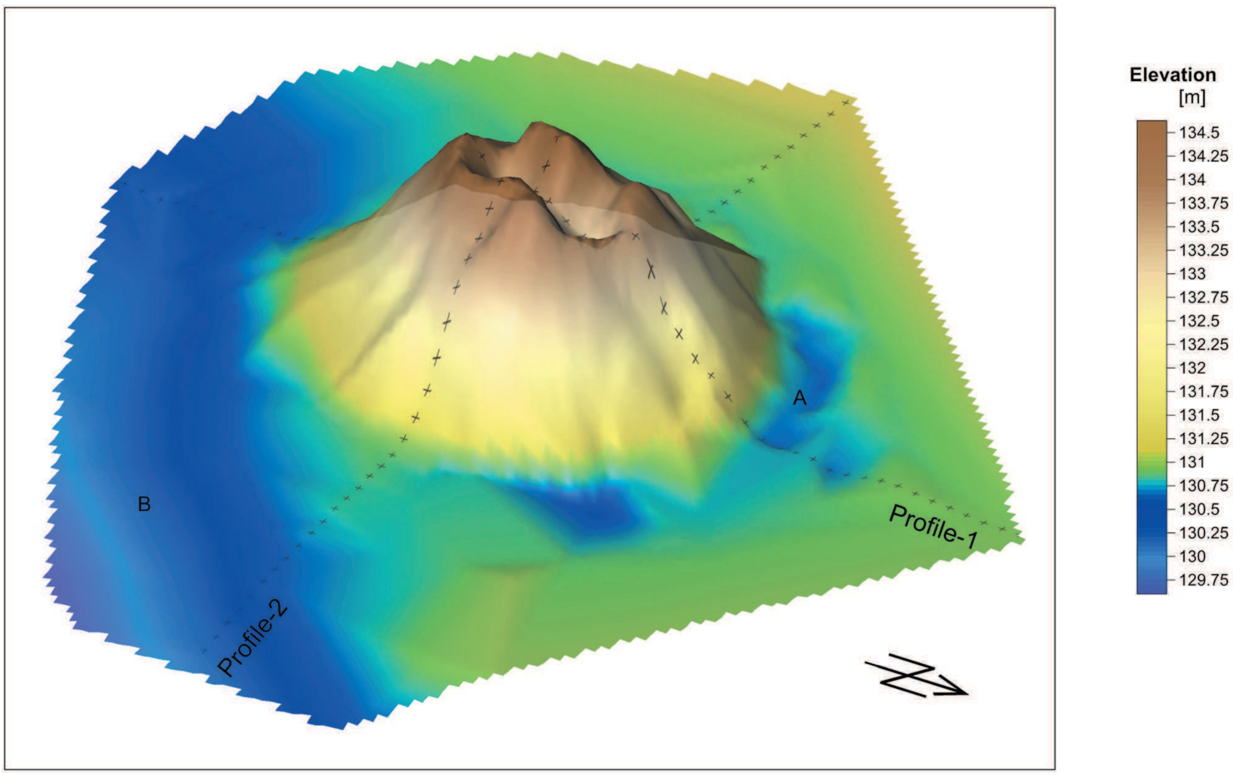

Fig. 4 Digital Terrain Model (DTM) of the site with positions of the ERT electrodes.
Obr. 4 Digitálny terénny model (DTM) lokality s pozíciou ERT meracích elektród.

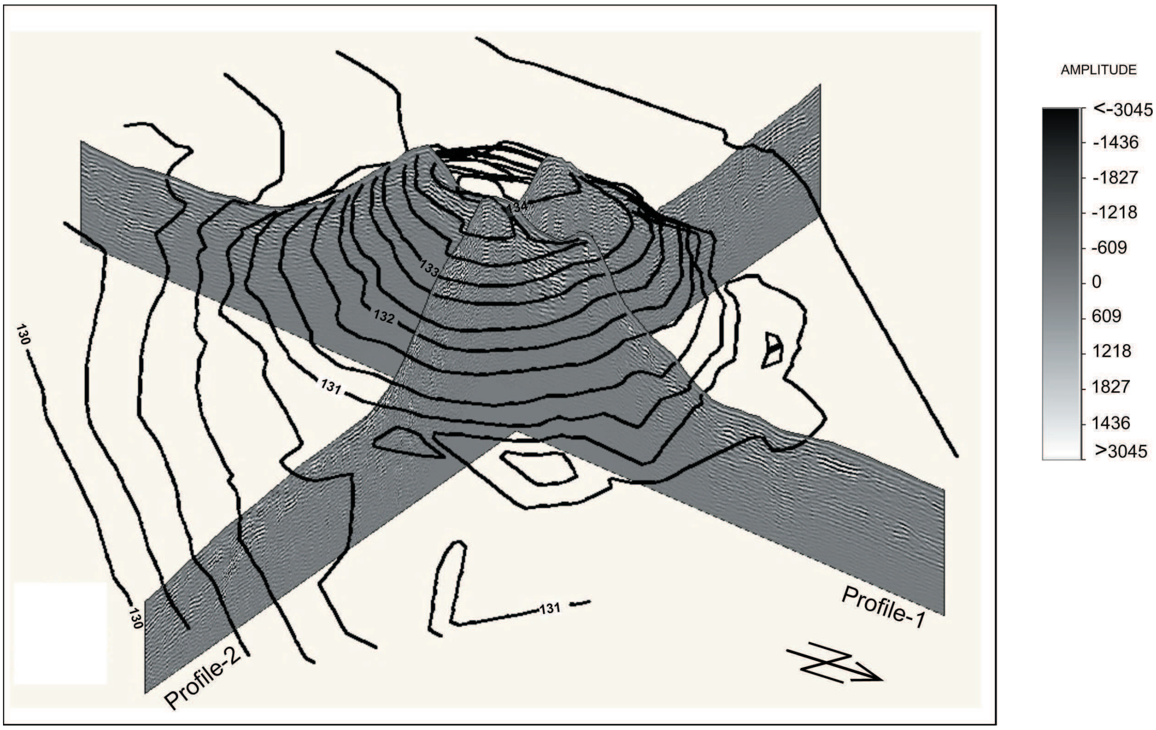

Fig. 5 GPR (400Mhz) profiles1and 2 combined with topographic contours.
Obr. 5 Profily 1 a 2 GPR (400Mhz) merania kombinované s vrstevnicami.

Results and discussion

Magnetic survey data are displayed in two strips along the profiles (Fig. 3). From anomalies at the base of the mound it is possible to identify a former metal fence around the mound. The results show generally higher anomalous values of earth's magnetic field over the top of the mound than on the surrounding surface area, this might be related to the fires made there on All Saints Day.

From GPS measurement data a detailed topographic map and DTM model (Fig. 4) was created. They show anomalous depressions (blue colour): at the base of the mound on the north side (feature labelled as A) and on the south-east side a declining surface area (feature labelled as B) correlating with geophysical results described below.

The feature (B) corresponds in location with the enclosing feature around the village visible on images from Google Earth (Fig. 6a) and on the historical military map (Fig. 6b) from the beginning of the 19th century. It was most probably a draining and protecting ditch-canal around the village, which might be originally an abandoned meander.

The GPR (400 MHz) profiles over the surveyed area are generally of good quality. Both GPR profiles (Fig. 7, 8) clearly show a ditch (feature A) at the base of the mound on the north-west side cutting the top soil and sandy clay sediment down to gravel layer. Further to the south-east from the mound on both profiles, it is possible to identify a buried horizon declining towards a wide ditch (feature B) with a visible bank. On the south-east side of the mound at its base it is possible to recognise in GPR profiles at 1 m depth the buried original surface slope (angle: 28°) of the mound (feature labelled as C). The mound itself is quite disturbed by modifications in history and amateur excavations, particularly the central part of the mound is affected.

The ERT profiles (Fig. 9, 10) confirm the information from GPR survey and show anomalies in the areas of located ditches (features A, B) and also show zonation-material differences in the mound. The top layer of the mound although widely disturbed seems to be a platform made from higher electric resistivity material.

In order to improve the depth of GPR penetration 100 MHz antenna was later used along profile-1. Due to the vegetation (trees) the surveyed profile was split into two parts. The results show deeper layers, around 1.5-2 m below the surface, with the slope angle (18-20°) on both sides of the mound (Fig. 11).

The following information resulted from the survey: the earthen mound with 23 m in diameter is 3,5 m high, has volume of 700 m^3, and slope of sides 27°-30°, the same slope of layers was detected on GPR (400Mhz) profiles up to one meter of depth. These details differ, except the height, from the parameters of the burial mounds described by Ms. M. Pichlerová [Table 1] in the location "Nové Košariská". The ERT results show that the top part of the mound

Fig. 6 Site location: a) Google earth image; (5. 4. 2005); b) Military map, II etape, from 19th century.
Obr. 6 Lokalizácia výskumu: a) Google Earth snímka (5. 4. 2005); b) Vojenské mapovanie, druhá etapa z 19. storočia.

has a higher resistivity and looks like a platform. An important outcome of the survey is the detection of a broader ditch (feature B), a part of the ditch-canal surrounding the village. It seems that the earthen mound was incorporated into this structure. The images released on Google Earth and historical maps show the position of the mound close to the historical approach over the ditch to the village (Fig. 6). All these results support the theory that the mound may have been used as a motte during the turbulent times of the 16^{th}-18^{th} century.

However, the additional GPR survey with 100 Mhz antenna brought new information. The deeper layers of the mound on both sides of the surveyed profile-1 (Fig. 11) show angle of the slope around 18°-20° which corresponds with the parameters of burial mounds described by M. Pichlerová [Table 1] and brings back the idea that the mound was originally a burial mound.

On the Fig.11c are shown interpreted model-sections based on the geophysical results, they represent the different shapes the earthen mound undertook during its history.

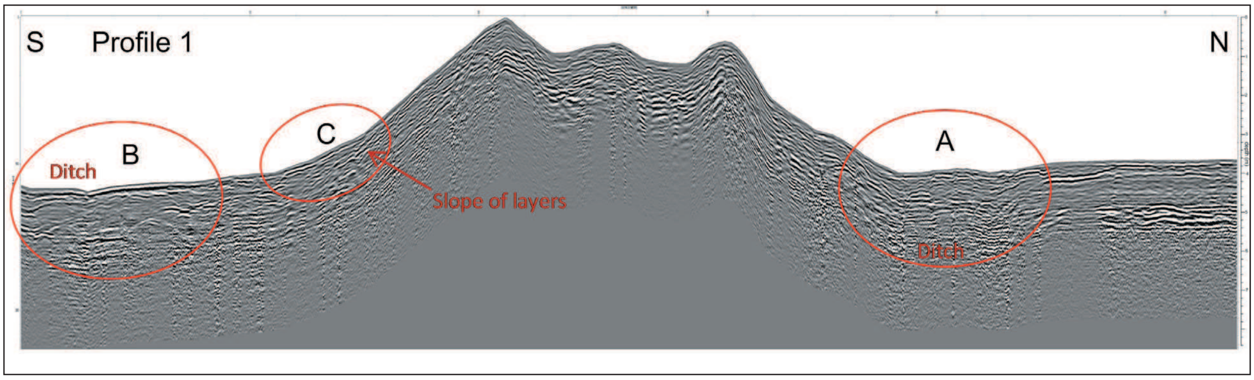

Fig. 7 GPR (400Mhz) profile-1, S-N.
Obr. 7, GPR (400Mhz) profil-1, J-S.

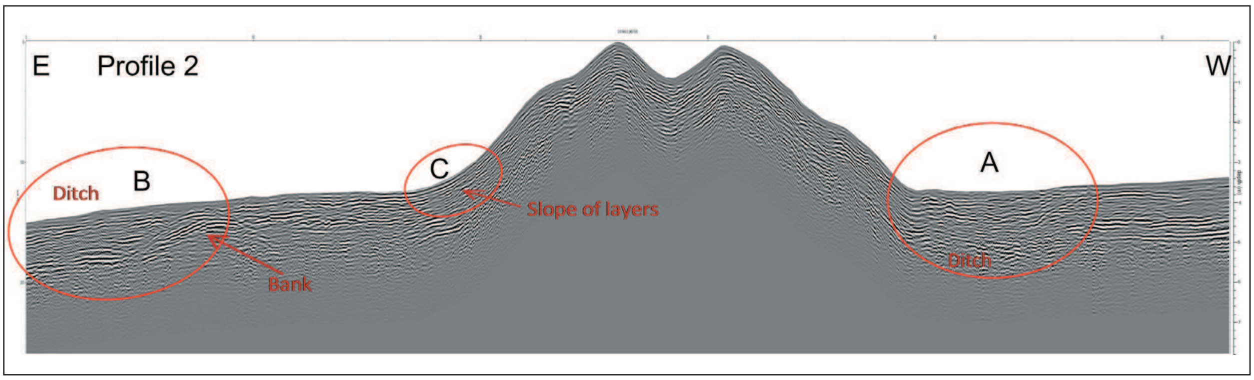

Fig. 8 GPR (400Mhz) profile-2, E-W.
Obr. 8 GPR (400Mhz)profil-2, V-Z.

Conclusion

The combination of the used geophysical methods, in this case study, successfully fulfilled the task and helped to shed a light on the origin and function of the investigated site, the earthen mound. ERT and GPR surveys show similar information in different ways that enables a better interpretation of the stratigraphy. This helps to determine the right velocity of EM waves for interpretation of GPR. The results can give information about the structural geometry of the site. However, these methods must be proceeded by a detailed topographical survey in order to create a real structural model of the site.

The magnetic survey shows less information and the results are associated with more recent time. There was also some noise probably from dumped material and waste from near development site and close urban area of the village.

The discovery of the closely located ditch-canal surrounding the village shows the complexity of the site, which supports the results that the earthen mound was modified and rebuilt to be used for various purposes during its history which all left its footprints.

The studying and investigation of the surrounding area appeared to have a significant role. Images from Google Earth and historical maps were of great help in this case study. It demonstrates the importance of using remote sensing and other sources which can increase our knowledge of the surveyed area. The results are indirect and the interpretation would need to be verified by an archaeological excavation.

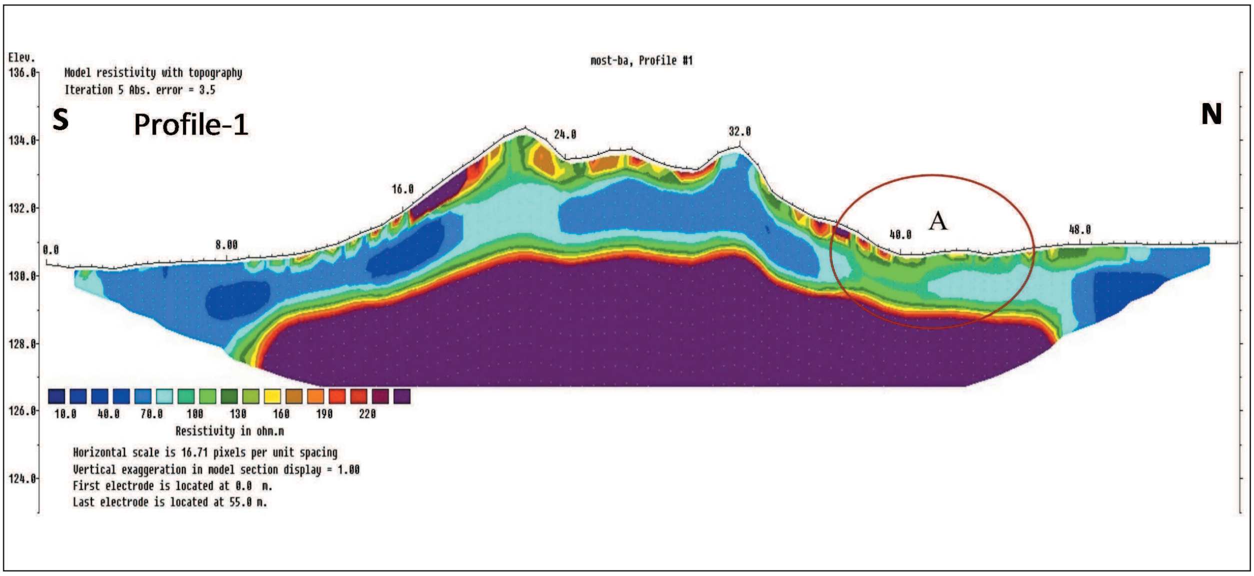

Fig. 9 ERT profile-1, S-N.
Obr. 9, ERT profil-1, J-S.

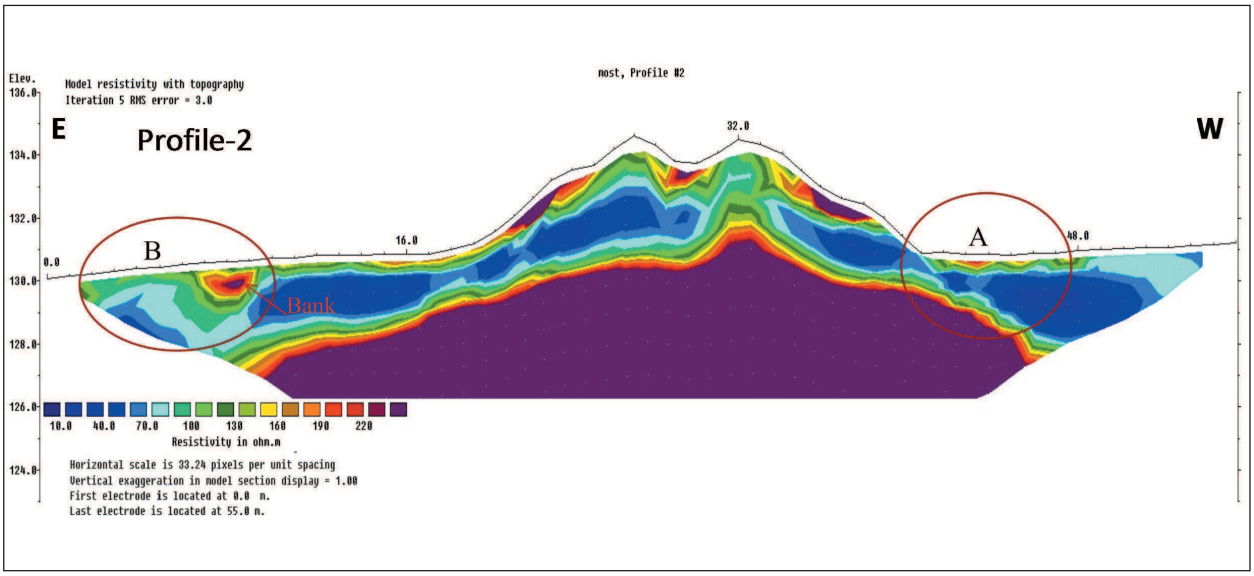

Fig. 10 ERT profile-2, E-W.
Obr. 10 ERT profil-2, V-Z.

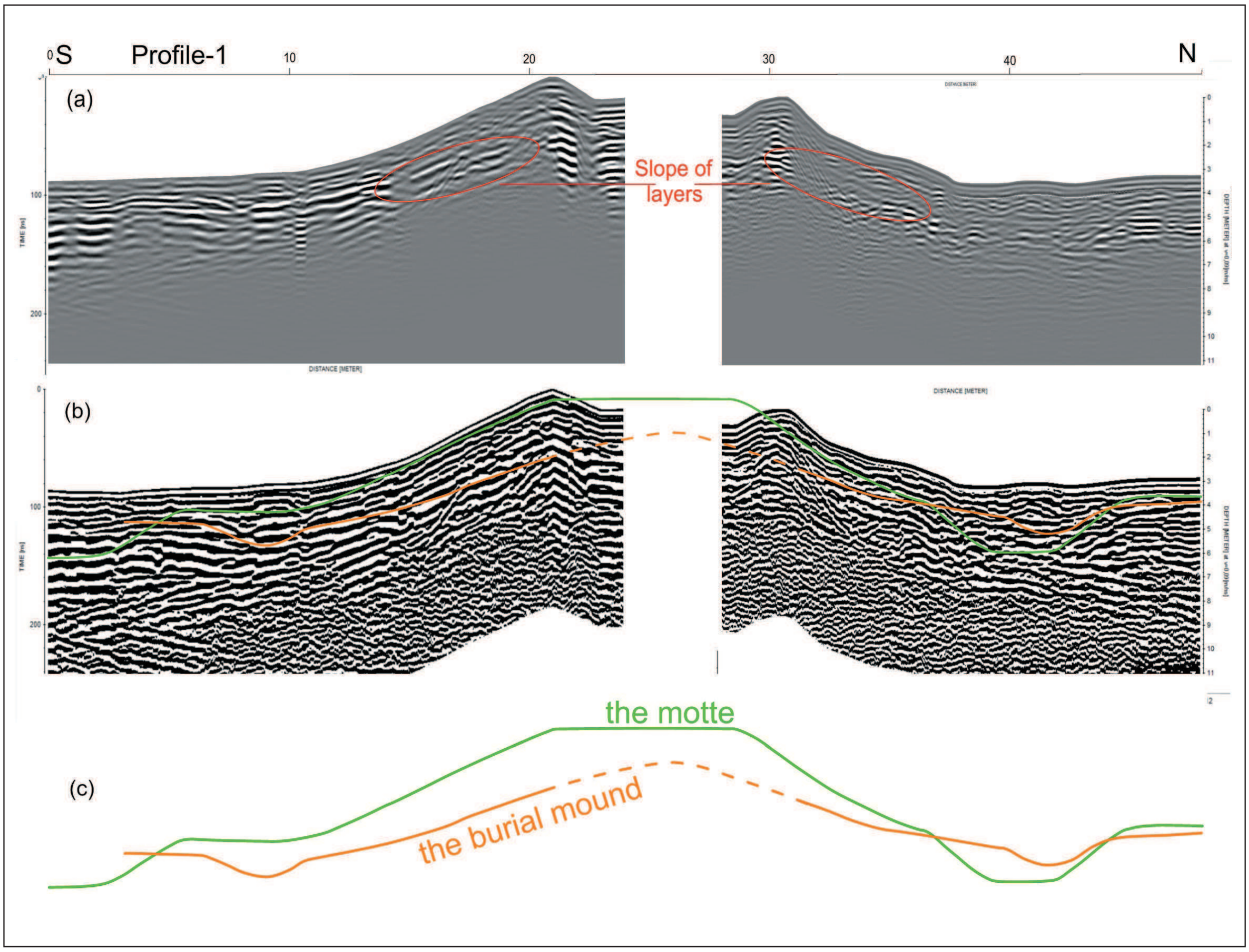

Fig. 11 (a) GPR (100Mhz) profile-1 (gray scale), (b) GPR (100Mhz) profile-1 (BW), (c) different stages of the mound.
Obr. 11 (a) GPR (100Mhz) profil-1(gray scale), (b) GPR (100Mhz) profil-1 (BW), (c) rozdielne etapy skúmaného zemného násypu.

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INTERPRETÁCIA GEOFYZIKÁLNYCH MERANÍ (ZEMNÉHO NÁSYPU) PRE ARCHEOLOGICKÉ ÚČELY, MOST PRI BRATISLAVE

IGOR MURÍN

Cieľom práce je interpretácia geofyzikálnych meraní za účelom archeologického prieskumu skúmaného objektu, zemného násypu (obr. 1). Merania boli realizované v dvoch etapách v roku 2013 na lokalite situovanej západne od obce Most pri Bratislave, 3 km východne od Bratislavy, v Podunajskej nížine na pravej strane rieky Malý Dunaj (obr. 2).

Na danej lokalite boli prevedené geodetické meranie pomocou GPS na ploche približne 55 x 55 m a geofyzikálne merania pomocou elektrickej odporovej tomografie (ERT), georadarom (GPR) a magnetometrom pozdĺž profilu-1 v smere juh-sever a profilu-2 v smere východ-západ (obr. 3-5). Obidva profily sa pretínajú v strede na vrchu zemného násypu. Skúmaný objekt lokálne nazývaný "Turecký kopec" je na základe výskytu mohýl v blízkom okolí označovaný za mohylu z halštatského obdobia. Vo vzdialenosti 5 km sa nachádza lokalita Nové Košariská, mohylník preskúmaný M. Pichlerovou (1969). S jej výsledkami a technickým opisom mohýl sú porovnávané výsledné parametre, získané v tejto práci.

Geofyzikálne výsledky

Na oboch GPR profiloch (Obr. 7, 8) nameraných so 400 Mhz anténou je na ich severnej a západnej strane zreteľne viditeľná štruktúra-priekopa (A). Na južnej a východnej strane profilov je viditeľný pôvodný svah návršia (C) so sklonom (28°-30°) a na okrajoch obidva profily zachytávajú časť širšej priekopy (B), vodného kanála, pôvodné mŕtve riečne rameno. Za účelom hlbšieho prieskumu bolo dodatočne prevedené GPR meranie pozdĺž profilu-1 so 100 Mhz anténou, ktorá ma hlbší dosah ale nižšiu rozlišovaciu schopnosť. Meranie bolo rozdelené kvôli vegetácii na vrchole návršia na dve časti. Výsledný profil (Obr. 11) zobrazuje vrstvy z väčších hĺbok 1.5 - 2 m so sklonom 18°-20° a to po oboch stranách násypu. Na profiloch z ERT merania (Obr. 9, 10) sa dajú rozoznať anomálie (A a B), ktoré sa zhodujú s výsledkami GPR merania. Taktiež vrchnú časť násypu tvorí vrstva-platforma s väčšími hodnotami elektrického odporu. Merania magnetometrom sú zobrazené v dvoch pásoch pozdĺž profilov 1 a 2. Vyššie anomálne hodnoty boli namerané nad zemným návrším čo môže byť spôsobené prepálením pôdy ako aj znečistením, kontamináciou železným materiálom. Po obvode návršia sú výraznejšie anomálie pravdepodobne spôsobené zvyškami po oplotení. Výsledkom geodetického merania je topografická mapa a digitálny terénny model (DTM) skúmanej lokality (Obr. 3, 4). Na obidvoch sú viditeľné terénne depresie, ktoré sa zhodujú s výsledkami ERT a GPR merania, anomálie (A a B) interpretované ako priekopy.

Výsledky meraní z prvej etapy prieskumu (apríl 2013) ukazujú, že skúmaný objekt má inú stavbu a rozmery, než halštatské mohyly opísané v práci M. Pichlerovej. Odlišuje sa svojím tvarom, objemom a sklonom svahov. Mohlo ísť o opevnený vŕšok "motte", čo dokazuje aj jeho poloha, v samotnej blízkosti sa nachádzal vodný kanál-priekopa (B) obklopujúca danú obec a priechod cez túto priekopu smerujúci do obce (obr. 2 a 6). Skúmaný objekt, zemný násyp sa zdá byť včlenený do tohto systému jeho okrajom, kým zvyšná vonkajšia časť je obklopená polkruhovou priekopou. V druhej etape prieskumu (november 2013) bol použitý GPR s anténou iných parametrov dovoľujúci prieskum väčších hĺbok. Výsledky z tohto merania zobrazujú hlbšie vrstvy skúmaného objektu so sklonom, ktorý sa zhoduje s parametrami mohýl opísanými v práci M. Pichlerovej, čo naznačuje že daný objekt mohol byť pôvodne postavený ako mohyla.

Tento výskum priniesol poznatky o stavbe a historickom vývoji skúmaného objektu, zemného násypu. Veľkým prínosom bolo aj štúdium historických máp a snímok z Google Earth. Z výsledkov sa dá usudzovať že daný objekt prešiel viacerými zmenami a bol využívaný na rôzne účely, pravdepodobne bol pôvodne postavený ako mohyla a neskôr v čase tureckého nebezpečenstva upravený a využívaný ako "motte". Získané výsledky sú nepriame a na ich potvrdenie by bol potrebný ďalší archeologický výskum.

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