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IDENTIFYING THE ROMAN AQUEDUCT OF BRIGETIO (KOMÁROM-SZŐNY, KOMÁROM-ESZTERGOM COUNTY / HU) USING HISTORICAL SOURCES, MAPS, GIS MODELLING AND NON-DESTRUCTIVE METHODS

People of the 21st century, increasingly disconnected from material reality, may be less interested in objects from the past than their predecessors, generations ago. On the other hand, we are now much better equipped not only to exhibit, reproduce, and breathe new life into these objects but also to tell their stories as never before. In archaeology, however, it is rare that the story is already known, but the object needs to be (re-)discovered.

The pillars and underground channel of the aqueduct of Roman Brigetio (Komárom-Szőny, Komárom-Esztergom county / HU) disappeared gradually throughout the centuries. Today they are only known from the notes, maps, and papers of foreign travellers, military engineers and teachers (on the history of research see: Benes 2018, 419–425). However, in the 19th century the aqueduct was still commonly known to the villagers living around Tata and Komárom: According to a local folk tale, King Matthias Corvinus, while visiting his royal residency in Tata, placed a golden-plated wooden duck into the water at the spring of the Roman aqueduct then jumped onto his horse and rode with his escort to Pannonia Castle, where he waited for it to arrive (Gyulai 1886, 348). Nowadays, while many still know about the aqueduct from the tale, only a few know about the real aqueduct of Brigetio. The subject of this paper is how the aqueduct from the tale of the golden duck was rediscovered near Naszály (Komárom-Esztergom county / HU) with the aid of historical sources, maps, GIS modelling, and non-destructive methods, allowing us to bring the material reality of the story closer to its 21st-century audience.

NATURAL GEOGRAPHICAL AND TOPOGRAPHICAL BACKGROUND

The legionary fortress and the settlement complex of Brigetio were located strategically within the regional and micro-regional landscape and topography (**fig. 1**). The Amber Road, which was the main route of Roman occupation and trade, had an eastern military branch road ending where the Váh River runs into the Danube (Mráv 2010–2013, 50 fig. 1). Brigetio was established here, where the crossing of the east-west and north-south axes of the main regional routes created a centre of power from which the middle and eastern part of the Little Hungarian Plain could be controlled[1]. The importance of the location is probably best reflected in a stone monument, which indicates that, as early as the 1st century AD, Brigetio was the place from which two tribal territories and the Danubian shoreline (*ripa*) were administered (CIL IX 5363; Kovács 2016, 62–63). Focusing on the narrower landscape, the settlement complex of Brigetio is situated in the Győr-Komárom terrace hills micro-region on the higher floodplain and right bank of the Danube (**fig. 2**; Dövényi 2010, 330–334; Nagy et al. 2013, 279). The micro-region rises southwards towards the highest geological terrace of the Danube, where the relatively low Kálvária Hill – an independent formation of the geologically and environmentally important Mesozoic exposure of Tata – is situated (Szente et al. 2019).

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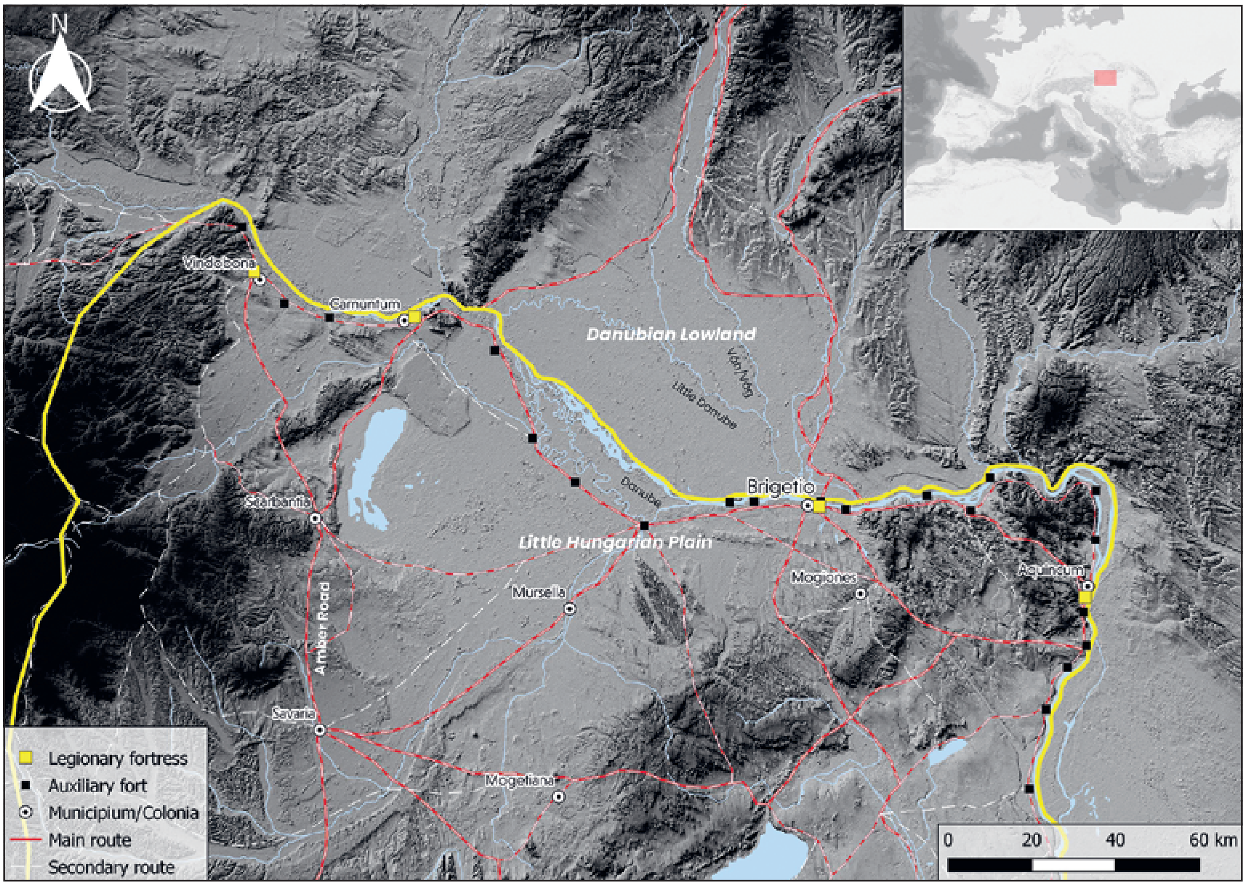

Fig. 1 The topographic location of Brigetio (Komárom-Szőny, Komárom-Esztergom county / HU) in Pannonia. – (Map B. Simon).

At the micro-regional level, the location of the settlement site was chosen on the basis of two essential strategic criteria: natural defence and fresh-water supply. Just like at the other legionary fortress of Aquincum in Pannonia (H. Kérdő / Schweitzer 2010) both of these circumstances were met where Brigetio was founded.

In the Roman period, a paleo-subchannel of the Danube protected the whole settlement complex from the south. The waters of this paleo-channel, which also collected the abundant Fényes Stream from the southeast, were dammed by an embankment with two flood-gates, which regulated the flow. In times of crisis, the paleo-channel could be flooded, leaving the settlement accessible through narrow passages on the east and west only (Deák et al. 2013; Nagy et al. 2013; Viczián et al. 2013; 2015).

Clearly, the settlement complex was deeply embedded in the landscape. This is also reflected in the use of natural resources, like the karst waters of Tata. The springs are located along and at the intersections of the main and transversal faults in the Mesozoic exposure (Horusitzky 1923, 51). These springs around the Kálvária Hill were the most likely source of fresh water for the military and civilian population of Brigetio, 13 km away.

THE DATA OF HISTORICAL MAPS

There are only two historical maps that both record the line of the Roman aqueduct of Brigetio and are suitable for further evaluation in a GIS-environment. The older map was made by the military engineer Sámuel

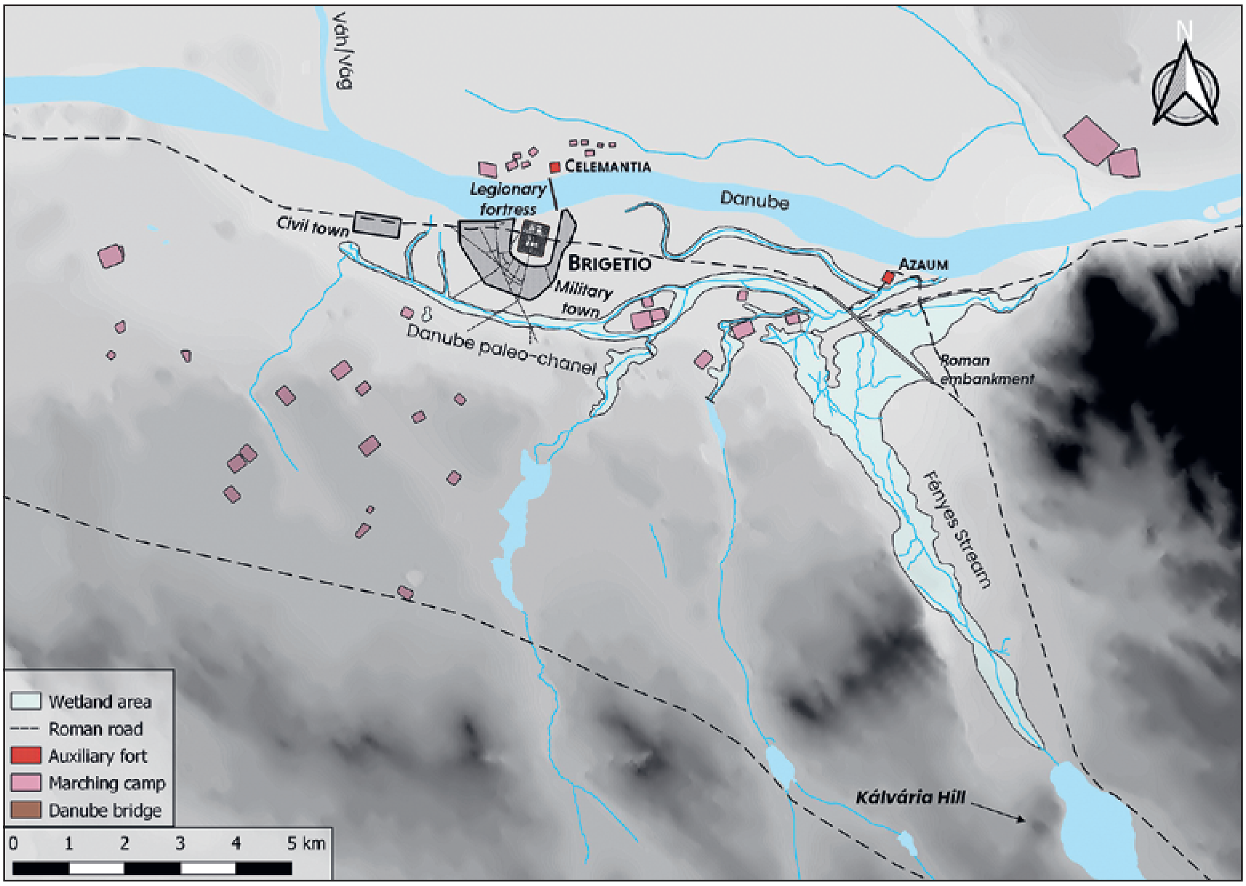

Fig. 2 The micro-regional landscape in the neighbourhood of Brigetio. – (Map B. Simon).

Mikoviny in 1746 in connection with his drainage works in the marshes of the Fényes Stream (National Archives of Hungary: HU-MNL-OL-S 11-290). He drew the map accurately, depicting not only the past natural environment and the contemporary boundary signs but also the Roman aqueduct, the embankment with the two dams, a smaller embankment, and the remains of the legionary fortress of Brigetio and the fort of Azaum.

This map could be georeferenced because it depicts landmarks (roads, canals, ditches, mills, etc.) that are identifiable in cadastral maps from the 19th century, the Third Military Survey, and satellite images. Unfortunately, the northwestern part of the map, where the aqueduct arrives at the legionary fortress was not accurately drawn.

The other map was also prepared by a military engineer, Milos Berkovics-Borota, around the final decades of the 19th century (Berkovics-Borota 1886, 393). He probably used the 1:75 000 Third Military Survey to create his sketch, making the map easy to georeference (Biszak et al. 2007; Molnár/Timár 2009).

There are certain landmarks and locations that appear the same on both maps (**fig. 3**). The starting point of the aqueduct is west of the reformed church on the Kálvária Hill in Tata, from where its line runs on the western side of the stream heading towards Naszály. After leaving the village it crosses two streams, where two embankments are recorded by S. Mikoviny. After georeferencing, these embankments match the channel of the aqueduct drawn by M. Berkovics-Borota. Finally, the water arrives at the Roman fortress from the southeast, passing next to a dirt road dividing two land plots. The landmarks that are common to both maps still exist today, making it possible to model the aqueduct's route in a GIS.

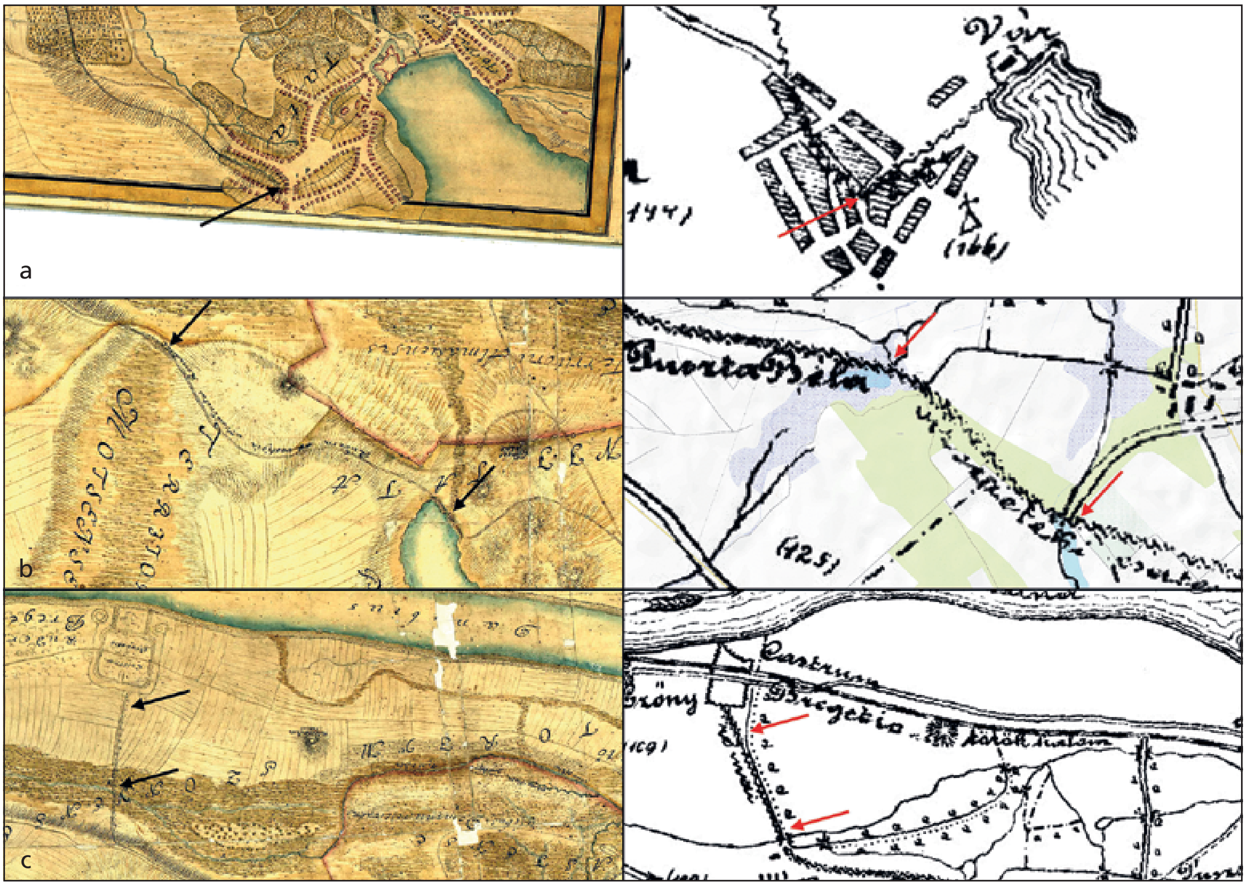

Fig. 3 Similar landmarks and locations on the maps of S. Mikoviny (left column, National Archives of Hungary: HU-MNL-OL-S 11-290) and M. Berkovics-Borota (right column). – **a** starting point of the aqueduct, west of two churches. – **b** aqueduct is running alongside a pond and a marsh. – **c** aqueduct crosses a stream and proceeds to the legionary fortress along the edge of a land-plot or a dirt road. – (Graphic design B. Simon; b right column: underlying topographic map is contributed by © TopoMap).

GIS-BASED PREDICTION AND CONTROLLING OF THE AQUEDUCT'S LINE

There have been other attempts to locate and analyse aqueducts from the Roman Empire using GIS modelling and landscape archaeological methods (Orengo/Miró Alaix 2011; Papakonstantinou et al. 2015; Ruggeri et al. 2017). Drawing ideas from these studies, a predictive GIS model was created for two purposes. The most important one was to provide background in preparation for a spatially confined, on-site research program. The model was also designed to analyse the previously mapped lines of the aqueduct in terms of gradient, which for a conduit moving water through gravity alone should be fairly constant. Better-known Pannonian aqueducts, such as the ones from Savaria (Anderkó 2006) and Carnuntum[2], transfer water from springs to Roman settlements along a mainly closed, underground channel with a steady slope. S. Mikoviny observed similar construction methods in the aqueduct of Brigetio[3].

Starting Point (fig. 4a)

The first step in creating the GIS-based prediction model was to determine the starting and end points of the aqueduct. The georeferenced archival maps of S. Mikoviny and M. Berkovics-Borota clearly indicate that the

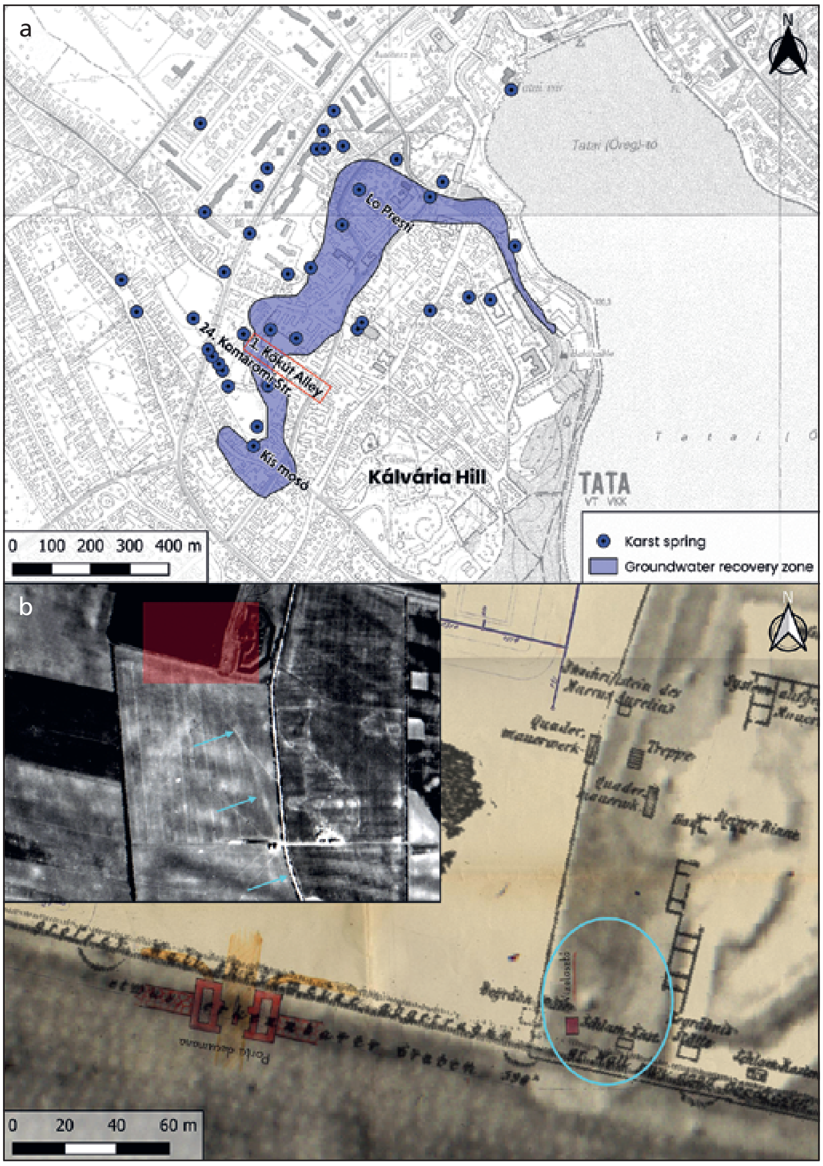

Fig. 4 **a** Mentioned and other springs around the Kálvária Hill, red marking the starting-point of the GIS model. – **b** end point of the aqueduct. Light soil mark shows possible aqueduct or road remains (above). – uncovered remains associated with Roman water management (below). – (Map B. Simon; a after Horusitzky 1923; b above after the Map Collection of the Institute and Museum of Military History 69396; b below after HNM Archives Nr. 54.Sz.I.).

Romans captured the waters of the karst springs in Tata, which are situated on the north-northwestern slopes of the Kálvária Hill (on the karst springs see: Horusitzky 1923), the highest point in town (**fig. 4a**). Based on the archival maps, the most likely starting point of the aqueduct is the spring group around Komáromi Street, where the springs almost form a straight line beginning with 24. Komáromi Street and ending at the Kis mosó Spring. In addition to this group, it is conceivable that the aqueduct also collected water from the northern slopes of the Kálvária Hill. In 1870, a stone altar dedicated to the Nymphs was discovered in the garden of the Esterházy Hospital (Gyulai 1886, 348), where the Lo Presti Spring is located (CIL III 10961; RIU 3, 686; Kisné Cseh/Petényi 2004, 10–11). Collecting from several sources was a common way for Roman engineers to provide the required volume of water to an aqueduct (Aquincum: Póczy 1972). The spring at 1. Kőkút Alley was chosen as the aqueduct's starting point in the model because this location could easily have been a node where water from the springs of the northern slopes and those around Komáromi Street could be combined. In any case, the spring at 1. Kőkút Alley, at 136 m asl, is lower than the Kis mosó Spring (136.5 m asl) and the Lo Presti Spring in the Esterházy Hospital (139.33 m asl) (Ballabás 2004, 4 tab. 2).

End Point (fig. 4b)

The end point of the aqueduct could be more securely determined, as all maps show the conduit leading towards the southeastern edge of the legionary fortress (**fig. 3c**). This is supported by the testimony of locals recorded by M. Berkovics-Borota and R. Gyulai, an archival photograph, and a map from the 1940's stored in the Hungarian National Museum (HNM Archives Nr. 54.Sz.I.).

The publications from the 19th century mention that the older villagers recalled the discovery of 40 pillars of a square fathom (c. 1.89 m × 1.89 m) spaced 5 steps (c. 3.5 m) apart on the right side of a dirt road heading from Béla-puszta Farm toward the legionary fortress (Gyulai 1885, 335; Berkovics-Borota 1887, 36 note 2). The southern part of the dirt road still exists today, therefore it is easily identifiable. A photo taken for military mapping purposes in 1940 (Map Collection of the Institute and Museum of Military History 69396) shows the dirt road. As it approaches the legionary fortress it turns slightly to the east, but where it turns, a light soil mark forms a straight line that continues the line of the road all the way up to the southern edge of the fortress (**fig. 4b**). The dirt road is recorded on the above mentioned photo the same way as it is depicted on the maps of the First (Col. X. Sec. 15) and the Second (Col. XXVIII. Sec. 48; Col. XXIX. Sec. 48) Military Survey. Only the map of S. Mikoviny shows, that it eventually ends near the middle of the eastern part of the legionary fortress (**fig. 3c**). The light soil mark is therefore likely to be associated with the remains of the aqueduct and the road adjacent to it, which supports the recorded oral testimonies.

The other two sources are the map of M. Berkovics-Borota and a map of the oil factory built above the southern part of the legionary fortress, on which the Roman findings were recorded. The author of the latter document is uncertain, but the georeferenced map seems to correctly mark the discovered Roman finds from a topographic point of view, as building remains and cemetery features were drawn where we would have expected them. Near the middle of the eastern part of the fortress, both maps mark remains connected with water management. The map of M. Berkovics-Borota depicts three »Schlammkästen / iszaptartó« on the territory of the fortress, which he describes as massively built settling basins measuring 1.2 m × 0.9 m (Berkovics-Borota 1887, 37). The westernmost basin nearly aligns with the »vízelosztó« (distribution basin) sketched on the map of the oil factory. As these two basins are located directly at the end of the aforementioned light soil mark, the end point of the aqueduct was considered to be the midpoint between them. Without knowing the exact height at which the aqueduct entered the fortress, it was necessary to set the elevation of the end point at its current elevation: 112 m asl.

Drawing the Model

The base of the predictive model was a DEM (Digital Elevation Model) with a pixel resolution of 10 m × 10 m, which was generated from the main contour lines of the Hungarian national topographical maps. The first step in creating the model was to change the symbology of the DEM to unique values ranging from the lowest elevation to 136 m asl, the height of the 1. Kőkút Alley Spring. After this, the slope gradient of the presumed aqueduct track was determined. It was calculated from the height difference (vertical height, leg »a« of the triangle: Δy) between the starting and the end point and their assumed distance (horizontal distance, leg »b« of the triangle: Δx), calculated from the length of the aqueduct (hypotenuse of the triangle: 15.750 m), recorded in the 19th century (Berkovics-Borota 1886, 393).

$$m = \frac{\Delta y}{\Delta x} = \frac{24}{15.750,02} = 0,001523807$$

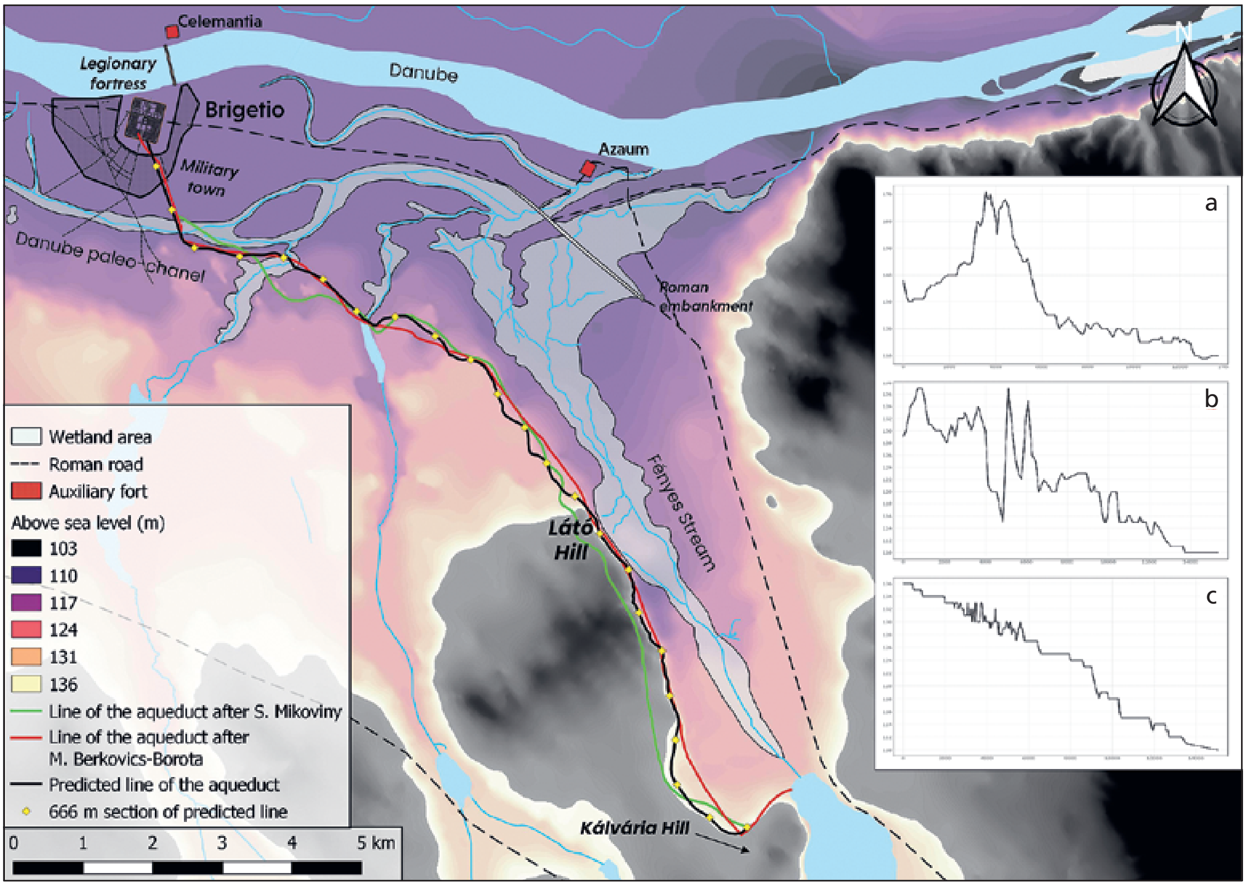

Fig. 5 GIS model and analysis of alternative aqueduct lines with profiles on a DEM (Digital Elevation Model). – **a** profile of line recorded by S. Mikoviny. – **b** profile of line recorded by M. Berkovics-Borota. – **c** profile of line proposed by authors. – (Graphic design B. Simon).

According to the formula, the percent slope of the Roman aqueduct is somewhat higher than 1.5‰, meaning it drops 3 m for every 2000 m run, 1.5 m for every 1000 m and 1 m for every 666.6 m. With this inclination the presumed line of the aqueduct was manually drawn from the starting point to the end, dropping 1 m at each 666.5-m section. The curve of the cells with the same elevation were followed, which prevented the predicted line from crossing any undesirable higher or lower elevations. The model was aligned to landmarks depicted on both the S. Mikoviny and M. Berkovics-Borota maps (such as the two embankments), the dirt road, and the modelled end point at the legionary fortress (**fig. 5**).

Rough Control of the Model

When the predicted line of the aqueduct was drawn, we compared its height profile to the profiles of the digitized lines recorded by S. Mikoviny and M. Berkovics-Borota (**fig. 5**). Neither of the latter two profiles was evenly sloped, meaning either the DEM or the recorded routes of the aqueduct are not accurate.

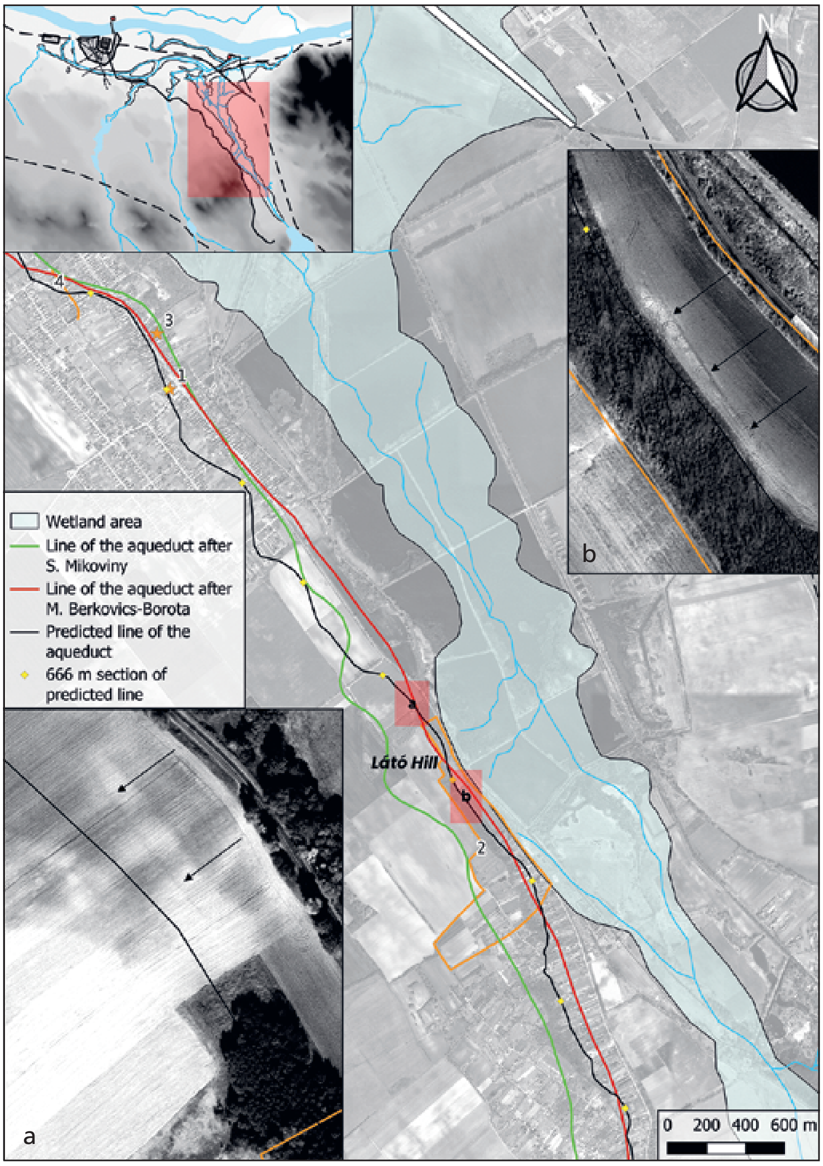

Fig. 6 Aqueduct locations mentioned by oral sources (orange) around Naszály and archival imagery from the area of the Látó Hill. – **a** dark-earth mark on an aerial photo (1978). – **b** dark-earth mark on a satellite photo taken 3.8.2011. – **1** residential block (127. Rákóczi Street). – **2** vineyard. – **3** 98–100. Rákóczi Street. – **4** Kossuth Street. – (Graphic design B. Simon; a https://www.fentrol.hu/en/aerial-photo/92385 [5.3.2024]; b Map Google Earth, Image © 2023 Maxar Technologies).

INVESTIGATIONS TO IDENTIFY THE AQUEDUCT AND VERIFY THE GIS MODEL

The Area of Naszály

To verify the GIS model, the testimonies of literary and oral sources were collected and the places mentioned therein were mapped. Three locations are in the residential area of Naszály, where an extensive survey is no longer possible, but two others are still in open fields today. The oldest testimonies, from the 19th century, mention a location southeast of the legionary fortress where the foundations of pillars were dug up (Gyulai 1885, 335; Berkovics-Borota 1887, 36 note 2), an identifiable residential block in Naszály[4] (**fig. 6, 1**), and a vineyard south of the village, west of the road, where the vaulted underground channel of the aqueduct was found (**fig. 6, 2**; Gyulai 1885, 334; Berkovics-Borota 1887, 36–37). Additional accounts were recently collected from local historians, Lenke Rabi (Jókai Mór Városi Könyvtár, Komárom) and Tamás Fehér. L. Rabi's grandfather reportedly found the aqueduct on their property (Naszály, 98–100.

Rákóczi Street; **fig. 6, 3**) when it collapsed under his feet while he was ploughing. Her parents filled in the hole, so L. Rabi could not see it. She also reported that part of the aqueduct had been demolished by excavators north of the Fekete-ér. T. Fehér was told by a resident that in the 1960's the aqueduct was torn apart during the excavation of a well in Kossuth Street (**fig. 6, 4**). The GIS model correlates well to these locations, but they were not sufficient to scientifically locate a section of the aqueduct. Therefore, a field survey was planned.

The Area of Látó Hill

The territory between the residential area of Naszály and the legionary fortress is too broad and flat to identify the aqueduct. Therefore, we looked for a natural corridor with greater slopes to narrow our search. The area between Tata and Naszály, more precisely the eastern side of the Látó Hill, was chosen for investigations as it is the hilliest location under agricultural cultivation (**figs 5–6**). This is also one of the areas where the aqueduct was observed in the 19th century: west of the road, in the vineyards of Naszály (Gyulai 1885, 334; Berkovics-Borota 1887, 36–37).

Aerial and Satellite Imagery

First, we looked for remote sensing data that could provide some information regarding the archaeology of the area and found some archival photos and satellite imagery that seemed to confirm our expectations. An aerial photo from 1978, which was in the archive uploaded to fentrol.hu[5], shows a dark linear soil mark in the northern area of the Látó Hill (**fig. 6a**).

400 m to the south, another linear feature around the eastern slopes of Látó Hill is observable on many Google Earth satellite images. This soil mark forms a darker line on the western side of a field, appearing on images from at least three years between 2011 and 2016. The mark is not visible in crops, only appearing in the soil exposed after harvest (**fig. 6b**).

Field-Walking

Based on these preliminary analyses, we launched on-site investigations on both fields, to define a location for a geophysical survey. Field-walking produced only stones in the northern field, but in the southern area, called Nagy-Csapási Field, we found *terrazzo*-like fragments of mortar with ground-brick inclusions, possibly Roman. The debris field was clearly visible for 200 m on the surface, spreading out in a 3 m-wide strip, the line of which was recorded with a hand-held GPS device (**fig. 7a; fig. 7**, blue). Among the fragments, larger chunks of building material also came to light (**fig. 7b**). The greatest *terrazzo*-like fragment was 20 cm wide, 11 cm long, and 5 cm thick, forming an arch on the top (**fig. 7c**). The fragment was interpreted as the upper part of the outer wall of the aqueduct, showing similarities with the vaulted channel of the aqueduct of Savaria (Anderkó 2006, 19 fig. 6, 15; 23 fig. 8, 18).

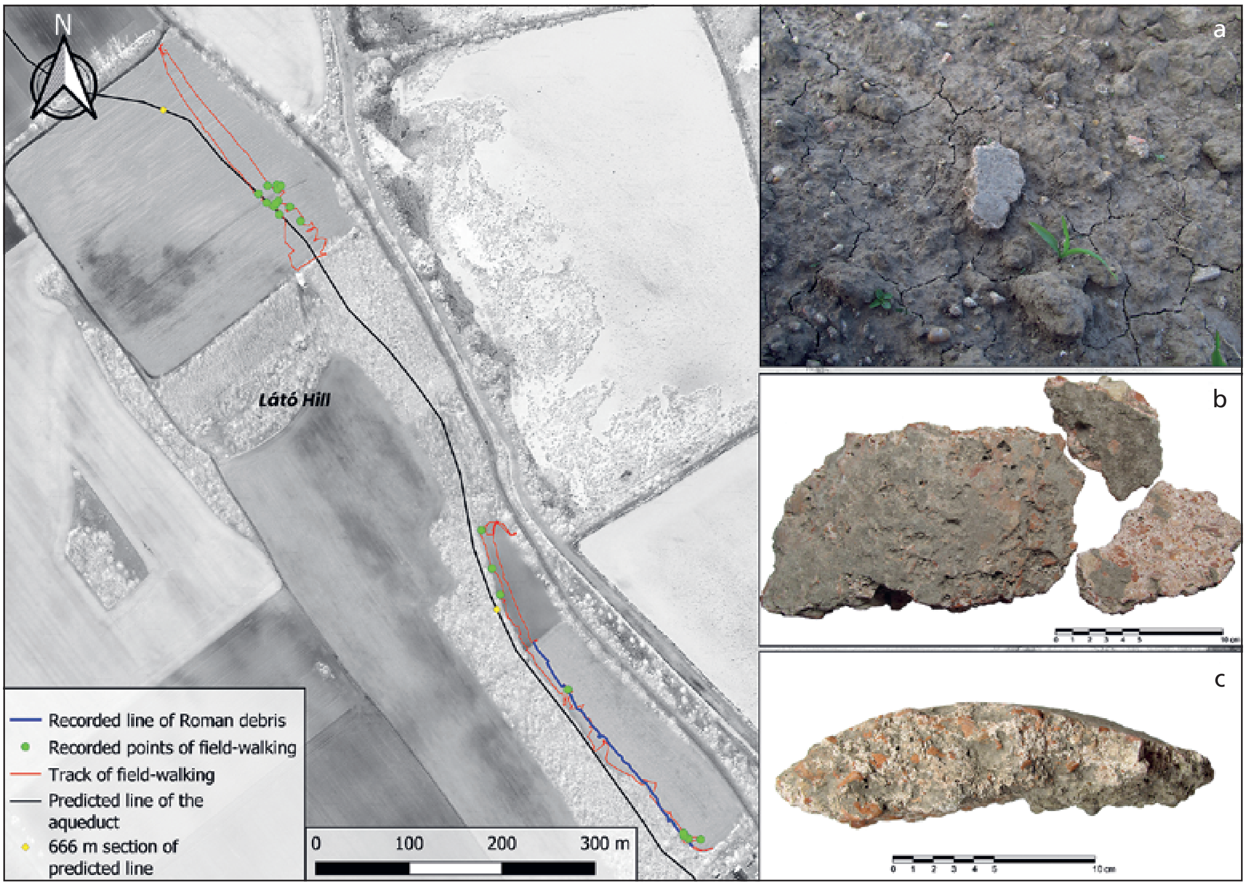

Fig. 7 Results of field-walking around Látó Hill. – **a** visible debris on field, south of Látó Hill. – **b** collected material. – **c** largest debris with smoothed arch on the top. – (Graphic design and photos B. Simon).

Magnetometer Survey

Based on the results of the field-walking survey, a 180 m × 50 m grid of 5 m × 5 m squares was laid out in the southeastern area of the Látó Hill in the Nagy-Csapási Field. The grid was aligned to the northern border of the field and contained the strip of debris. The survey was conducted with two Overhauser GSM-19 cesium magnetometers along the northwestern-southeastern axis. The magnetometers were suspended 75 cm apart straddling the line of the transect. Transects were spaced 150 cm apart. Also, a control measurement was performed in a shoelace manner, with turns at the sides of the surveyed area. The magnetometers were used identically during the surveys, while temporal magnetic changes were compared to the measurements of a locally deployed base magnetometer of similar type (on the technical details of the complete surveying kit see: Czajlik et al. 2019, 196). Geomagnetic prospection identified a clear, linear anomaly exactly where the debris strip had been recorded (**fig. 8**).

RESULTS

In the present study we collected topographic information regarding the aqueduct of Brigetio from two historical maps, one archival sketch, and local oral testimonies from the past 150 years. After the successful

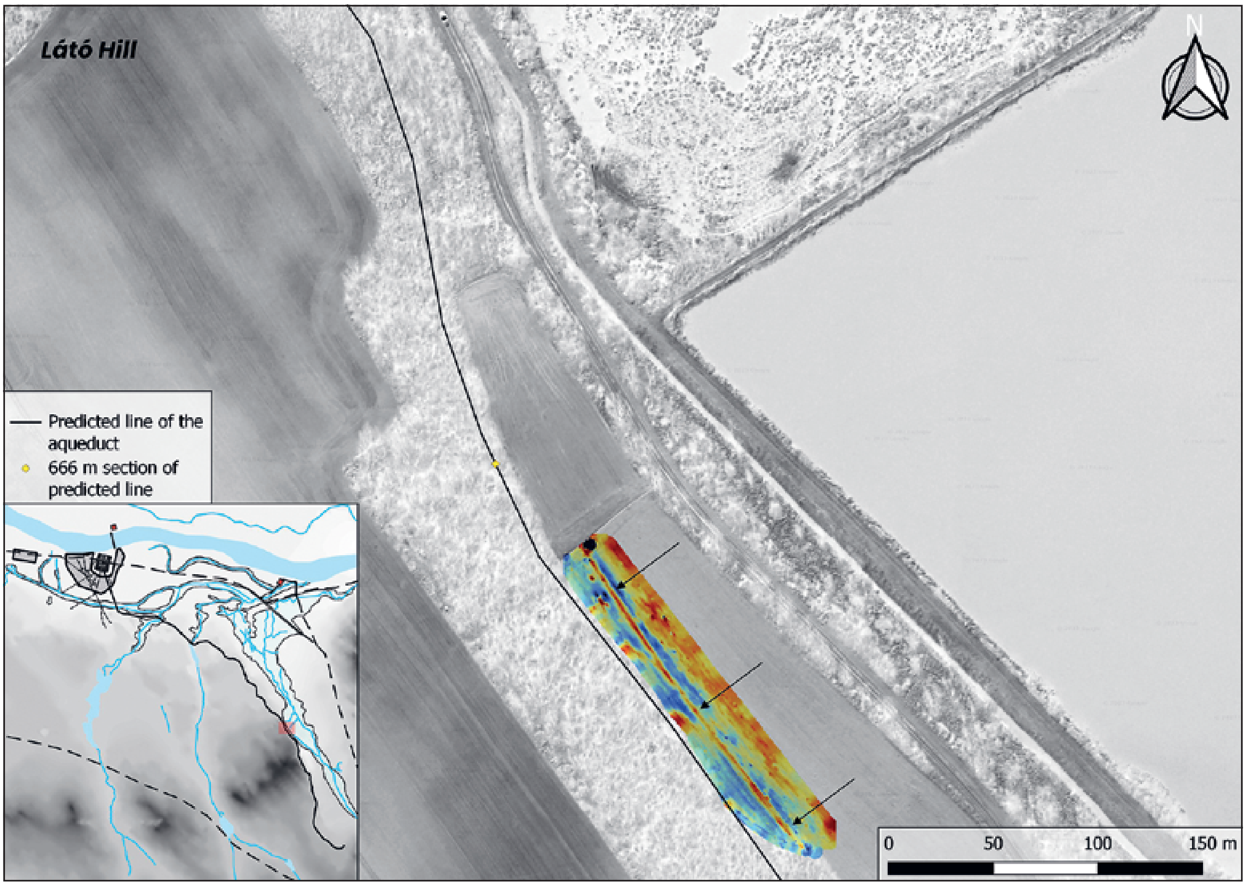

Fig. 8 Result of the geomagnetic survey south of the Látó Hill. – (Graphic design B. Simon).

georeferencing of the previously recorded aqueduct lines, it became obvious that the aqueduct of Brigetio was not sketched consistently. The lines deviate from each other by as much as 350 m, and the elevation profiles of the lines are not evenly sloped. Despite the apparent inaccuracies, observations from the 19th century were used as the basis for the GIS model, which suggested that the average inclination of the aqueduct was around 1.5 ‰. This figure is in line with the 5 to 0.2 ‰ inclination recommended by ancient authors (Vitr. 8, 6, 1; Plin. nat. 31, 31) and the average slopes of better-preserved Roman aqueducts, especially those at Rome and the one at Aquincum[6]. Moreover, the predicted line of the aqueduct, modelled in the GIS to have a slope of 1.5 ‰, stays within the 350 m margin of error defined by the data from archival maps. The difference was that the model was more in line with the track recorded by M. Berkovics-Borota.

The GIS model and the DEM outlined a narrower natural corridor southeast of Naszály on the slopes of Látó Hill where the line of the aqueduct should be identifiable. In this corridor, dark soil marks appear in an archival image and multiple satellite photos. The mark on the Nagy-Csapási Field was surveyed by field-walking and magnetometer, producing Roman building material and a clear magnetic anomaly. The observed line of debris detected during field-walking and the 180 m long and 3 m wide magnetic anomaly coincided with each other and with the soil mark of the satellite image, but not entirely with the predicted line of the aqueduct. The actual feature is located at an altitude of 125–124 m asl and the modelled line was around 128 m asl. Despite the height difference, the altitude of the detected section suggests that the springs around the Kálvária Hill were indeed the source of the water, not the more abundant springs around

118–119 m asl (Fényes Spring, contra: Benes 2018, 425). Results confirm the accuracy of oral sources, maps, and the predictions of the GIS model developed here. All non-invasive methods suggest that the aqueduct of Brigetio has been rediscovered.

DISCUSSION

Location awareness, data from historical maps and oral sources, the use of GIS technologies and non-destructive survey methods, and the order of the investigation were all important for the rediscovery of the aqueduct of Brigetio. As in our study, it is common practice to use GIS methods and all available – even century-old – data to map sections of Roman aqueducts (Pérez Marrero 2012; Sánchez López 2012; GIS-related papers: Orengo/Miró Alaix 2011; Papakonstantinou et al. 2015; Ruggeri et al. 2017). But most of these aqueducts have already been archaeologically identified. Our research was conducted in an irregular order, compared to these studies. First, old data were assessed, then the line of the aqueduct was predicted based on this information, and finally non-invasive methods were used to identify the aqueduct archaeologically.

Based on old data, four common landmarks or sections were identified: the starting and end points of the aqueduct and two embankments crossing waterways. The embankments still exist today and are available for archaeological investigation, but the precise locations of the starting and end points are not known. This lack of information raises questions regarding the accuracy of the predicted line and the structure and hydraulic engineering of the aqueduct. It would be valuable to accurately determine both points so that the average slope could be calculated more accurately. Although the present model uses the current ground level of the end point to calculate slope, it is known that the last section of the aqueduct reaching the legionary fortress from the southeast was an open channel resting on an elevated archway. The structure of the arch, its length, and height are unknown, which makes predictive modelling and future hydraulic calculations problematic.

The height difference between the detected aqueduct section and the modelled line shows that the slope and track of the aqueduct cannot be modelled in a straightforward way, as some sections could have been steeper, others more level, some were under ground and closed, others were open and raised up on an archway. However, the identified section proves that GIS modelling can be useful in narrowing the search for an actual aqueduct section, in spite of the quite rough resolution of the DEM (10 m × 10 m).

Because the terrain north of the Látó Hill is heterogeneous with low sand hills and without long ridges, it could be useful to rerun the model with the same methodology and DEM presented above but starting from the identified section. In addition, with a finer DEM it would also be useful to rule out the lower-lying areas with an inundation model, a procedure used in Least Cost Path (LCP) modelling in generally flat areas (Mesterházy 2017).

It is crucial to stress, that our modelling method does not correspond to LCP modelling. The latter does not generate the path with an even slope gradient, it only calculates the most energy-efficient way to get from one point to another (Simon 2015, 117; Herzog 2020). A model or algorithm that can automatically draw the shortest path between two points with a steady slope based on a DEM remains a desideratum.

CONCLUSION

The results of this study provide a solid basis for future mapping of the entire route of the aqueduct of Brigetio and trial excavations to examine its structure and technical details. It also proves the usefulness of archival imagery, historical maps, and GIS modelling in identifying unknown aqueduct sections, and it raises the question of further modelling and its automatization. Moreover, the rediscovery of the subject of the golden duck's tale, the aqueduct of Brigetio, enriches local, regional, and global cultural heritage and provides new knowledge about Roman water management in Pannonia.

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Notes

1) On the main transport and strategic routes see: Rajtár 2008 (»north-south route«); Mráv 2010–2013, 50 fig. 1 (»east-west route«). On the archaeologically verified Pannonian roads see: Bödőcs 2008.

2) Konecny et al. 2020 (»civil town«); Doneus et al. 2013, 100–114 (»legionary fortress, military town«).

3) Komjáti 1944/1945, 250 citing S. Mikoviny [16 December 1747]: *In quibus duo maxime memoranda observantur: aquaeductus nimirum subterraneus solido muro, ac fornice clausus, multaque tenacissima undiquaque obductus, ultra duo milliaria longus, quo salubrium, ac recentium scaturiginum Tatensium aquae per latera collium demissioribus locis, ac vallibus, aggeribus, pilis, ac fornicatis arcubus, exaequatis, ad usum coloniae deferebantur*.

4) Nr. 121 on Habsburg cadastral map from 19th century: https://maps.arcanum.com/hu/map/cadastral/?layers=3%2C4&bbox=2032410.9420034238%2C6056639.851818492%2C2033593.9244489935%2C6057061.449802627 (5.3.2024).

5) Lechner Nonprofit Kft.; 1978-0238-5109: https://www.fentrol.hu/en/aerialphoto/92385 (5.3.2024).

6) Anderkó 2006, 38 (»second column of table«); Aquincum: c. 1.3‰, Foerk 1923, 39–41. 48.

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Zusammenfassung / Summary / Résumé

Identifizierung des römischen Aquädukts von Brigetio (Komárom-Szőny, Kom. Komárom-Esztergom/HU) anhand historischer Quellen, Karten, GIS-Modellierung und zerstörungsfreier Methoden

Archivdaten, GIS-Modellierung, zerstörungsfreie archäologische Methoden und geodätische Messungen werden regelmäßig zur Untersuchung von Abschnitten römischer Aquädukte und ihrer Wassertechnik eingesetzt. Ausgangspunkt dieser Untersuchungen sind jedoch die Überreste und bekannten Ruinen ausgegrabener Aquädukte. Die vorliegende Studie geht den umgekehrten Weg: Sie beschreibt, wie der römische Aquädukt von Brigetio (Komárom-Szőny, Kom. Komárom-Esztergom/HU) in drei Schritten wiederentdeckt wurde. Zunächst wurden alle relevanten archivalischen und modernen Daten zur Lage des Aquädukts, insbesondere zu seinem Anfangs- und Endpunkt, zusammengetragen. Anschließend wurde anhand der Höhenlage des Anfangs- und Endpunktes manuell ein gleichmäßig geneigter Verlauf prognostiziert. Schließlich wurden vor Ort zerstörungsfreie Untersuchungen durchgeführt, um einen Abschnitt des Aquädukts zu lokalisieren. Die Ergebnisse deuten darauf hin, dass die hier entwickelte umgekehrte Methode für die Entdeckung antiker Aquädukte nützlich ist und wahrscheinlich für die Entdeckung aller Arten von Schwerkraftleitungen aus allen historischen Epochen geeignet ist.

Identifying the Roman Aqueduct of Brigetio (Komárom-Szőny, Komárom-Esztergom County/HU) Using Historical Sources, Maps, GIS Modelling and Non-Destructive Methods

Archival data, GIS modelling, non-destructive archaeological methods and geodetic measurements are regularly used to study sections of Roman aqueducts and their hydraulic engineering. However, the starting points of these investigations are the remains and known ruins of excavated aqueducts. The present study takes the reverse approach. It describes how the Roman aqueduct of Brigetio (Komárom-Szőny, Komárom-Esztergom county/HU) was rediscovered in three steps. First, all the relevant archival and modern data regarding the location of the aqueduct, especially its starting and end points, were summarized. Then, an evenly sloping course prediction was manually created by using the elevation of the starting and end points. Finally, on-site non-destructive surveys were undertaken to find a section of the aqueduct. The results suggest that the reversed methodology developed here is useful in the detection of ancient aqueducts and is likely to be suitable for the discovery of all types of gravity-based conduits from all historical periods.

Identification de l'aqueduc romain de Brigetio (Komárom-Szőny, comté de Komárom-Esztergom/HU) à l'aide de sources historiques, cartes, modélisation SIG et méthodes non destructives

Les données d'archives, la modélisation SIG, les méthodes archéologiques non destructives et les mesures géodésiques sont régulièrement utilisées pour étudier des tronçons d'aqueducs romains et leur technique hydraulique. Mais ces investigations partent des vestiges et des ruines d'aqueducs fouillés. Cette étude, par contre, adopte l'approche inverse. Elle décrit la redécouverte en trois étapes de l'aqueduc romain de Brigetio (Komárom-Szőny, comté de Komárom-Esztergom/HU). Tout d'abord, on a synthétisé toutes les données significatives modernes et provenant d'archives concernant la localisation de l'aqueduc, particulièrement les points initial et final. Puis fut élaborée manuellement une prédiction de trajectoire à pente régulière en utilisant l'altitude du point initial et du point final. Finalement, plusieurs prospections non destructives furent menées sur le site en vue d'identifier un tronçon de l'aqueduc. Les résultats suggèrent que la méthodologie inverse développée ici est d'une grande utilité pour détecter d'anciens aqueducs et qu'elle pourrait convenir à la découverte de tous types de conduites gravitaires de toute période historique.

Traduction: Y. Gautier

Schlüsselwörter / Keywords / Mots-clés

Römischer Aquädukt von Brigetio / historische Karten / GIS-Modellierung / geophysikalischer Survey / Landschaftsarchäologie
Roman aqueduct of Brigetio / historical maps / GIS modelling / geophysical survey / landscape archaeology
Aqueduc romain de Brigetio / cartes historiques / modélisation SIG / prospection géophysique / archéologie du paysage

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