

## THE POTENTIAL OF AIRBORNE LASER SCANNING (ALS) IN ARCHAEOLOGICAL INVESTIGATIONS AT JAKAB-HEGY, PÉCS, SOUTHERN HUNGARY

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*The enormous Iron Age hillfort near Pécs (circa 50 hectares) has appeared in archaeological literature since the 19<sup>th</sup> century. Beyond its walls, dozens of small burial tumuli can be found. The finds from these burial sites indicate that the hillfort's principle period of use was most probably the early Iron Age (8<sup>th</sup>-6<sup>th</sup> century BC), although there are traces of habitation in both the Celtic and Roman periods. The walls of the hillfort, in places 10 meters in height, are clearly visible on aerial and satellite photographs. In 2012 and 2013, within the frame of the ArcLand Project, we had the opportunity to make an airborne LiDAR survey of the hillfort and surrounding areas. The results have shown a very detailed plan of the barrow cemetery and the complete structure of the earthworks: new elements of the fortress walls were discerned that indicate a multi-period construction for the fortification. This paper will give a brief introduction to our new findings.*

The Jakab-hegy [Jakab Hill] site in Southwest Hungary (Fig. 1), with an area of circa 50 hectares, is one of the largest known Iron Age hillforts in the Carpathian Basin. The highest point of the hill is about 600m above sea level. The hill lies 6-7km to the northwest of Pécs and forms part of the western Mecsek range of hills. The bedrock of the hill consists mostly of red sandstone with many caves and swallets. Nowadays, this woodland area is densely covered with vegetation partly covered by nature protection.

The area was inhabited in the Bronze Age, and with a few interruptions has been used continuously until today. However, the exact scale and character of the anthropogenic impact is now hard to estimate; and because the hill has a history of at least 3000 years, distinguishing the various traces of human activity of different periods is a difficult task. Even with regard to utilization in the 20th century, only few archive sources exist.

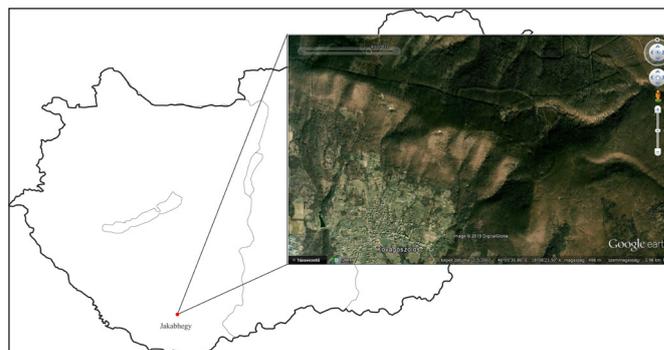


Fig. 1: Localization of Pécs-Jakab-hegy and the visible ramparts on Google Earth

### THE KNOWN ARCHAEOLOGICAL–HISTORICAL PERIODS ON THE HILL

#### Prehistoric settlement

The hillfort, with its great ramparts, has been known as an archaeological site since the 19th century. The oldest publication dates its main features, the ramparts and a barrow cemetery, to the Iron Age and the Copper Age.<sup>1</sup> The first documented archaeological excavation at the site took place in 1948 when Gyula Török excavated 9 burial mounds. The most important find he recovered from one of the tumuli was a bi-metallic dagger dated to the Early Iron Age.<sup>2</sup>

Between 1976 and 1996 Borbála Maráz excavated the site. She estimated the number of barrows on the western side of the hillfort to be around 300, but without a precise survey of the cemetery. She excavated 32

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<sup>1</sup> HORVÁTH 1878.

<sup>2</sup> TÖRÖK 1950.

barrows and cross-sectioned the fortress walls and the inner area of the hillfort at several places.<sup>3</sup> The excavations showed that the tumuli have a more-or-less uniform structure: each mound was enclosed by a circle of stones, and the burnt remains of the deceased and the grave goods burned on the pyre were placed in a simple or stone-lined cist in the center (Fig. 2). The tumuli can be dated to the 9<sup>th</sup>-7<sup>th</sup> centuries BC.<sup>4</sup>

Maráz observed that in many cases the filling material of the barrows and the ramparts contains Late Bronze Age (ca. 1200–800 BC) pottery shards. However, on the Bronze Age settlement she could make only a few unconfirmed observations: evidently, the area immediately to the west of the hillfort was inhabited in the Bronze Age;<sup>5</sup> a hoard of bronze that was uncovered on the western side of the main rampart also indicates a significant Bronze Age presence in the area;<sup>6</sup> the ramparts (or at least some parts of them) were presumably raised in the Early Iron Age, contemporaneously with the barrows.

The habitation in the Celtic period (ca. 300-0 BC) is marked by some scattered ceramic shards and some Greek drachmas from the 2nd century BC.<sup>7</sup> The great number of iron nails collected during our field walks in 2011 may also belong to this period. All this data indicates that the hillfort may have functioned as an *oppidum* in the Celtic period.

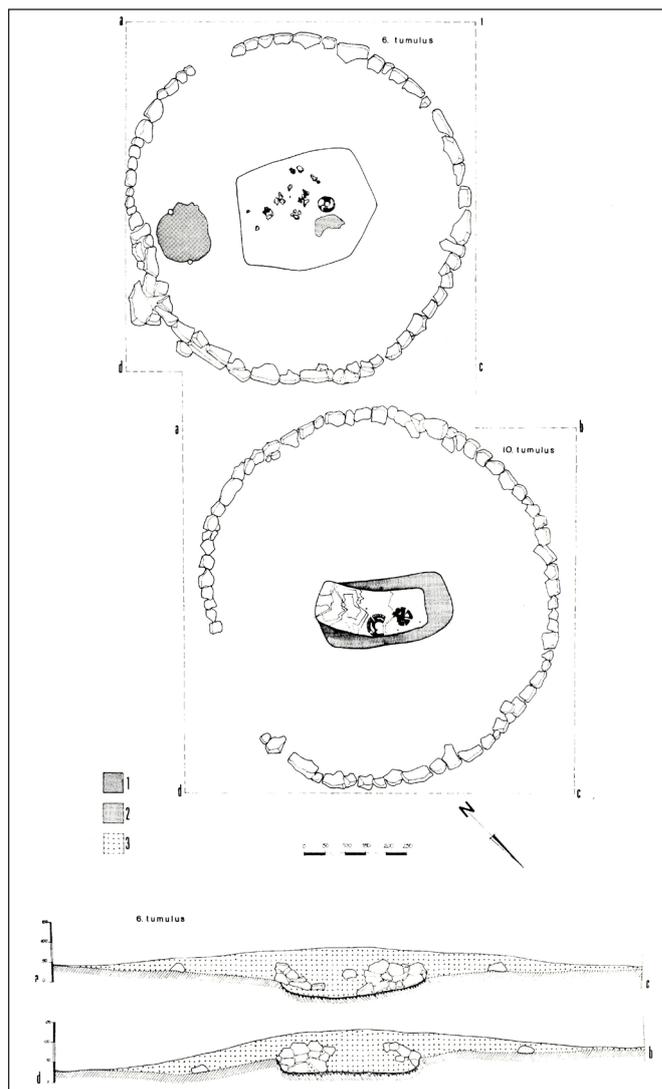


Fig. 2: Construction of the barrows (after MARÁZ 1978, Fig. 4)

### Roman remains

There was no information regarding the Roman Era utilization of the area until recently. Our field walks in recent years brought to light a Roman coin (2<sup>nd</sup> century AD sestertius of Faustian), a key, and some fragments of fibulae from the western part of the hillfort.<sup>8</sup> However, because of the lack of excavations, at the moment we have no further data for this period.

### The Middle Ages

At the beginning of the 13<sup>th</sup> century, a Pauline monastery with a walled garden, water reservoirs and a well-established irrigation system was founded on the top of the hill. According to literary sources, the monastery was founded in 1225. However, there is some data indicating that a settlement extant in the 9<sup>th</sup>-10<sup>th</sup> centuries had preceded the monastery. This early dating of the settlement is indicated by the fact

<sup>3</sup> Unfortunately, the documentation is unpublished even today. Concerning the excavations of the inner area, we just have short, preliminary publications (MARÁZ 2013, 78).

<sup>4</sup> MARÁZ 1978, 1996. For a summary of the results, see: MARÁZ 2013.

<sup>5</sup> MARÁZ 1986.

<sup>6</sup> MARÁZ 1986, 46.

<sup>7</sup> MARÁZ 2008, 69–70.

<sup>8</sup> BERTÓK–GÁTI 2014, 123.

that by the 13<sup>th</sup> century its church had already been reconstructed four times.<sup>9</sup> The village of the Early Medieval Period may have lain west of the church, the life of which may have been extinguished by the foundation of the monastery.

The main buildings of the monastery were surrounded by a small ‘fortification’ with bastion-like appendices against wild animals and marauders (for example, in 1334 when the monks had to run away from raiders). Inside the walled area there were gardens and ponds.<sup>10</sup> The extant ruins of the monastery show traces of Baroque style renovations.<sup>11</sup> The monastery functioned until the end of the 18<sup>th</sup> century, the time when Emperor Joseph II dissolved the monastic orders.

By 1828 the monastery had fallen entirely into disuse, but 19<sup>th</sup> century photographs show that the walls of the buildings were still standing at that point. In 1926-27, Gyula Gosztonyi made the first survey of the then largely erect walls. Gábor Kárpáti excavated the Pauline monastery between 1976 and 1983. The majority of the monastery buildings were unearthed, but they were not subjected to restoration or preservation. Under the leadership of Gergely Buzás, the complete geodetic survey and conservation of the buildings were carried out in 2004.<sup>12</sup>

### Modern times

The hill was certainly used since at least the Middle Ages for forestry and mining purposes. In the second half of the 20<sup>th</sup> century some (secret) military facilities were located on the top of the hill, and boreholes for uranium ore prospecting were made. Uranium prospecting started here in the 50s, continuing until the 80s.

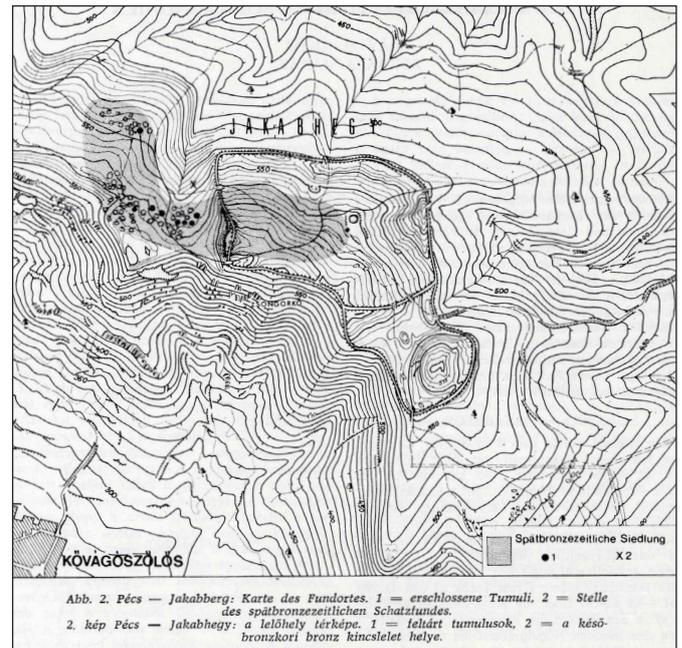
During excavations of the barrow cemetery in the 1970s and 1980s, some trial trenches at undocumented locations were also excavated. Nowadays, touristic paths also cross the hilltop, some certainly following the lines of earlier routes of communication.

## REMOTE SENSING AND GIS IN THE ARCHAEOLOGICAL RESEARCH OF JAKAB-HEGY

The main area of the hillfort extends to 50 hectares. Additionally, the area of the tumulus field is ca. 16 hectares. As mentioned above, the site was in use for an extended period (ca. 3000 years!), but the precise chronology of the periods of use is unclear. The hill has been surveyed several times, but the resulting maps show just the main ramparts, and estimates only were published on the number and distribution of the barrows (*Fig. 3*).

### Problems concerning the surveys

A precise survey of the embankments and the barrow cemetery, and archaeological research has long been hindered by the density of the woods and undergrowth. Trees obstruct the view necessary for a geodetic



*Fig. 3: Plan of the hillfort, surveyed during the excavations between 1978-1983 (after MARÁZ 1978, Fig. 2)*

<sup>9</sup> KÁRPÁTI 2001, 51.

<sup>10</sup> KÁRPÁTI 2001, BUZÁS 2007.

<sup>11</sup> The history of the monastery after: BUZÁS 2007.

<sup>12</sup> BUZÁS 2007.

ground survey, as well as global navigation satellite system (GNSS) signals. Dense vegetation often covers the shallow (20–50cm tall) tumuli.

Although the monastery buildings could be precisely surveyed with ground-based methods,<sup>13</sup> and a geodetic survey of the whole hill has been made, the geodetic survey is not accurate enough for an archaeological interpretation.<sup>14</sup>

### Remote sensing data of the area

Thanks to its size, the main ridge of the embankments is visible on aerial photos, as well on satellite images, although the density of the forest makes it hard to use these photographs to create a detailed map of the archaeological features (*Fig. 4*).

The aerial images show more or less the same situation: on the western side lies the larger part of the settlement, and on the eastern the so called ‘acropolis’. The buildings of the monastery are mostly recognizable, but there is no sign of the barrows at all.<sup>15</sup>



*Fig. 4: Aerial photo of the ramparts (Janus Pannonius Museum, Csilla Gáti 13.11.2016)*

### AIRBORNE LASER SWATH SURVEY<sup>16</sup>

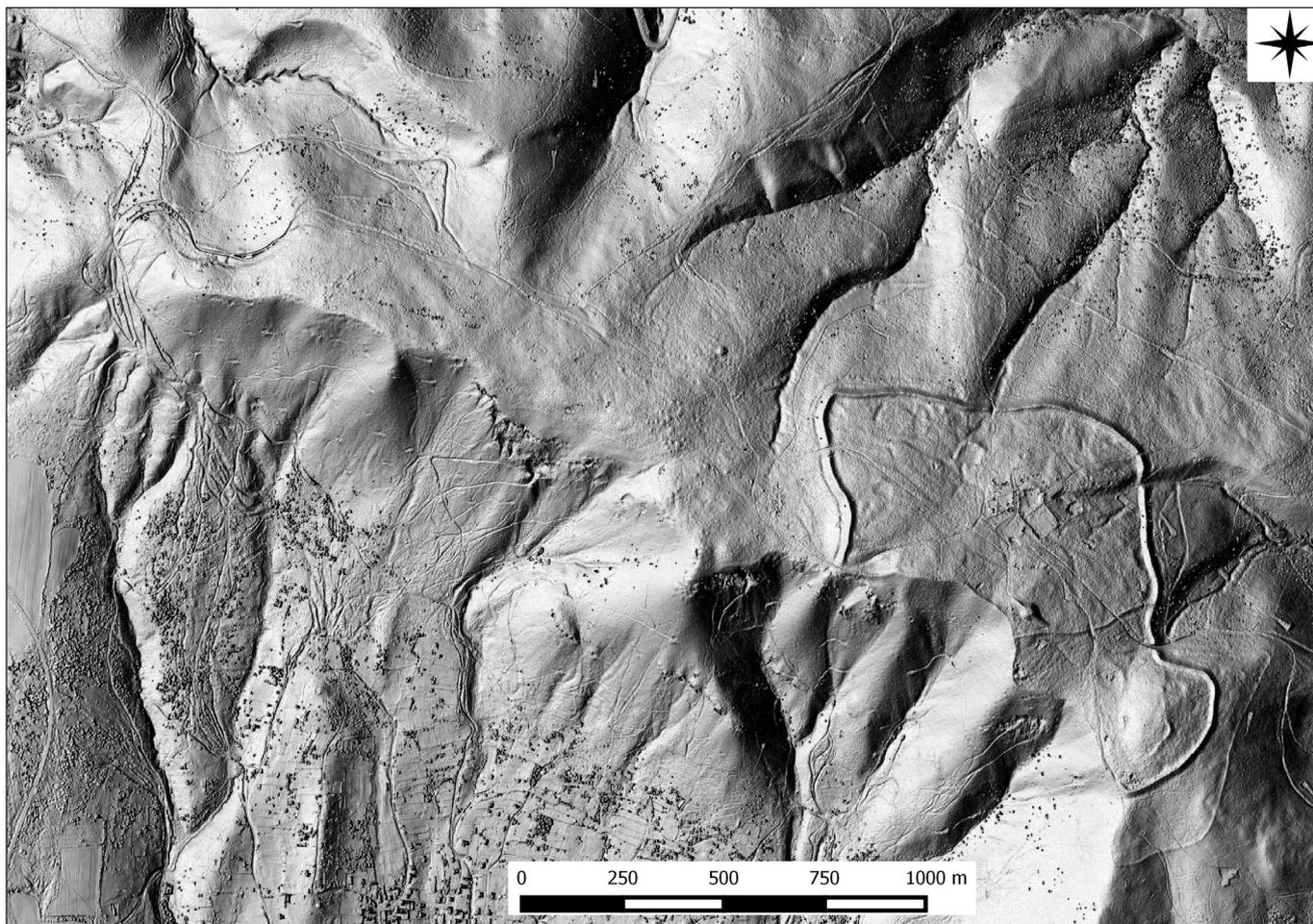
Considering all the above-mentioned problems, an airborne laser swath (ALS) survey seemed to be the most effective method of archaeologically mapping an area. Organized in a database that can be queried, the data of the ALS survey and the earlier results could serve as a basis for further research, and help in understanding the relationship between the various features.

<sup>13</sup> The survey was carried out by Tamás Göbölös in 2004.

<sup>14</sup> The original survey documentation could not be located, only a published map of it (MARÁZ 1978) without any further information on the circumstances and methodology.

<sup>15</sup> Strangely, no traces of the ramparts are shown in the military maps of the 18th and 19th centuries.

<sup>16</sup> These results are partially published: BERTÓK–GÁTI 2014; GÁTI–BERTÓK 2015.



*Fig. 5: DTM generated from the ALS data*

The ALS survey was undertaken in the spring of 2013,<sup>17</sup> with an average density of 8 p/m, which is generally suitable for an archaeological evaluation. For the interpretation I used the high resolution DTM (0.4m) gridded from the dataset. After rasterizing the filtered point cloud, it was possible to use different visualization methods and load them into a Geographic Information System (GIS). (*Fig. 5*) The following archaeological conclusions were made by comparing the ALS-based data with the known archaeological records. (*Fig. 6*)

### EMBANKMENTS

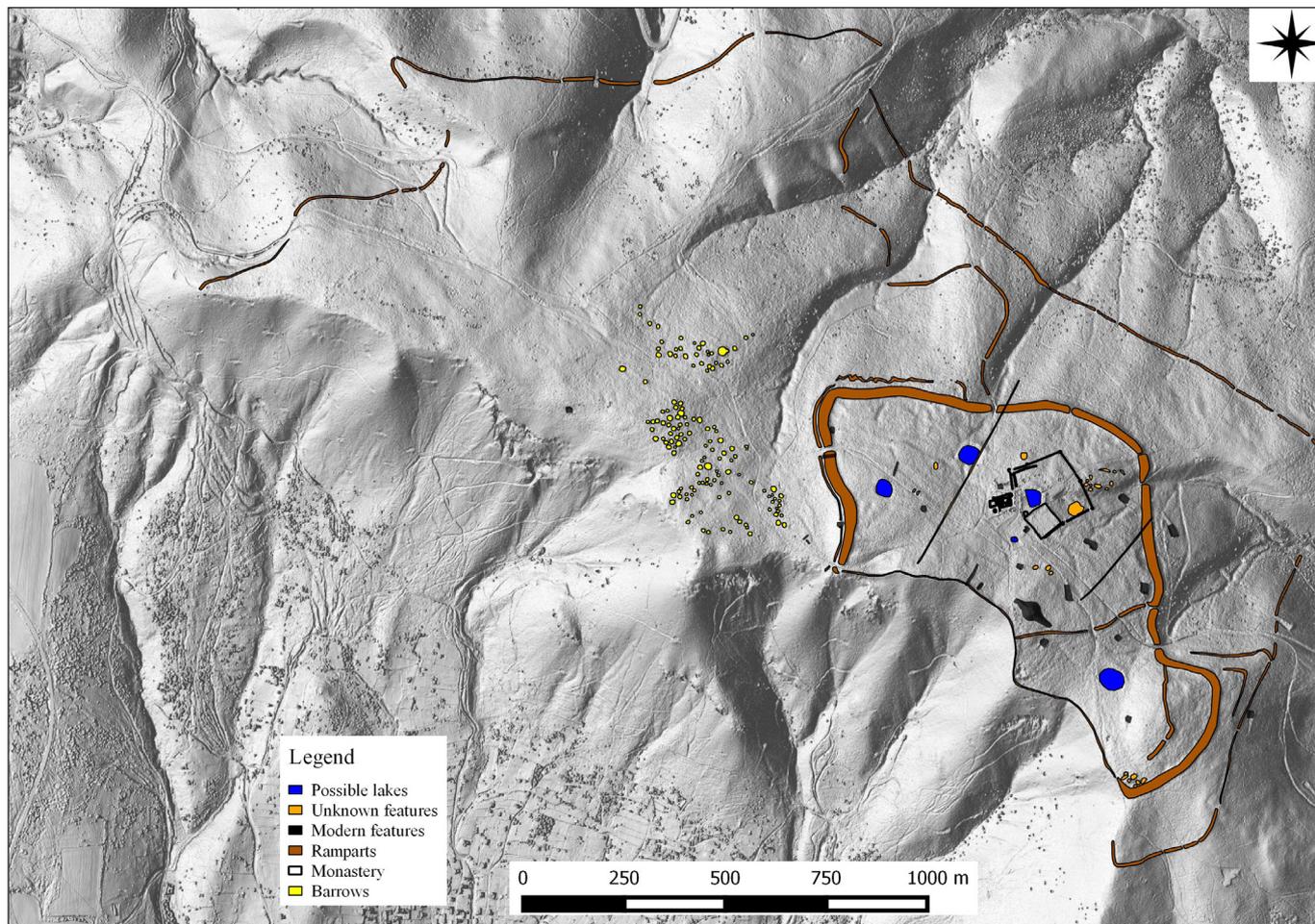
Thanks to the ALS data, the dimensions of the embankments can now be measured at any place. In addition, new parts of the earthworks became visible. The main ridge of the rampart, the dividing rampart of the acropolis, as well as the smaller section at the southern edge of the plateau are also clearly visible. The main ramparts are as much as 10 meters tall at some points.

In front of the ramparts that enclose the acropolis, the presence of another smaller rampart that had been postulated on the basis of aerial photographs, could be confirmed.

The presence of a shallow rampart on the northern and western side, surrounding the main ridge, is a surprise. The dating of this minor earthwork is still debatable; however, it seems to be connected to the outer rampart-section of the acropolis, which may date it to the Prehistoric Period. This rampart is between 20-50 centimeters tall.

On the western side, the rampart has a double construction along its length, although looking at it in the field, only the southern part of this section seems to have two ridges. The outer ridge may turn east at the corner and have a connection to the main rampart on the northern part.

<sup>17</sup> The survey was undertaken by the Károly Róbert University College, Gyöngyös.



*Fig. 6: Interpreted map of the ALS results*

In the central, highest-lying area of the acropolis, a new ramparts-section could be identified. The exact extension of this earthwork is uncertain, but it seems clear, that it has a starting point at the outer wall.

The temporal relationship of the embankments is still very uncertain. Since the area was in use during the Bronze and Iron Ages, that is for more than 1000 years, it is highly likely that the individual ramparts-sections were built in different periods. Evidently, the outermost embankment had no defensive function, given its low height, and enclosed an enormous territory (230 hectares). Most probably, it was merely a fence to keep wild animals out of or the herds within the enclosed area, and may also have had a demarcating function. Prior to more detailed examinations, we can postulate that this outer rampart belonged to the former, Late Bronze Age settlement.

Compared with the previous survey, it shows that the main ridge of the rampart overlaps with this, although the map of the barrow cemetery and the lower rampart were imprecise before.

As for the gates, it seems that aside from one or two modern transections, the two or three extant gates have been in use since prehistory. There is no sign of other gateways in the ramparts. The most sophisticated gate-constructions with a possible defensive function are close to the southwestern and southeastern entrances.

The ALS images clearly show that several watercourses interrupt the embankments. This is most evident in the case of the outer, shallow rampart. These streams drain the enclosed plateau.

### Inner area

The contour-map clearly shows that the hillfort was built on the highest plateau of the area, which slopes from the direction of the cliff to the north. The inhabitants of various periods seem to have utilized the original geological potential of the hill, and most probably enhanced the natural features according to their needs. For

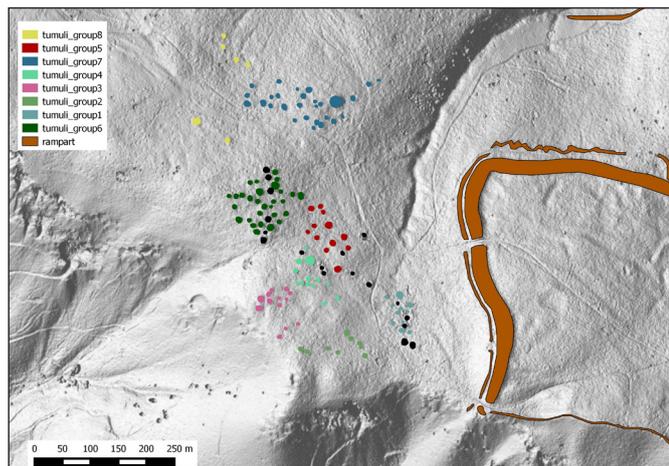


Fig. 7: Map of the barrow-cemetery

example, the ramparts were placed where the natural differences in height are the greatest. This is most visible at the eastern side of the earthwork complex.

On the contour-map the terraces of the inner area are noticeable. These may have functioned as housing plots. The drainage analysis also showed that the rainwater flows from the terraces to the embankments and lakes.

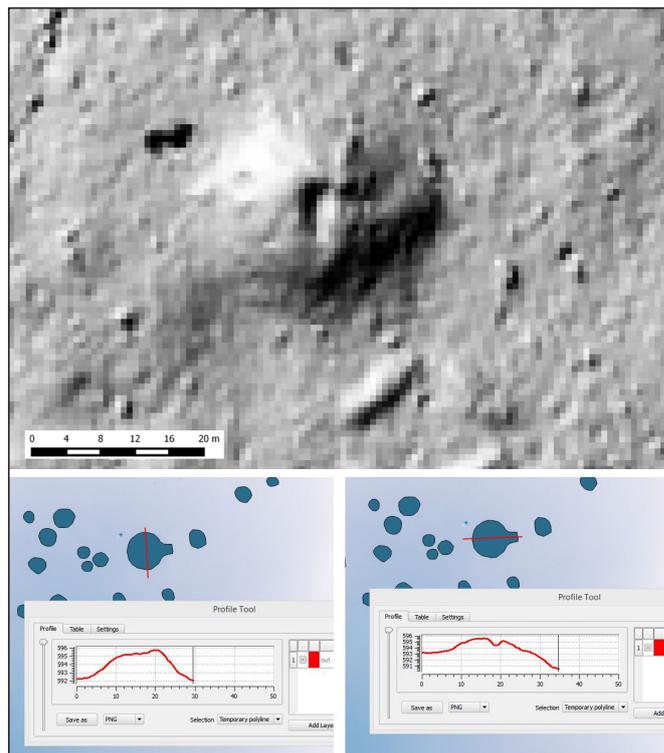


Fig. 8: Plan of the biggest barrow with sections

### Tumulus field

The barrows lie in the area in front of the western ramparts of the hillfort. It should be noted that not every barrow is clearly visible. The less-perceptible barrows are only shallow bumps on the ground, detectable only with the help of prior knowledge of the site. These barrows are recognizable only by exaggerating the height of the digital terrain model (DTM) by 2-3 times. Since there are no archaeological features on other parts of the hill, the area of the barrow cemetery can be clearly determined. In the identification of the barrows the visualization techniques have a prominent role; the different light conditions have an effect on the visualization of the smaller barrows. In the end it was possible to identify circa 150 barrows in all, which is only half of the former estimate.

Based on their territorial distribution it was also possible to create 7 groups of barrows (Fig. 7). These divisions may be indicative of temporal, as well as social differences.

Only half of the documented traces of several excavated barrows were also clearly recognizable, although their number was just half of the 41 excavated features mentioned in the earlier publications. The excavated barrows belong to my Groups 1. and 3.

As a result of the analysis of the ALS data we now have a more detailed map of the barrow cemetery than we had before. The ALS data also enables us to examine the vertical profiles of the barrows.

Some observations concerning the construction of the largest barrow were also made. It lies near the northern edge of the cemetery and is encircled by smaller burial sites. The ALS survey data suggest that there was possibly a corridor leading into the barrow on its eastern side (Fig. 8). This feature could barely be detected with the naked eye in the field.

### The monastery and its surroundings

The filtered ALS data shows a coarse picture of the monastery buildings. The DSM (first reflections), however, give us a more or less precise picture of the still erect walls (Fig. 9a, b). The inner division of the nave and the outbuildings are only recognizable in the filtered data (Fig. 10a, b). This inner division indicating a former phase of the church was identified during the excavations, and shows up in the filtered

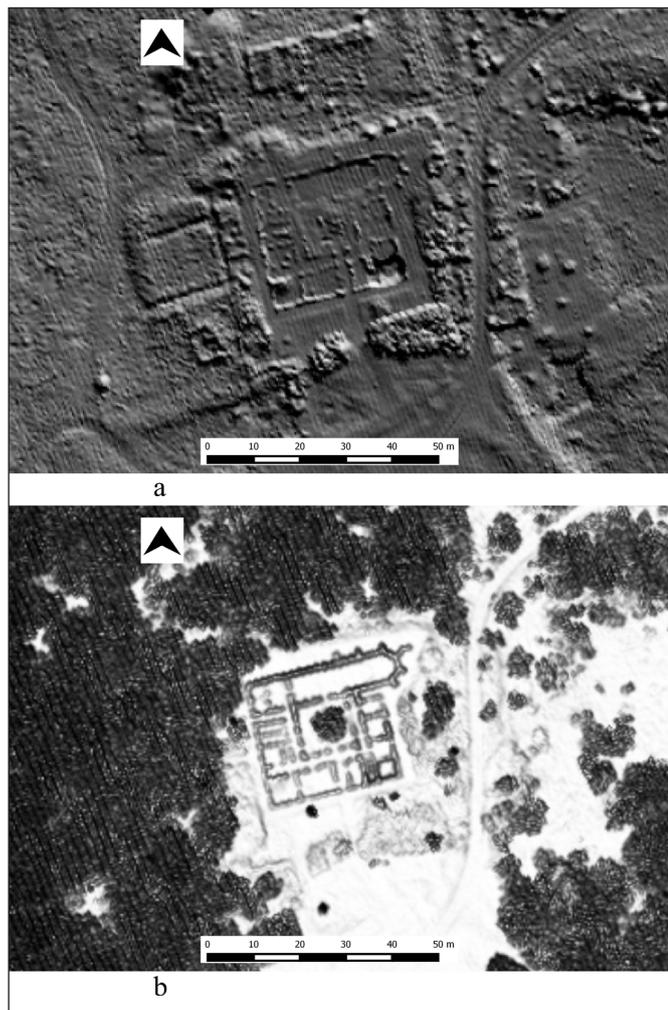


Fig. 9a: DTM (filtered with *mcc lidar*); b: DSM data of the monastery

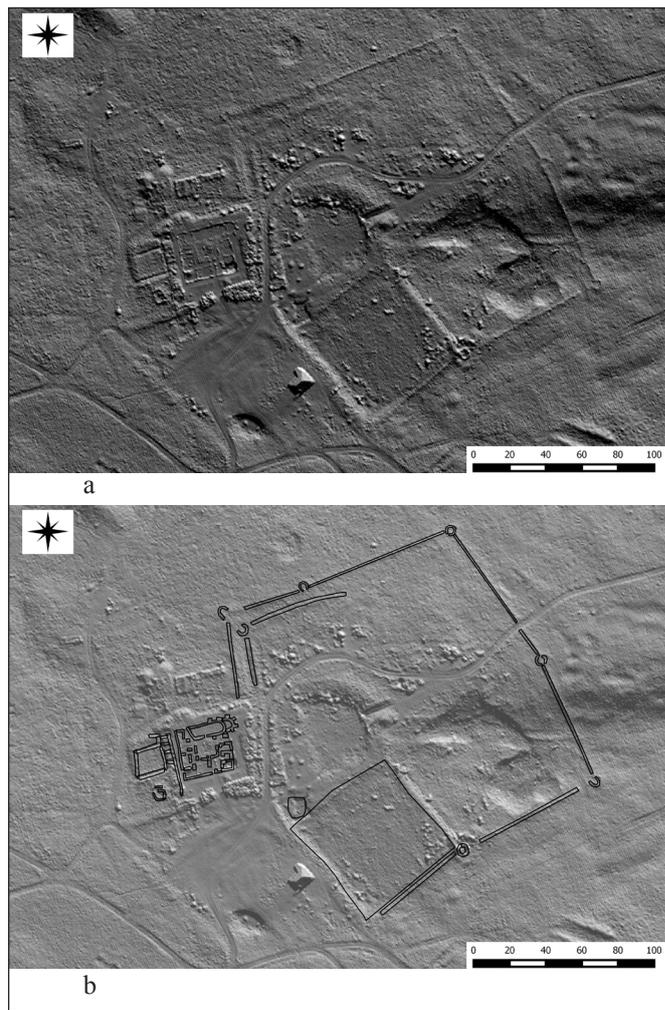


Fig. 10a, b: DTM of the monastery building and interpretation

data as shallow differences of height on the surface. The walls in the northern area are not visible in the ALS data because of the dense scrub that covers them.

The previous geodetic survey of the extant erect buildings gives a more detailed picture that can be approximated only by the joint use of the filtered and non-filtered ALS data (Fig. 11a, b, c). In the case of the monastery garden, there are features on the ALS data which are less clearly visible on the ground, likewise the line of the fence and the 'towers'. The fence-section and the towers in the inner, western area of the compound are newly discovered features showing that the outer fence had at least two building periods. This small fence-section only has a height of 20cm. This wall may continue to the North in a form of a semicircle.

Over the centuries, more ponds/water reservoirs were formed on the hilltop. They may have been built utilizing natural geological formations; evidently they collected the runoff water from a significant part of the hillfort. Nowadays they contain just a little water, the strongly acidic pH has hindered soil formation so their dating is uncertain.

### Modern features

On the ALS map, remains from uranium prospecting and a military antenna are clearly identifiable. The trial trenches of the former excavations may also be visible.

### Unknown features

Aside from the features described above, there are several traces of soil disturbance and linear features of unknown origin on the surface. Most probably the disturbances of the topsoil on the eastern and southern part can be regarded as remains from mining activities.

### SUMMARY

The ALS data for Jakab-hegy provided us with new data on the archaeological, as well as the natural landscape features of the hill. We now have a more detailed and better analyzable dataset than before. However, interpreting and classifying all the visible features is a hard task; it really is a ‘palimpsest’.

Having combined the ALS data with the former geodetic and archaeological surveys, it is apparent that the representations of the main ridge of the rampart overlap. However, the smaller rampart-sections do not show up, and the map of the barrow cemetery is very inaccurate in the older data.

In the case of larger features and those in dense woodland (ramparts, barrows) the ALS dataset provided new information; while in case of the smaller, more detailed constructions (monastery) the former, ground-based surveys proved to be more useful.

The laser was unable to penetrate the dense bushes, so in these cases we can rely only on the field surveys. Alternatively, an ALS survey of ultra-high density might have produced a better result.

The ALS survey has the potential to serve as a basis for our future investigations. Our next step will be to check the DTM features in the field.

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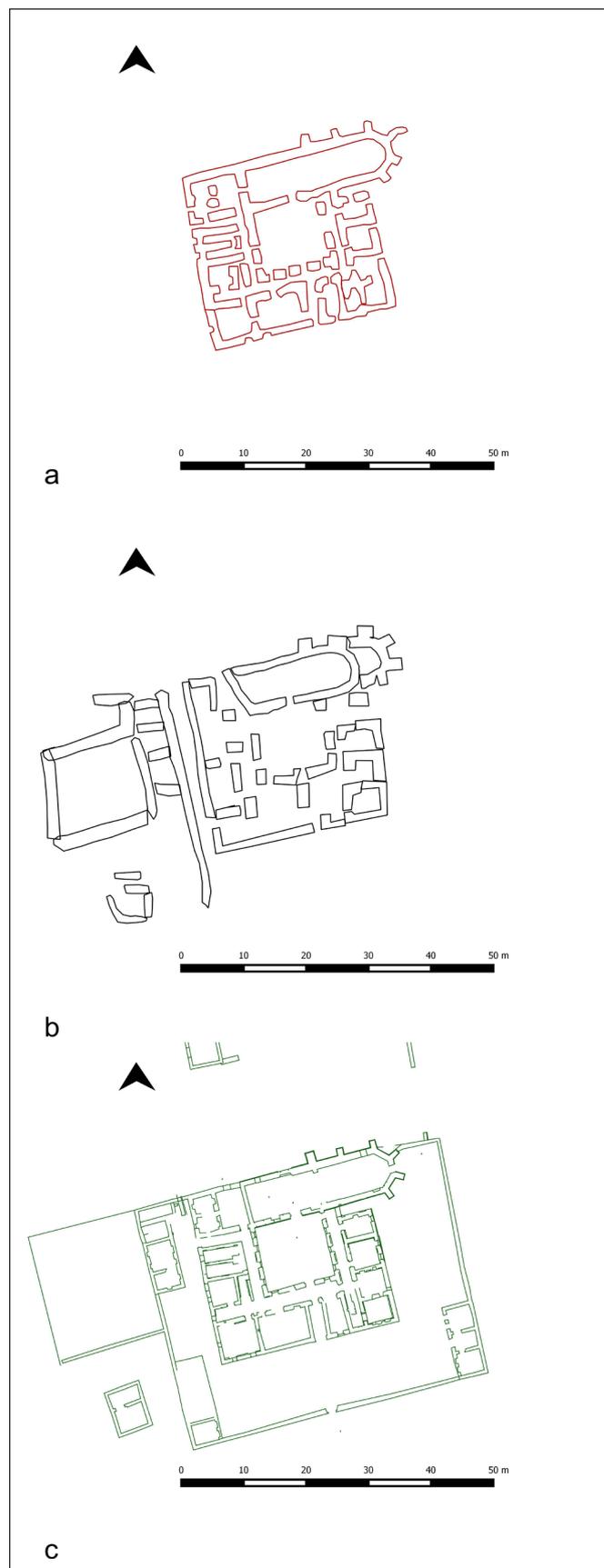


Fig. 11: Plans of various survey data of the monastery buildings, a: DSM, b: DTM generated from the ALS data, c: geodetic survey

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