Where are all the *tumuli*? Problems of interpretation in aerial archaeology

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In our earlier studies, we covered the potentials of the identification of Iron Age tumuli through aerial photography (CZAJLIK *et al.* 2008) and satellite photos, magnetometer and geophysical surveys, as well as ALS (CZAJLIK *et al.* 2012a). We found that various approaches can be used depending on the vegetation cover: burial tumuli and their traces can best be identified from satellite photos and through aerial archaeological reconnaissance and geophysical surveys in open areas, as well as with ALS and, in fortunate cases, from archive aerial photos in areas covered with woodland.

However, the identification of burial tumuli whose remains cannot be conclusively identified in the field raises several problems. In the lack of control excavations, the patches and ring-like features appearing on aerial photos and on the maps generated by geophysical surveys cannot automatically be interpreted as indications of former, destroyed burial mounds, and in many cases, we cannot be absolutely certain that these features are indeed archaeological phenomena, despite many years of experience. A discussion of the archaeological interpretation of patches and ring-like features has been presented elsewhere (CZAJLIK 2008) and thus we shall here focus on the theoretical/mathematical aspects of the interpretation of the various features appearing on aerial photos.

PREVIOUS RESEARCH

Most of the Iron Age tumulus cemeteries in Transdanubia have been known since the 19th century – in fact, one of the largest burial grounds of this type, the tumulus cemetery at Százhalombatta, is mentioned in medieval chronicles. The town of Százhalombatta was named after the tumulus cemetery (Százhalombatta, "hundred huge mounds"). Several cemeteries, such as the ones at Nagyberki–Szalacska and Zalaszántó–Tátika, were identified and systematically surveyed already in the 19th century by Flóris Rómer (RÓMER 1878), and the burial mounds at Sopron–Várhely were similarly described and surveyed, mostly through the activity of Lajos Bella (BELLA 1891). The awareness of the existence of the Szalacska and Százhalombatta tumuli in the archaeological community and the fact that these mounds did not lie in forested areas undoubtedly explain why they appear on the photos made during the heroic age of Hungarian aerial archaeological photography. Sándor Neogrády's photos of the Szalacska tumuli (fig. 1) and István Gersi's orthophotos (fig. 2), probably from 18 cm x 12 cm glass negatives, discovered recently in the archives of the Hungarian National Museum, were made with the period's most modern technique available to the Hungarian Royal Cartographic Institute. The photos were made in July 1929 and May 1934; however, only some details of the photos of the Szalacska mounds were interpreted (NEOGRÁDY 1948–50, 298). Neogrády, who had considerable expertise in interpreting aerial photos, marked not only the still standing, well-preserved burial mounds on his interpretative drawing, but also the traces of the mounds that had been destroyed by steam ploughs.

Several decades elapsed before this work was continued. In the 1970s, István Torma and Dénes Virágh surveyed the tumulus cemetery at Érd–Százhalombatta as part of the Archaeological Topography of Hungary project. In addition to the first known survey made in the mid-19th century and their own fieldwork, they also made good use of the aerial photos in the Cartographic Institute of the Hungarian People's Army, an enormous advance at a time that aerial archaeological reconnaissance and photography were forbidden. János Varsányi's survey from 1847 (fig. 3) reported 122 tumuli, probably corresponding to the number of burial mounds that could be clearly identified in the field. By 1978, no more than 91 could still be observed in the ploughed fields, the vineyards and orchards, while in 23 cases, it was unclear whether the soilmarks indicated wholly destroyed tumuli or were natural terrain features (MRT 7, 228, cp. also fig. 29 and pl. 57).

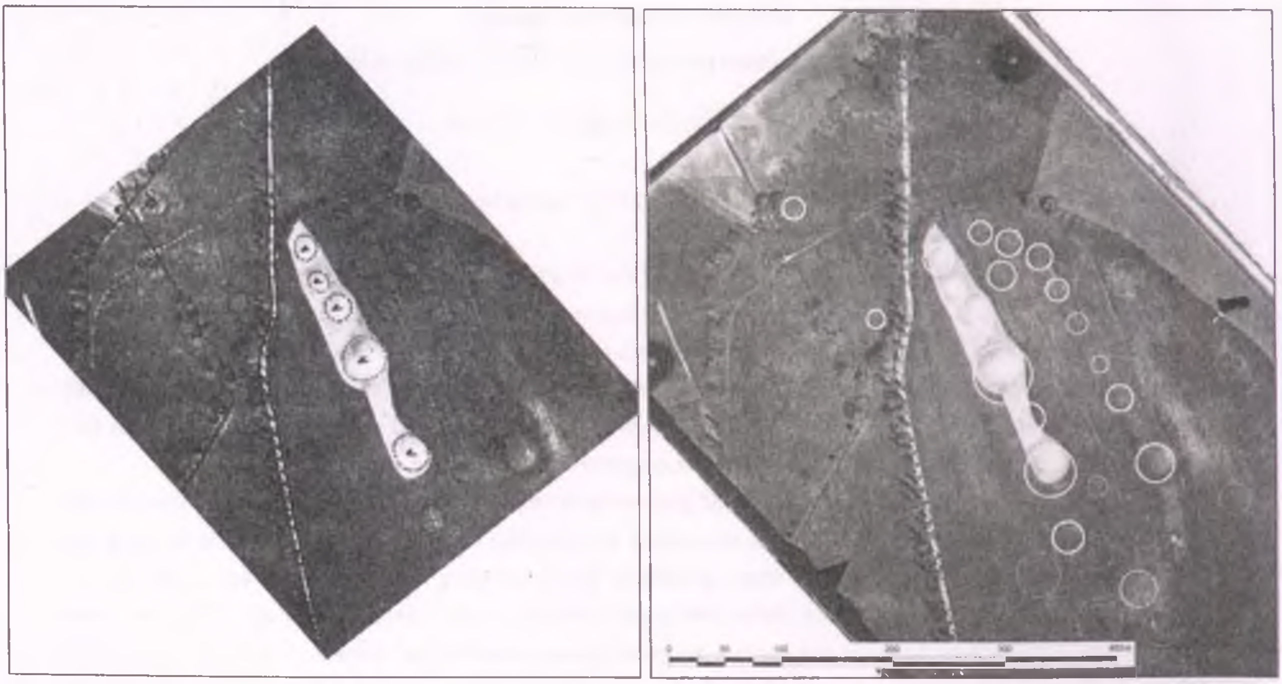

Fig. 1. Nagyberki–Szalacska. Sándor Neogrády's rectified photo from 1929, with Neogrády's interpretation and the assessment of the same area based on the currently known data (source: Neogrády 1948-50, 298 and Museum of Military History, Budapest)

The aerial archaeological survey project launched in 1993 by the Institute of Archaeological Sciences of the Eötvös Loránd University was, from 2008 onward, complemented with magnetometer geophysical surveys and aerial laser scanning for exploring the potentials of discovering tumulus cemeteries, the latter in collaboration with Sopron University (Czajlik *et al.* 2012a). It became clear from the assessment of the result of the different surveying procedures that the more eroded a tumulus, the more difficult it is to distinguish these mounds from natural formations. This was true in the 19th century and it is especially true of lower mounds and of ditched burials without a mound raised over the grave. Thus, even the use of more sensitive instruments does not eliminate the original dilemma, but merely modifies the range of identification: formerly uncertain structures can be more confidently categorised, while new features that elude exact classification are detected. The problem thus refuses to go away despite the advances in the applied technologies; however, the problem can perhaps be better addressed by applying fuzzy logic, a mathematical procedure. (Italian researchers used the same procedure for decreasing the uncertainties in the age and sex determination during the assessment of burials: see Crescioli *et al.* 2000.)

The form, condition and number of mounds in a particular area

Burial mounds are simple geometric formations, whose mapping is a simple affair using their central point. Their current form is of secondary importance from an archaeological point of view because their original form was undoubtedly modified during the millennia that have elapsed since their construction. Their original diameter can be estimated from the mound appearing on aerial photos, while their height can be measured in the field. The mounds documented using these data form a binary system: there either is a mound in a given location or there isn't.

The number of tumuli in a particular location and their original condition can be extrapolated from conditions documented earlier, but we can only make estimates regarding their one-time number and dimensions. The extent to which burial mounds can be recognised changes during the process of their erosion both in the field, during geophysical surveys and on aerial photos. High mounds are usually left uncultivated and are eventually covered by shrubs. Lower mounds are often ploughed away, but their vestiges are still indicated by shadowmarks. The earth of mounds that have been completely ploughed away is usu-

Fig. 2. István Gersi's photo of the hillfort and tumulus cemetery at Százhalombatta from 1934 (source: Hungarian National Museum)

ally spread out in the field, obliterating all traces of their former presence, including the mound's inner structure. In the last phase of their erosion or destruction, the remains of the buried features become visible: the ring of the ditch enclosing the mound appears as a cropmark or soilmark. While the process of destruction itself can be traced on aerial photos (pl. 4), the dominant features always change. The relevant features can be better or less well made out depending on the light, the direction of photographing, the vegetation cover and the weather. The more information we have from different, independent sources, the more certain we can be regarding the one-time presence of a burial mound, but even in cases when there is no previous information, we cannot claim with absolute certainty that the area lacked tumuli. The existence of a burial mound is hardly influenced by its visibility; its presence can be described with a probability value. In order to make our calculations simpler, we reckoned with uncertainty instead of secure information. If there are no data, uncertainty is 100% (1), while if we are convinced of a mound's presence, uncertainty is 0% (0). If a mound or a feature that can be interpreted as such can be faintly made out, but we are uncertain regarding interpretation, we assigned a value between 0 and 1. The greater our certainty regarding the one-time existence of a mound, the smaller the uncertainty, and the smaller the assigned value. Instead of the binary solution applied in the case of an obvious structure, we used an "existing – perhaps – don't know" relation. However, we shall never be able to decide whether a specific location lacked a burial mound or whether the mound had perished without a trace.

Every piece of information such as aerial photos, field surveys and geophysical surveys can contribute to decreasing uncertainty and thus the sum of uncertain data can decrease uncertainty. By default, the value of uncertainty is 1, i.e. there is no information. The overall uncertainty is a product of the uncertainties of the various contributing uncertainties and thus in cases when there are no data, multipli-

Fig. 3. Nagyberki - Szalacska, 1953. Assessment of the burial mounds using colour coding – stronger colours mark more secure data (source: Military History Museum, Budapest)

cation by 1 does not change the result. If, however, we have one certain piece of data, multiplying by 0 will give 0, and thus uncertain data are overwritten by certain ones. We can incorporate any number of new elements into the analysis and thus, for example, the information provided by new aerial photos does not downgrade the conclusions drawn from the assessment of earlier, archival data.

When evaluating aerial photos, certain and uncertain data can be marked with colour or signs (fig. 3) to illustrate the current state of research. By arbitrarily separating the uncertainty level, we can switch to a binary visualisation. For example, we can decide to regard tumuli with a value of less than 0.5 as certain, while the others can be marked as uncertain. Alternatively, we can decide on the distinction that if a data is highly uncertain, it is discarded as invalid. For example, values between 0–0.5 can appear as certain and values between 0.51–0.9 as uncertain, while features assigned a value between 0.91–1 are not regarded as burial mounds. This type of data handling is known as fuzzy logic in mathematics.

Application of fuzzy logic in determining site area

The enumeration by fractions can be applied to an entire site. In this case, the burial mounds are not counted as one, but are assigned a probability value (=1, uncertainty). In this case, the two 0.5 values yield a whole. It follows from the above that we can state that the tumulus cemetery contains ca. 70 mounds, of which 50 are certain, while 40 are half uncertain. Obviously, this is only true statistically: the existence of a mound can only be treated on its own level of uncertainty and the application of this procedure only offers a lower estimate of the burial mounds on a particular site.

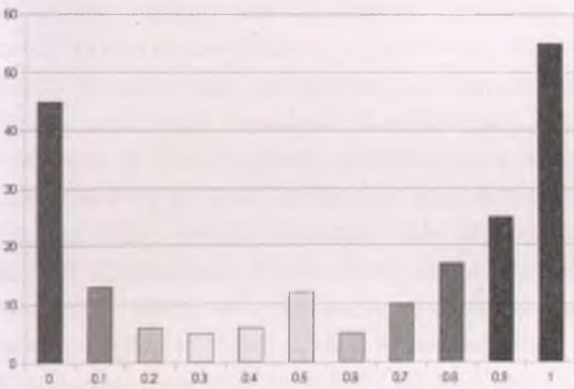

Fig. 4. Nagyberki–Szalacska. Distribution of burial mounds according to the uncertainty of the data. There are few intermediate values between the outstanding certain (0) and uncertain (1) values, probably owing to the subjectivity of the assessment

The extent of a particular site can, obviously, be determined from the location of the outermost burial mounds. However, if the outermost mounds are uncertain, the site's boundaries are also uncertain. If, on the other hand, the outermost mounds are certain, but there are uncertain tumuli between the outermost ones, the site's internal layout becomes uncertain. One crucial issue is to determine the distance range within which mounds or mound clusters are regarded as belonging to the same site because the areas between the mounds do not necessarily contain archaeological features. It the outermost mounds are connected with a straight line beyond which there are no other mounds, we get a convex formation (pl. 5). This often encloses an unduly large area and the site boundary becomes bizarrely angular. However, the area becomes even larger if we take a traditional, simple form such as an ellipse.

The number of burial mounds at Szalacska and the site's extent

In our earlier studies, we noted that the tumulus cemetery at Nagyberki–Szalacska was probably much more extensive and had more burial mounds than indicated by the survey made in the 19th century and the later investigations conducted in the area. Several mound clusters can be distinguished: the number of mounds is at least 190, even though most of them are uncertain. The remains of 45 securely identifiable tumuli have been registered in the field (of which the largest one currently has a diameter of 85 m), and an additional 40 features were interpreted as tumuli or the remains of tumuli. The high number of uncertain mounds (over 100!) is very striking and can probably be explained by the advanced erosion of the site.

In contrast to earlier estimates of 1 km x 1.5 km, the greatest extent of the tumulus cemetery based on modern calculations is 2 km x 3 km. Earlier research mainly focused on the securely identifiable, elongated central mound cluster. The aerial photos indicated that the site extended well beyond the earlier assumed boundaries: a larger mound cluster could be observed towards the east and several smaller clusters towards the south. The central cluster is made up of mounds arranged in regular rows that conform to the site's topography and the separation of mounds grading into one another occasionally runs into difficulties. The assessment of the eastern cluster of mounds in the cultivated fields adjacent to the hillfort is difficult owing to the overlapping soilmarks of the wholly destroyed tumuli (fig. 4).

Summary

The aerial archaeological research of the Early Iron Age tumulus cemeteries in Transdanubia brought major advances in archaeological topography and methodology, and it has also highlighted the difficulties in the assessment of information originating from diverse sources. The interpretation of features standing out against the natural background that can be regarded as simple circular structures with binary data handling is only feasible in the case of well-preserved cemeteries such as Sopron–Várhely; in the case of burial grounds strongly affected by erosion such as Nagyberki–Szalacska, the number of burials and the geometric traits of the site can be better described using fuzzy logic. The broadening and the refinement of the interpretative framework enables a better understanding of the topography of Early Iron Age burial mounds and it can also contribute to the prevention of the further destruction of these key sites.

Acknowledgements

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