AERIAL ARCHAEOLOGY AND REMOTE SENSING FROM THE BALTIC TO THE ADRIATIC

Edited by Zoltán Czajlik and András Bödőcs

INSTITUTE OF ARCHAEOLOGICAL SCIENCES, EÖTVÖS LORÁND UNIVERSITY

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Edited by Zoltán Czajlik and András Bödőcs

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Translated by
Magdaléna Seleanu and the Authors

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Foreword

The Aerial Archaeology Research Group (AARG) – under whose banner the papers in this volume were presented – is an organization that promotes the advancement of aerial archaeology and remote sensing techniques. AARG has provided a forum for the exchange of ideas and information for all those actively involved in aerial photography, photo interpretation, field archaeology and landscape history for the last thirty years. While there has been an emphasis on keeping abreast of the quickly changing field of aerial archaeology through the exchanges of its members on new research, there has also been the development of guidance and advice for policies that have helped to preserve archaeological sites and landscapes.

Recent advances in aerial archaeology – promoting the techniques and approaches that employ aerial photographs, satellite images, and other 'remote' techniques such as airborne laser scanning (ALS)/lidar/LiDAR – have been an influential force used to re-examine the archaeological sites and landscapes of many regions, such as those *from the Baltic to the Adriatic.* The present volume contains a series of selected papers from AARG's annual conference held in Budapest in 2012, hosted by Eötvös Loránd University, and published by L'Harmattan.

It is a pleasure to introduce this publication with a foreword as all the papers have drawn on the techniques associated with aerial photography, satellite and other imagery to re-shape an understanding of the long-term human presence that has been affected by, but has also shaped the topography of the Baltic to the Adriatic region. As such, the selected papers from the conference represent innovative research being undertaken in a region at the time of the conference (in 2012). And although these techniques are being advanced in new directions every day, the present volume's focus on the region's archaeology that has been enhanced by these techniques should allow it to help perpetuate further research that will continue to understand the past. Like many of the papers, the knowledge of the past has been enhanced by using multiple techniques, presenting side-by-side in the field research such as walk over surveys or geophysics, alongside aerial archaeology and with remote sensing techniques such as analysing a satellite's hyperspectral bands or extracting features from ALS data. The collective impact of these techniques results in a richer, deeper understanding of how sites and landscapes were connected to past people's lives.

I am certain that this volume will remain a standard text for those working in the region. I congratulate and I am pleased for Zoltán and András whose hard work has put this volume together, and I also commend those contributing to this publication.

Oscar Aldred
University of Newcastle
Chairman of AARG

Editorial preface

The creation of an Aerial Archaeological Photo Archive in the Institute of Archaeological Sciences of the Eötvös Loránd University was one of the many fruits of the eight years long Hungarian-French aerial archaeology collaboration begun in 1993, exactly twenty years ago. The research project initiated by Miklós Szabó and directed by René Goguey led to the discovery of a series of remarkable sites, which were presented to the Hungarian and international archaeological community. The first presentation was held in 1995 at the Eötvös Loránd University; concurrently with the conference, the French Institute of Hungary organised an exhibition linked to the conference and published a bilingual colour catalogue to the exhibition.

When the Eötvös Loránd University was entrusted with organising the AARG conference of 2012, our goal was not merely to provide a venue for a major international event serving as a forum for the presentation and discussion of new advances in aerial archaeology and remote sensing seventeen years after the previous similar conference, but also to learn about the many new research findings from this region. The past fifteen to twenty years have seen profound political and economic changes in the countries lying between the Baltic and the Adriatic, amongst them in Hungary too, which have provided new opportunities for archaeological remote sensing after the forced gap of over forty years and have led to a series of amazing archaeological discoveries and results following the initial delight over the first aerial archaeological photos.

The presentation of new directions in methodological research is an important part of the activities of the Department of Archaeometry and Archaeological Methodology of the Institute of Archaeological Sciences of the Eötvös Loránd University, founded ten years ago in 2003. We therefore turned to the AARG leadership and proposed that the most important new advances and research findings relevant to this region presented at the conference be published in a separate volume. To our great delight, this proposal was favourably received not only by the younger generation of researchers, but also by our older colleagues such as Zsuzsa Miklós and René Goguey, who had played an active role in reviving aerial archaeological reconnaissance in Hungary during the 1990s. We divided the volume into two major parts: the studies addressing various issues of traditional and modern research techniques are followed by studies covering various archaeological periods. It is our hope that the present volume, marking an important anniversary for us, will offer a meaningful overview of the current state of aerial archaeological research and remote sensing in East Central Europe.

The Faculty of Humanities of the Eötvös Loránd University, the Aerial Archaeology Research Group and, not least, the National Cultural Fund of Hungary played a key role in organising the conference attended by over a hundred researchers from sixteen countries, as well as in the publication of the studies with a relevance for this region. Thanks are due to the Matrica Museum of Százhalombatta for organising the excursion for the conference participants. We are greatly indebted to Tamás Dezső, Dean of the Faculty, Oscar Aldred, Chairman of AARG, and Magdolna Vicze, Director of the Matrica Museum for their enthusiastic and generous help in all matters pertaining to the conference, and to Szilvia Bartus-Szöllősi, who tirelessly dealt with the practicalities during the organisation of the event and during the conference itself.

Zoltán Czajlik – András Bödőcs
Budapest, November 18, 2013

Les techniques de la photographie aérienne en France et dans le Bassin des Carpates: photographie oblique en couleurs et en infra-rouge, photographie verticale.

René Goguey–Alexandra Cordier

Mots-clés : coopération franco-hongroise en archéologie, photographie aérienne oblique et verticale, photographie aérienne en couleurs et en infra-rouge

A l'heure des photographies satellitaires de plus en plus précises et du Lidar, est-il encore utile de quadriller l'espace à basse altitude pour photographier les traces des sites archéologiques disparus? Les résultats obtenus en Europe de l'ouest et plus récemment dans le Bassin des Carpates prouvent que cette méthode de prospection n'est pas obsolète. Mais elle est d'autant plus efficace qu'elle peut bénéficier d'une conjonction de moyens techniques appropriés.

En Angleterre, parmi quelques autres, J. Bardford codifia les bases de l'archéologie aérienne en montrant l'importance des «crop sites» (Bradford 1957), dont R. Agache prouva l'efficacité dans le nord de la France (Agache 1978). La distinction entre deux types d'indices en fonction de leur durée plutôt que de leur origine permit d'affiner une méthode de prospection adaptée aux moyens aériens (Goguey 1968). Les indices permanents sont en effet visibles en toutes saisons: microreliefs, anomalies du parcellaire peuvent être décelés sur toutes les «couvertures» standard, telles que celles de l'I.G.N. en France, celle de GoogleEarth dans le monde. Des clichés à basse altitude en éclairage rasant apporteront des suppléments d'information (Goguey 1966).

Pour les indices fugitifs... la chasse est ouverte! Que ce soit sur les céréales, les luzernes, les colzas, les tournesols, parfois les maïs, les plans qui se dessinent à l'aplomb des vestiges arasés sont toujours brefs. Ils n'apparaissent que certaines années favorables, en général après une sécheresse sévère (Cordier 2012). Ce sont les plus précis pour l'archéologue, les plus spectaculaires pour le profane. Mais ils exigent une présence au bon moment, donc de nombreux survols: quelque 200 heures de vol par an dans les années 1993-2000 en France et en Hongrie.

Des moyens exceptionnels: l'aviation militaire en France

Comment obtenir de ces indices, lorsqu'ils sont repérés, les documents photographiques les plus complets? C'est ici que les recherches menées depuis Dijon de 1958 à 1974 avec la collaboration depuis l'Armée de l'Air Française ont permis de mettre au point un processus associant photographies obliques sur films en couleurs normales, en infra-rouge et en verticales stéréoscopiques.

La prospection à bord d'avions monomoteurs (dérivés de Messerschmitt, Broussard (fig. 3), Morane 733...) tenait du «straffing» (chasse libre) utilisé par les pilotes anglais en 1943–1944 pour déceler convois allemands, chars, locomotives... La caméra remplaçait la mitrailleuse. Les sites détectés à vue étaient aussitôt photographiés sous les angles et à l'altitude les plus favorables.

Dès le lendemain étaient organisées des «missions» à bord de bimoteurs Dassault équipés pour la photographie verticale stéréoscopique (caméras à intervallomètre avec film «aviation» format 18 x 24 cm) (fig. 4). Parallèlement à cette activité sur la Base Aérienne Guynemer de Dijon – Longvic était effectué chaque année un stage s'entrainement à la 33e Escadre de Reconnaissance – celle qui vit dans ses rangs A. de Saint-Exupéry – basée à Strasbourg. Des tests d'affectation des «Mirage III R» à des missions d'archéologie montrèrent la qualité des résultats obtenus avec les cinq caméras «tous azimuts» dont ils étaient dotés (figs. 1 et 2), et la capacité des pilotes à repérer, localiser et photographier y compris avec un détecteur infra-rouge des sites archéologiques sur une zone de grandes dimensions.

Cette concentration de moyens fit ressortir l'intérêt de chaque technique, et ce que leur conjugaison pouvait apporter. Ainsi, dès les premiers vols sur Vix, nécropoles et sanctuaire inconnus

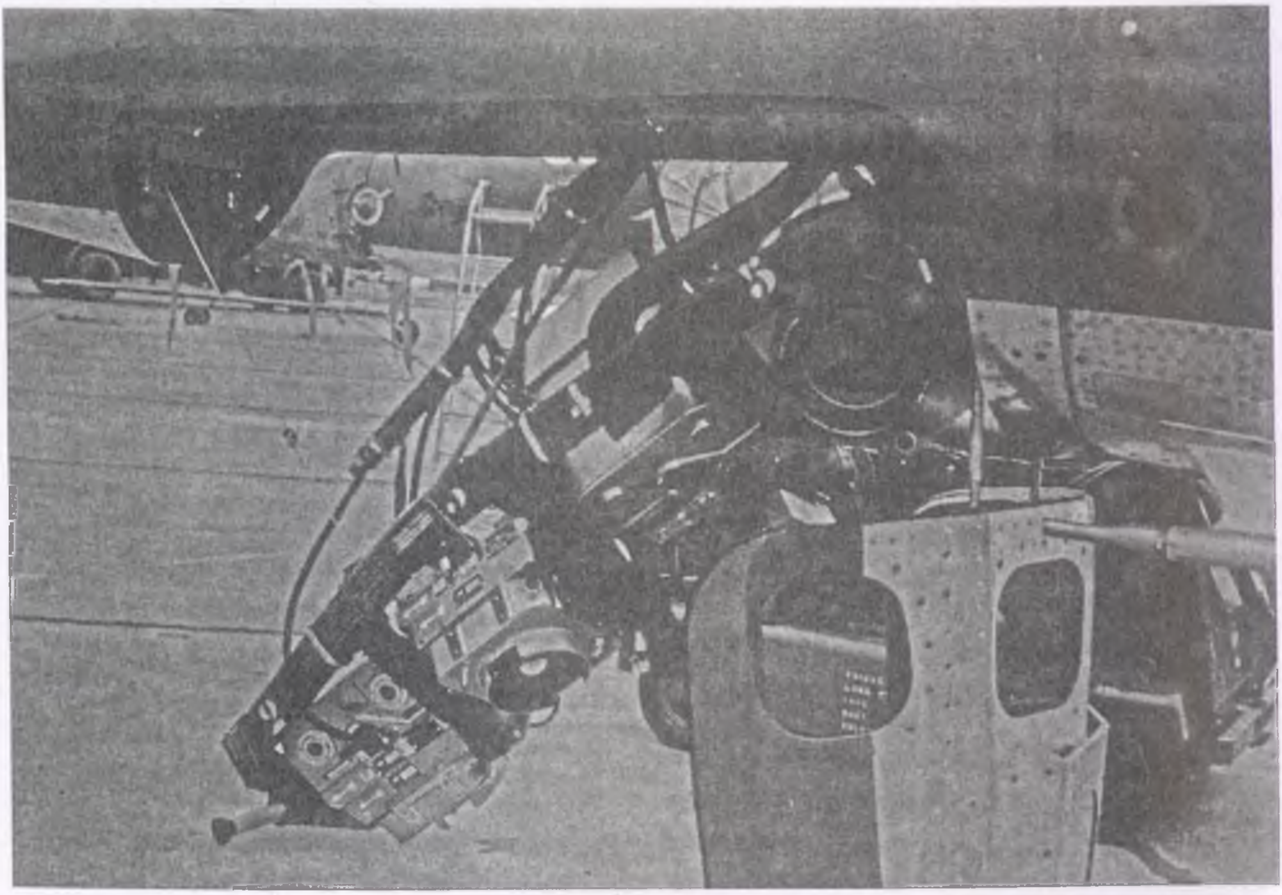

Fig. 1. Les cinq caméras sur berceau amovible du Mirage III R (photo R. Goguey)

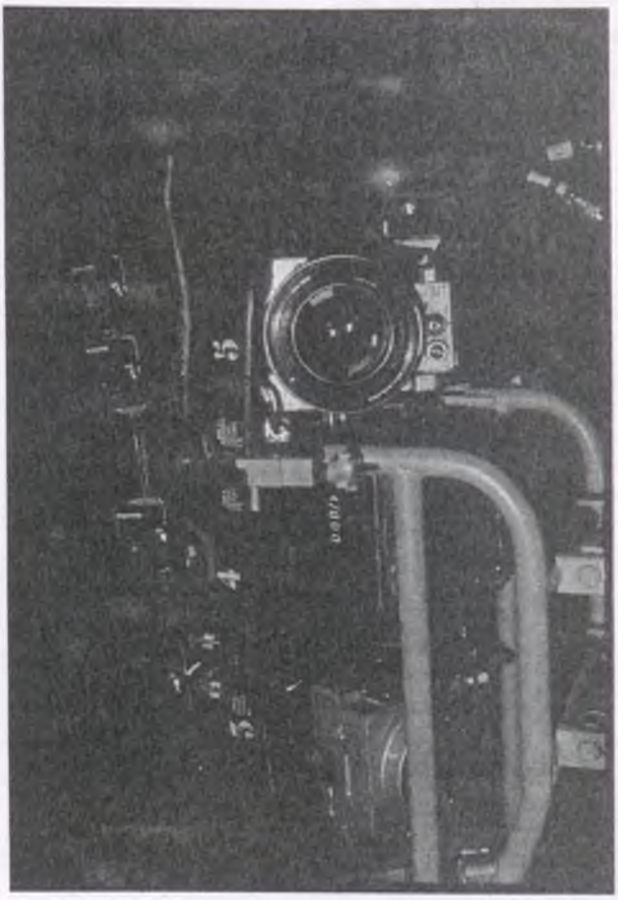

Fig. 2. L'une des 5 caméras du Mirage III R (photo: R. Goguey, 28.08. 1968)

Fig. 3. R. Goguey au départ d'une 'mission-photo archéologique' à bord du Broussard (1973)

étaient photographiés en oblique en couleurs normales et en infra-rouge, et le lendemain en «strips» verticaux: ce dossier est resté sans égal (Goguey 1997). Il en est de même pour le camp de la VIII^e Légion romaine à Mirebeau, découvert au retour d'un vol sur Broussard, immédiatement enregistré en oblique couleur et infra-rouge, et le lendemain à bord d'un bimoteur en bandes verticales. Deux jours après, toutes les traces étaient effacées (Goguey–Reddé 1995).

Dans un cas extrême, l'utilisation d'un avion équipé IFR (vol aux instruments) et caméra stéréoscopique a permis d'enregistrer les multiples traces repérées sur la neige, le 3 janvier 1969. Sur un sol profondément gelé, le réchauffement rapide et la pluie ont provoqué une fusion rapide de la couche de neige et l'apparition de sites si nombreux et si vite effacés qu'il était impossible de les photographier un par un en oblique. En bandes verticales, ils ont tous été rapidement enregistrés avec une grande qualité grâce à la luminosité de la neige (Goguey 1972; fig. 12).

L'archéologie aérienne et l'aviation civile

La photographie aérienne militaire, qui exige des moyens aussi importants, peut-elle être appliquée à des équipes archéologiques civiles, de type universitaire, C.N.R.S. ou I.N.R.A.P.? L'utilisation d'avions à aile haute comme la gamme des Cessna donne de bons résultats en photographie oblique, d'autant plus que la photographie numérique permet d'enregistrer en continu, à haute définition et à vitesse d'obturation suffisamment élevée. Mais l'aile haute limite l'angle d'inclinaison. Avec un avion à aile basse, on peut travailler en virage serré et obtenir des clichés proches de la verticale. Mais le pilote doit être assez qualifié pour ne pas se laisser partir en «virage engagé» qui ne pardonne pas à basse altitude. Mieux vaut prévoir des prises de vue en bandes verticales réelles, d'où l'utilité d'un appareil spécialement aménagé.

Ce fut le cas à Dijon où le Conseil Régional de Bourgogne accepta de financer un avion affecté à «la recherche archéologique et scientifique». Cet appareil «R 3000», avec une autonomie de cinq heures de vol, fut construit sous les directives de R. Goguey à l'usine Robin de Darois. Il disposait de deux trappes latérales pour les photographies obliques et une large trappe dans le plancher pour les photographies verticales (fig. 5). Dans sa configuration optimum, l'équipage associait le pilote-archéologue responsable de la mission (R. Goguey), un co-pilote navigateur qui prenait les commandes au moment des photographies obliques (en Hongrie, pilote professionnel, parfois un pilote de ligne, sortant de l'E.N.A.C.), une documentaliste chargée des cartes et des photographies verticales (A. Richeton). Dès les premiers vols en France en juin 1990 étaient photographiées les défenses des camps de César à Alésia (Goguey 1991). Des détails aussi précis que les trous de poteaux des tours, les étroits fossés parallèles des cippi décrits dans la Guerre des Gaules, la porte à titulus étaient confirmés point par point en 1993 par les fouilles de Michel Reddé (Goguey 1999; Reddé–Schnurbein 2001).

En 1991 était organisée une première campagne en Europe Centrale avec la République Tchèque, à Brno et à Prague. Puis ce fut la Hongrie de 1993 à 2000, grâce au soutien de Miklós Szabó et de l'Université Eötvös Loránd avec les financements croisés du Ministère Français des Affaires Etrangères (Goguey 2005) et du Conseil Régional de Bourgogne, dont il faut souligner ici l'action exemplaire en faveur du Patrimoine Européen. Les résultats ont fait l'objet de rapports annuels, et une exposition «A Történelem Madártávlatból» a été présentée en 1995 au Centre Culturel Français de Budapest, dans les principales villes de Hongrie et en France (Goguey–Szabó 1995). L'extension des recherches menées avec Zoltán Czajlik fut pour celui-ci l'occasion d'acquérir une connaissance approfondie de l'archéologie aérienne et de mener ce type de prospection en Hongrie et en Roumanie à partir de 2001 (Czajlik 2007). De 1993 à 1998, le R 3000 put être utilisé comme prévu en Hongrie, basé chaque année sur un aérodrome différent (fig. 10), ce qui favorisait une prospection plus intense de chaque région et nous donna l'occasion de rencontrer à Kiliti Otto Braasch prospectant la même zone (Braasch 2003). Mais cet avion n'étant pas équipé IFR (vol aux instruments sans visibilité), le trajet Dijon–Budapest fut perturbé par une mauvaise météo (Goguey 2000) et en 1999 et 2000 fut utilisé un Cessna 172 loué en Hongrie.

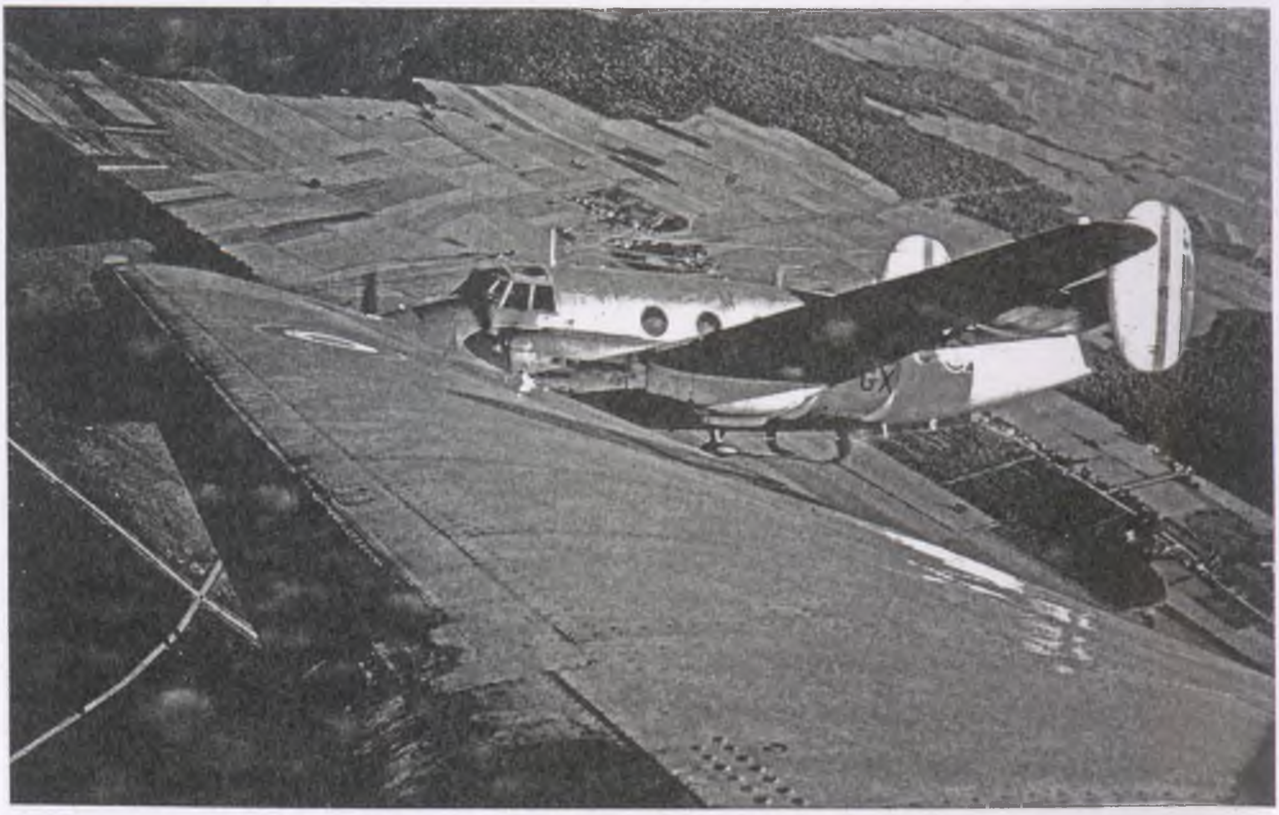

Fig. 4. Bimoteurs Dassault 312 en vol de patrouille (photo R. Goguey)

Fig. 5. Avion R3000 'Recherche archéologique et scientifique' en vol sur Alésia, 1990

Fig. 6. Und (Hongrie), détail d'une photographie verticale (photo: R. Goguey, 09.06. 1993)

Fig. 7. Nicey (France) (photo R. Goguey, 01.07. 1976)

Fig. 8. Plan d'interprétation des sites de Szalkszentmarton (1993)

Fig. 9. Középpeszér. Traces d'habitat en relief dans le blé (photo: R. Goguey, 21.06. 2000)

Photographie oblique et photographie verticale

Les conditions climatiques favorables de 1993 donnèrent l'occasion d'expérimenter en Hongrie la conjugaison «photographies obliques – photographies verticales» avec le R 3000. L'un des sites les plus caractéristiques fut celui de Und à l'ouest de la Transdanubie. Ses alignements de trous de poteaux étaient visibles sous forme de points en relief sur fond de polygones de cryoturbation. Leur étendue justifiait une prise de vues en bandes continues verticales sur film en couleurs, à basse altitude pour obtenir le maximum de détails (pl. 1). Des photographies obliques en virages serrés ont complété le dossier.

Cette expérience fait ressortir la complémentarité des deux techniques. Les verticales donnent d'emblée un plan proche de «l'orthophotoplan» professionnel, ce que l'oblique peut difficilement atteindre, même avec des logiciels de redressement. D'autre part, les clichés réalisés avant l'accès aux logiciels de redressement par les archéologues n'étaient pas cadrés de façon à avoir suffisamment de points de calage nécessaires au redressement et le maximum de détails indispensables à l'interprétation. Cette question se pose toujours aujourd'hui lors de la prise de vue, lorsque l'environnement du site à photographier est uniforme, sans points de référence à proximité immédiate.

Dans le cas de traces en microrelief sans différences de couleurs, l'oblique à contre-jour est plus révélatrice des détails. On peut ainsi distinguer les trous – d'un diamètre supérieur à un mètre – des poteaux porteurs des habitats des pointillés des piquets de palissades. La maison principale, rectangulaire (hors tout 33 x 20 mètres) est structurée par cinq rangs de huit poteaux. A proximité, les quatre poteaux porteurs d'un grenier, et une organisation orthogonale de l'espace par des palissades (fig. 6).

A Polgár en 1994, la photographie verticale permit d'enregistrer rapidement la multitude de taches sombres dont les fouilles liées à l'autoroute ont prouvé l'origine archéologique (fig. 11). Elles correspondent pour la plupart à des habitats semi-enterrés allant du néolithique au Moyen-Âge.

La photographie infra-rouge «fausses couleurs»

Le procédé de photographie aérienne infra-rouge dit «fausses couleurs» fut mis au point par Kodak à des fins militaires. Il s'agissait de détecter les camouflages dont les branches coupées apparaissent en couleurs différentes. Utilisé dès 1960 sur film 24/36 dans nos recherches il donna d'excellents résultats, mais au prix d'essais sur la mise au point, la vitesse d'obturation et de contraintes telles que sensibilité à la chaleur, à la lumière et aux procédés de développement. C'est au cours de l'exceptionnelle sécheresse de 1976 en France qu'il démontra son intérêt, suivi par la Direction de Kodak qui envisageait de le présenter en U.R.S.S. (Goguey 1969).

Le parallèle porte sur la villa à grande cour péristyle de Nicey en Bourgogne, photographiée avec les deux types de film: Ektachrome Infra-Red et Kodachrome 25. En dehors de son aspect spectaculaire, l'infra-rouge est incontestablement supérieur: détails des bassins du balnéaire, bases de colonnes, lignes de murs très fins (pl. 2.2 et fig. 7).

Utilisé en Hongrie jusqu'en 1998, l'Infra-Rouge donna de bons résultats malgré les difficultés de stockage et de développement. Ainsi dans les méandres de la Tisza, à Tiszasas et à Zagyvarékas, de nombreuses traces d'origine hygrométrique, invisibles sur le Kodachrome normal, apparaissent-elles nettement sur l'Infra-Rouge en 1993 et 1996 (pl. 2.1). Il en est de même dans la vallée du Danube, où le filtre jaune de la caméra infra-rouge traverse plus facilement les brumes souvent présentes (Czajlik 2010).

Le passage au numérique n'a pas facilité la photographie infra-rouge. Elle reste possible en sacrifiant une caméra par suppression d'un filtre intégré, mais avec des résultats médiocres. Les «couvertures» verticales «proche infra-rouge», réalisées par exemple par l'Institut Géographique National en France, sont excellentes: elles permettent à l'Institut National Forestier de cartographier les espèces végétales, le degré d'activité chlorophyllienne, les zones d'humidité... Mais leur échelle est difficilement exploitable pour l'archéologie.

Par contre les progrès réalisés par la photographie numérique en couleurs normales favorisent la

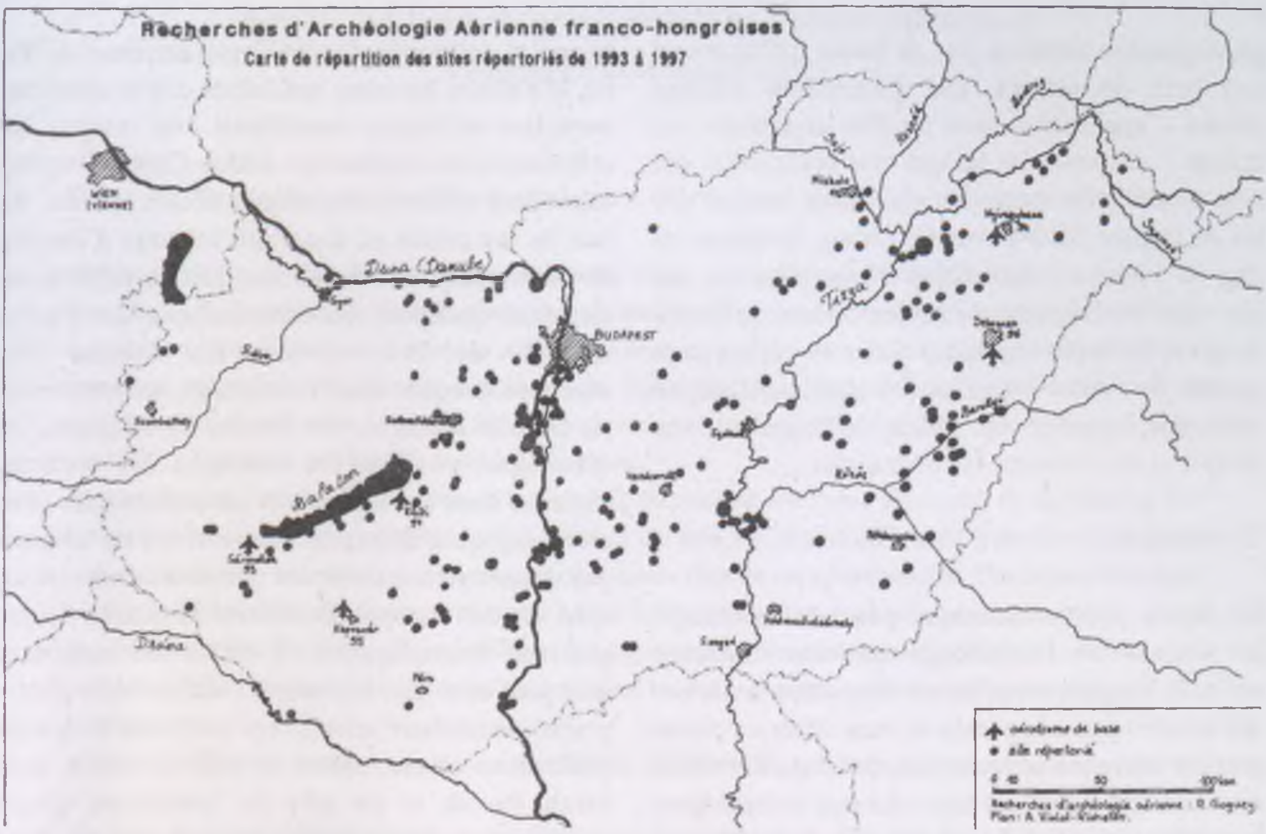

Fig. 10. Archéologie aérienne en Hongrie. Etat des recherches de 1993 à 1997 (R. Goguey)

Fig. 11. Polgár (Hongrie), photo verticale (photo: R. Goguey, 04.07. 1994)

Fig. 12. Mirebeau, thermes de la VIII^{e} Légion, photo verticale sur neige fondante (photo: R. Goguey, 03.01. 1969)

photographie aérienne par sa haute définition et son prix de revient. Les traitements d'image Adobe – applicables aussi au film argentique numérisé – donnent des images très contrastées qui font ressortir les traces les plus fines, comme celles de l'année 2000 à Adony, Dabas, Középpeszér (fig. 9). Mais leur abondance et leur précision ont fait regretter l'absence de l'avion R3000, de l'infrarouge et de la photographie verticale qui auraient permis de mieux exploiter des sites aussi importants que l'oppidum de plaine de Bugyi avec ses remparts, ses maisons, ses nécropoles...

Conclusion

Ce rapide aperçu technique pourrait décourager les acteurs de l'archéologie aérienne traditionnelle. Il s'appuie en effet sur des moyens aériens qui ne sont pas à la portée de tous. Mais en photographie aérienne la recherche de la qualité est essentielle. On a souvent reproché aux archéologues la publication de clichés médiocres, et en 2012 encore, le photographe professionnel est opposé au «photographe amateur» (Paitier 2012). A l'un des premiers colloques d'archéologie aérienne de Paris, le colonel Baradez, spécialiste des couvertures verticales militaires, considérait avec mépris les utilisateurs de «trottinettes d'Aéro-Club». On peut cependant réaliser d'excellents clichés à bord de l'un de ces avions et, dans tous les pays d'Europe, les Aéro-Clubs ont formé des pilotes expérimentés, dont quelques-uns sont devenus des professionnels de haut niveau. La richesse des aérophotothèques ainsi constituées, en particulier en Grande-Bretagne, en France, en Belgique, en Allemagne, en Hongrie, témoigne des résultats obtenus, dont beaucoup sont les archives des sites archéologiques disparus. Même si on ne dispose pas des moyens techniques présentés dans cet article, on doit essayer d'améliorer la qualité de ces archives irremplaçables. Il suffit de comparer quelques-unes de ces images à celles de la photographie satellitaire infra-rouge pour voir ce qui les différencie encore, même si celle-ci révèle, avec Sarah Parcak et en peu de temps, un grand nombre de vestiges inconnus en Egypte et dans l'Empire Romain (Parcak 2009).

Aerial and field reconnaissance of Velebit mountain

Vedrana Glavaš-Rog Palmer

Keywords: Aerial photography, field reconnaissance, Velebit, karst terrain, photo interpretation

Although rich in archaeological sites, the coastal slope of the Velebit Mountain Range is mostly archaeologically unexplored. Karst surface, maquis and weather conditions slow down the research and aggravate approach to known sites, as well as the discovery of new ones. Despite that, research of the mountain range has intensified in last few years, and field reconnaissance resulted in the dicovery of great number of new sites. In March 2012, aerial reconnaissance was conducted for the first time in the area of the Northern and Middle Velebit Mountains.

Archaeological remains in the area of the Velebit Mountains are today preserved as upstanding features (drystone walls and collapsed walls). Most of the sites are more clearly seen from the air because some remains are not visible due to maquis or because they lie on a karst surfce. The largest numbers of sites recorded from the air are prehistoric hillforts, whose number doubled after this research.

In addition to the discovery of new hillforts, we also revealed many features of hillforts which have not been recognized in the field until now. This resulted in many changes in the current groundplan of the localities.

With the hillforts, a number of sites are prehistoric and historic enclosures that were used for economic purposes.

All data obtained within this airborne recording are processed in ArcGIS program. Photos of the sites are georeferenced and digital descriptions of the structures were made as well as digital terrain models of individual sites. The results enabled the precise mapping of all archaeological features in their landscape and a better understanding of the changes that have taken place during the process of Romanization in this part of the Velebit Mountains.

Introduction

The Velebit mountain range in Croatia extends along the Adriatic Sea for 145 km between the Vratnik mountain pass above Senj in the north-west to the Zrmanja River in the south-east (fig. 1). The average width of the mountain is 14 km, and the highest peak is Vaganski vrh, at 1757 meters. Velebit is a particularly significant spatial element in this part of Croatia because it has always been the connection of the continent to the sea, the division of two climate zones and the crossroad of ethnic groups.

The Velebit Range has different characters on its coastal and inland sides. The inland slope is greener and more wooded, and the coastal one is covered by macchia and has a very karst appearance. Prominent terraces stretch along the coastal slope of Velebit. The first terrace spreads directly from the sea, and sub-Velebit villages are located on it. The second terrace, with karst fields and valleys, is located between 800 and 1000 meters (Pelivan 2007, 29).

Velebit's location also separates and affects two climatic regions: the Mediterranean and the continental. Insolation of the coastal slope of Velebit in the summer causes strong evaporation and extreme aridity, while severe drought affects a high rate of denudation. Higher parts of Velebit and its inland side are characterized by a high amount of moisture, as opposed to the coastal slope, which has a lower rainfall throughout the year, although it is higher during the colder period of the year (Perica–Orešić 1999, 6–29).

The most important climatic phenomenon in this region is the bura wind. It is a wind that is distinguished for its strength, coldness and extreme dryness. Bura occurs due to the penetration of cold air from the north towards the sea. It has greatly influenced past life on the mountain range and the appearance of the archaeological sites today. This wind blows in gusts at gale force and it scours away loose material from the ground (Perica–Orešić 1999, 30–33). Its strongest intensity is felt in places such as the mountain passes where the terrain is lowest. But because of the strategic

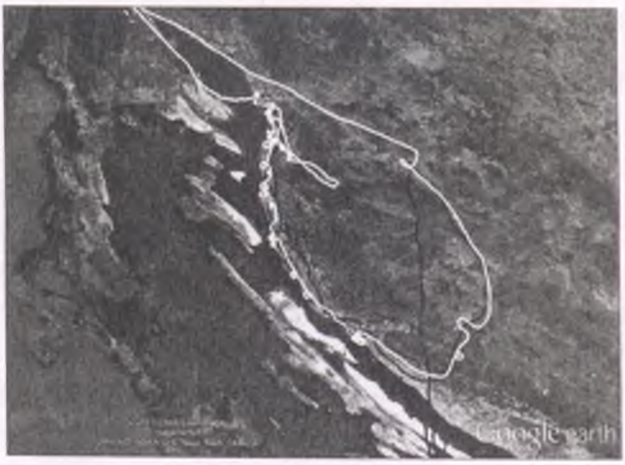

Fig. 1. Tracks of flights over the Velebit Range (source: Google Earth)

and transportation significance of mountain passes, they are exactly where the largest concentration of sites occurs.

The most significant karst phenomena in the Velebit mountains are cracks in limestone which can reach a depth of over 15 meters and give the mountain range its distinctive look. They can also occur under plant cover where the disappearing forest has led to the loss of the topsoil (Pelivan 2007, 31–32). The rest of the coastal slope is covered by macchia, which is greatly degraded and generally comprises prickly shrubs. Summer droughts, heat and gusts of bura significantly hinder regeneration of other vegetation. The lack of a soil cover, and under minimal vegetation, the cracks and stones make parts of Velebit look like the Moon surface.

Research of the Velebit Mountains

For these reasons, in the context of the mountain range's natural characteristics, it is necessary to consider the locations of archaeological sites and the current level of their preservation. In the current landscape of the Velebit, the human presence in all historical eras is clearly visible in abandoned settlements and fields. Today's few inhabitants still remember the mountain teeming with life up until the development of tourism fifty years ago. All these facts are necessary to begin to understand the prehistoric and historic landscapes of the Velebit.

This area has generally attracted little archaeological attention due to its terrain morphology that makes research considerably more difficult (Glavaš 2011, 24–30). In addition, as this part of the mountain range is now bare or covered by macchia, it might initially seem that archaeological remains are rare in this wild landscape. But if we look a little harder, we can identify traces of the presence of man in shaping the landscape which has been used for agricultural, social, economical and other purposes since prehistoric times.

Considering the large number of archaeological sites, excavations have been rare. On the one hand, this is understandable because there is nothing to dig on many sites, as there are no cultural layers. Consequently, there is a lack of 'factual' evidence for the area, but since the Velebit is the study area for Vedrana Glavaš's PhD research, it was necessary to find a method that will give useful results in this landscape.

The extent of the research area made it necessary to use ground reconnaissance as the initial survey method. Combined with accurately locating the true positions of the sites, this was an important step in creating a database from which the investigations could be extended. But such research of the Velebit brings many difficulties.

Velebit is extremely difficult for ground reconnaissance. Sharp cracks, macchia and thus a great physical effort greatly complicate the job. Low vegetation prevents the good visibility of sites and makes it difficult to access the location, while cracks in the ground tremendously impede walking and therefore slow the research progress.

Locating previously-known sites is also very difficult. In the literature, sites are mostly located descriptively, with no data about coordinates, and the positions that were designated as sites, sometimes do not contain any remains of the former presence of man. Thus, at the beginning of this research, it was necessary to visit all known sites and revise previous research. However, field examination allows very limited conclusions to be made about individual sites, all without deeper understanding of the relationship between them and the landscape itself. These are all reasons why, together with field reconnaissance, aerial photography was applied.

Aerial Photography

The use of aerial photographs to survey and review the landscape is still in its infancy in Croatia and photographing from the air is most often conducted to capture the situation on the ground during or after excavation. Therefore, our airborne recording of the Velebit in this way is a pioneering endeavour because the goal was to discover new sites and provide insights into the landscape from a wider perspective.

To help plan the aerial survey flights, data were collected from field survey, from literature, and through the spatial analysis of potential zones of interest from online services, Google Earth and Arkod. However, the resolution of Google Earth and Arkod is in many places too low to allow recognition of many sites. Aerial and satellite images on both servers were recorded at the time of year when vegetation was green and luxuriant, and this significantly reduces the visibility of sites. All data collected during field reconnaissance and by reviewing the imagery were used initially to direct research toward certain zones.

Aerial survey was conducted in March 2012 by the authors. The main goals of the research are closely related to the doctoral thesis "Romanization of autochthonous civitates in the northern and central Velebit Mountain". These are:

- To undertake aerial reconnaissance of areas that have not yet been examined in the field with the prospect of discovering new archaeological structures in the Velebit area;
- To photograph known sites and their environs in order to understand the context and setting of each site in the landscape;
- To make georeferenced digital descriptions of all archaeological features identified on aerial photographs of the coastal slope of the Velebit;
- To document an overview of the entire landscape from the air to review the settlement trends in the coastal area of the northern and middle Velebit;

Past occupants on the Velebit had different Iron Age ethnic backgrounds (*Liburniani* and *Iapodes*) and their unique experiences with the Romans, but they shared the same resource space – the

Fig. 2. The Jablanova hillfort - defensive wall on the left, and enclosed area on the right (photo: R. Palmer)

mountain. A long-term goal of this research is to create a large number of representative patterns of settlement of different types of landscapes on the Velebit Mountains (inland and coastal slope), which will provide data for comparative studies of settlement and land use on the Velebit.

Aerial reconnaissance was conducted in the area roughly limited by the Roman towns of Senia (present-day Senj) and Vegium (present Karlobag), and the border on the Velebit was the peak zone of the mountain (fig. 1). Research covered an area of about 320 km² and included observation flights and the recording of each potential site using hand-held cameras. Two flights were conducted using a Cessna 172 (9A-DVW) piloted by Ivan Drnasin for a total of 6 hours and 20 minutes. For recording, two cameras were used: an Olympus C8080WZ on the left side of the aircraft through an open window, and a Nikon D700 through an open window if possible, but more often through reflective Perspex. Known sites were marked on a topographic map of 1:25,000 scale and during the flights, two GPS units were used for site positioning and flight track recording. In total, 2280 pictures were taken, including stereo pairs and overlapping series from orbiting that can be used with Structure from Motion software to create orthophotos and digital terrain models.

Although the main goal of this project is to develop an understanding of settlement patterns on the Velebit in the Iron Age and of Romanization, sites of all types have been recorded, without attempting to determine them temporally and culturally. In subsequent stages of the project, research should focus on the inland side of the mountain range in order to provide primary information about archaeological sites and synthesizing all sites on both slopes of the Velebit.

Archaeological features

Archaeological remains on the Velebit are preserved today as upstanding features (dry stone walls and eroded walls) as a result of the method of their construction and the geomorphology of the terrain. Most of the sites are more clearly seen from the air, as some of the remains on the ground may not be recognised because of macchia or because they lie on a bed of karst.

Hillforts and enclosures on the hill are easily recognizable from the air because of their defensive walls which today are preserved in the form of a collapsed stone bank next to an enclosed area of settlement. Their recognition on the ground can, in places, be simple. However, aerial reconnaissance revealed some previously unknown sites of this type, and on many known sites have added elements that had not been identified in preliminary field examination. Jablanova hillfort, for example, had been examined previously on the ground on several occasions. Extremely deep cracks in the limestone bedrock on the plateau of the hillfort, and a high degree of macchia over some parts of site today, make an overview by ground survey really difficult (fig. 2). Two knaps make up the whole hillfort. The higher one is not suitable for living and it was probably used only for the surveillance of the surrounding territory. Eroded walls and remains of terraces can be seen both on aerial photographs and in the field. The lower knap is larger and its plateau is surrounded by a dry stonewall of a simple or even primitive construction, approximately 2.5 to 3 meters wide. In the south-western part of the site there is a *tumulus* that is now severely damaged. Examination of our aerial photographs revealed some new elements of this site (pl. 3). For example, several small structures that are probably remains of

Fig. 3. Collapsed dry stone walls in the vicinity of Senj – economic activities zones (photo: V. Glavaš)

shepherds' houses are adjacent to the defensive wall. These are almost impossible to see and understand on the ground, even though they are upstanding features. Also, the remains of terraces on the eastern slope of the site were observed for the first time as a result of aerial research. This hillfort does not appear to show characteristics of a permanent settlement and its exact purpose will be difficult to determine because the ground is almost completely eroded and archaeological excavation may be unrewarding.

Besides hillforts and enclosures, field reconnaissance and aerial photography also recorded a number of sites that appear to be the remains of economic zones of prehistoric and historic sites used mostly for agriculture and livestock (fig. 3). Because of a very small amount of soil on the coastal slope of the Velebit, almost every green area was walled to combat soil erosion and help retain and exploit the resource. Besides preventing soil erosion, these walls have been used as land divisions. Because such locations were used for hundreds of years, it is very difficult to date their origin. Many of the dry stone walls that surround them have quite irregular shapes and have probably evolved over the years as stones from land clearance were thrown on or against them. However, there has been no systematic research about this type of site in the area of the Velebit.

Unlike hillforts, enclosures and economic zones, tumuli are poorly visible from the air. In the area of the Velebit, they were built from amorphous raw limestone rocks that were piled together over the stone casket in which the deceased was placed. Due to their construction, tumuli are not easily visible as most of them are located on the bed of karst or are masked by the macchia that surrounds them. All tumuli recorded in this survey had previously been discovered on the ground and aerial photography didn't reveal any new ones despite the fact that some of them were photographed. For example, one tumulus was found during the field examination of the Glavaši hillfort that was recorded during the aerial survey, but it is very difficult to recognise it on the aerial photographs.

One of the goals of our aerial survey was to locate both known and new sites as accurately as possible. On the Velebit, this was done by matching our oblique photographs to the georeferenced images in Google Earth, which provided the base map. As noted above, our aerial survey was conducted in March when vegetation was still low. While it provided a better visibility of sites, it made it difficult to match ground control points with those on Google Earth images that had been taken in a period of luxuriant vegetation. When georeferencing photographs in ArcGis and AirPhoto SE, some problems arose primarily because of the rugged relief of the Velebit. One oblique photograph may record a targeted site, but also show other hills in the background. This makes it very difficult or impossible to rectify the complete oblique image, but smaller localised areas can be matched more successfully to georeferenced backgrounds. Despite that, the oblique photographs can provide new information about each site and its context in the surrounding landscape.

Conclusion

Because of soil erosion on many sites, it can be suggested that excavation on the coastal slope of the northern and middle Velebit is not the right approach and is unlikely to produce informative results. Therefore, other ways are needed to extract more information from these mountainous sites. Although excavation can give the most information about the site itself, it does not always need to be undertaken. For example, excavating most sites would not provide answers to the questions about chronology and stratigraphy because if cultural layers exist, they are thin and eroded at the very best. The only other way of dating such sites is from pottery found on their surface and in the cracks. Therefore, other methods have to be used to help us understand the landscape and the sites. Aerial archaeology has proven to be an excellent method of identifying less visible aspects of the known sites of the Velebit and for discovering new ones, confirmed by a dozen newly discovered sites. But to know more about their chronology, they still must be observed on the ground. To understand the landscape and gain empirical knowledge about it, it is essential to study it from different perspectives – from the air and on the ground – and to return to the field over and over, in every season of the year. Only then will we be able to interpret the cultural image that landscape provides and to understand the remains of the past, which created our modern world.

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

Balázs Holl–Zoltán Czajlik

Keywords: Burials, topography, aerial archaeological photography, interpretation, fuzzy logic

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).

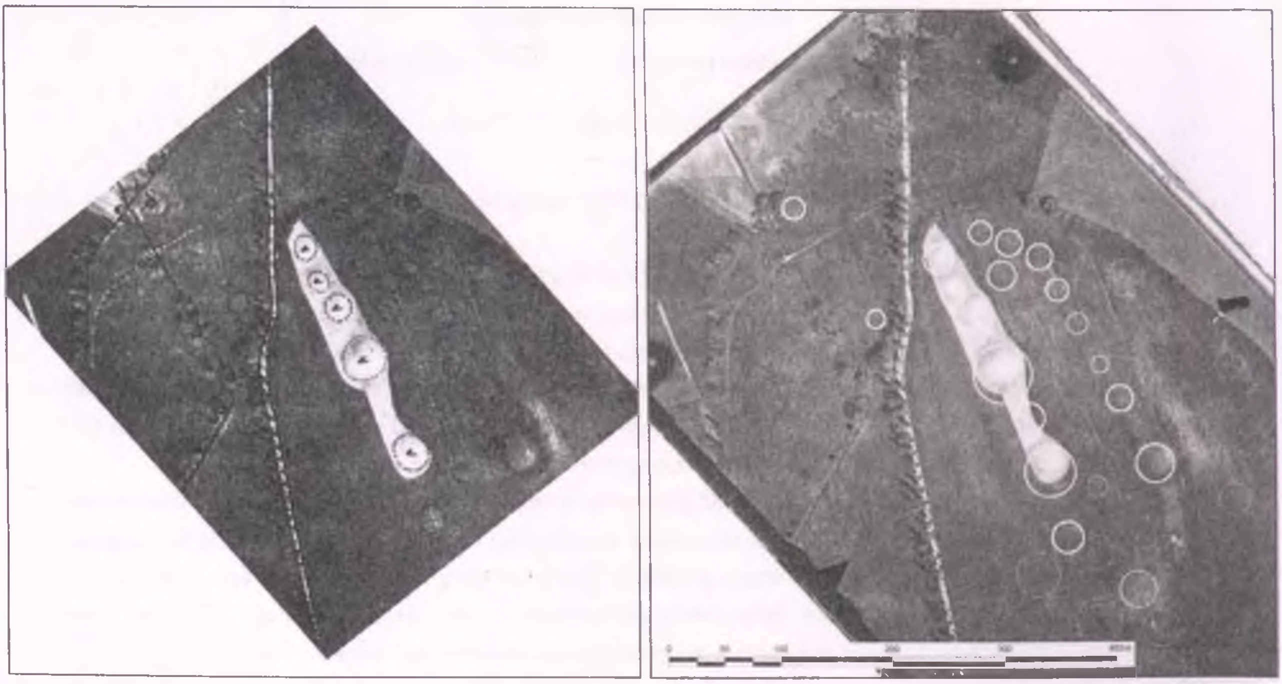

Fig. 1. Nagyberki–Szalacska. Sándor Neogrády's rectified photo from 1929, with Neogrády's interpretation and the assessment of the same area based on the currently known data (source: Neogrády 1948-50, 298 and Museum of Military History, Budapest)

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.

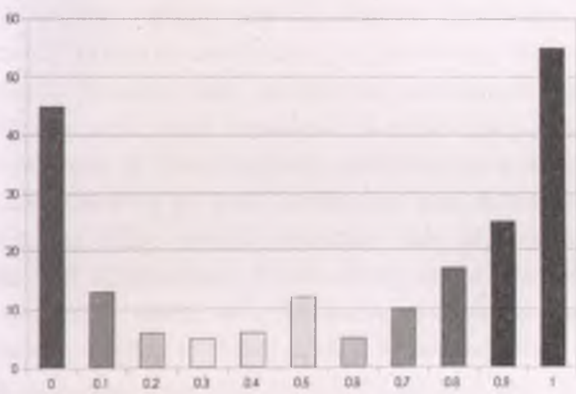

Fig. 4. Nagyberki–Szalacska. Distribution of burial mounds according to the uncertainty of the data. There are few intermediate values between the outstanding certain (0) and uncertain (1) values, probably owing to the subjectivity of the assessment

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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Lidarchaeology.
Airborne Laser Scanning of the forested landscapes around Polanów (Pomerania, Poland)

Łukasz Banaszek

Keywords: Airborne Laser Scanning, forested landscapes, archaeological prospection, Polish National Record of Archaeological Sites, Polanów

Comparison of recognized inhabitation patterns with land-use maps shows that the formation of concentrations of archaeological sites is strictly linked to the accessibility of surveyed areas. Wherever a forest grows, the archaeological evidence is meagre. To alter this situation, previously unpenetrated regions have to be surveyed, using a method characterized by a high potential of prospection in densely vegetated areas. The aim of the paper is to present the advantages of Airborne Laser Scanning application in the studies on forested landscapes in the border area of Polanów and its influence on archaeological interpretation. Using this case study, I will try to demonstrate that the concept of settlement concentrations and voids is more a scientific "myth" (in sense of Kołakowski 1972; Rączkowski 2003) born due to the lack of an effective method of prospection than a real aspect of past human behaviour.

Current practice

Field walking within AZP (Polish National Record of Archaeological Sites) remains the main method of archaeological prospection in Poland (e.g. Jaskanis 1996; Rączkowski 2005). Moreover, it is one of the components of complex landscape research projects conducted in particular regions, which include also aerial reconnaissance, geophysics and trial trenches (Rączkowski 2011). Outcomes of those laminar studies allow a deeper understanding of past landscapes and settlement patterns than results obtained due to a single method application. While above-mentioned are integrated, some of restrictive weaknesses are overcome (Rączkowski 2006). However, their archaeological potential is strictly limited due to a distinct site formation processes (in sense of Schiffer 1987). To identify a site, in case of aerial imagery interpretation particular marks have to occur (e.g. Crawford 1929), while during a field survey, the artefacts have to be ploughed up in order to be spotted on the soil surface (under special circumstances). This means, in general, that current land-use patterns have a huge impact on archaeological prospection. Consequently, commonly used methods of archaeological prospection, aerial reconnaissance and field walking have a limited potential in surveying non-arable lands. Although this concerns various areas, such as meadows, pastures, wastelands and marshy grounds, it is the forested landscape that remains the biggest void in the identification of archaeological sites.

High afforestation of some regions and methods' limitations create a particular picture of past settlement patterns. Due to that, on various maps, concentrations of recognized human presence within the past landscape are separated by areas where neither a single pottery sherd/an individual flint has been found during field walking, nor marks indispensable in aerial imagery interpretation have occurred/been spotted so far (e.g. Pelisiak 2003). To some extent, those restrictions enforced linking site location with e.g. soil type, relief, access to water etc. (e.g. Rybicka 1995). To simplify, it was the decision of a present-day farmer to cultivate a particular land which led indirectly to the identification of an archaeological site located at the place. State of the art (in fact exclusively based on field walking) has misled the understanding of human behaviour in the past so far. Thus, a concept of settlement concentrations and voids is present in the literature (e.g. Garbacz 2009). Following Kołakowski (1972), this concept is a scientific myth created due to a random experience of the reality and accidental character of the world in which we live in. According to that, researchers are trying to add a non-accidental and simplified values to their understanding of the past, using all (arbitrarily created) links between site location and e.g. soil type. The main goal of this process of mythologisation is to validate one's intuition and ignore the accidental nature of the

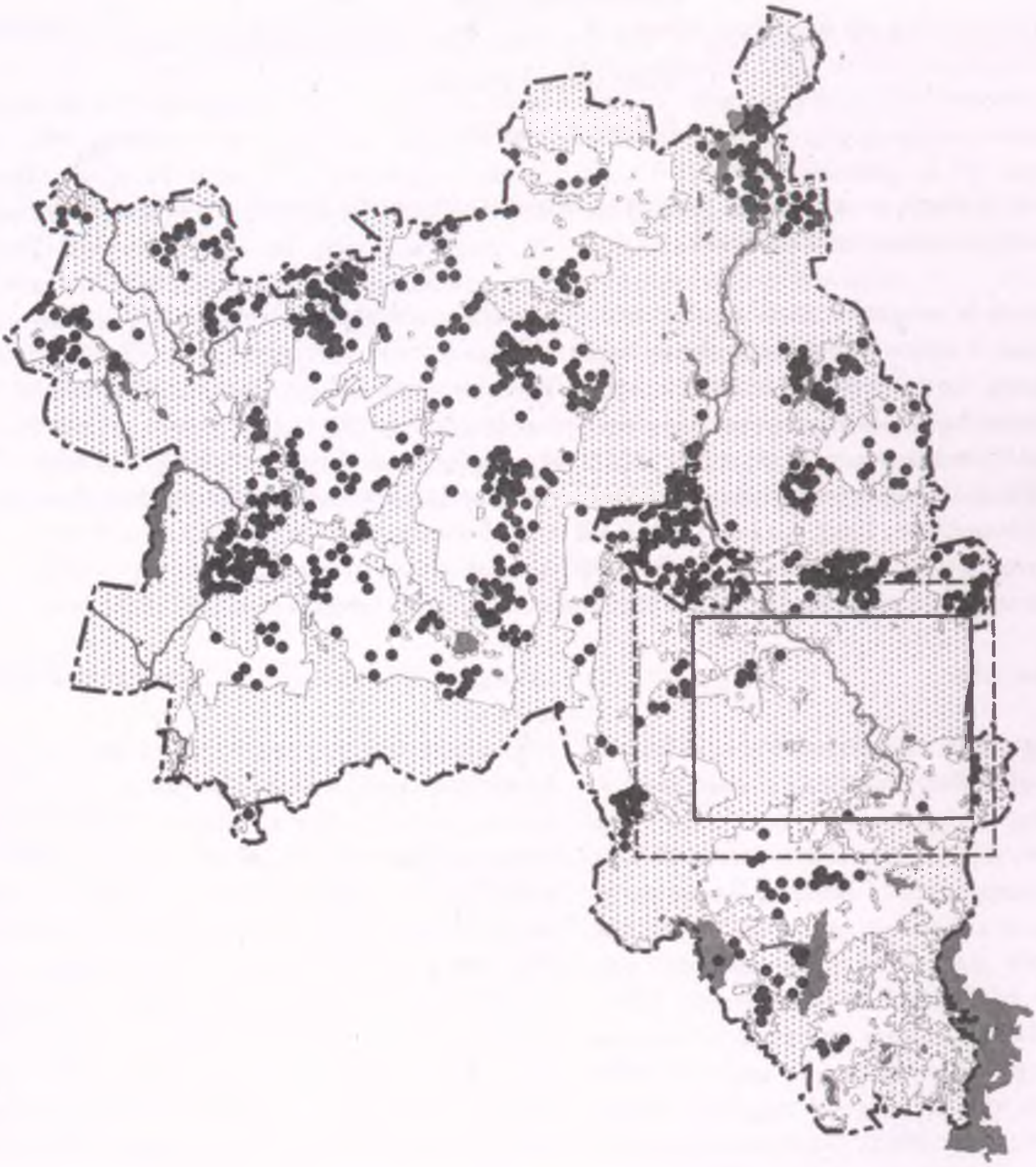

Fig. 1. County of Polanów. Location of archaeological sites

research, which is strictly a matter of limitations of the methods used. As a result, archaeologists think about the past landscape in categories of individual sites separated by empty spaces, not as a fully integrated landscape, in which various material elements and meanings are intertwined.

Airborne Laser Scanning in Pomerania

County of Polanów is characterized by a significant degree of afforestation (fig. 1, described below). About 53% of the region's surface is covered by wooded areas of all types: deciduous, coniferous and mixed. In 2010, an on-ground survey of the forests of Polanów was undertaken (Banaszek–Rączkowski 2010). Its results were surprisingly fruitful and showed numerous archaeological objects located in the forested landscapes (fig. 2, described below). During the survey, huge numbers of barrows have drawn the attention. However, some of them were very flat, calling for a better prospection method. Moreover, the afforestation of the areas of burial mounds significantly hampers on-ground prospection.

Airborne Laser Scanning (ALS), based on the Light Detection and Ranging (LiDAR) technology (e.g. Wagner *et al.* 2006) is a highly effective method of prospection, including in densely vegetated regions. Since the probably first lecture concerning possibilities of airborne laser scanning application

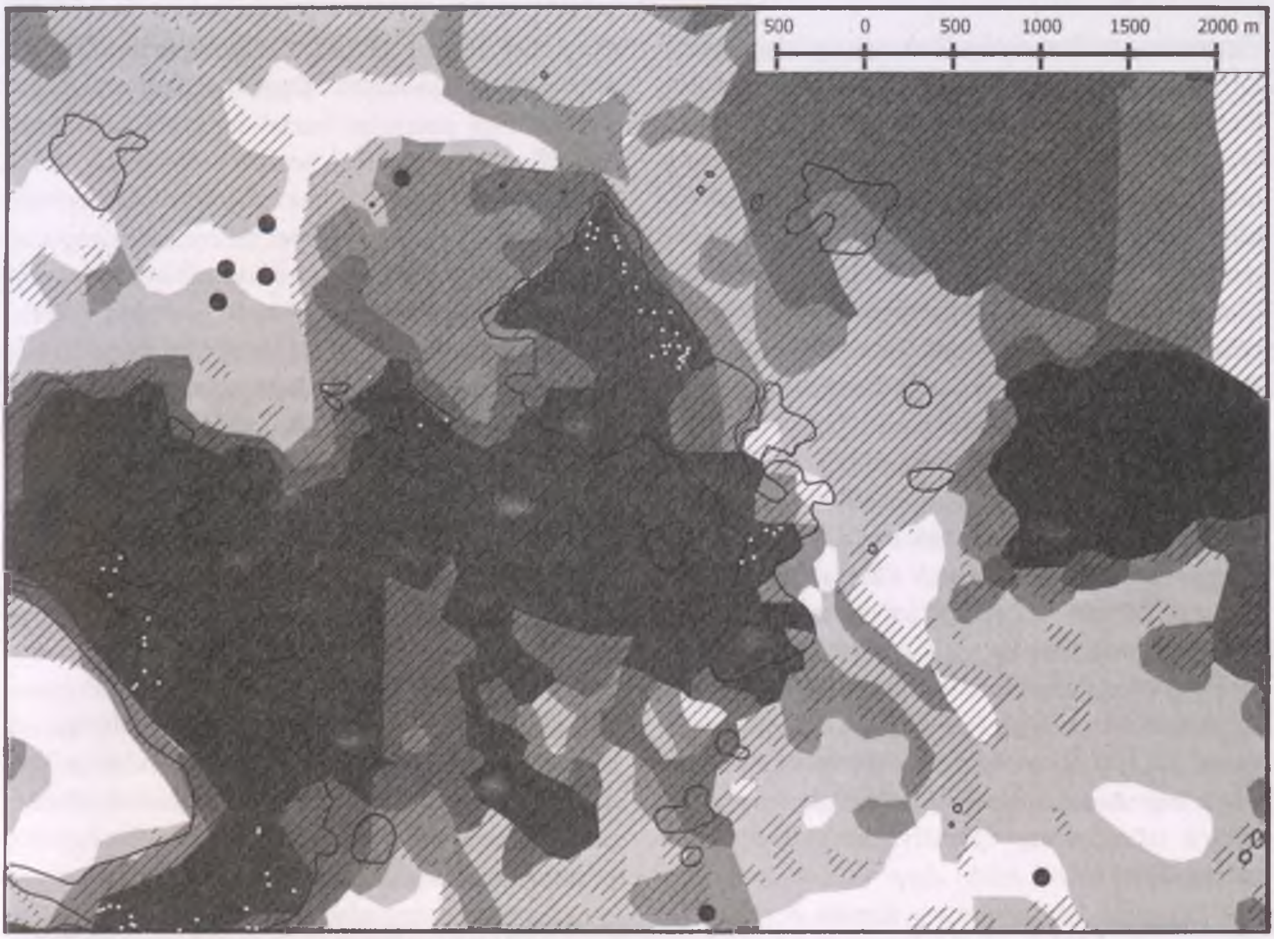

Fig. 2. Sheet 17-26 of AZP maps. Location of sites recognized through to use of various methods (after PLIT 2010, 286; modified)

in archaeological research given by N. Holden in Leszno (HOLDEN *et al.* 2002), the method has been drastically developed and used in numerous projects around the world (CHALLIS 2006; CRUTCHLEY 2006; DE MAN ET AL. 2005; LASAPONARA *et al.* 2010; CORNS–SHAW 2009; GALLAGHER–JOSEPHS 2008) as well as in Poland (KOBYLIŃSKI *et al.* 2012; BUDZISZEWSKI–WYSOCKI 2012; ORLICKA-JASNOCH 2012). In the meantime, various aspects of the technology and data processing have been examined (DONEUS–BRIESE 2006; DONEUS–BRIESE 2011; SHAW–CORNS 2011; HESSE 2010; ZAKŠEK *et al.* 2011) offering a fuller exploration of ALS application in archaeology. The method, due to its potential, was chosen to identify sites located in the forests of Middle Pomerania, a region previously poorly known in archaeological senses.

In April 2012, while the vegetation has been stopped yet, an ALS survey was conducted in parts of the counties of Sławno and Polanów. A total area of ca. 135 km² was scanned.[1] 8 points per square metre were collected and as a consequence of the point cloud classification (executed within the TerraSolid software environment), Digital Terrain Models of 0.5 m spatial resolution were generated.[2] Additionally, vertical aerial photos (of pixel size 13 cm) were taken in order to assist outcome verification. Archaeological interpretation of the models was conducted and various methods of the visualization of DTM were used, i.e. single and multiplied hill shading analysis, sky-view factor (ZAKŠEK *et al.* 2011), principal component analysis (DEVEREUX *et al.* 2008), etc.[3]

[1] The research project on the forested landscapes of Pomerania was conducted through the financial support of The Ministry of Science and Higher Education of the Republic of Poland (projects no. 260/Kultura/2011/2012/2 and 1061/B/H03/2011/40), The Anna Pasek Foundation and the EU funded project "ArchaeoLandscapes Europe" – ARCLAND (no. 2010-1486/001-001).

[2] I would like to thank MGGP Aero Company for provided LiDAR products and skills gained during data processing.

[3] I am extremely grateful to R. Hesse for his help in exploring the data and access to the LiDAR Toolbox Sofware, as well as to R. Shaw and The Discovery Programme crew for their support in the process of learning about the interpretation of LiDAR imagery.

Vicinities of Polanów. Domain of the dead?

The location of archaeological sites mainly identified during AZP in the county of Polanów is presented on fig. 1 (solid black dots). Without any additional information, sites could be perceived as grouped in particular areas, which are separated from one another (e.g. Skrzypek 2010). This simplification leads to a misunderstanding of the past landscape and forms grounds for the concept of settlement concentrations and voids. Nevertheless, it is the land use layer, in particular the afforestation degree (fig. 1, areas filled with small black dots), which gives an explanation of why clusters of sites are isolated. One of the greatest blanks is located south-east of the town of Polanów. It was chosen for ALS survey, which in this case was executed across ca. 70 square km (within the dashed black line). For the sake of argument, I would like to focus on Sheet 17-26 of the AZP maps (fig. 1, solid black line) which shows that only 7 sites were previously recognized in the analysed 35 km^2.

The range of contemporary forests is presented using areas filled with diagonal black lines (without any borders) on fig. 2. Sites recognized during field walking are marked by large black dots. Among them, only one (an early medieval stronghold) was recognized in the woodland (Łosiński *et al.* 1971), which covers ca. 75% of the area. Taking into consideration previous prospection results, it is hard to speak about any settlement patterns in this region due to the lack of evidence. In extreme, archaeologists tend to argue that the void of this type is the consequence of the existence of forests in a particular area for ages. According to that, people of the past used to avoid terrains currently covered by woods (which usually grow on poor quality soils). However, the above-mentioned on-ground survey conducted in 2010 led to the identification of numerous burial mounds located in forests (fig. 2, small white dots). At that time, countless barrows were documented by means of photography and mapped using GPS receivers (Banaszek–Rączkowski 2010).

A survey executed 3 years ago had shown the archaeological potential of the region; however, it is the interpretation of LiDAR data that revealed the scale of the problem. Due to that, enormous numbers of potential burial mounds have been identified (fig. 2, areas within solid black lines). Although not every concentration of barrows has been verified in the field yet (it concerns especially smaller groups), already conducted surveys confirm the existence of two extended "burial fields" (located in the middle of the sheet and in the south-western part). Both of the regions were partially recognized in 2010; however, interpretation of LiDAR data allowed us to fill the gaps between some of the identified concentrations. Moreover, an approximated range of those areas could be counted (reaching up to 3.3 km in length) as well as each and every barrow could be mapped and analyzed (fig. 3).

The location of recognized "burial fields" seems to follow a specific pattern. J. Plit (2010) has examined archive charts of county of Polanów and shown changes in the extent of the afforestation as well as the use of woodland within the last 400 years. Her analysis of cartographic products was based on the maps of E. Lubinus' Novo illustrissimi principatus Pomeraniae descriptis... (1618; scale 1:227,000), D. Gilly's Karte des Königl. Preuss. Herzogthum Vor- und Hinter-Pommern (1789; scale 1:180,000), G. D. Reymann's Special-Karte des Prussischen Staats (1850; scale 1:200,000), Karte des Deutschen Reiches (1893; scale 1:100,000), Polish Army Geographic Institute's Tactical Map (1935; 1:100,000) and Topographic Board of the Polish Army General Staff's Topographic Map of Poland (1993; scale 1:100,000) (Plit 2010, 270). As a result of the analysis, a forests' permanence chart was created, according to which wooded regions are grouped into 5 classes: 1 – areas of permanent use (clerical grey); 2 – areas of predominant use (grey); 3 – areas of changeable use (light grey); 4 – areas of occasional use (bright grey); 5 – treeless areas (white) (Plit 2010, 286). I have partially taken advantage of Plit's map and set it as a background of fig. 2 (colours as described above). Although one can spot some shifts (due to a different scale and quality of archive maps as well as problems with georeferencing Plit's figure), in my opinion, "burial fields" (especially those extended ones) follow (to some extent) the shapes of wooded areas of permanent use.

Summary

The results of the airborne laser scanning reach far beyond previous archaeological investigation. The identification of numerous barrows provides a totally different picture of the landscape inhabitation. Archaeological features covered by woodland, thus previously lying beyond the range of a proper archaeological prospection, allow perceiving the forested landscapes of Polanów as regions of spatially continuous settlement.

Barrows near Polanów are neither recognized everywhere a contemporary forest occurs, nor are they located in every area of permanent presence of the woodland (at least within the last 400 years). The results of LiDAR imagery interpretation integrated with historical data give a diametrically different picture of settlement patterns than previously. Instead of thinking about the forested landscapes as voids, neglected by archaeologists (due to lack of a proper method of prospection) and avoided by humans in the past (due to argued permanence of woodland in particular areas as well as e.g. poor quality soil on which trees grow), one has to take into account that current forested landscapes had been fully exploited once.

The 400 years long presence of forests in a particular region is not an argument for the thesis that humans avoided those areas in the past. First of all, historic sources offer a great possibility to better understand human interrelation with woodland (e.g. Labuda 2003). Forest clearing for building and firewood purposes, gaining fodder out of young trees and pasturing within the woods as well as the need for fields and pastures led to deforestation. J. Plit argues that almost the whole of the contemporary county of Polanów was used as fields and pastures in the 17th century, as it is mapped by Labinus (Plit 2010, 275). Secondly, the process of afforestation, which started in 18th century, led to a better preservation of earlier archaeological sites. Thus, paradoxically, regions once perceived as voids could become "densely in-

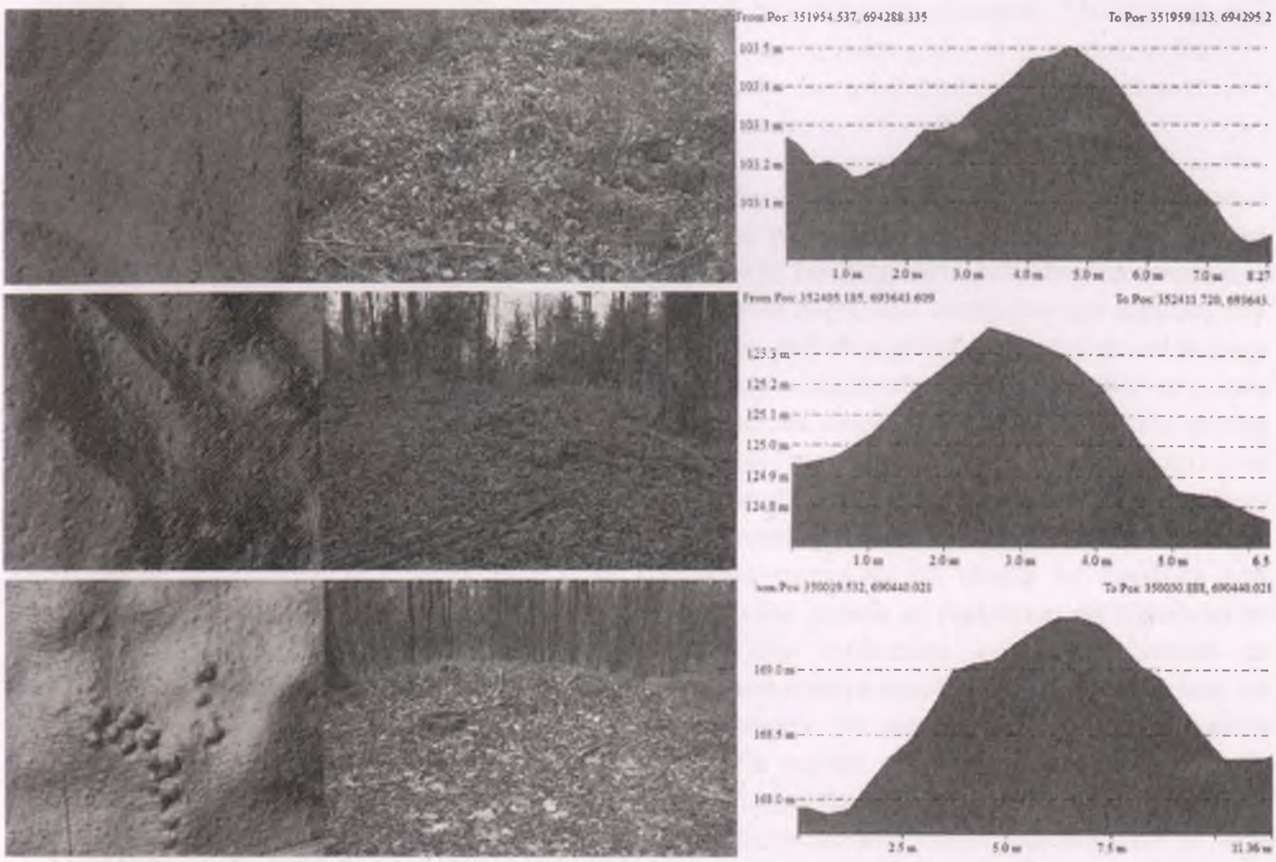

Fig. 3. Examples of barrows identified through to LiDAR data interpretation

habited" due to a wider application of ALS .

Describing vicinities of Polanów as domains of the dead would be an exaggeration. It would lead to another scientific myth, built in the same manner as the concept of settlement concentrations and voids. Although airborne laser scanning is a method of a great potential, researchers have to be aware not only of its limitations and drawbacks (of a technological provenience), but also remember that it is a specific method, which application allows to identify particular type of objects, preserved until now in a definite form as a consequence of particular site formation processes (SCHIFFER 1987). Although LiDAR could help in ending up with the concept of settlement concentrations and voids, it has to be used in a way not leading to another scientific myth.

Roads to nowhere?
Disentangling meshworks of holloways

Dimitrij MLEKUŽ

Keywords: landscape, movement, mobility, holloways, paths, traces, meshwork, LiDAR

LiDAR reveals landscapes previously hidden below a woodland canopy with amazing clarity. One of the most ubiquitous features of the woodland floor are holloways or sunken lanes. Despite their ubiquity, there has been surprisingly little work on them. Holloways are usually treated as primitive communications, a first, muddy step toward a developed road system (see MUIR 2000, 94–99; HINDLE 2001, 1–11).

In this paper, I want to develop an argument that holloways are rather something different. Holloways are about the movement and the mutual constitutions of movement and landscapes. They can teach us how landscapes are always in the process of becoming, made and remade through the movement of people, material culture, substances... Movement is a material practice that constantly creates new relations between things. In this way, holloways, as a material traces of past movement, have the power to move us, landscape archaeologists, around the landscape, helping us to weave and re-make past landscapes.

The recent rise of mobility studies in sociology, geography and other social sciences is about incorporating concerns of movement into a broader discourse (see SHELER–URRY 2006; URRY 2007; HANNAM *et al.* 2006). Archaeology should not be and is not immune to these concerns (see ALDRED–SEKEDAT 2010, 2011a, 2011b, 2011c). How did people in past landscapes move? How did this movement mutually constitute people who moved and landscapes? How do landscapes move us?

From the perspective of mobility, landscapes, places but also bodies and things can be understood as a product of practices, trajectories, interrelations and flows realised through movement. Landscape is thus a continuous weaving, relating and associating, forever in the making, always in motion, in the process of becoming. This perspective, in my opinion, is much more productive than static notions of landscape in terms of territory, boundedness, area, scale and so on.

HOLLOWAYS: PATHS, RIVERS ...

Holloways are material traces of movement, movement that is being materialised in the form of traces left in the soil (fig. 1).

We can tackle those traces using ichnology, or traces science, a study of processes of the interaction between organisms and substrates and their products (see BUATOIS–MANGANO 2011; BAUCON *et al.* 2008). The products are traces themselves, which comprise structures of biogenic origins, related to the morphology and behaviour of producers and sedimentary fabric. Traces are evidence of the behaviour of organism, the way they move, rest, graze, feed and dwell in the landscape (BUATOIS–MANGANO 2011). Human animals, travellers, make their way through the landscape, and as they walk, they plant their feet on the ground. Soil compaction by trampling changes physical soil properties and affects site quality by reducing macropore space, soil infiltration capacity, and soil aeration and increasing soil resistance to root penetration. It also affect regeneration success by injuring roots, reducing the respiratory activity of roots, and restricting the effective rooting area and root growth. Severity of soil damage increases nonlinearly with the number of passes; most of the resulting compaction occurs during the first few passes. Effects of soil disturbance may persist for several decades because of very slow recovery rates (ARNUP 1998).

Regular trampling by people or livestock suppresses the growth of vegetation on trails and reduces the infiltration rate. This results in increased surface runoff along trails, especially on steep slopes. During the dry season, trampling displaces surface soil, providing a source of sediment during the rainy season. The trails become a conduit for surface runoff and a source of sediment, resulting in increased erosion rates (MELVIN *et al.* 2004). Thus holloways were never built, but eroded by the flow of people, animals and carts. As

Fig. 1. Swarm of holloways around Iron Age barrows (Tupalice, Northern Slovenia)

such, they became water conduits too. Water erosion speeded the hollowing-out process and made some lanes muddy and impassable. When this happened, alternative routes were taken by people traveling along them, leading in some places to formation of river-like braided channels, branching and converging (Edgeworth 2011, 109).

Holloways are therefore rivers, gullies and tracks at the same time (fig. 1). In this way, they render the nature/culture dichotomy meaningless (Edgeworth 2011, 109). Doing fieldwork, I needed some time to adjust to the idea that the gullies I saw are holloways, anthropogenic in origin. But then I accepted that any gully can become a holloway, a way to move across the landscape. Thus instead of nice, planned connections between places in the landscape they are rather unruly swarms of merging, branching, diverging and re-uniting trackways.

They are messy. They are not messy only in the sense of being muddy, they are messy because they were built in a messy way. They are not simply layered, accumulated one upon another as a palimpsest, but a result of the duration of movement, created through repetition, improvisation and re-use (see Mlekuž 2012; 2013). They are messy because they were being made by using, re-using, re-working or just relating to existing tracks, water, mud, and other features already present in the landscape. They are messy because they are being made by many agents who work in different rhythms and by different speeds. Made by movement of people, animals, material culture, sediments, water, in various combinations, moving in different rhythms and interacting in many complex ways (fig. 2).

Holloways are made through duration and repetition. Therefore, we cannot disentangle them in nice simple layers, successions. In this perspective, questions such as how old are they, are meaningless because they are still potentially in use and being hollowed out. In a similar way, attempts to date them using their associations with dateable features are rather meaningless, as well. People moved from places to other places, moving along the tracks they passed barrows, hillforts, limekilns... They related to these features in the same way they related to existing tracks and created new ones. Thus trackways and the rest of the landscape mutually constitute each other, creating thick, multi-temporal landscapes or landscapes of duration.

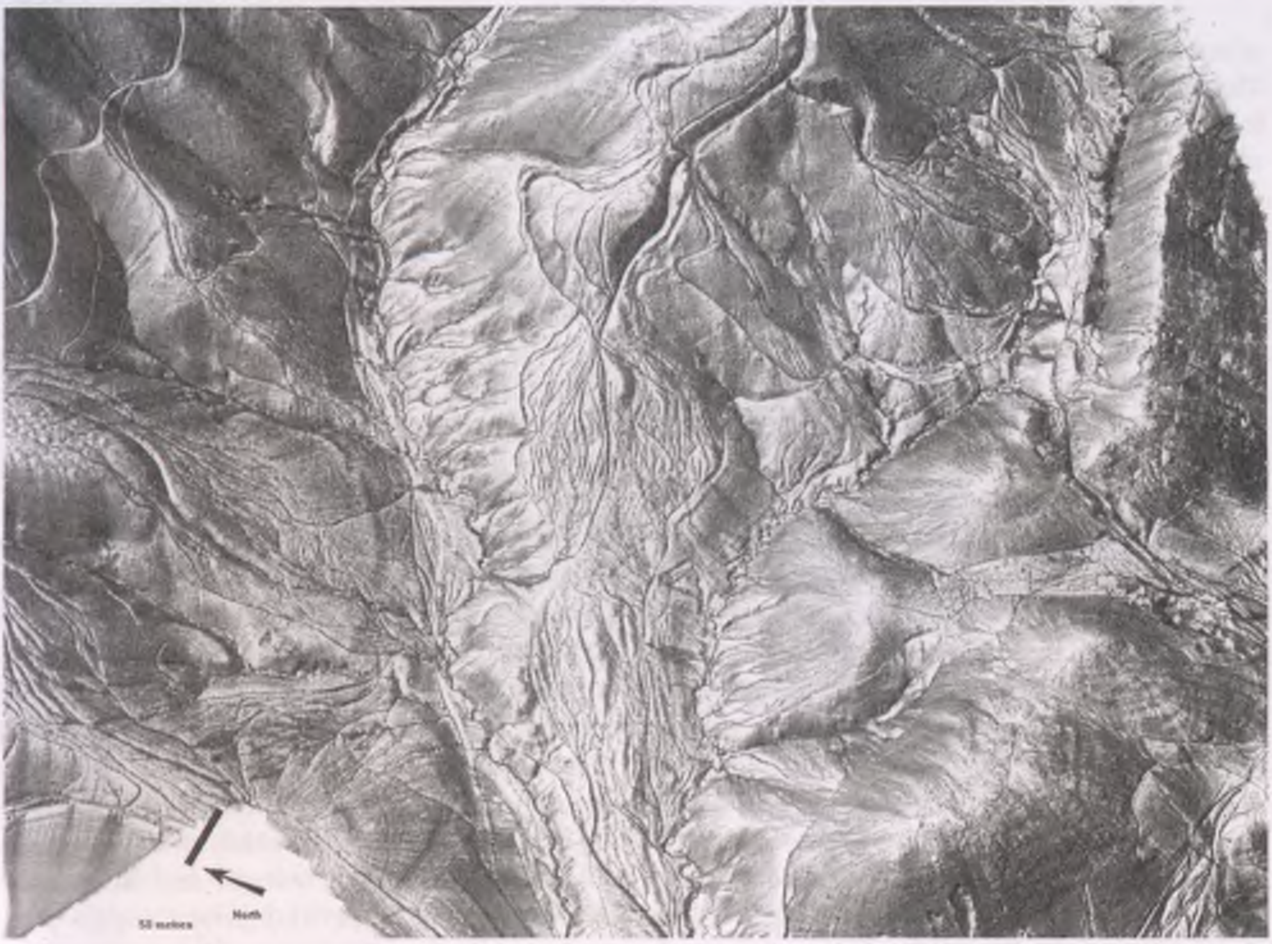

Fig. 2. Simulated surface runoff on a landscape with holloways (Tupalice, Northern Slovenia). Holloways are diverting the flow of water over the landscape, becoming a streams

Thus, are not simply layered, accumulated one upon another, but a result of the duration of movement, created through repetition and improvisation, truly morphogenetic figures forged in time and space. The morphogenesis can thus be defined as a form obtained as a result of processes of differentiation and evolution. The opposite of emergence is design: it is a form conceived by a designer, which will be used as a blueprint for its realisation.

On the other hand, as they were created by people and other things moving, they have a power to move us too. Their material traces can guide us when we are moving through the landscapes, either by walking by interpreting LiDAR images. They can be itineraries that connect past places. By following them, we re-weave connections that once existed and we create past landscape.

They teach us that we need to become more accepting of these blurred, messy things rather than demanding sharp, clear ones. Our job is not to make then clean. Trying to describe complex, diffuse and messy things, landscapes, in simple terms would only make more mess out of them.

The landscape where we find those traces is thus not just a background, or simple constraint, where these features are imprinted, but becomes a flow itself, a changing assemblage of individualised points, inhomogeneities, trajectories, complex relations ... being assembled and re-assembled during movement, through walking (Kwinter 2001, 31). Holloways are a constitutive part of the landscape, and acts of walking along them are acts of landscaping, creating, making and reproducing landscape.

People make creative decisions from one moment to the next, based on observation, through negotiation with the environment. They can chose to ignore rules, avoid regulated directions, resisting the predominant logic of spatial order.

Unlike water, people are constrained but not restricted by gravity. They can move uphill as well as downhill and in more than one direction at the same time. In this way, branching holloways form on the slopes, converging on passes and corridors (Edgeworth 2011, 109–110). Slopes, boggy terrain, mud ... might slow down movement, and obstacles have to be negotiated. On the other hand, passes, corridors and passages are conduits of movement, directing and guiding movement.

The development of swarms of holloways does not programatically reproduce what is already here, formed and given in advance, either by mental template in the heads of people, or constraints of the landscape. Instead, it is an active dynamic process of differentiation and evolution, a permanent creative invention; or if we use a biological term, morphogenesis, a form obtained as a result of processes of differentiation and evolution.

This bring us back to ichnology or trace science. The recent developments in ichnology see complex traces as a record of active control of the habitat by the organism (Buatois–Mangano 2011, 24–25). Thus, they are not seen as a simple passive response to the prevailing environmental conditions, but as an extended phenotype (Dawkins 1989), extended in a sense that it does not contain biological processes such as tissue growth only, but also other influences of a gene on its environment, either inside or outside of the body of the individual organism. In this way, holloways can be understood as material traces of the ways people inhabit their environment. This perspective resonates with recent developments in landscape archaeology and mobility studies.

Movement, travel and meshworks

Tim Ingold observes that travel, as a distinct category from walking, daily movement from task to task, emerged only around 18th century (Ingold 2011, 37–39, Ingold 2004, 321–322). Travel was an activity of the wealthy, who did not undertake travel for their own sake, but to get somewhere. Therefore, time spent on travel is to be minimised. Travel is destination-oriented. In this way, a traveller does not move, he or she is rather being moved, "carried across", becoming a passenger. When traveling, movement is reduced to sheer mechanical displacement.

Before the 17th century, most people walked on foot (and even barefoot; Ingold 2004; Ingold 2011, 37–40). Before paved roads and public transport, the only way to get around was on foot. Walking was a mundane, daily activity, part of daily life and connected with other activities, such as management of animals, working on the field, getting stuff from the forest to the houses, going to church ...

Time spent moving, walking around the landscape is not dead time that people seek to minimise. Activities occur while on the move and being on the move can involve sets of 'occasioned' activities. Claudio Aporta (2004, 14) writes, when discussing the movement of Inuit communities: "Travelling for the Inuit is not a transitional activity of going from point A to point B. Life happens while travelling. Other travellers are met, children are born, and hunting, fishing and other subsistence activities are performed." Landscape is shaped through doing, engaging with contiguous places through moving, walking (see Olwig 2008).

Thus, lives are not led only within places, but on the way from and to them, through embodied experience of perambulatory movement (Ingold 2004). Life unfolds along the paths. Where inhabitants meet, trails are entwined, they form a knot, place, where the life of each becomes bound with each other.

Places are thus not fixed entities but parts of complex networks, knots by which people, animals, things, substances are brought together to produce new associations. This perspective on place suggests a continual process of becoming. Places are not so much defined by their location, their boundaries or shape, but by the flows and convergences flowing through them (Aldred–Sekedat 2011b). Places are gatherings of people and stuff that are continuously on the move.

The different ways of moving around create different patterns

By inhabiting the world through moving and walking, a pattern of interwoven trails is created rather than a network of intersecting transport routes (Ingold 2007, 80). Henri Lefebvre (1991, 117–118) speaks of "reticular patterns left by animals, both wild and domestic, and by people (in and around the houses of village or small town, as in towns's immediate environs." Tim Ingold calls this pattern meshwork (Ingold 2007, 80). It is an entanglement of lines, "trails along which life is lived" (Ingold 2007, 81), where people are "coming and going" (Ingold 2007, 117), as they move back and forth between pastures, fields, forests and villages within the daily and seasonal cycle. This coming and going creates an intricate web of paths, a meshwork, that fans from the settlement to the landscape and back. This is a meshwork of interwoven trails, along which life is lived rather than a fixed network of intersecting routes, made to reduce travel time and trouble. It is an extended phenotype, traces left by people engaging with the environment. This entanglement, the meshwork, is the texture people and other creatures continuously weave while they inhabit the world (Ingold 2011, 71).

Conclusions

Instead of fragments of transport networks connecting fixed points in the landscape, holloways are rather "messy" landscapes of movement, interwoven swarms of different scrapes and traces of movement, almost biological shapes, "organic" entanglement of lines that emerges from growth and differentiation through rhythms of human and animal movement, change of seasons, water dynamics...

Holloways are not primitive roads. They are places, marked by the passage of human life, "conduits of inscribed activity" (Weiner 1991, 38). They are not about getting somewhere, from point A to point B, but about being in the landscape, living the daily life. People inhabit the landscape along these paths. They are lines along which past landscapes were created, in a messy way, from things and features encountered along the path.

They force us to move beyond static network topologies, of communications between fixed places, to also consider topologies that may be more fluid, emerging, changing, always becoming. Modelling the emergence and development of such complex patterns is important for future mobilities research as it intersects with the research of complex dynamic systems (Hannam *et al.* 2006; Sheller–Urry 2006; Urry 2007). In this way, we can approach landscape as ever-evolving meshworks, threaded from acts of movement. As Barbara Bender says (2002, 103): "landscape is time materialising: landscapes, like time, never stand still".

By studying material traces of past movement, we can discover the structure of how we move around the landscape (Aldred–Sekedat 2011c). They move us too. They move us to interpret the landscape from the moving point of view. Instead of focusing on fixed places, our attention shifts to the spaces in-between, through and along which movement occurs and on the ways movement and places mutually constitute each other. These paths also structure our narratives, they can be plot lines along which our narratives about landscape are unwound.

Thus, humble, ubiquitous, muddy and messy holloways are not roads to nowhere, but ways into the past landscapes.

An Experimental Application of Airborne Laser Scanning for Landscape Archaeology in Northeastern Poland

Cezary Sobczak

Keywords: Suwałki (Poland), landscape archeology, the Baltic, ALS, field verification

The Suwałki region in north-eastern Poland is one of the most attractive tourist destinations in the country. It is a strongly undulating area with numerous glacial features and boulders. Differences in altitude reach sometimes over 100 m. The area consists of numerous wetlands and post-glacial lakes, including the deepest Polish lake – Hańcza (-108.5 m). It is the part of the Lithuanian Lake District. This is one of the coldest areas in Poland. It has quite a harsh continental climate with the longest and coldest winters in the country. The area is covered with snow on average for 100 days a year. In result, it has the shortest early spring and the shortest growing season in the country, not including the mountainous areas in Southern Poland. Because of the climate and poor soils, the Suwałki region is mostly meadowland, fields and forests (usually mixed). Characteristic for this area is a low population density of about 20–30 people per sq. km. The main occupation of people is animal husbandry and agriculture. Forestry, fishing and agrotourism are well represented, but less popular. The area is inhabited mainly by Poles and a small Lithuanian minority. In the past, it was a place of settlement of Baltic tribes, the Yatvingians. We know of them from historical and archaeological sources.

Historical background

The origins of the interest in the cultural heritage of the Suwałki region are dated to the mid-19th century, but professional archaeological research started much later – in the second half of 20th century. Despite of 60 years of studies: excavations and surface survey under the Polish Archaeological Record (AZP), the Suwałki region is one of the archaeologically least known areas in Poland. This is caused by high costs of research and a small number of archaeologists interested in studying the subject. Many areas are difficult to reach and even inaccessible because of postglacial morphology, forests, wetlands and swamps. New archaeological earthwork sites (mounds, hillforts) are still awaiting discovery (Brzozowski-Siemaszko 2009, 637).

Low settlement density and difficult terrain have helped preserve many important earthwork and flat archaeological sites. Their state of preservation is relatively good due to the fact that the area was overgrown by Polish Royal forests from the end of 14th to the 17th century. New settlers in the 18th and 19th centuries had large parts of the forests cut and drained. However, they had only small negative impact on the overall state of preservation of archaeological sites and the area has since been devoid of large industrial modern investments. These circumstances cause that the archaeological landscape of the area of Poland is one of the most unharmed and "original" in its forms.

Besides settlement sites, the area consists of different kinds of the sites with their own topographic form. The oldest ones are hilltop settlements dating from the end of Bronze Age to the Early Iron Age. They were settled on flatted hills, whose slopes were artificially made steep to be more defensive. The most characteristic sites are barrow cemeteries. In the Suwałki District, over 30 such cemeteries, dating from Roman Age to the Migration period have been researched. Usually these barrows occur in groups of tens. They have different sizes and construction consisted of stone and earth. Their diameter ranges from 2–3 m to over 20 m and from 0.2 m to almost 1 m of height.

The most important archaeological sites are early medieval hillforts. They are accompanied by extensive defense systems of different types of ramparts, ditches and watchtower mounds connected by routes. The most developed complex of such sites is located around Lake Szurpiły (Engel *et al.* 2009, 517–544; fig. 1).

There are also elements of the landscape associat-

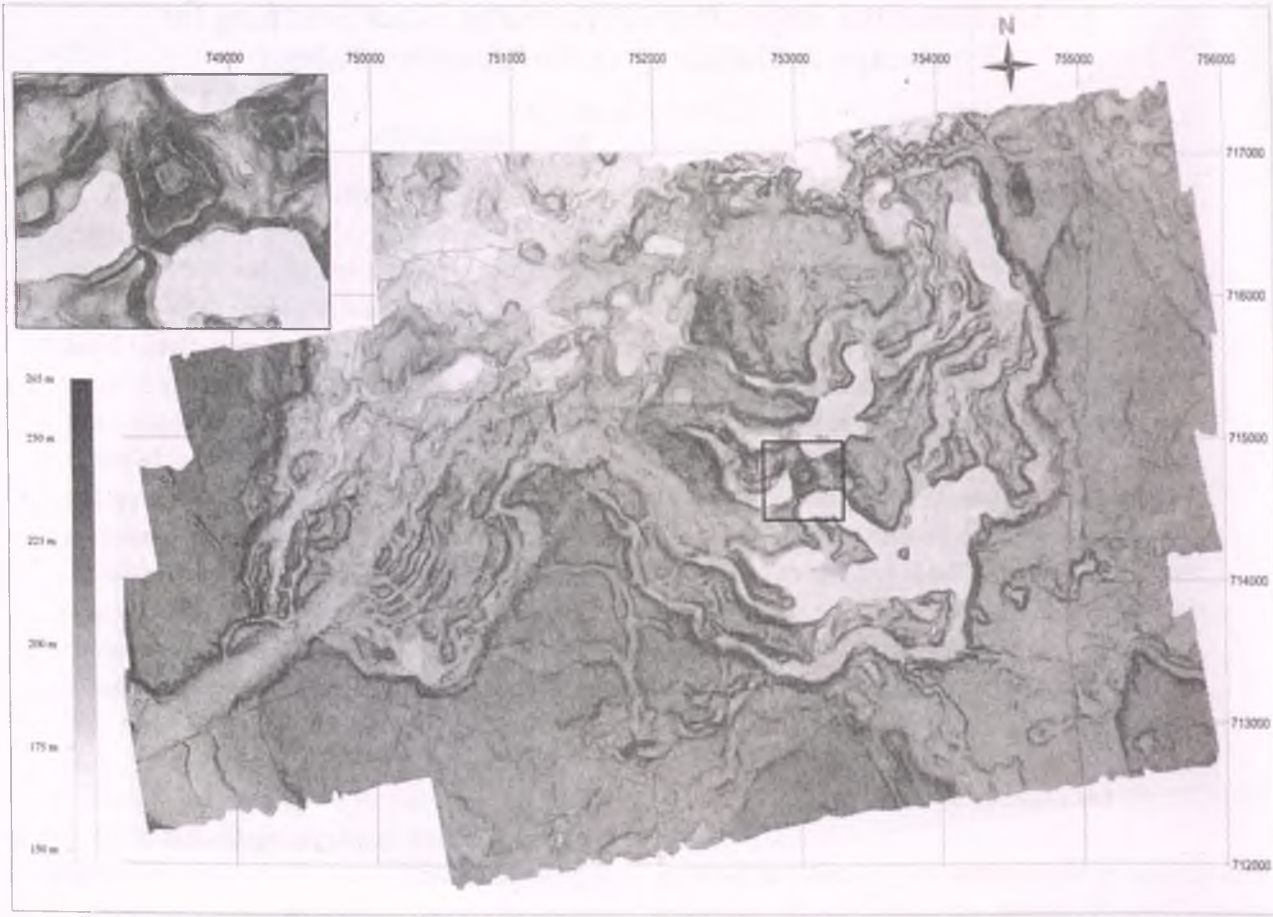

Fig. 1. DTM of the Szurpiły area (Suwałki District), CRS EPSG:2180

ed with the rich multicultural history of the region dated to modern times. These are the remains of houses and cemeteries of different faiths, different kinds of embankments and ditches on the property boundaries, cuttings relating to the drainage area, relics of trenches, bunkers and other war fortifications.

Because of the intensification of the use of heavy agricultural equipment on farms, the massive extraction of stones, sand and gravel, archaeological sites have been regularly destroyed since the middle of 20th century.

Due to low level of reconnaissance of the archaeological landscape and its progressive damage, it is extremely important to engage in the identification and registration of new sites and further knowledge about existing sites before it is too late.

In order to allow monument protection procedures to be put in motion, it is necessary to precisely define the various sites' boundaries and the state of preservation of known sites and use the most time and economically efficient prospection techniques to identify the still unknown archaeological components.

After the Airborne Laser Scanning (ALS) technique was presented in 2010, it was deemed that this technique perfectly accommodates to the various nuances of archaeological research and heritage protection of the Suwałki region (Doneus-Briese 2011).

Project

The State Archaeological Museum in Warsaw (SAM) managed to procure funds for an ALS project in the beginning of 2012 named "New methods for the identification and verification of the sites in Suwałki District", which was co-financed by the Ministry of Culture and National Heritage.

The basis of the project was an archaeological landscape study of Suwałki region. For this purpose, known sites were to be verified and new ones, especially with their own topographic forms, would be identified with the help of ALS survey.

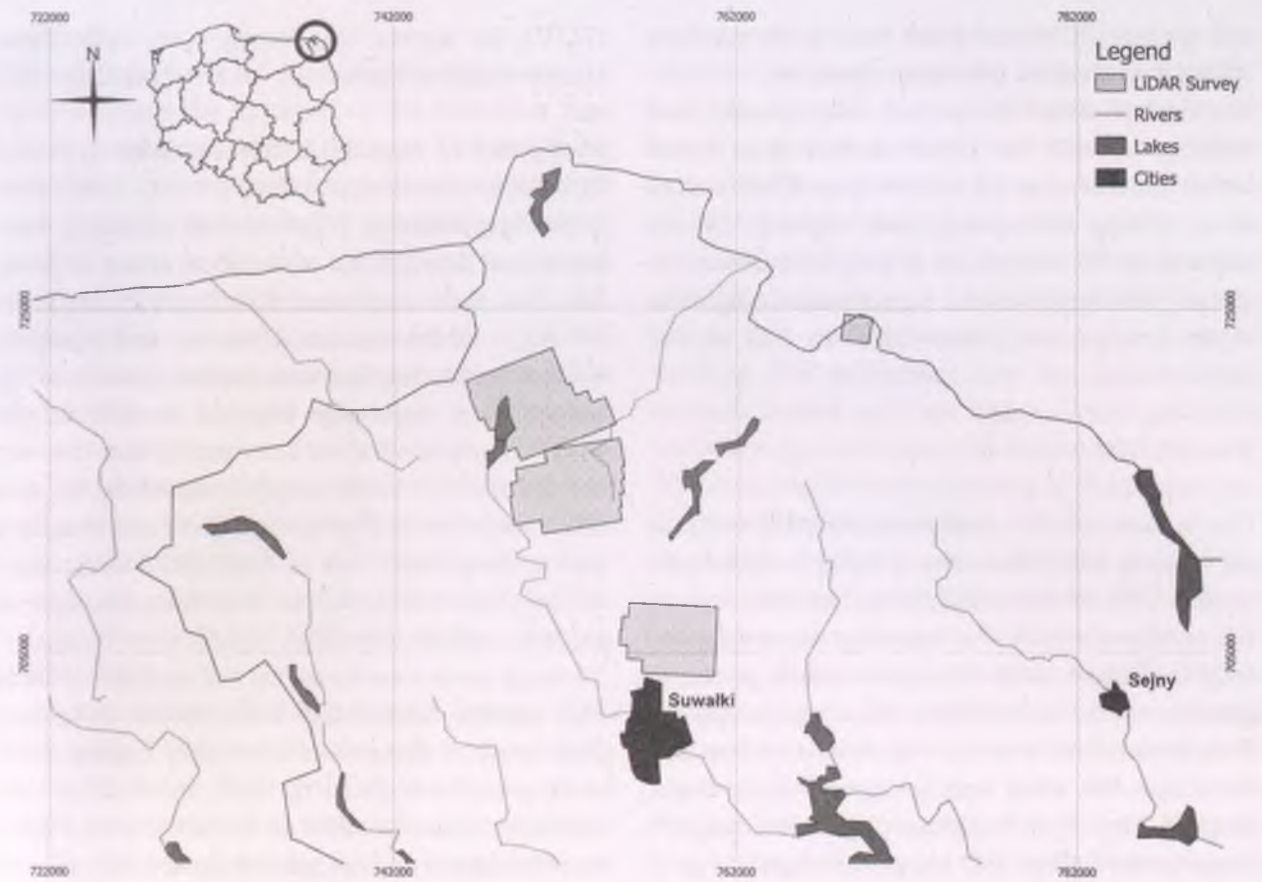

Fig. 2. Map showing the extent of the LiDAR Surveys

The end product of the research was a working DTM and DSM which would be subjected to a thorough and holistic archaeological interpretation. The interpretation model apart from ALS would be based on traditional field walking methods, spatial analysis with GIS software, archival and geomorphological data.

As this was one of the first few ALS projects in Poland and the first undertaken by SAM, many question surfaced whilst determining project objectives and activities.

After long consultations, four regions in the Suwałki District with a total area about 60 square kilometers were selected to scan. Natural conditions of the area and their archaeological potential were taken into account. More than twenty known archaeological sites with visible earthworks forms were registered previously in the study area, many of them by SAM, which has been researching these areas intensively over the past years.

Among the selected, known sites were 3 hillforts, 2 hilltop settlements and over a dozen barrow cemeteries. The most famous of them is located in Szwajcaria near Suwałki, currently registered as an archaeological reserve, with many of the barrows standing reconstructed as a tourist attraction.

We hoped that the analysis of a bigger area with different geomorphological and archeological features will show all the possibilities of ALS. Selection of already known earthworks sites was done purposely in order to verify the effectiveness of ALS in the specific realities of the study area and also of the hired contractor's data acquisition techniques as well as their post-processing.

The company contracted to perform Airborne Laser Scanning was MGGP Aero. This company had several years of experience in ALS survey, analyses of obtained data, and implementation of the projects commissioned by archaeologists (Wyczółkowski 2011).

The MGGP Aero's offer provided a scan with RIEGL LMS-Q680i with the frequency of 4 pts/m^2. The measurement accuracy was mh $\leq$ 15 cm. To process the point cloud, provide a file format LAS and execute DTM and DSM were to be provided within 4 weeks after data acquisition.

The next phase of the project encompassed field walking to verify the obtained ALS data. It had lasted 3 weeks, carried out on two different occasions during the spring and autumn. It was planned to be carried by 6 people: 4 archaeologists, 1 photographer and 1 geodesist. Completion of the project was planned for the end of Dec 2012.

Realization

Due to atmospheric conditions, scanning could be performed later than the project schedule assumed. Due to snow still lying in forests and on the northern slopes, the scanning was postponed until mid-April. Once the snow melted, strong vegetation almost immediately started sprouting.

Despite constant contact with forest services and the contractor, scans were performed at the beginning of May. Due to optimizing flight routes, a larger area of about 100 square kilometers was ultimately scanned (fig. 2). Scanning parameters and data processing were as follows: flight altitude: 950 m, scan frequency: 360 kHz, scan angle (FOV): 60 degrees, the density scan: 4pts/m^2, accuracy studies: horizontal <0.5 m vertical <0.15 m.

At the end of May 2012, the contractor provided the first, preliminary, results of the scan which were quite disappointing. DTM seemed to lack in resolution and detail. A lot of technical errors were visible. The main ones were differences in height on the edges of the measured squares and interpolation errors. In this first version, the number of registered sites, especially barrows located in the woods, was almost zero. Low quality data was not only caused by forest canopy vegetation because also open areas such as plough fields and meadows also suffered from lack of detail. Four corrections of the processed data were necessary in order to achieve a satisfactory effect (fig. 1).

70 study areas were based on the analysis of DTM and archival information were chosen to be verified, most of them were previously known earthwork sites. In addition to these, other areas with visible terrain anomalies on the DTM were also to be investigated such as several clusters of potential mounds, more or less isolated hills bearing the traces of anthropogenic transformations, as well as trenches, shafts and remains of various types of

Fig. 3. The "invisible" barrow in Szurpiły (Suwałki District)

buildings.

The spring phase of field verification was performed before the approval of the final data version from the contractor. Despite the extremely unfavourable conditions (vegetation), several sites were verified. This included previously unknown possible earthwork sites. Numerous comments were reported to the contractor.

Total station geodetic measurements of forest-covered sites showed average errors in the DTM at about 50 cm in high. As a result, many barrow mounds which were found during the field walking, which reached the height of 50–70 cm and with a diameter of 2–3 m were totally not visible on the DTM (fig. 3). The same problems were observed with objects of similar size but of a different, geomorphological character, such as recesses or boulders.

Final data were verified in a second, autumn fieldwork stage. Field verification allowed reaching nearly 70 places. Half of them, already registered sites, were monitored in terms of conservation status. 25 of them, appearing to be potential barrow cemeteries, were selected in the analysis of DTM and DSM. However, the majority of them were ordinary stone piles, built by the systematic gathering of stones from the fields during the last decades. The preliminary analysis in principle ruled out their archaeological character. The remaining were identified and registered as ramparts, watchtower mounds and hilltop settlements.

As planned in the project, the information obtained from the DTM and field studies and archival data of the registered sites were gathered in the GIS database.

Conclusions

The project allowed the participants to acquaint themselves with a non-invasive method which is the ALS and its practical usage in studying the archaeological landscape of north-eastern Poland. The completed project confirmed the extraordinary usefulness of ALS in the difficult archaeological and natural setting of the Suwałki region. Good results were obtained, especially in forested areas, which are for most of the year an impassable barrier for traditional field walking surveys. ALS was also useful on hilly, swampy areas (on meadows, fields and fallow lands) which are also difficult to explore with limited manpower and funding. The obtained data is the basis for the further scientific analyses, not only for archaeologists, but also for foresters, geomorphologists and other researchers. It also has huge potential for popularizing archaeology. We hope that our collective experiences in conducting this project can help build awareness in national archaeological circles about the various pitfalls and problems with planning and implementing ALS techniques into the archaeological research record and can help to avoid problems with scanning and data processing in the future.

The first, preliminary summary of the project can be closed in a few comments:

Vegetation during the scan had the greatest impact on the reduced quality of the DTM. It resulted from the extremely short early spring. The late time of scanning most likely had the biggest impact on the relatively small number of identified potential archaeological sites. However, it is worth considering whether only the vegetation was an obstacle? It appears that only to some extent, taking into account that each new version of DTM supplied by the contractor was better.

Will a simple increase in the number of measurement points (and unfortunately higher costs) when scanning very dense forests give better results? Lack of knowledge and case studies from this area of Poland does not permit one to assume how big of an impact during ALS surveys the characteristics of the studied area have on the number of potential archaeological targets.

When selecting the scan parameters, it seems that the contractor should pay special attention to the natural and archaeological conditions of the region. It must be remembered that the contractor is not always able or willing to understand the archaeologists. Polish contractors still have relatively limited experience with archaeological surveys (treating them rather as "side jobs") carrying out mostly work for forestry and river services. A short-term collaboration, such as on this project, will not help to achieve a mutual understanding between archaeologists and contractors.

To reduce the number of problems in determining the conditions of ALS implementation, it should be clearly précised at what forest transparency ALS should be conducted, especially in areas with a short early spring. The possibility of an eventual transfer or even scan re-implementation in the autumn should be also foreseen. These activities will probably increase costs. Even though there is no guarantee for perfect weather, this action should increase the chances of better results and help the contractor clearly understand the needs of an archaeological research project, which usually differs from their typical line of work.

Another thought that comes to mind is the need for a full-time cooperation with a professional geomorphologist during the fieldwork and interpretation phase. In a strongly transformed, post-glacial terrain, his experience and knowledge is essential. It helps in solving problems with the terrain forms bearing any traces of anthropogenic transformation.

At the end, it is worth adding that the regulations of this program, co-founded by the Ministry of Culture and National Heritage, exclude the use of excavations as verification method. Unfortunately, ALS like other modern, non-invasive methods, does not answer the question whether it is the archeological site or offer clues about its chronology.

No artifacts were found on the newly discovered sites. Without using traditional excavations, it was not possible to confirm the functions of newly discovered features. It was also impossible to determine the chronology and cultural affiliation of the sites, as the basic information for the archaeologist.

In spite of these comments, the project was a success and the original objectives have been achieved. Thirteen previously unknown archaeological sites have been discovered and reported to be protected by heritage officials. The acquired information is crucial for the reconstruction of the cultural landscape of the Suwałki region.

It is extremely important to collect experience from the implementation of this type of project and performing it in Polish conditions. It is crucial to build a database of case studies revealing not only the successes of such surveys, but also (what is often omitted in articles and conference papers) the problems that occurred during their implementation. These problems are caused by many factors, the most important being that ALS is still a novelty that university education curriculum and heritage officials have not caught up with. Even though new techniques are used with much enthusiasm more and more often, local archaeologists more often than not lack technical and scholarly abilities to use them to their full potential. It is hoped that our practical experiences will be of help to researchers from Poland and Eastern Europe and allow them to avoid our mistakes in the future.

Circles in the Field through Circles in the Air: Late Neolithic Earthworks and Settlements in County Baranya, Hungary

Gábor Bertók–Csilla Gáti

Keywords: Late Neolithic, Lengyel culture, rondel, settlement, aerial reconnaissance, geophysical survey

Supported by several national and international grants,[1] we have conducted an intensive aerial archaeological survey of County Baranya, SW Hungary, since 2005. The six to ten aerial archaeological reconnaissance flights per year and the repeated examination of freely available satellite images resulted in the discovery and mapping of nearly 250 sites, including various earthworks and enclosures. Many of the sites discovered from the air were then studied in greater detail by collating the data with archive information, fieldwalking, geophysical surveys, and test excavation. Lately, the range of non-invasive methods we apply was broadened to include LiDAR and digital infra-red photography.
One of the main archaeological results of the integrated use of the afore-mentioned methods was a fundamental change in our view of the Late Neolithic settlement system in County Baranya and the neighbouring areas.

Mostly showing up as cropmarks and soilmarks, 33 more-or-less destroyed earthworks dating from various prehistoric periods have been documented during the surveys in County Baranya (Bertók *et al.* 2008a; Bertók *et al.* 2008b; Bertók–Gáti 2009; Bertók–Gáti 2011). Based on surface finds, 18 of these monuments can be securely assigned to the Late Neolithic Lengyel culture, while another three or four can be tentatively be regarded as Neolithic (the reason for the uncertainty is that the latter enclosures "look like" Neolithic ones, but we have not had the chance yet to collect dating material from them).

The Neolithic settlement system in our area has not been systematically surveyed in the field. The results of earlier research (cf. Kalicz 1983-84; Zalai-Gaál 1990a, 1990b), as well as the fmdings of large-scale rescue excavations in western and southern Transdanubia in the 2000s indicated a dense network of settlements, some of them including circular earthworks (Somogyi 2007; Osztás *et al.* 2004; Tokai 2008; P. Barna 2005). However, a genuine breakthrough in this field of research only came after systematic aerial and field surveys were begun in County Baranya in 2005.

Showing up as cropmarks in wheat, the remains of an enormous earthwork were photographed by Otto Braasch with a smaller, triple-ditched enclosure adjacent to it in 2003 near Pécs in County Baranya. He gave the photos of the enclosure he later nicknamed "Mother of all Henges" to the Aerial Archaeological Archive of Pécs, but the site was not examined further at that time (Braasch 2007, 89, 94).

Unaware of Braasch's results, we also "discovered" the site in 2005 (pl. 6.2), at the beginning of the aerial archaeological survey campaign funded by the European Landscapes – Past, Present, and Future project. Surface finds indicated that the Szemely site, as well as a number of other circular earthworks photographed since date from the same period, namely the Late Neolithic Lengyel culture. These results kick-started our efforts to investigate in detail the Late Neolithic settlements in our area (Bertók *et al.* 2008b). We have applied an integrated methodology, whereby

- site detection has been carried out mostly by repeated aerial surveys that have been supplemented by the scanning of freely available satellite imagery (pl. 6-7) since 2010;
- dating material has been collected from each "aerial" site through field surveys;
- finer details of the plan of several sites have been acquired by geophysical surveys (figs 1-3);

[1] Our research has been supported by several grants, including the European Landscapes – Past, Present and Future (reg. no. 2004-1495001-001-CLT CA22 within the EU Culture 2000 framework), the grants NKA 6031/0010, 2731/0009, 2731/105 and 2731/137 of the National Cultural Fund of Hungary, and recently by the Archaeolandscapes Europe EU Culture 2007-2013 framework (reg. no. CU7-MULT7, Strand 1.1 Multi-Annual Cooperation Projects).

Fig. 1. Magnetogram of the two rondels of Szemely

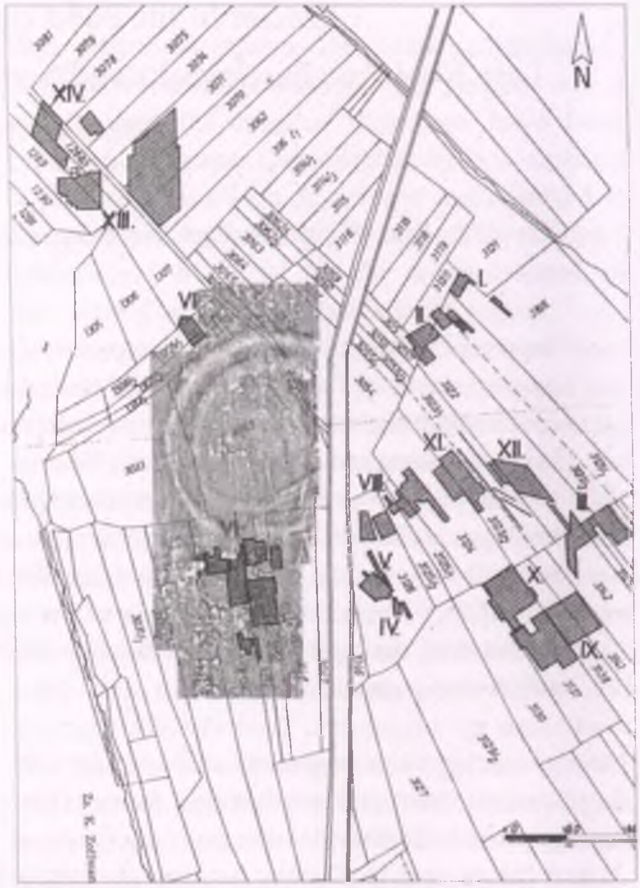

Fig. 2. The former trenches of J. Dombay's excavations at the Neolithic settlement of Zengővárkony and the rondel explored by geophysics

- excavation data, collected both by ourselves and by others, were included in the site assessments and site interpretations;
- the majority of the sites were subjected to LiDAR survey to see whether any further details could be discovered.

Though our project has lasted for eight years now, new sites still show up both during aerial surveys and on newly published satellite images. The latest discoveries seem to fill the gap in the network of Lengyel settlements between the area north-east and south of the Mecsek Mountains, on the border between Baranya and Tolna counties, but some new sites were also detected in 2012 in our core research area south of the Mecsek Mountains.

Our investigations revealed a settlement network with a much higher density and complexity than was earlier expected. It would appear that "mega-cities" covering more than 50 hectares and circular earthworks constructed in association with these settlements in the research area during the Late Neolithic are not rare phenomena, but a "natural way" of using the landscape.

The Belvárdgyula site (pl. 7.1) provides a typical example: the settlement itself was found during fieldwalking that preceded motorway construction (Bertók *et al.* 2008a). The site was partially uncovered in 2007 and 2008 as part of the salvage excavations. A rondel was discovered on the northern edge of the settlement in 2007 by aerial photography. The following year, we conducted a magnetometer survey and surface find collection that proved that the settlement and the enclosure were contemporary.

Another major event in 2007 was the discovery and geophysical survey results of the rondel at the well-known Lengyel site of Zengővárkony, which came as a genuine surprise since large areas of the settlement had already been excavated in the 1930s and 1950s by J. Dombay (Dombay 1939, 1960b). He uncovered over 350 graves and nu-

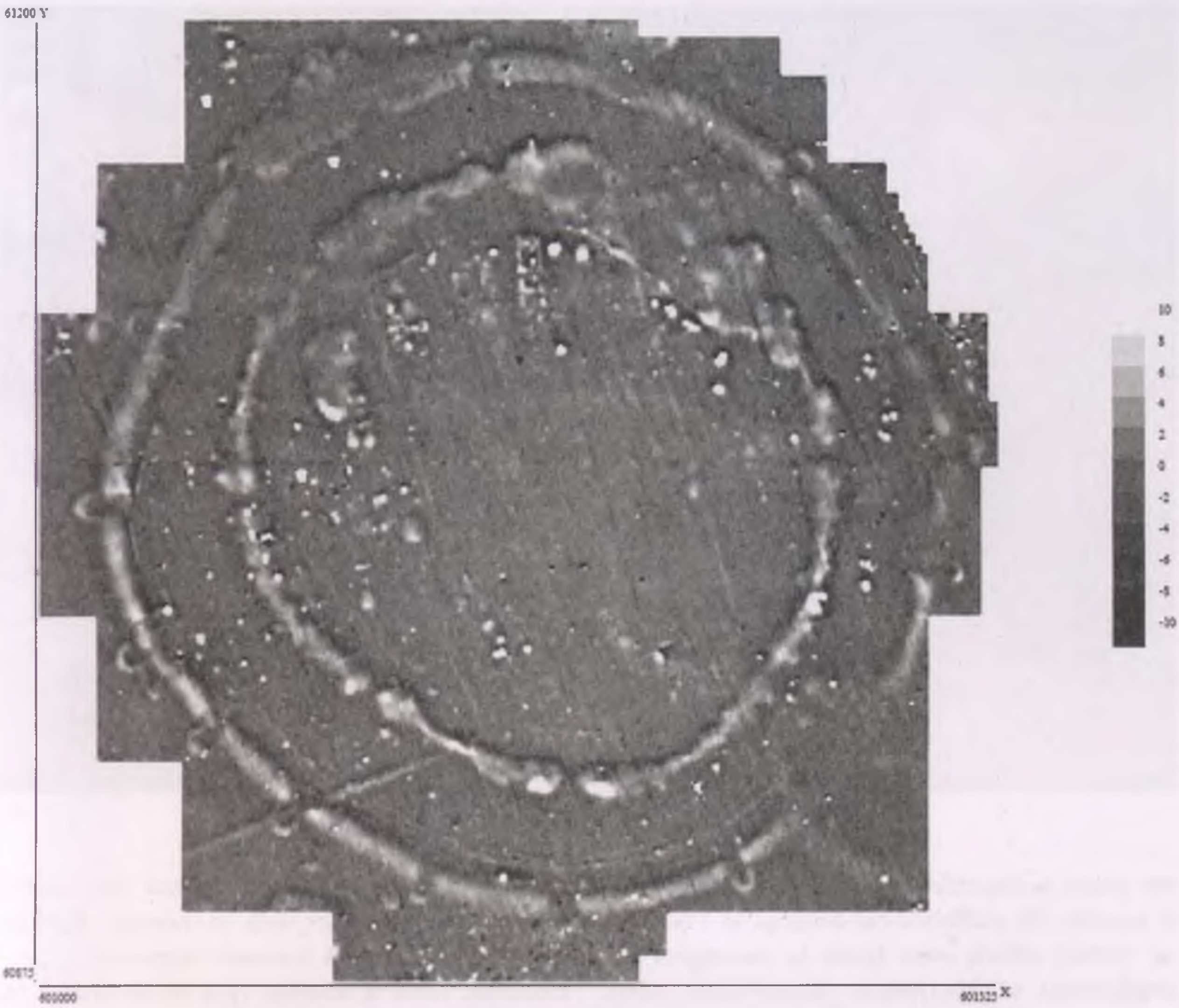

Fig. 3. Result of the geophysical survey of the Villánykövesd rondel

merous settlement features, and he was among the first archaeologists to have the site and its broader area photographed from the air; however, he did not detect any traces of major earthworks. Ironically, the comparison of his maps and our rectified aerial images and geophysical survey map shows that by accident he had opened his trenches all around the enclosure, never once intersecting it. Therefore, he had no chance of realising the complexity of the settlement, no matter how thorough his efforts were. The latest results show that – no matter what we could achieve using a different approach – our knowledge of the site is still incomplete. Published by Google in 2012, a satellite image shows an oval enclosure with a diameter of 260 m in the field next to the south-eastern boundary of what was considered as "the Zengővárkony Lengyel site". Surface finds indicate that this feature also belongs to the Lengyel period, thus extending the area of the site by almost a third (fig. 2). Though not a typical Lengyel rondel, this oval enclosure has good parallels in our area and may rather be considered as one that surrounded either an entire settlement or a part of it.

Another since long known Lengyel site lies near the village of Villánykövesd, which was also investigated by J. Dombay in the 1950s (Dombay 1960a). Dombay conducted a field survey in the broader area of the Late Neolithic settlement and opened a few trial trenches; he found that the site extended across an area larger than a square kilometre.

His excavation results were similar to those at Zengővárkony: he identified groups of graves and "dwelling pits", but could not gather more information on the site's general layout.

István Zalai-Gaál performed the first aerial archaeological survey of the area in 1987. Being a researcher of the Late Neolithic, he specifically searched for rondels and other settlement features of the period, taking photos of the Villánykövesd

Fig. 4. Enclosed Lengyel site near Nagykozár in Google Earth

site where he identified several soilmarks as possible rondels. He published his findings in 1990, but no further efforts were made to investigate the implications of his results (Zalai-Gaál 1990a; 1990b).

During our aerial surveys, we also identified and photographed the site, noting that at least one circular enclosure lay next to the settlement (pl. 7.2). Between 2009 and 2011, we had the opportunity to perform a magnetometer survey of the suspected rondel (fig. 3). While the feature always showed up as an indefinite, double circular mark on aerial images, the enclosure turned out to be a highly complex structure of two major concentric ditches with several interruptions, augmented by U shaped extensions on its outer perimeter. On the inner side of each main ditch ran palisades, of which the outer had a triple line.

The interior of the structure seems mostly empty, apart from its northern side where two or three longhouses and other traces of occupation can be found. The houses seem to be in alignment with the inner palisade, so they may be contemporary.

Several of the Late Neolithic earthworks found in County Baranya seem to conform to the "classical" category of rondels and may be characterised by a cultic/communal function, but they exceed most of their counterparts in Austria, Slovakia and Germany both in size and complexity.

However, there is another type of earthwork we have identified in our research area. The builders of these latter enclosures did not intend to create structures with a regular circular plan; the surface finds suggest that these earthworks with an irregular oval plan, such as the ones at Magyarsarlós, Feked and Nagykozár, and perhaps also the outer ditches of the larger enclosure at Szemely, surrounded entire settlements and possibly served a defensive purpose.

Accordingly, from the viewpoint of settlement structure there were

- open settlements without any (known) earthworks;
- often large, open settlements without defensive structures around them, but with circular enclosures associated with them (Belvárdgyula, Villánykövesd, Máriakéménd);
- settlements entirely enclosed by earthworks (fig. 4) with a possibly defensive function (Nagykozár, Feked, Magyarsarlós);
- settlements including both types of earthworks (Zengővárkony, Szemely).

This varied settlement typology may be the first direct evidence of an otherwise logical assumption: the 6–700 year long period in question was not uneventful, it had its own history of peaceful and violent phases to which the population tried to adapt. At the same time, these earthworks serve as proof of the economic power of the communities that were capable of providing for their members taking part in their construction and maintenance.

We can therefore conclude that we now have a far more detailed picture of the Late Neolithic earthworks and settlement structure than before we began our integrated survey. We not only know of more of these features, but we have also gained a better understanding of their internal structure, and can distinguish several types of enclosures and settlement types.

However, it remains a task for further research to determine whether these differences have a chronological, functional, social or other significance.

From the viewpoint of methodology, we could draw the conclusion that the integrated use of various remote sensing and other non-invasive methods in archaeological prospecting can fundamentally change our knowledge of the archaeological heritage of an area.

Archaeological and pedological investigations at the fortified Bronze Age settlement of Perkáta–Forrás-dűlő

László Reményi–Ákos Pető–Árpád Kenéz–Szandra Baklanov

Keywords: Bronze Age, Vatya culture, Carpathian Basin, Perkáta, geoarchaeology, LiDAR, settlement pattern

The goal of the archaeological research project in the catchment area of the Cikola watershed system was the reconstruction of the structural changes in land and landscape use based on the archaeological record. The area was first intensively settled during the Bronze Age, when communities of the Vatya, Tumulus and Urnfield cultures established their settlements. The chronology of the successive occupation periods is vital in the reconstruction of settlement patterns, as is the knowledge of the spatial pattern, layout and stratigraphy of the archaeological sites of each period. In addition to the topographical survey of the study area through field surveys, aerial archaeological reconnaissance and the assessment of archival records, we systematically surveyed the Perkáta–Forrás-dűlő site and conducted pedological and geoarchaeological investigations. Our field investigations were aided by the archaeological interpretation of aerial photos and a terrain model generated by a LiDAR survey.

Bronze Age settlement patterns in the Cikola catchment area

We identified some fifty Bronze Age sites over the 300 km² large area of the catchment area in the course of traditional archaeological topographical data collection that included the field survey of almost the entire study area, as well as the review of the relevant archaeological literature and archival records, and the assessment of earlier aerial archaeological photos. The sites all lie on a north-west to south-east loess hill range extending across the study area; we did not find any Bronze Age sites on the more gentle slopes and in the western part of the study area criss-crossed by smaller watercourses preferred in other periods. The settlement network of the Vatya period (Reinecke BA2–BB, 1900–1450 BC) showed an even greater concentration: with the exception of a single site, the period's sites were all established on the southern, higher-lying part of the loess range, generally along the plateau's steep slope. The layout of the sites was more or less identical: the hill spur was cut off with a ditch and the extensive outer settlement was often also bounded by a ditch. Several smaller and less intensively occupied Bronze Age sites were identified beyond the ditch at a number of locations. The interpretation of the latter sites is aided by the fact that a site of this type could be clearly identified as a Bronze Age urn cemetery at Perkáta–Sánc-dűlő.

Two settlements and a cemetery lying close to each other can be securely dated to the Tumulus period (Reinecke BC, 1450–1250 BC). The area was more intensively settled during the Urnfield period (Reinecke BD–Ha B, 1250–800 BC): the period's sites in part overlie the earlier settlements of the Vatya culture and are in part located in a broader area, on the more gentle slopes of the loess hill range.

The complex investigation of the Perkáta–Forrás-dűlő site: vertical and horizontal structure

The site was identified during aerial archaeological prospecting (Czajlik 2004). The deep ditch separating the hillfort and two additional concentric, semi-circular ditches, as well as the ditch enclosing the roughly 400 m by 300 m large outer settlement could be clearly identified on the aerial photos and the terrain model generated after the site's partial LiDAR survey (pl. 8).

Finds of both the Vatya and the Urnfield period were collected in the area of the outer settlement during the intensive field survey, conducted repeatedly over the site under good visibility conditions. In order to clarify the spatial patterns of the two occupations, the outer settlement, the concentric ditches near the hillfort and the ditch enclosing the outer settlement, we laid out 10 m by 10 m grids that were systematically sampled. The results indicated that the finds of the Vatya culture were scattered across the entire site, while artefacts of the Urnfield culture showed a concentration in those parts of the outer settlement that lay near the hillfort. The area of the hillfort could not be systematically sampled because it was covered by an artificial acacia grove and shrubs, and we could only collect finds in the areas disturbed by foxholes. We collected a fairly high number of Vatya pottery sherds and intact vessels from the disturbed archaeological layers, but we did not find any artefacts typical for the Urnfield period. We investigated the vertical structure of the hillfort using geoarchaeological and archaeological pedological analyses.

Methodology and preliminary findings of the geoarchaeological analyses

We performed the systematic pedological survey of the hillfort and the outer settlement; however, the borings supplemented with detailed geoarchaeological analyses were focused on the area of the hillfort (pl. 9). The pedology and stratigraphy of this roughly 21,000 m² large area were investigated with ten shallow geological borings. The aim was to gain an overall picture of the soil formations and the position of the occupation levels, as well as of their position relative to each other.

We submitted samples from the two designated representative cores to pedological laboratory analyses (pH [HOH, KCl], CaCO3% TOC%, P_{total}, K_A) in order determine as accurately as possible the levels affected by human occupation and to distinguish the occupation phases from each other based on the physical and chemical properties of the soil material. The detailed archaeobotanical analysis of the cores (pollens, seeds, charcoal and phytoliths) and the radiocarbon dating of the occupation levels are currently in progress.

The ten shallow geological borings in the area of the hillfort were extended to the parent material underlying the occupation layer. The cores indicated that the parent material is in part sand of fluvio-aeolian origin and in part loose aeolian loess sediment. The area's stratigraphy is made up of three units of different genetic origin: 1) the sand deposited during the Holocene as a result of fluvial and aeolian processes, and loess, 2) the overlying human occupation deposit, and 3) the uppermost aeolian sediment and the recent soil formation covering it.

The cores from the outer perimeter of the hillfort indicated faded yellow (2.5Y 8/4) loess with a high carbonate content, while the cores from the inner area were made up of light yellow (2.5Y 7/4) unconsolidated sand with a high carbonate content.

The thickness of the occupation layer ranged between 190 and 20 cm, suggesting that the occupation layer which had a more or less similar thickness had thinned toward the fort's perimeter owing to erosion after its abandonment. The macroscopic traits of the occupation layer observed in the field were identical in all the cores. The base of the core was made up of soil rich in humus mixed with the bedrock, suggesting that the area was covered with a topsoil at the time the settlement was established. It would appear that the human occupation led to the degradation of this soil because nowhere else did we detect this soil layer in an intact position. The cores contained various indications of human activity: fragments of burnt daub, pottery fragments, animal bones, fish scales, charred grains, charcoal and ash. The occupation layer was strongly disturbed both as regards its colour (dark brown, light brown, grey) and its texture, and it was often burnt.

The macromorphological observations made in the field and the laboratory analyses of the occupation layer confirm the archaeological assumption that this anthropogenic layer, which accumulated to a thickness of 2 m in several spots, reflects different intensities of land and landscape use. This is indicated by the wide range of textures ranging from fine sand to clay and their frequent alternation, and the fluctuations in total phosphorous concentrations reflecting human activity.

The occupation layer of the hillfort is covered by a well-sorted, greyish (2.5Y 6/1) sediment with loamy properties of probably aeolian origin. The soil overlying this sediment could be characterised as a chernozem-like soil formation. The thickness of this layer ranged between 50 and 70 cm in locations where the surface was not eroded. The fact that undisturbed soil formation had begun over the occupation layer reflecting intensive settlement would suggest that the site was not re-settled in other archaeological periods after the departure of the community occupying the site.

Summary

Following a scanty Neolithic Linearbandkeramik occupation, the catchment of the Cikola watershed system was first intensively occupied during the Bronze Age, when sites of the Vatya culture appeared along the steep perimeter of the loess range. The settlements featuring a hillfort separated from the extensive outer settlement by one or more ditches can be assigned to the fortified hillforts of the Vatya culture, of which over fifty are currently known (Kovács 1984). The presence of an urn cemetery beside the fortified settlement could be securely established in one case and tentatively assumed at other sites. We identified a thick occupation layer at Perkáta-Forrás-dűlő in the cores from the shallow geological borings, suggesting that similar sites, which in the lack of stratigraphic data were earlier regarded as pseudo-tells (Kovács 1969; Bóna 1975, 57–59), can be interpreted as genuine tell settlements not only in terms of their social and economic role (Gogâltan 2002; P. Fischl–Reményi 2007), but also regarding their stratigraphic properties. Following the area's less intensive occupation during the Tumulus period, the sites of the Urnfield culture could be recorded across a much wider area than in the Vatya period. At the same time, the lower-lying areas that were more intensively settled during later periods remained uninhabited.

Borders. The problems of the aerial archaeological reserach of a Roman *limitatio* in Pannonia

András Bödőcs

Keywords: *centuriatio*, *limitatio*, cadastral system, Roman road, aerial archaeology, Savaria, Pannonia, GIS, predictive model

During the past five years, we had the opportunity to build up a research method series in order to prove and verify the Roman land allocation system in the broader area of Szombathely (County Vas, western Hungary), the oldest continuously populated town of Hungary. These methods are derived from the "classical" landscape archaeology package: the combination of GIS modelling, aerial archaeological reconnaissance, field survey and geophysical prospection. The focus of our investigations more recently was the extent of the Roman cadastral system (called *limitatio*) and its impact on the landscape.

Introduction

With the support of the Hungarian Scientific Research Fund (OTKA), the Zoltán Magyary Fellowship and, more recently, of the János Bolyai Research Scholarship of the Hungarian Academy of Sciences, a structured research project was initiated for new studies in this field, a rather neglected area in Hungarian archaeological research.

The project is essentially based on a model presented earlier in the form of a PhD dissertation (Bödőcs 2008) and of a MSc thesis (Bödőcs 2009), in which I proposed a new basic grid reconstruction of the ancient cadastral system of the Roman colony of Savaria (Szombathely). Following the GIS-based analysis of Roman roads in 2008, an interesting relationship was noted between some ancient road sections; the post-processing of their coordinate values led to the calculation and reconstruction of a theoretical grid. This reconstructed grid layout was employed to detect possible vestiges of the Roman cadastral system on various, already accessible aerial and satellite images, e.g. it was adapted to Google Earth. During the detailed examination of these aerial and satellite images, new potential sites were registered in 2009, which were treated as preliminary results. The new data thus gained enable the fine-tuning of the theoretical reconstruction model and our pilot project was to test the model in the field through aerial archaeological investigation.

The grants mentioned in the above permitted a series of targeted aerial archaeological flights along this virtual grid. We spent over thirty hours above the study area in western Hungary. The reconnaissance was carried out by Zoltán Czajlik, whose expertise ensured the project's initial success already in 2010, despite the nowhere near ideal weather conditions for aerial archaeological reconnaissance. We also had the opportunity to conduct a brief archaeological field survey and geophysical prospection to test our model for further research.

The research objective

The project's goal was to study the so-called *limitatio* (or *centuriatio*) of the Roman colony of Savaria. Savaria had been established in the mid-1st century AD, during the reign of the Emperor Claudius (Mócsy 1974). While the many still unresolved problems surrounding the foundation of the settlement is not the subject of this paper, the land allotment is directly connected to our research project. One of the many questions is how and why had the colony been founded at the time when the province of Pannonia was still in the phase of formation.

There is epigraphic evidence that the veterans of the *legio XV Apollinaris* had been settled in this region (RIU 1, 185; RIU 1, 146; RIU 1, 145; RIU 1, 194; RIU 1, 213; RIU 1, 32; RIU 1,149) and that the surrounding area was divided and allotted among them. Accordingly, research on the *centuriatio* plays an important role in the reconstruction of the town's first period, as well as of the province's early history. In 1965, András Mócsy proposed a hypothetical reconstruction of the

town's street system (Mócsy 1965) based on surviving traces of the road and the hydrological network, as well as on the forest borders that had the same or a perpendicular alignment. Endre Tóth based his reconstruction of the entire assumed territory of Savaria on more or less the same evidence (Tóth 1977a). Despite the attractiveness of their theoretical reconstruction, the lack of adequate archaeological data means that many uncertainties remain regarding the exact line of the colony's boundaries and how and which regions were pacified by the Roman settlers (fig. 1).
The development-led excavations on the former territory of the colony during the past decade have brought to light Roman road sections (Ilon 2001, Redő 2006, Mátyás 2007). These sections can be interpreted as part of the *centuriatio*, even though they have a different size and orientation than previously reconstructed (Bödőcs 2009). Based on this new theoretical reconstruction model, we began a topographical project to determine the finer details, the boundary and the extent of the Roman land plot system and of the territory of Savaria.

Fig. 1. Location of *colonia Claudia Savariensis*

Aerial archaeological examples

First, we tried to gather evidence that would confirm our hypothesis of *centuriatio*, and thus we had to search for and document the surviving remains of gravel roads, ditches (channels) and visible boundaries on the available material such as archive oblique and vertical aerial photos, Google Earth images, etc. With help of a some kind of "black lines"-tools created in GIS environments (in various projections and file formats), we were able to identify cropmarks and soilmarks that had a very convincing correspondence with our model, fitting into it like the pieces of a huge jigsaw puzzle.

1. Vasasszonyfa (HUN)
Soilmarks enabled the identification of a wide road or ditch (channel) junction in the location where it was assumed to be in the predictive model on images taken from Google Earth dating from 2003. The form, the size and the alignment of this feature leaves no doubt that it can be identified as the boundary of a *centuria* unit of the Roman land plot system (fig. 2).

2. Bildein (A)
The Google Earth images were also helpful in identifying a visible cropmark feature on the satellite images lying immediately beyond the current Hungarian border. This rectangular linear feature is similarly consistent with the model regarding its size and orientation (fig. 3).

Aerial archaeological reconnaissance

Following our successful search for possible traces on earlier vertical photos, we organised short test flights arranged along our grid model. The theoretical "grid corner" coordinates were used as guide points during the prospection and the targeted areas were the ones where there was a promising concentration of road or ditch-like features identified from the preliminary examination of maps and photos. To ensure positive results, we first flew over the broader area of the one-time colony because the land in that area was certain to have been centuriated as indicated by the excavated Roman gravel road sections mentioned above.

1. Vép (HUN)
A Roman road leading eastward from Savaria crosses the area in question. This road is well known from Endre Tóth's research (Tóth 1977b). Unfortunately, no cropmarks were visible during the flight; however, the line of this road can be traced clearly on the Google Earth map and other archive photos. The road could be interpreted as the east-west main axis of the Roman land use

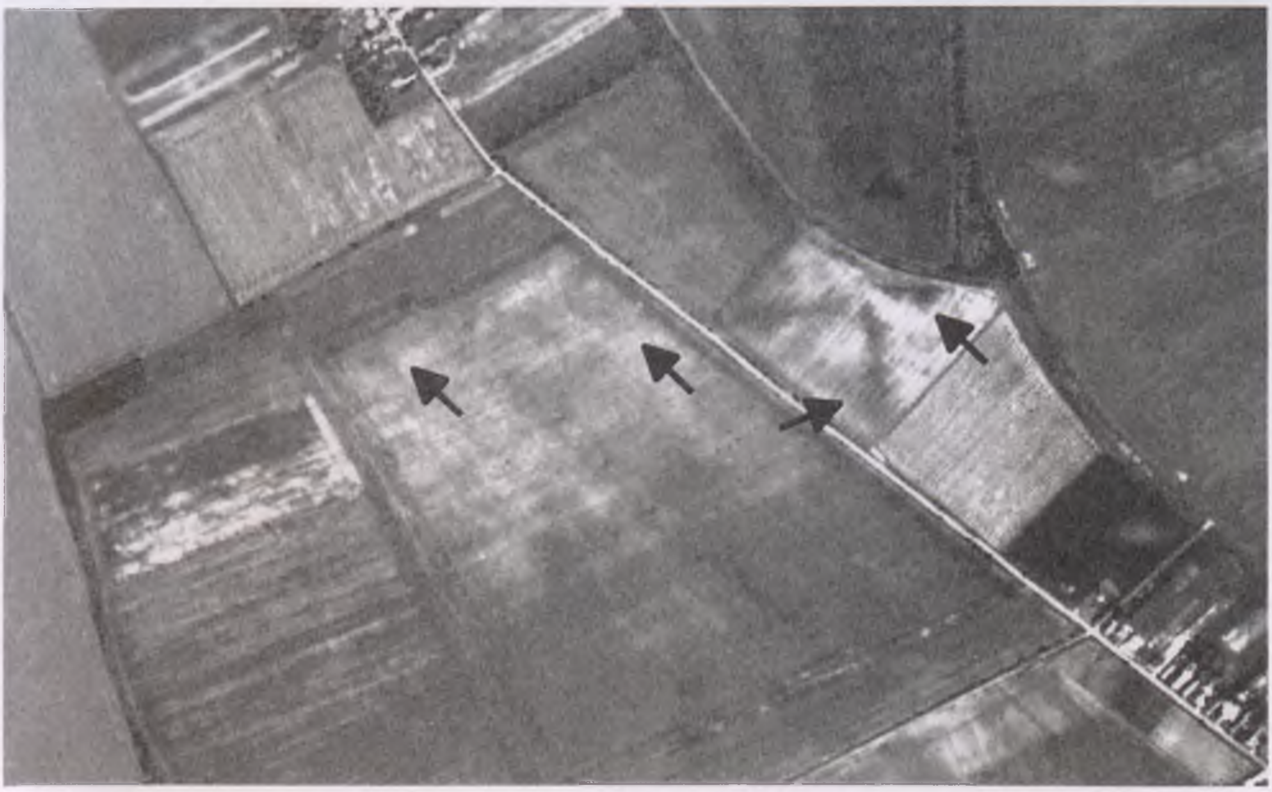

Fig. 2. Vasasszonyfa-Tüskés. *Centuria* border (source: Google Earth)

Fig. 3. Bildein (A). *Centuria* border (source: Google Earth)

system, the so-called *decumanus maximus* (Bödőcs 2009; Bödőcs–Kovács 2011; Czajlik *et al.* 2012b). Despite the absence of any visible traces of the road, other features of interest could be identified in the target area. One of these was a north to south aligned linear feature crossing the fields that could be interpreted as the border-road (*limes*) of the Roman cadastral system based on our model. Other parallel features visible in the area perhaps indicate the inner divisions of a *centuria* (fig. 4).

2. Rum (HUN)

In the summer of 2010, the rainy weather was not too favourable for aerial survey, but this year, we had the opportunity to test the correctness of the model in the field. We were able to identify the double ditches of a Roman road from cropmarks

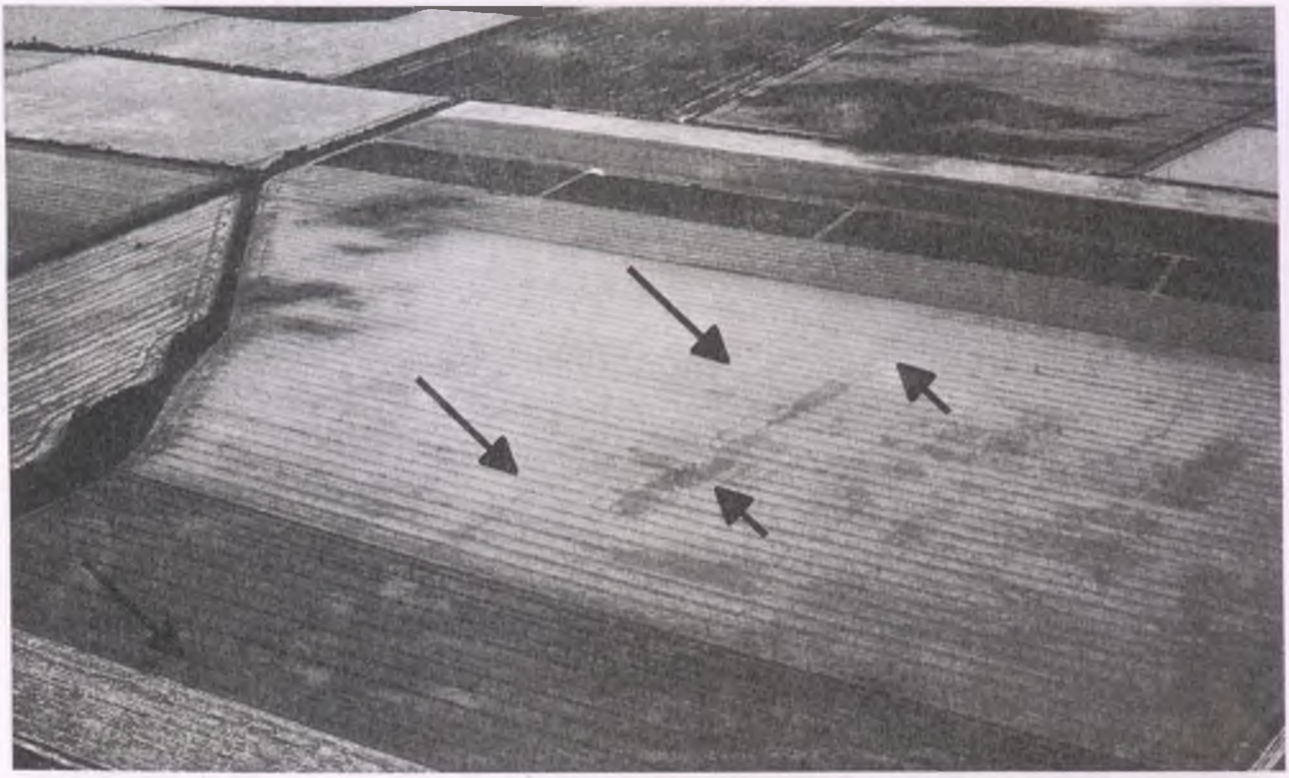

Fig. 4. Vép. (photo: Zoltán Czajlik, 28.06. 2010)

in the south-eastern part of the colony's assumed territory (fig. 5). The size, the location and the orientation conformed to the expectations, the documented Roman road was of the same type as the excavated parallels. The distance between the two road ditches was ca. 5.4–6 m, conforming to the width of the known Roman gravel roads unearthed near the colony (ILON 2001; MÁTYÁS 2007).
Because the aerial reconnaissance had yielded very interesting results, the investigation was expanded to include the possible boundary of the colony's one-time territory. The potential region was searched for remains that would fit the predictive model. It is still too early to link the (road)marks documented in this region to the Roman land plot system, but the planned, detailed topographical survey will hopefully verify an association between the two.
The most interesting locations in these regions lie in the eastern and north-eastern boundary zone of the colony's assumed *territorium*.

3. Külsővat (HUN)
There are many visible features indicated by cropmarks and soilmarks that correspond to the orientation and location of our reconstructed grid on the outskirts of Külsővat. This zone is located along the River Marcal, east of the River Rába, where many sites from the Roman Age have been documented (MRT 4, Site No. 4/40). These include a few dating from the turn of 1st–2nd centuries AD (MRT 4, Site No. 4/6, 4/10; VIDA 1996). The presented aerial archaeological site photographed in 2010 is a potential road junction on the *centuria* border, indicated by light linear cropmarks. There were no similar linear features of this type on the photos known until 2012; however, the images published on Google Earth in 2012 from this area contained some parallel and right-angled linear soilmarks, including our previously photographed location. The preliminary photogrammetrical measuring revealed that the distance between these lines is roughly 240 Roman feet (*pedes*), i.e. 2 *acti* and all of them correspond to the hypothetical model (fig. 6).

FIELD SURVEY

Parallel to the aerial reconnaissance, we also wanted to test the feasibility of the model in the field and thus we conducted control field surveys in the areas where Roman land allotment can be taken for certain. An approximately 50–100 m wide buffer zone was checked along the hypothet-

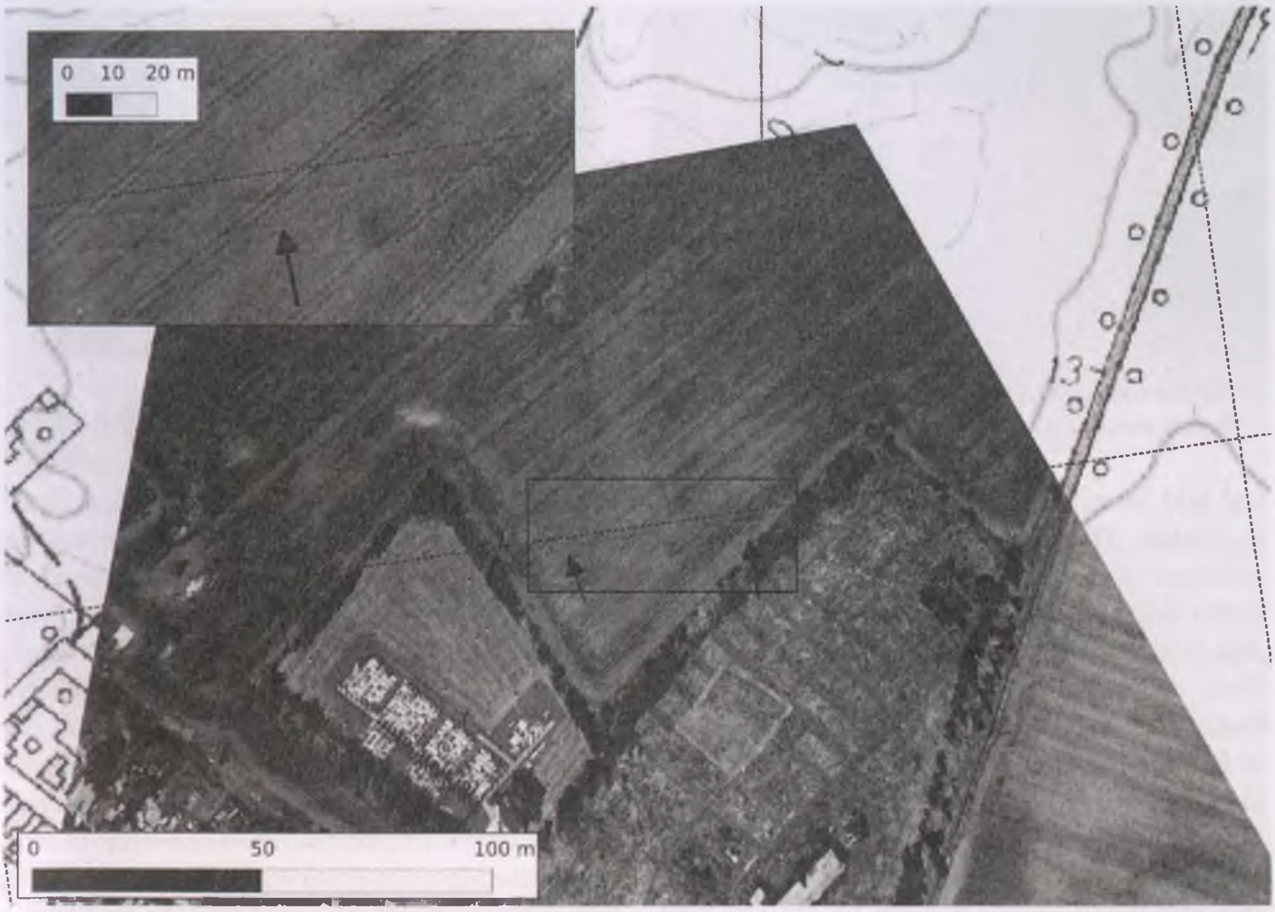

Fig. 5. Rum (photo: Zoltán Czajlik, 28.06. 2010)

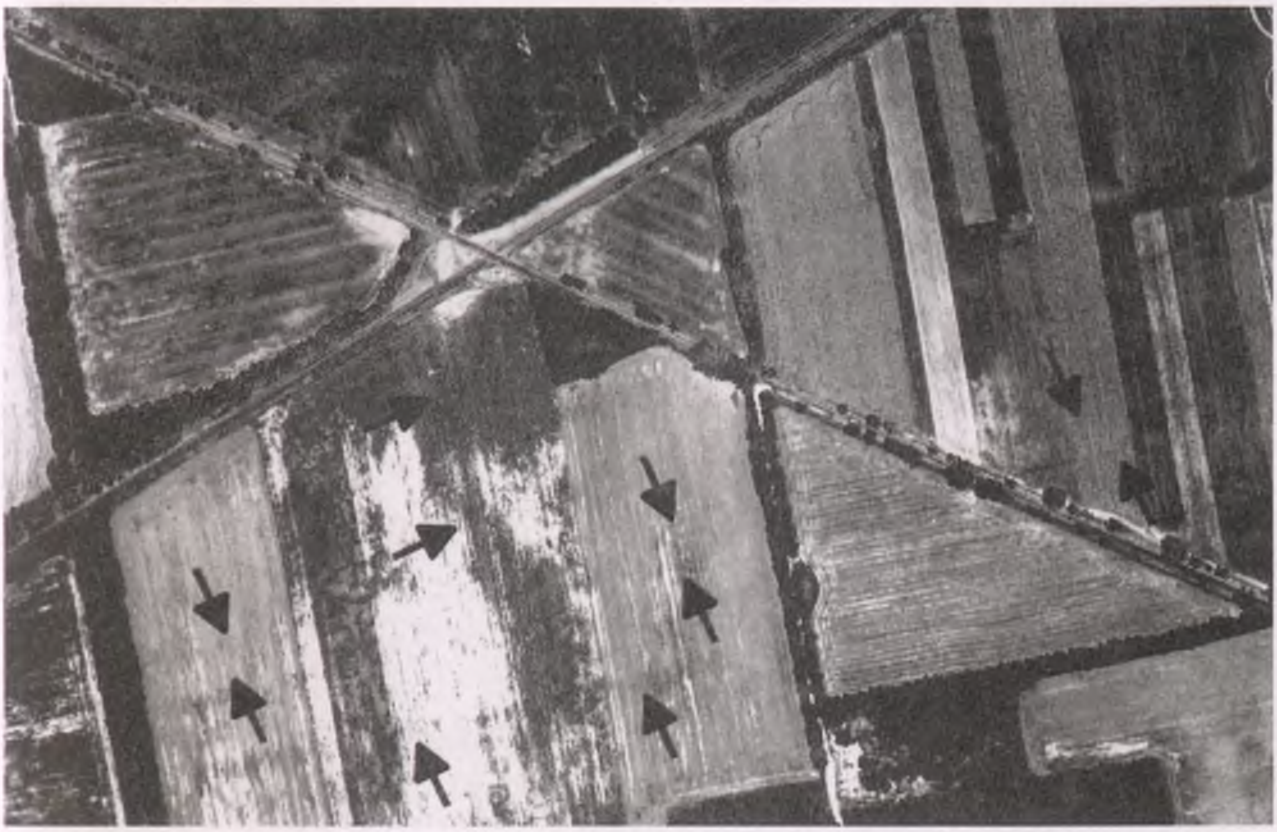

Fig. 6. Külsővat (photo: Zoltán Czajlik, 28.06. 2010)

Fig. 7. Buffer zones of the field walkings (source: Google Earth)

ical grid lines, along the one-time ancient boundary roads. The basic concept was the assumed existence of Roman sites along the lines in the buffer zone yielding material from the Roman Age, from the turn of the 1st and 2nd centuries AD. This concept was based on the excavation findings of the past decade, namely the discovery of Roman graves and settlement remains near the identified road sections (Ilon 2001, Bíró 2006, Mátyás 2006). In our case, positive results and the identification of sites would confirm the association with the *centuriatio* grid (fig. 7).

We encountered several problems during the field survey, some practical, some theoretical. Firstly, we only had one season for testing our model and even though the field surveys were scheduled for the ideal periods (in Hungary, for example, the best time is after most crops have been harvested). The archaeological identification of the farm-like sites turned out to be the most relevant methodical issue because smaller Roman farms, smaller *villa*s and residential buildings are usually indicated by poor surface finds only. The one-time sporadic existence of individual farms across a wider area is one of the reasons, others being that the use-life of these buildings was rarely more than a few decades and that they were usually wooden buildings that were rarely rebuilt in stone. Very often, sites have disappeared owing to deep ploughing. We nonetheless managed to identify a handful of previously unknown sites using this method, all of which lay close to our hypothetical grid border as shown by the following few examples.

1. Vasasszonyfa (HUN)

At Vasasszonyfa, we discovered two separate sites on both sides of the assumed road junction. The

Fig. 8. Roman ceramics from Vasasszonyfa (photo: A. Bödőcs)

imbrices indicate a settlement, while the ceramics with perforated base and the various vessel types rather suggest a small destroyed cemetery. In both cases, the distance from the assumed boundary was no more 10–15 m. In addition to the Roman artefacts, we also found a Copper Age arrowhead without any other prehistoric material (fig. 8).

2. Felsőcsatár 1 (HUN)

We found traces of a small Roman settlement near Felsőcsatár near the Austrian border, west of the former colony. Similarly to the above-described site, we assumed that there was an intersection of the theoretically reconstructed *centuria* boundaries. An ancient road, usually assumed to have Roman origins, runs near the site and there are Roman sites along it. Although the remains of the so-called "katanzki put", the "soldier's road" (VMFN 34/127; Bödőcs 2008) could be identified in this location, it seems more likely that the Roman sites known from the area can be linked to the land allotment system rather than to the road of uncertain date (fig. 9).

3. Felsőcsatár 2 (HUN)

A few hundred meters west of Site 2, we found a small scatter of Roman ceramics in the field survey's buffer zone. This site was indicated only by these finds; more importantly, however, it has a very interesting location, as will be discussed below.

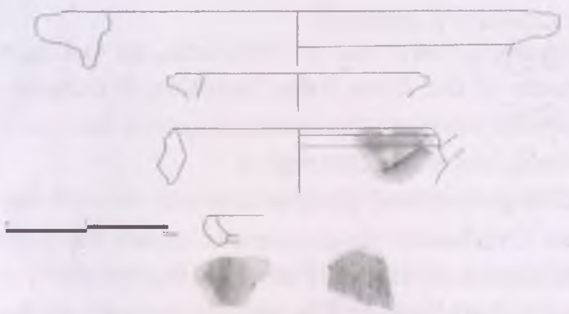

Fig. 9. Roman ceramics from Felsőcsatár (drawing: B. Simon)

4. Rum (HUN)

Remains of the above-described Roman road could not be identified in the kohlrabi fields and neither were there any finds 2–300 m to the east; however, the remains of a smaller Roman settlement were identified along this road in the field survey's zone. The bank of the River Rába was densely populated in the Roman Age, as shown by the archaeological sites recorded during previous field surveys (based on the official site register of the National Office of Cultural Heritage (KÖH) No. 43239-40, 42651, 42656, 42681-83, 64226, 64228, 64232). The visible remains of the *centuriatio* confirm the existence of the subdivision in this region and they also indicate that Savaria's *territorium* extended at least as far as the River Rába (fig. 10).

It was noted earlier that even though the model

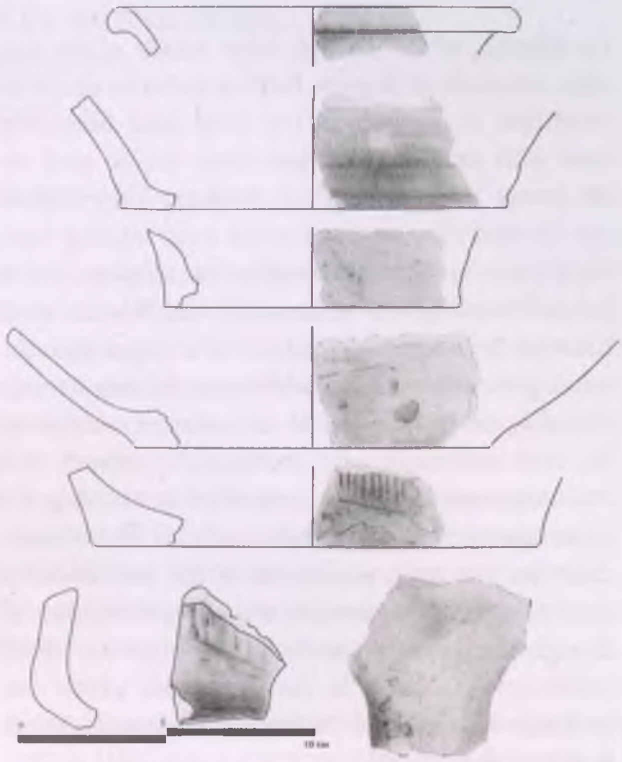

Fig. 10. Roman ceramics from Rum (drawing: B. Simon)

does not always correspond to the features in the field, the control points based on excavation data verify its goodness. The regions where the field surveys were conducted were checked again on vertical aerial photos from different sources not used previously. Following the post-processing and

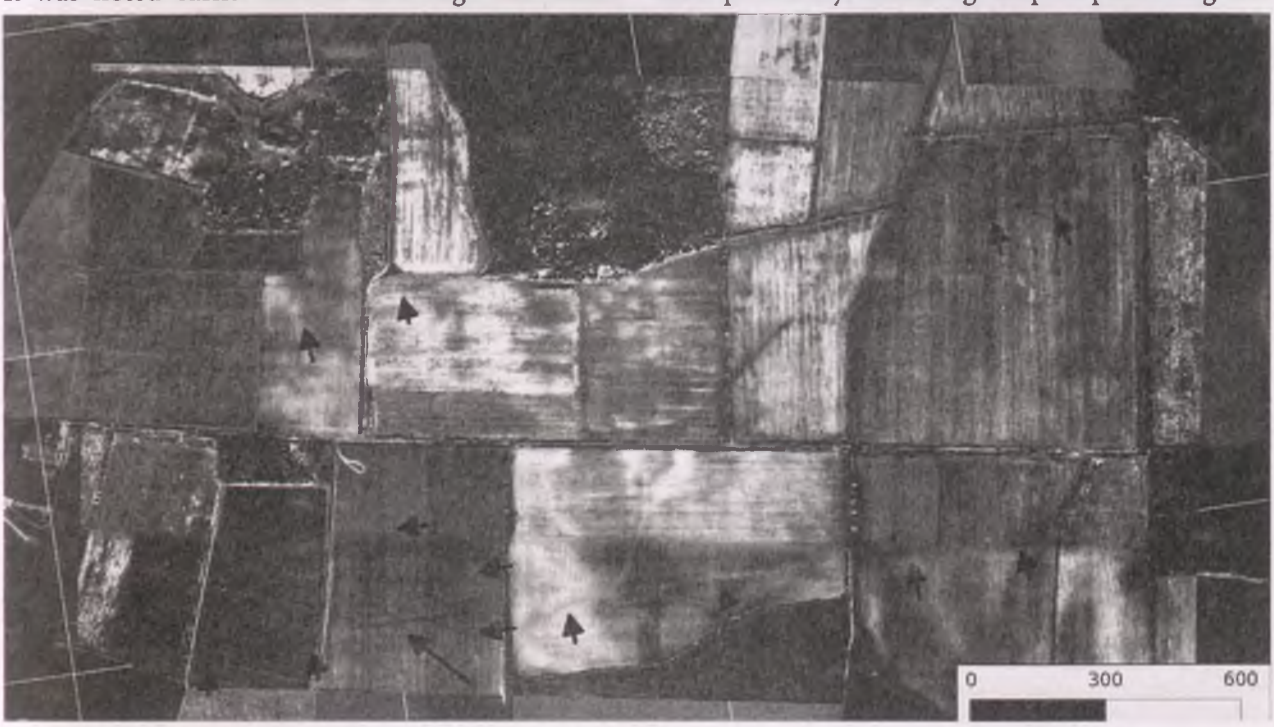

Fig 11. Felsőcsatár. Visible traces of the *limites* (border roads) of the *centuriatio*. Photomosaic (Google Earth, Archive of IAS, ELTE) with the vector model of the *centuriatio* (white lines)

the filtering of the images, other details of the possible remnants of Roman field boundaries could be identified. A roughly 2 km long field boundary road with multiple road junctions can be seen on the image mosaic (fig. 11.): it seems likely that it can be identified as the Roman road leading westward from Savaria and because this road section is located more or less in line with the Roman road between Savaria and Bassiana – a straight line connecting them can be draw between the two – it can probably be interpreted as the western section of the east-west main axis (*decumanus maximus*). The road junctions could be interpreted as marking the inner divisions of the *centuria* units. It also became clear that the main parameters of the theoretical reconstruction of the *centuriatio*'s grid was reliable, although there were some deviations from the "ideal" construction already in Roman times, which can probably be explained by the non-identical ancient land plot sizes (fig. 11).

Geophysical prospection

In 1999, a geophysical survey was conducted at Zanat near Szombathely, where a Roman road junction was excavated by Gábor Ilon (Ilon 2001). This geophysical prospection was carried out by Sándor Puszta. The smaller ditches of a Roman gravel road were identified. The results clearly outline the small and shallow ditches of the road. Because of the difficulties in identifying gravel roads in the field, we performed a short geophysical investigation in order to determine whether there was a *centuriatio* on the eastern bank of the River Rába; however, it remains uncertain whether the cadastral system had been actually laid out in this region.

The geophysical prospection was carried out by an Overhauser magnetometer under the superintendence of Sándor Puszta in the area of the assumed grid nodes. The test area was chosen based on the presence of several features with the "right" orientation and the presence of *tumuli* indicated by circular soilmarks that had been identified earlier on archive photos and on Google Earth maps. Two ca. 2500 m² large areas were selected near the River Rába, where Roman sites have already been found during earlier topographical field surveys conducted by the specialists working in the County Vas Museum.

Despite prior negotiations with the field's owner, the conditions were not suitable for prospection: for example, one of the areas had been deep ploughed. The results from this area showed nothing but the direction of the ploughed furrows. Neither did our other test region near Sárvár produce any obvious results: the post-processing of the data, however, indicated trench-like phenomena running parallel to the lines of the theoretical grid, but there were no convincing sign of the roads visible. Unfortunately, this field was heavily disturbed owing to road constructions in the modern times.

Thus, even after the prospection, the question remains open of whether or not the Roman *centuriatio* existed east of the River Rába.

Roman Potaissa and its surroundings. A view from above

Florin Fodorean

Keywords: Potaissa, topography, aerial archaeology, landscape, fortress, tower, rural settlements

In the lack of a national archaeological repository and topographic researches using aerial photography, the reconstruction of the Dacian landscape is still today a difficult task to achieve. The Romanian archaeologists and historians made efforts to know the topography of Roman Dacia. They used classical methods, i.e. fieldwalkings and excavations, in a period of 'romantic archeology', when there were no economic pressures, no 'deadlines', no preventive archaeology. During the 1950's, a project started in Romania, focusing on the creation of the National Archaeological Repertory. Soon afterwards, due to the lack of cooperation between specialists, and lack of sufficient implications of the archaeologists, the project was partially abandoned. A big problem occurred during this period. Because of the communist regime, the topographical maps published by the Military Topographical Direction were considered strictly secret. The aerial photographs had the same status. However, to produce topographic studies and landscape analysis, one needs, first and foremost, maps and aerial photographs.

Topographical researches in Romania

Beginning with the 1960's, the Romanian researchers, archaeologists and historians contributed to the publication of the so-called archaeological repertories. Today, a part of the counties which cover the former territory of Roman Dacia benefit from these repertories. So far, the following regions benefited from the publication of archaeological repertories: Cluj, 1992; Sălaj, 2010; Alba, 1995; Mureş, 1995; Hunedoara, 2005; Sibiu, 2003; Harghita, 2000; Covasna, 1998; Braşov, 2004; Arad, 1999; Caraş-Severin, 2004.[1] All of them are structured using a common model. The settlements are alphabetically ordered and a large number of archaeological findings are briefly described, but a big problem is still unsolved in that the topographic indications and the maps from these repertories are, in many cases, almost useless. The indications in text, in many cases, are formulated like this: "in that part of the village", "within the territory of the settlement" or "South, North, East or West of this point/road/terrace/river" etc. The maps published within these repertories are extremely general, sometimes with no scale, difficult to read, to understand. Nowadays, intensive preventive archaeological research takes place every year, and the first step is to present a prognosis of the archaeological potential of a territory. In the lack of concrete, accurate information, mapped and catalogued, one cannot estimate the archaeological potential of an area.

Potaissa and its surroundings

The conquest of Dacia (pl. 10) and its turning into a Roman province in 106 AD meant the beginning of a new era: the Roman civilization penetrated all geographical areas of the newly-founded province. The first epigraphic mention of Potaissa appears on a *milliarium* discovered in Aiton, dated to 108 AD (Fodorean 2006, 64–68). First, Potaissa was only a *vicus*, as we can see from inscriptions, but after the arrival here of the *legio V Macedonica*, the city experienced an economic and social "boom" (for Potaissa, see Bărbulescu 1994). During the civil wars from the beginning of Septimius Severus' reign, the legion was loyal to the emperor. The result was not unexpected: in 193 AD, Severus granted the status of *municipium* to Potaissa and immediately that of *colonia*. It was

[1] Some of them can be consulted online:
The archaeological repertory of Sălaj County, Sibiu, 2010 (http://www.brukenthalmuseum.ro/pdf/Biblioteca_Brukenthal/XLV/BBXLV.pdf); the archaeological repertory of Hunedoara County, Alba Iulia, 2005 (http://arheologie.ulbsibiu.ro/publicatii/bibliotheca/xvi/repertoriu%20arheologic%20hunedoara%20mic.pdf); the archaeological repertory of Sibiu County, Sibiu, 2003 (available on http://arheologie.ulbsibiu.ro/publcatii/bibliotheca/repsibiu/cuprins.htm); archaeology and history. Discoveries from the Caraş-Severin County, Sibiu, 2004 (http://arheologie.ulbsibiu.ro/publicatii/bibliotheca/arheologie/istorie/cuprins.htm).

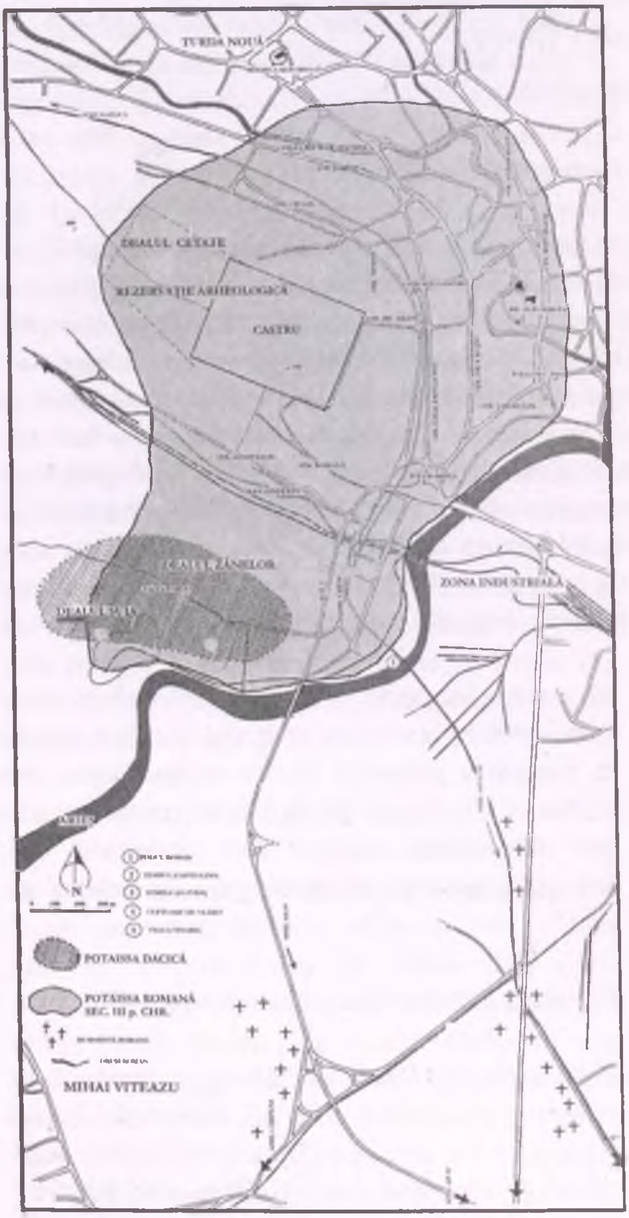

Fig. 1. Potaissa and its surroundings

the beginning of important changes here, in the central part of the Transylvanian Plateau. Today we can establish certain features used by the Romans in developing this city: 1. it is positioned very close to the main imperial road of the province (FODOREAN 2012, 255–279); 2. it has all the elements that characterize a Roman settlement: a military fortress (BĂRBULESCU 1987); aqueducts (FODOREAN 2011, 95-108), roads; 3. the city developed in the vicinity of the fortress, at the base of the "Cetate" hill. Today, the Roman civilian settlement is covered by the modern town; 4. a bridge was constructed along the route of the main Roman road, south of the city and the military camp and close to the current bridge (FODOREAN 2011a, 143–147); 5. the Roman cemetery is positioned south of the city, close to the former Roman road (fig. 1); 6. close to the city, at Copăceni, Valea Sărată, Ceanu Mic, Călăraşi, Bogata, Petreşti and Poiana-Lişca, traces of Roman settlements were found in the terrain (CRIŞAN *et al.* 1992) and on aerial photographs.

Because Potaissa was granted the *ius Italicum*, i.e. exemption from land taxes, numerous rural settlements developed around the city, within a radius of at least 20 kilometers. Nowadays, almost all of them are unknown, and unmapped.

THE ROMAN WATCHTOWERS WEST OF THE LEGIONARY FORTRESS

Recently we were able to identify, based on archaeological data, information from modern manuscripts and aerial photographs, three watchtowers, all of them positioned west of the legionary fortress from Potaissa.[2]

The first, the northernmost one, is recorded in the manuscripts of István Téglás (BAJUSZ 2005, 545–546). Téglás describes the ruins of this tower: "January, 1911. West of the fortress, in the area of the Cetate Hill, close to the Sind rivulet, on the land of dr. Lajos Szentkirályi, close to the pit called Ördöngös, a watchtower was found (*specula*). Because it caused problems for the agricultural works, in January 1911, the walls were excavated and the stones were transported from there. I saw the walls of the foundation, 96 cm above the terrain, and I could make a drawing. The walls were constructed using chalk from Sănduleşti, without mortar. Big tiles were also found. They also found there a millstone. If the Romans used stone for the foundation, it seems possible that the walls were from wood, and the roof was of tiles. To fix the wooden beams, they cut deep holes with a diam. of 42 cm into the walls. The distance between these holes is 1.46 cm. The diameter of the tower was 11.56 m. The walls were 0.92 cm thick. From the tower walls, a 2.5 m large part is missing." The tower is positioned circa

[2] I would like to thank my colleague Mariana Pîslaru for some of the information.

1050 meters west of the south-western corner of the legionary fortress.

The second tower is positioned approximately 880 meters south (in straight line) of the first one and it was discovered during the preventive archaeological excavations necessitated by the construction of the Transylvanian highway, in 2006 (11–29 September, km 14 + 500). A section of 9 x 7 m, oriented N-S, with the maximum depth of -2.25 m was excavated. The tower is located in the northern part, close to a small road heading west, towards Sănduleşti. The stone foundation of the tower was discovered. The dimensions of the tower, on the inside, are (S-N 2.90 m, close to 10 *pedes*), and E-W 3.60 m. The shape is rectangular, with the long sides oriented east-west and the short sides oriented north-south. The foundation is preserved to a total height of 2 meters. The thickness of the walls is about 0.5 m.

The third tower is located on the hill called Şuia ("Suja-domb"). This hill is located north of the Arieş (Aranyos) River, and south-east of the hill called Nagytündér ("Fairies"). The Suia Hill lies south of the Nagytündér Hill, and they are separated by the river called Pardei. The tower is again described by the same István Téglás: "1906. North-west of Turda, at Suia, along the road heading towards Cheile Turzii, in 1906, at the end of a trench, the foundations of a Roman building were discovered. A large quantity of bricks and tiles was also found. Probably it was a Roman farm, but it could also be the foundation of a Roman watchtower, because it has a circular shape. The people travelling towards Meszko (Mischiu) observed that circular shape in the terrain." (Bajusz 2005, 779).

Roman settlements within the rural territory of Potaissa. Mihai Viteazu

The archaeological repository of Cluj County mentions several settlements at Mihai Viteazu. One is particularly interesting for this paper. In the place called Pataklejáró (meaning "descent towards the river") or Lejáró ("descent"), fragments of prehistoric and Roman pottery were found. The river in the valley is called Bădeni, which flows from the south, crosses the village and finally flows into the Arieş (Aranyos) River. In the archaeological repository of Cluj County, these points are erroneously marked north of the village. Analyzing the ortophotographs, I was able to locate these points south of the village. The terrain investigation led to the discovery of a very important rural settlement.[3] I found, on the surface of the terrain, fragments of ceramics, stones, tiles. So, this was a prehistoric settlement and it was also occupied during Roman times, due to its location, close to a river, with a view to the north.

The prehistoric and Roman settlement from Valea Sărată (the Salted Valley)

Until recently, no archaeological sites were known in the north-eastern area of Potaissa. Several investigations in the field confirmed the information from the ortophotographs. On a large area (circa 180 x 160 m), the surface examination of the location revealed the presence of Roman and prehistoric pottery, stones, mortar and bricks. The site is positioned relatively close to the salt mines. It is again a new discovery, as no archaeological site was ever recorded at this location. This might be a former Roman construction, maybe a *villa rustica* (Rădeanu–Fodorean 2011, 331).

The village of Luncani

The village of Luncani is located in the lower basin of the Arieş River, 19 kilometers south-east of Turda (Roman Potaissa). The settlement belongs, administratively, to the village of Luna. The large valley of the Arieş River (much larger in the western part compared to the eastern one) permitted, during Roman times until the modern period, activities related to the cultivation of a fertile land. The name of the settlement during modern times was Grind (Aranyosgerend in Hungarian, or Gerend). On the Austrian maps of the First Military Ordnance Survey, the settlement is mentioned as Gerend.

The archaeological repository of Cluj County presents some general archaeological finds discovered within the territory of the settlement. It is

[3] Terrain investigation during the spring of 2012 with my colleague Sorin Nemeti.

Fig. 2. The site of Luncani

very important to stress one fact: some monuments and other artifacts were collected in Luncani in the 19th century by József Kemény, in his castle. The Roman road was identified within the territory of the village, but this indication is useless.

István Téglás (1853–1915) made a decisive contribution to the understanding and location of the archaological discoveries in and around Potaissa (BAJUSZ 2005, 30). Téglás provides a short description of the archaeological sites identified within the territory of Luncani: "On 26th of March 1906, I was guided by Pál Bálint. I saw the Roman settlement at Luncani. That surface is positioned on the northern side of the land of Count Kemény (currently this land belongs to Mrs. Hischmaier), on the field, in the triangle made by the two big water springs of the rivulet Tyukeria. The remains of the settlement are scattered across on a surface of circa 0.5 kilometers in length. I saw a lot of Roman bricks and tiles and ceramic fragments. These are strewn here and there on the field."

The analysis of the maps from the First, Second and Third Military Ordnance Surveys lead to the observation that Téglás copied his data using these maps (fig. 2). 994 m south-east of the current road DN 15 (measured on digital maps and using a straight line, perpendicular to DN 15), 963 m south of the southern corner of the village of Luna, and 1369 m WNW of the corner of the former "CAP" (agricultural complex before 1989 – Cooperativa Agricolă de Producţie), I located the Roman site.

CONCLUDING REMARKS

Using aerial photographs, combined with data from archaeological repositories, and fieldwalkings, we were able to identify several new rural settlements close to Potaissa. In the future, we will extend our investigations to a larger territory.

Aerial archaeological survey of the legionary camp and military town at Brigetio

László Rupnik–Zoltán Czajlik

Keywords: Aerial archaeology, topography, Roman Age, Brigetio, *canabae*, legionary camp, mapping

Brigetio (Komárom/Szőny) is one of the most important Roman sites of the *ripa Pannonica* in modern Hungary. The l*egio I adiutrix* was stationed in the legionary camp during the greater part of the Roman Age. The *canabae* evolved around the fort, while the extensive civilian town and the associated industrial quarters and cemeteries lay slightly to its west (Barkóczi 1951; Borhy *et al.* 2011; Borhy 2006; Számadó–Borhy 2003; Számadó 2010). Although the ruins of Brigetio have since long been known to research, their fate in the 19th–20th century was far from enviable. Their greater portion fell prey to the expansion of the modern town and the systematic robbing of the stone masonry for modern buildings, as well as to the construction of an oil refinery in the mid-20th century. The Roman Age topography was pieced together from the observations made during the inspection of construction sites and the small-scale rescue excavations, determined in part by the period's professional standards and in part by the political environment. The situation is best illustrated by the fact that until very recently, László Barkóczi's work on the Roman town's topography was all we had to go by (fig. 2). In the early 1990s, when systematic archaeological explorations and a few rescue excavations were both conducted, it became clear that significant results could be obtained from the application of remote sensing techniques, even though the ruins lie in a highly built-up area. Research in Carnuntum offers an idea of the immense potentials of this type of research (Doneus 2004; Doneus 2006; Gugl *et al.* 2006). In the following, we shall describe the findings of the investigations carried out by the Institute of Archaeological Sciences of the Eötvös Loránd University, and of the data suitable for mapping gained from aerial archaeological photography and their integration with the already known evidence.

History of aerial archaeological research at Brigetio

Although currently we do not know of any aerial photos made in the broader Komárom/Szőny area predating World War 2, it is possible that early photos will be discovered during the cataloguing of archival collections. It seems quite certain that Sándor Neogrády, who pioneered aerial archaeology in Hungary, had reconnoitred the area because he published a photo of the nearby Roman *castrum* at Almásfüzítő (Neogrády 1948–50, 320, fig. 23). The oil refinery built over the military camp in 1943 was heavily bombed during the war and thus the archive aerial photos in various collections may contain relevant archaeological information. These photos could be of crucial importance in the case of areas that have since been built up, where aerial archaeological reconnaissance will hardly yield any results.

The assessment of the available archival photographs of the area was first performed by Zsolt Visy in his studies on the *ripa Pannonica*. During the modern surveys begun in the 1990s, René Goguey and Otto Braasch often made flights in this zone which played a prominent role in the Danubian defence system. The first breakthrough came in 1994: as part of the collaboration with Pécs University, Braasch documented twelve archaeological features that could be interpreted as Roman marching camps during a single one-hour flight (Braasch 2003, 44, Abb. 1–2). The results were soon published (Visy 1995, 216–218, Abb. 9–14). During subsequent flights over the area, Braasch identified several new installations that could be linked to the Roman frontier defences (Visy 2000; Visy 2003a), bringing the number of these features to eighteen (Szabó–Visy 2011, 107). It must here be noted that Ivan Kuzma identified a series of similar camps north of Brigetio, on the northern side of the Roman (and the modern) border (Kuzma 1995).

R. Goguey's made his first successful aerial archaeological reconnaissance in the area in 1997–1998, when in addition to the assumed camp remains, he also identified several roads

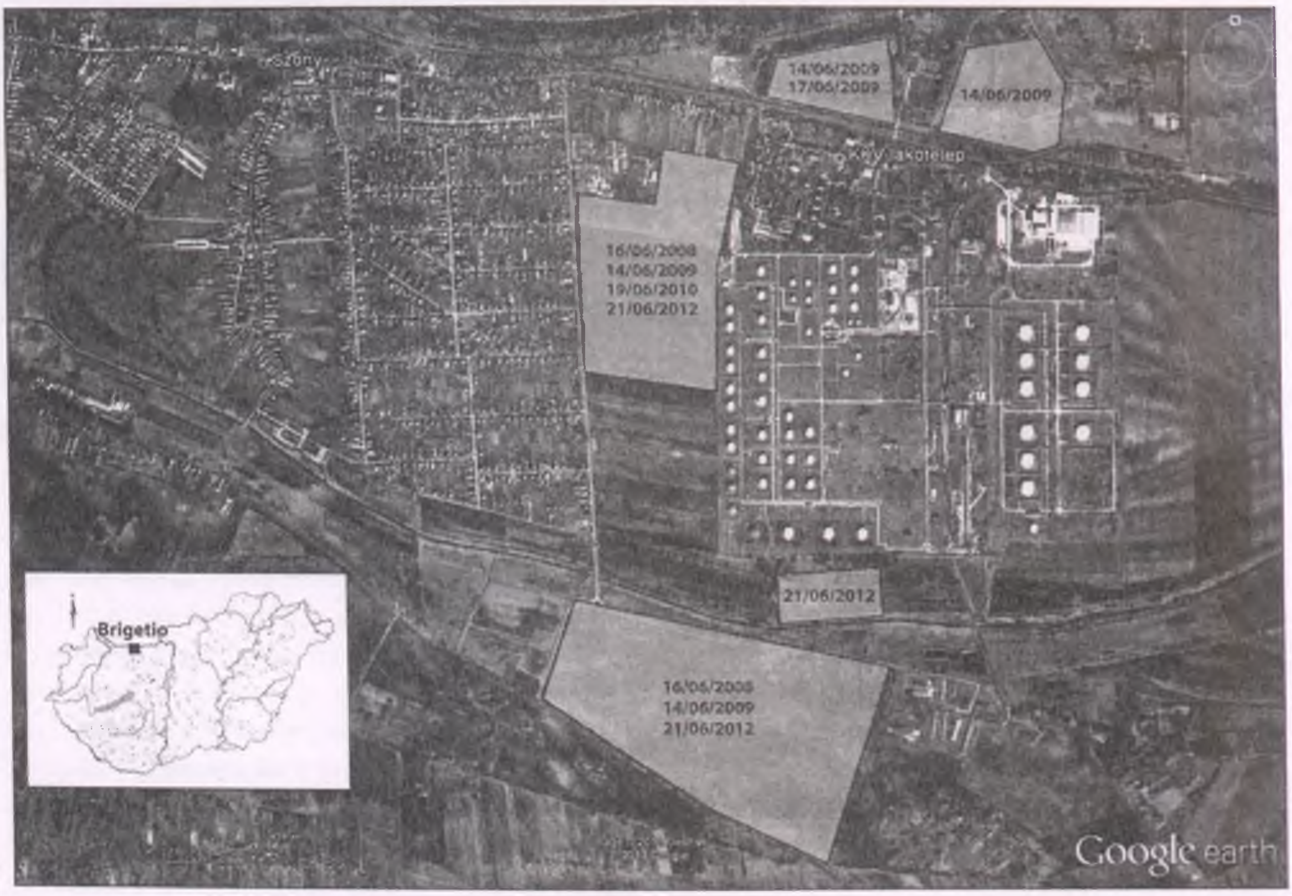

Fig. 1. The research area around the modern settlement of Komárom/Szőny (source: Google Earth)

Fig. 2. The legionary fort and its surroundings in a vertical photograph overlaid by the map of L. Barkóczi (source: BARKÓCZI 1949, Google Earth)

presumably dating from the Roman Age. However, the aerial reconnaissance did not clarify the relation between the legionary fort of Brigetio and the various remains in the adjacent, fairly extensive agricultural fields. The reason for this is that in the 1990s, foreign researchers were not allowed to approach the areas lying along the Danube owing to the nearness of the Hungarian-Slovakian border.

Parallel to the ongoing aerial archaeological reconnaissance, researchers from Pécs University began a systematic field survey to identify the assumed camps; however, none of the sites, whose number had grown to thirty-four by then, yielded any finds that would verify a date in the Roman Age (Szabó–Visy 2011, 107).

The systematic aerial archaeological survey of the Roman Age sites in the Brigetio area by Zoltán Czajlik eventually bore fruit in Summer 2008, when a smaller section of the *canabae* was outlined by cropmarks in the fields between the refinery's oil tanks and the modern residential area (for an overview of the research conducted in 2008–2009, see Borhy *et al.* 2011). The area is divided into several smaller fields, which meant that despite the area's favourable soil conditions, there would be need for additional surveys owing to the practice of crop rotation. The area was repeatedly photographed during the ensuing years (fig. 1). The greatest body of data was gathered in 2009 and 2011, when sections of the military town lying under the cultivated fields could be identified and various archaeological features were also observed in the camp's northern third and in the area to its east. These findings were also known to Máté Szabó, our colleague working in the Aerial Archaeological Archives in Pécs, who had studied the site as part of the research project for inscribing the *ripa Pannonica* on the list of World Heritage sites (Visy 2011a; Szabó 2011a, 92–93, Abb. 102).

Aerial photos and their assessment

The aerial photos were made by Zoltán Czajlik for the research conducted in the Institute of Archaeological Sciences of the Eötvös Loránd University. The flights were made with Cessna 152/172 planes since 2008, the photos with a Nikon D300, Leica type camera, Nikkor ED 24/70 lens, using direct GPS coordinate identification. During the flights, the nearness of the Hungarian-Slovakian border had to be taken into consideration (especially when turning), as well as the required minimal flight altitude of 1500 feet owing to the urban areas and to ensure that industrial installations would be avoided. The photos were processed by László Rupnik: the photos were rectified and integrated into a photomap using the ArcGis 9.3 and RadCor 2.06 softwares (fig. 3). We have also begun the gathering of archival material, principally old maps and aerial photos, and their integration into a GIS system. This work is currently in progress; it is our hope that it can be broadened into a research project involving the site's complex investigation and survey through non-destructive methods as well.

Assessment of the aerial photos

Castrum legionis

Measuring 540 m by 430 m, the northern third of the rectangular fort (the *praetentura*) falls into the ploughland north of the main road and the railway line. Good quality aerial photos of this area were made on June 14 and 17, 2009 (fig. 1). The number of archaeological features diminished towards the field's western part, perhaps because the area lies slightly lower and was waterlogged at the time the photographs were made.

Although the location of the *porta praetoria* can be clearly seen on the photos, the walls themselves could not be distinguished because the gravelled surface of the road leading out of the fort and the rubble of the camp formed a contiguous feature. Neither can the exact location of the trenches of the 1941 excavation be made out, and it seems likely that the former excavation trenches obliterated some of the smaller details. The line of the northern wall is clearly indicated by the 6–7 m wide negative cropmarks. The smaller soundings opened in the area suggested that the roughly 160–180 cm wide wall was removed during the modern period (Paulovics 1941, Abb. 8). A rampart of turf blocks extended along the wall's inner face (Barkóczi 1949, 70–71). It would appear that this section has survived in the form of a line of rubble whose compactness is indicated by the stunted growth of the cereals and the shrubs along the football field. Even though its position cannot be identified, it seems likely that there was anoth-

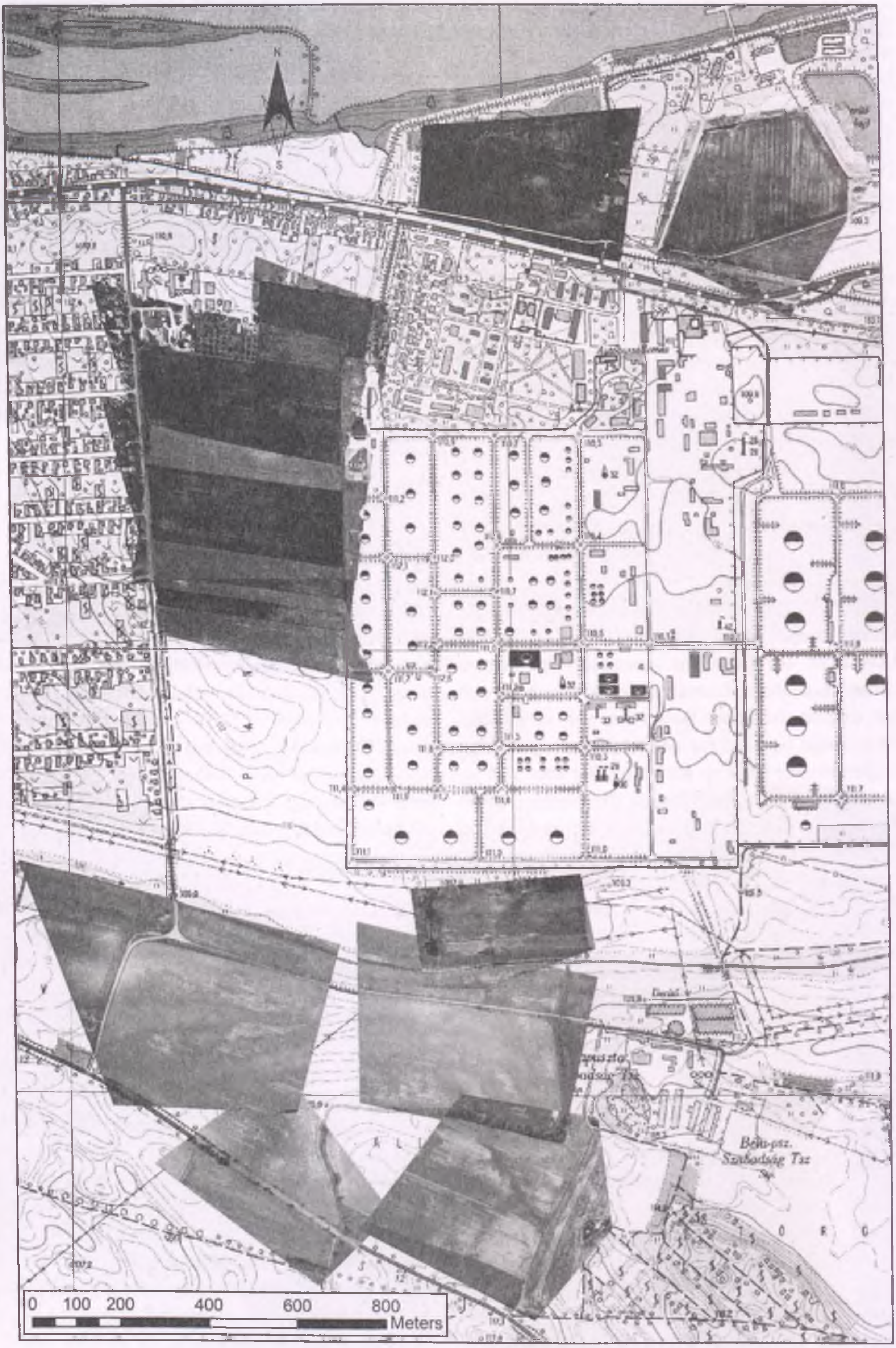

Fig. 3. Aerial photo mosaic of the research area (background map: Institute of Geodesy, Cartography and Remote Sensing)

er tower in the photographed area. The sketch made by Milos Berkovics-Borota (Berkovics-Borota 1886, 395) led several scholars to assume that the fort had been constructed with semicircular corner towers and side towers (Borhy–Számadó 2003; 75–76; Számadó 2010, 144; Visy *et al.* 2011, 63); in contrast, Barkóczi explicitly writes about rectangular towers placed on the inner wall faces (Barkóczi 1949, 71).

The double structure of the roughly 25 m wide *fossa* can be clearly identified. A paved road ran along its outer side and we could also ascertain that the road led straight to the Danube, perhaps with another road branching off to the north-east. The area between the fort and the river was described as being strongly disturbed (Barkóczi 1949, 70; Barkóczi 51, 9), and it is therefore hardly surprising that aside from a single building, the positive cropmarks indicated the presence of pits and ditches.

The photos revealed fewer details about the internal layout of the fort than we had hoped. The line of the *via praetoria* and its eastern and western side-branches can be clearly seen, but only smaller sections of the walls of the buildings inside the fort are outlined. One exception is the groundplan of a 18 m by 73 m large barrack and the apsidal building on the eastern site (fig. 4). The high number of positive cropmarks outlining pits and ditches is a reflection of the Roman Age occupation, as well as of the documented later intrusions disturbing the area. Modern sources report that the walls had been systematically robbed, but the area between the walls was not disturbed (Számadó 1997, 153). It seems to us that the greater part of the ditches, whose alignment corresponded to the fort's orientation and in some areas visibly bounded patches with rubble, can be linked to the robbing of the Roman masonry and indicate the line of the one-time walls.

The area east of the fort

Large tracts of ploughland lie in the area east of the one-time fort. The results of our research suggest that several *villa* buildings lay at some distance from one another in the foreground of the *castrum legionis*. A multi-period *villa* stood on the northern side of the *limes* road, immediately by the *vallum* (Barkóczi 1949, 68; B. Thomas 1964, 265-267, Abb. 142), and the remains of various buildings were also identified in the area of the sports field and to its east (Barkóczi 1951, 9, fig. 1; Barkóczi 1949, 68; Számadó 2010, 151, fig. 38). On the testimony of the aerial photos made in 2009, earlier reports on these buildings were correct. Even though the photos were not made under ideal conditions, the buildings forming smaller clusters at some distance from one another were clearly outlined by the negative cropmarks (fig. 5, A). The interpretation of the features appearing on the photos sometimes runs into difficulties because the alignment of the freshly-ploughed furrows is virtually identical with the orientation of the buildings and thus it is not always easy to distinguish the line of the walls from the furrows. The interpretation of the large, round, positive cropmarks was aided by a comparison with the orthophoto of the area made after World War 2, which revealed that these showed the location of bomb craters from the air raids on the oil refinery. One of the bombs had hit a Roman building and had partly destroyed its walls (fig. 5, B).

Canabae

The location and layout of the *canabae* were adjusted the military fort. The *canabae* enclosed the fort to its south and west, although the nearness of the Danube and the conditions on its floodplain too influenced its growth (Viczián–Horváth 2006, 267, fig. 1). The extent of the military town was determined by Barkóczi (fig. 2). The area covered by the *canabae* can be determined from his map and the land registry records in his description (Barkóczi 1949, 68–69). The canabae extended from the northern side of the military fort to the railway station along the *limes* road, then southward to the second or third plot east of the granary and south-eastward to the Caecilia cemetery and the old bed of the Danube, now the Szőny–Füzitői Channel. The *canabae*'s eastern part probably lay under the oil tanks and most likely extended to the fort's south-eastern corner. Recent salvage excavations in the area to the east brought to light sporadic traces of occupation and burials, confirming Barkóczi's observations. The *canabae* covered an area of ca. 133 ha, of which approx. 29–30 ha could be reconnoitred from the air (fig. 3).

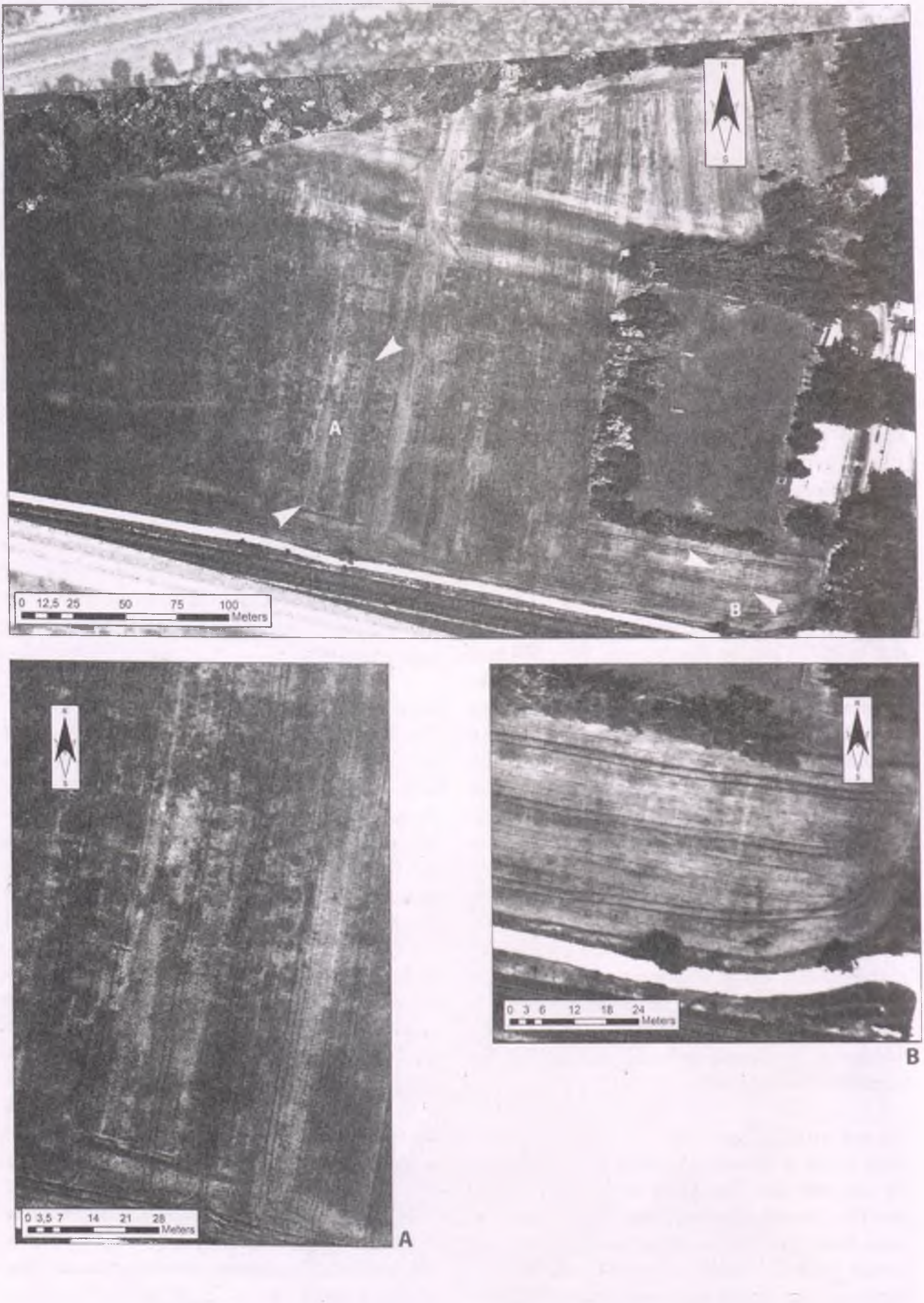

Fig. 4. The northern third of the legionary fort in a rectified image showing the location of the barrack building (A), the apsidal building (B) and the *porta praetoria* (C) (photo: Z. Czajlik, 14.06. 2009)

The layout of the *canabae* was essentially determined by the street network linking the *limes* road and the road leading southward from the camp which branched off towards Aquincum and Savaria. Wider areas can be noted at the junctions with roads branching off radially, this being the reason for the lack of a regular *insula* system. We tried to reconstruct these roads from the remains appearing on archive photos and from other archaeological evidence. The roads running north and north-west in the mapped area probably led to the *limes* road. The line of these roads can be roughly determined (pl. 12). One of these probably led to the fort's gate (pl. 11, B). Barkóczi published the remains of a road that ran to the *limes* road from the granary (Barkóczi 1949, 68). Because the area was not built up at the time, he was able to trace the line of this road towards the south-east, which in his view joined the road to Aquincum. The road section marked with "A" on the map probably corresponds to this road, although its southern and south-eastern continuation is uncertain, as is the exact location of its junction with the above-mentioned road (pl. 11). The reconstructed line would be logical because the traffic from the civilian town could have proceeded towards Aquincum without having to pass through the military fort. The road from the *porta decumana* can still be made out on an aerial photo made after World War 2, although the location where it branched off cannot be determined owing to the oil tanks and the many bomb craters. István Paulovics found the remains of an aqueduct running along the road from Tata 200 m south of the gate (Paulovics 1941, 143–152, Abb. 1–2). A Mithraeum probably stood beside the road leading to Aquincum; the sanctuary was discovered in 1943, when the last oil tank was constructed (Radnóti 1946–48, 137). This might provide a clue for reconstructing the line of the road, but we do not know which was the oil tank in question. The next certain section of the road is the area where the road crossed the waterlogged territory marked by the modern Szőny–Füzítői Channel. The gravelled section of the road could be observed in the channel's wall. This gravelled surface was often detected in the course of geological borings made in the former Danube channel. Other geographic considerations too would suggest that the road and the aqueduct beside it passed through this area (Viczián–Horváth 2006, 269). The aerial photos made in 2012 do not offer sufficient information. The exact course of the road to Savaria and the location of the crossing are still unknown and we therefore only marked the assumed line of the road on our map (pl. 11).

Although we know that a Dolichenum was uncovered in the *canabae* in 1899, its exact location remains unknown (Milch 1901; Láng 1941). It probably lay near the legionary fort's south-eastern corner, slightly to its south. Its distance from the fort's corner is specified variously: it is described as lying 150 steps away in one publication (Láng 1941, 165–166) and as 300 m away in another (Barkóczi 1949, 69). It is possible that the sanctuary was erected beside the continuation of the road marked with "C" (pl. 11).

The *canabae*'s most important buildings included the amphitheatre, whose ruins were for a long time visible in the field. Richard Pococke and Jeremiah Milles, two English travellers who visited the area, described the ruins as lying west of the fort (Visy 2000, fig. 34; Számadó 2010, fig. 3). Several scholars believe that the amphitheatre was located in the area along the *limes* road (Visy 2003, 33, fig. 32; Számadó 2010, 146; Szabó 2011, 157–158, fig. 144). This area has since been built up. Barkóczi believed that the amphitheatre lay slightly farther from the *limes* road. A round feature can be seen in this area on an aerial photo from 1951 (Museum and Institute of Military History, inv. no. 22924). The latter location would be consistent with the assumed street system of the *canabae*. However, only a geophysical survey and/or excavation can confirm where the ruins of the amphitheatre actually lie.

The buildings outlined by the negative cropmarks lay beside the roads and were aligned in the same direction. The cropmarks were weaker in the area's northern part at the time the photos were made and thus we could only securely identify smaller wall sections and few finer details of the groundplans. Although some smaller areas lacked any indications of buildings, this does not imply that these parts were not built in. The stone rubble often caused worn, dry surfaces where the walls had either completely perished or the crops did not indicate their presence. In his analysis of the area, Máté Szabó pointed out the anomalies caused by the modern terrain and the depth differences of the various archaeological features (Szabó 2011, 155–156, fig.

Fig. 5. Traces of the stone buildings (A) and WW2 bomb craters (B) east of the legionary fort (photo: Z. Czajlik, 14.06. 2009)

146). The detection of former buildings in the area lying closer to the military fort is also difficult because the earlier buildings had been considerably disturbed by the graves of the later Roman cemetery established in the same area, a phenomenon confirmed by the smaller rescue excavations conducted here.

Although the number and density of buildings diminishes towards the south and east, the area was not devoid of various structures. It would appear that this area was covered by larger plots with a few scattered buildings only. The plots were bounded by ditches and, in a few cases, by stone fences, at least judging from the negative cropmarks. While the number of stone houses decreases, the positive cropmarks indicated the presence of sunken houses and pits (pl. 12).

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Using remote sensing and non-invasive archaeological methods in the research of Roman villas and the ancient landscape of Pannonia

Máté Szabó

Keywords: Aerial survey, Cserdi, field survey, GIS, landscape archaeology, multirotor copter, non-invasive methods, Pannonia, photo 3D, photo interpretation, remote sensing, Roman *villa*, test excavation, UAV

Research on the Roman *villa*s of Pannonia is predominantly based on topographic surveys and archaeological excavations (B. Thomas 1964, Bíró 1974, Gabler 1994, Visy 1994), although non-invasive archaeological methods have also made an important contribution to our knowledge. Since its creation in 1994, the collection of aerial photos in the Aerial Archaeological Archives of Pécs[1] has continuously grown, and these photos provide important information on Roman buildings and – in exceptionally good cases – on the broader area and layout of the *villa*s and their environs in Transdanubia, Hungary.

In recent years, the Culture 2000 and Central Europe Danube *limes* WHS programs have yielded significant results in the research of Roman remains in Hungary – primarily through so-called non-invasive archaeological methods and using remote sensing, mainly aerial archaeology. These programs – which created the opportunity for Hungary to prepare the World Heritage Site nomination documentation for the Hungarian section of the frontier of the Roman Empire – have provided a large amount of information about the military and civilian localities of the *limes*. Besides these results, by flying over Transdanubia, further aerial photographs were taken of several other Roman sites. Since our research focused on the *limes*, the *villa*s that are distributed throughout the whole province could only be subjected to primary identification. More extensive mapping or groundtruthing was only sporadically possible.

One of the most important observations was made at the Roman *villa* in the immediate neighbourhood of the Late Roman fort of Tokod, Komárom-Esztergom County (Szabó 2011b). A smaller excavation had already been carried out at the site (Kelemen 2010), but at that time, the real extent of the site, and the number and function of the buildings were unknown. It seems certain, however, that the main building of the *villa* was erected rather late, in the last third of the 4th century AD (fig. 1).

During these flights, a number of important sites could be photographed further away from the *limes* as well. Among these, a Late Roman inner fortress in Tolna County should be highlighted. A number of excavations have already been carried out in the fortress of Alsóhetény, Tolna County (Tóth 2009), but aerial photos still showed a number of new buildings. Furthermore, photos were taken of an important Roman *villa* right beside the fortress (fig. 2), which is probably contemporary with it. Its future research should be continued in connection with the research of the closely related *villa* at Tokod.

With the help of the personnel of the Pécs–Pogány Airfield, who generously provided the necessary technical background, we could gather a wealth of new information on the *villa*s around Sopianae (Pécs, Baranya County), the one-time administrative centre of the Late Roman province of Valeria. Some *villa*s had been investigated earlier and thus we could fit our findings into an already existing framework. The broadening of the investigations will contribute to a better understanding of the region's settlement patterns during the Roman period and to new advances in the region's landscape archaeology.

Of the photographed sites, we have conducted extensive investigations at the site of the *villa* near Cserdi, Baranya County west of Pécs, using non-invasive methods during the past few years. This *villa* was first detected on an aerial photo in 2008, but as it turned out later, local amateurs, collectors and treasure hunters have known it for decades. The features outlined by the vegetation indicated that we had located a complex of buildings remarkable even by Pannonian standards.

[1] http://plt.btk.pte.hu/

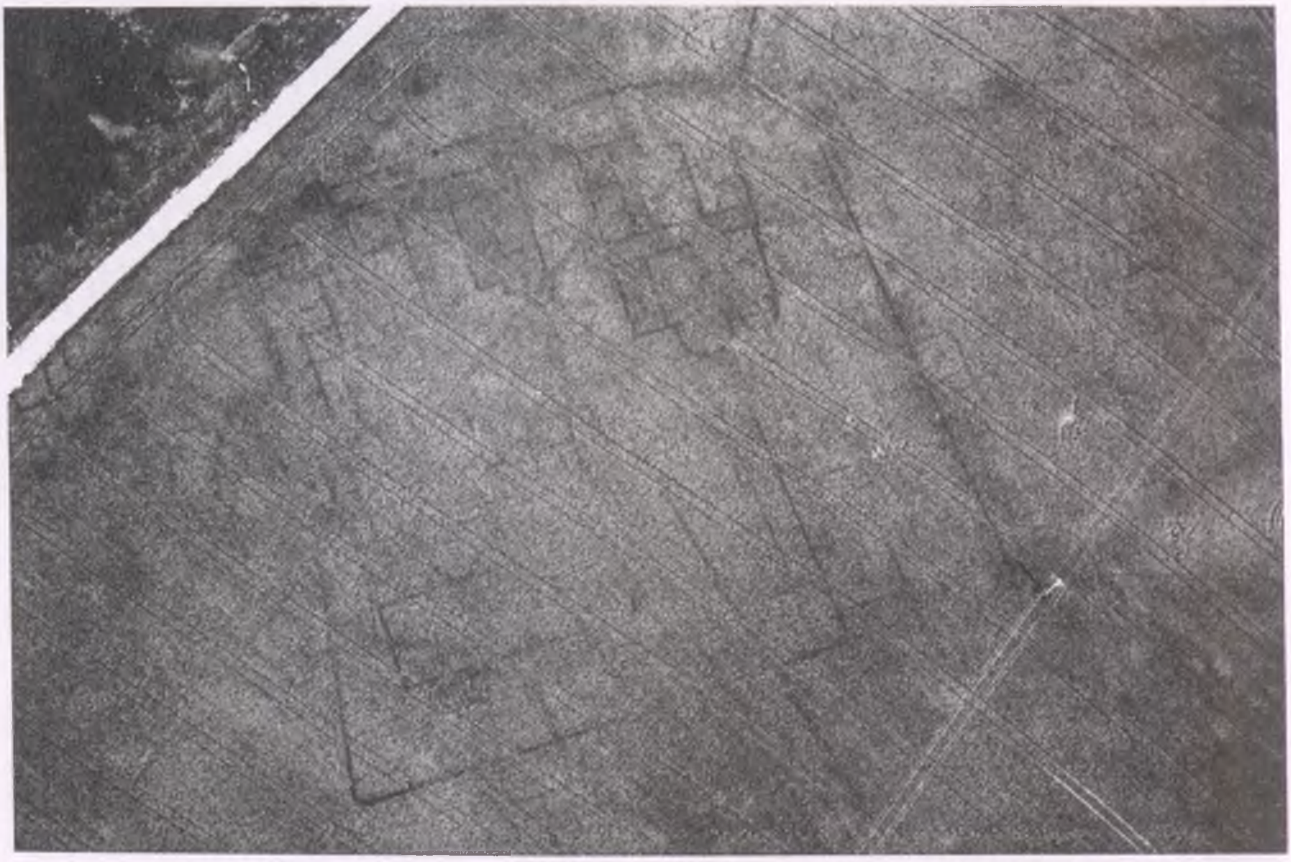


Fig. 1. The Roman *villa* at Tokod, Komárom-Esztergom County (photo: M. Szabó, PLT 33180)

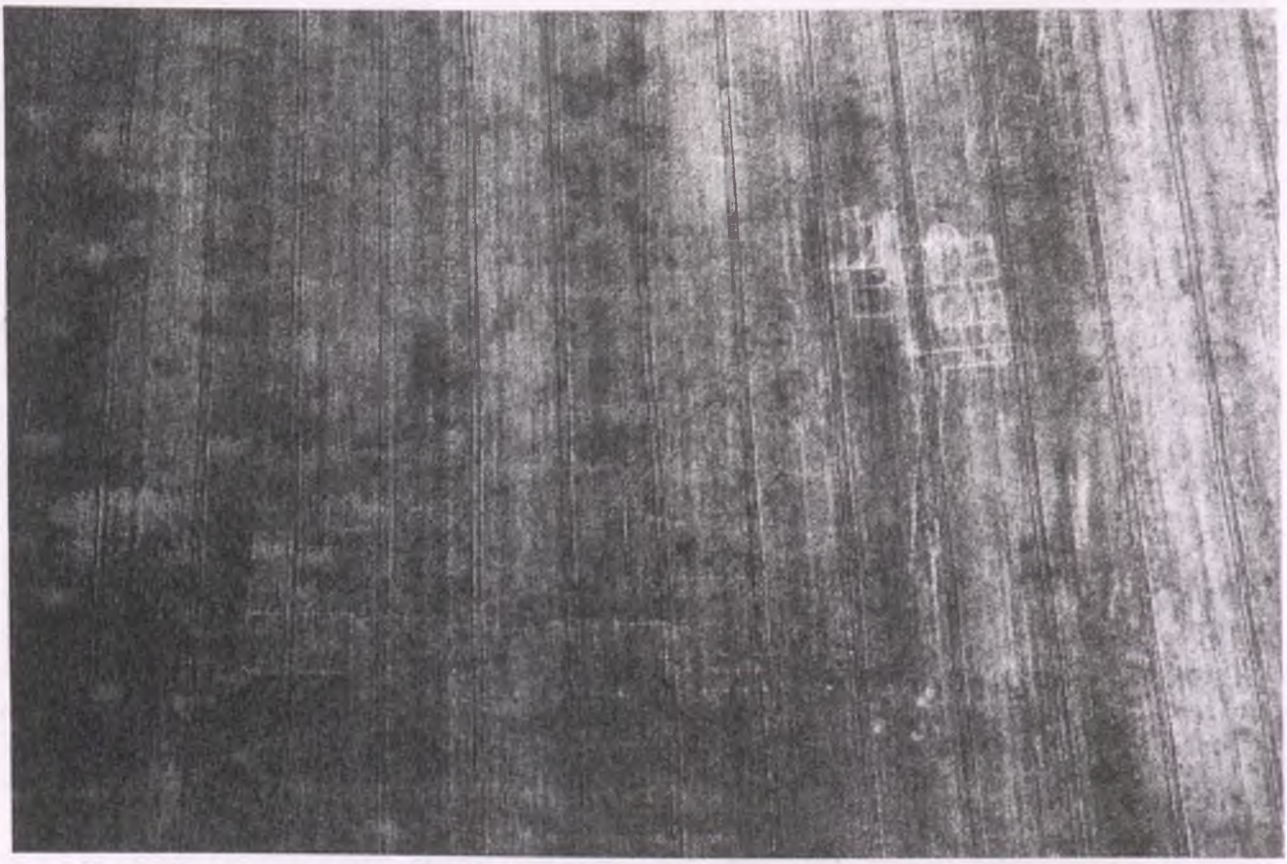


Fig. 2. The Roman *villa* next to the Late Roman inner fortress of Alsóhetény, Tolna County (photo: M. Szabó, PLT 39350)

Owing to the seasonally changing vegetation cover, we were able to study the smaller details of the site's layout on the photos. We could identify only negative crop marks, which showed the buried walls of buildings spread across an area of ca. 1.5 hectares, and beyond these, soil marks were also of help and may contribute some landscape data.

Two large main buildings were identified on the photos. Their orientation is NW to SE and they lay parallel to each other. The smaller one's size is approximately 35×25 meters (1); the northern one is the larger, ca. 50×38 meters (2). The intensity of the crop marks indicated that the larger *villa* was built later. There had been some modifications which were identifiable on the photos and gave some information for relative chronology. Beside the later main building, there are two smaller buildings with apsidal rooms, most likely bathhouses from different periods (3). Their location affirms their function, as the two buildings were built in a deeper spot of the *villa*'s territory, near the stream. On the western and south-western sides of the main buildings, some other buildings were also identified of different form and size.

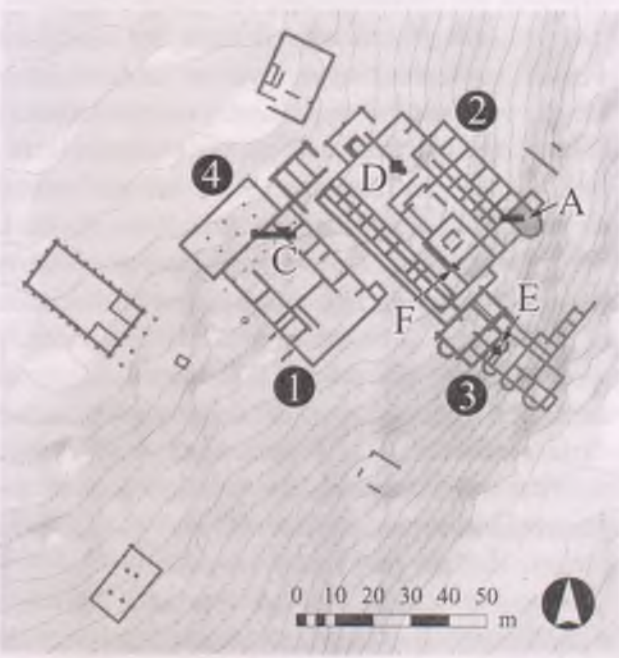


Fig. 3. Groundplan of the Roman *villa* near Cserdi by aerial photos with the excavation trenches (A-F)

Some of them might be identified as storage buildings or *horrea* by their inner pillars or outer buttresses, but the function of the other buildings have not yet been defined. Two of them have the same orientation as the main buildings and were built upon the foundation of the earlier main building (4). In front of those storehouses, a *porticus* was also indentified. Besides these, we could indentify other remains of some smaller stone structures of undefined function (fig. 3).

The photos of the site were first examined using the segmentation and transformation procedures customary in photogrammetry. During this phase, we highlighted or homogenised the archaeological features based on similarities in order to achieve a better understanding of the images. The multi-step segmentation and transformation yielded false colour images, which – according to our assumption – provided more detailed information on the condition of the buried remains. We could distinguish wall remains and the rubble around them, and we could also draw some conclusions regarding the site's stratigraphy, which was groundtruthed during a test excavation. Nevertheless, our hands were tied by the fact that the photos were limited to the visible spectrum of light; our results, however, urge us to collect more data and control earlier results, for example by hyperspectral imaging (pl. 13.1).

Yet another result of the assessment of the photos was that the primary interpretation of the archaeological features was based on an "objective" image generated by a computer which could also be automatically vectorised.[2]

Following the preliminary assessment of the site, we received permission from the landowner to map the features outlined in the field sown with barley.[3] The geodesic survey enabled the high-precision mapping of the archaeological features outlined by negative crop marks and, also, to check the accuracy of earlier surveys. We measured approximately 60 points from the buildings, spread in an area of ca. 1.5 hectares. As was to be expected, the archaeological features appeared

[2] It must be repeatedly emphasized that the goal of segmentation is not to automatise perception, which is a very complex biological, psychological and learning process (see Sekuler–Blake 1994). Perception can hardly be left to computers; at the same time, the procedure enables the extraction and homogenisation of certain details that make the interpretation of aerial photos much easier.

[3] I would here like to thank Szabolcs Czigány, Nóra Ilisics and Tamás Szücs from the Department of Soil Sciences and Climatology, University of Pécs, and Róbert Lóki from the Department of Archaeology, University of Pécs, for their help.

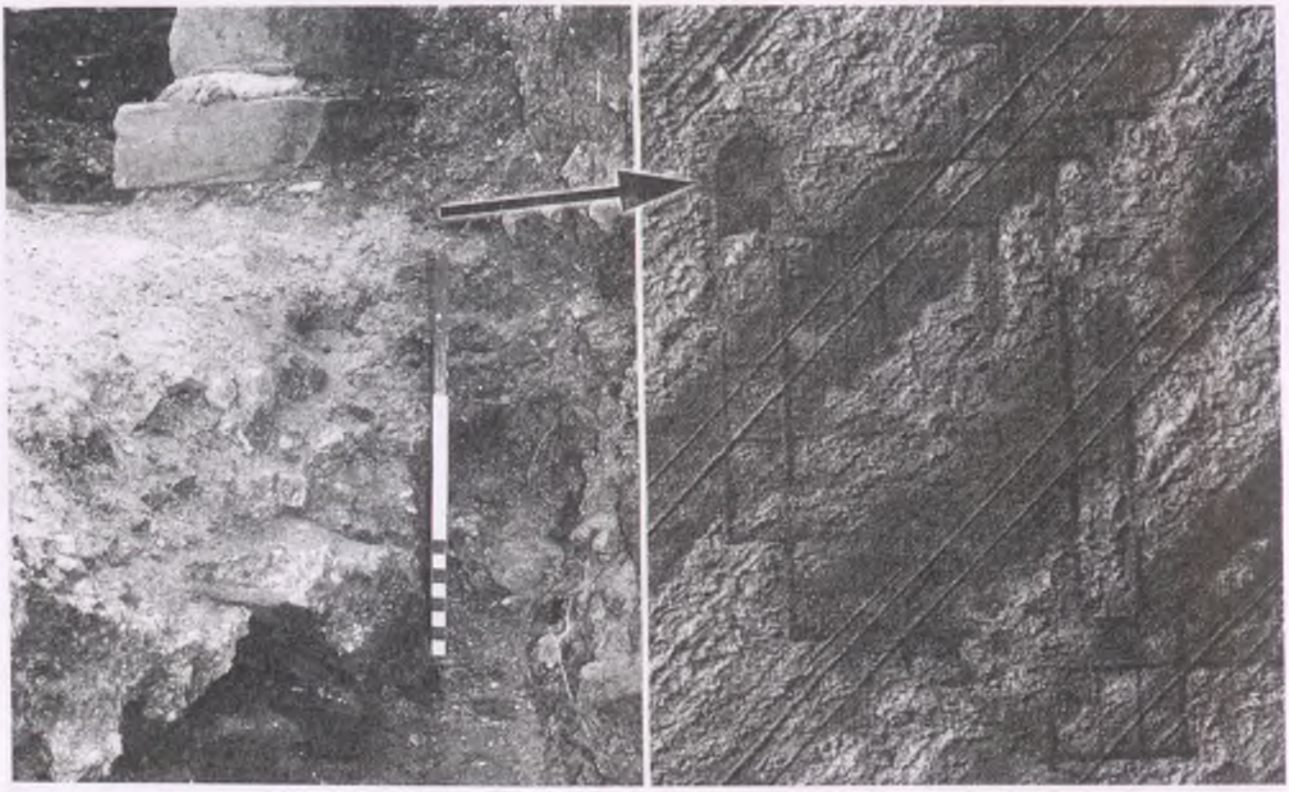


Fig. 4. Cserdi. The ca. 30 cm thick mortar of the hypocaust in Trench A, and the negative anomaly of the room on the aerial photo (photo: M. Szabó, PLT 29150)

with a divergence of one to ten meters caused by oblique photographs, terrain and the triangular formed field. With the help of the geodesic survey, we could increase the accuracy to under 0.5 meters which has to be tested through excavation (pl. 13.2).

Our knowledge about the Roman *villa* was enhanced by a survey using Unmanned Aerial Vehicles (UAV).[4] Opinions differ regarding the archaeological usefulness of these instruments in Hungary – for our part, we believe that their role in documentation is indispensable. In knowledge of the growth phase of the crops covering the site, the flights were made at sundown, the ideal time of day for aerial archaeology. The UAVs were controlled with the aid of a HD quality live-streaming video, and thus the operator and the archaeologist could immediately correct flight paths based on live images. The First Person View (FPV) flying device enabled the exploration of the environs of the *villa*, while the multirotor copter provided a highly detailed documentation. With the help of the images, we could refine our site plan and also had an opportunity to use them as stereoscopic pairs. An educational video (http://vimeo.com/34774675) was also made for the broader public (pl. 13.3.).

Based on the collected data and following the actual pedestrian surveys of the site, we continued with more detailed investigations. Unfortunately, we did not have an opportunity to use Airborne Laser Scanning, but our measurements on the ground for the creation of a terrain model provided the basis for basic GIS analyses. In 2012, the survey of the site continued parallel with a two-week-long excavation campaign. The location of the features to be explored could be accurately planned using the precise measurements gained earlier. In addition to the excavation, we collected surface finds and also performed a systematic metal detector survey.[5] The primary goal of the excavation was to map the *villa* and to assess the potentials of the site's future research.

We opened trenches in five locations (Trenches A–F; fig. 3).[6] The excavated area totalled 34.5 m². The location of the trenches, the units of stratification and the finds were all recorded with geodesic accuracy. The documentation also included photo

[4] I would here like to thank András Balogh and Norbert Sandó (Pazirik Ltd.) and Péter Szalánczay for their help.

[5] The project was conducted with a team of volunteers through grants from the University of Pécs and the National Cultural Fund of Hungary (NKA).

[6] Originally, we had also planned on opening a trench in another location too (this would have been Trench B), but the area was not investigated and in order to avoid later confusion, we did not use this letter for denoting another trench.

Fig. 5. Cserdi. The place of Trench D on the rectified aerial photo of the multirotor copter

3D and ground-penetrating radar survey,[7] which indicated the main walls of the last period of the main building, and as an experiment, the trenches were documented through the use of UAVs as well, on which another educational film[8] was made.

The accuracy of the phenomena measured with GPS was also confirmed. The largest deviation was attested in Trench C, where the difference between the location of the pillar on the aerial photos and its real position was 40 cm. The chronology of the buildings identified through image segmentation was also confirmed. The foundations of the earlier buildings were weakly signalled by the vegetation, while those of the later ones were clearly visible.

Trench A was opened to investigate features that were hypothesized to be an occupation level or underfloor heating or a mosaic floor based on the aerial photos. This was based on the mostly homogeneous negative anomaly observed in the whole room. We were disappointed, since the floor level had already been destroyed; it was observed, however, that the anomaly was caused by the approximately 30 cm thick mortar of the foundation of the hypocaust. Underneath the mortary foundation, we discovered the rubble of earlier buildings, which in turn overlay Celtic pits. Small fragments of painted wall plasters were all that survived of the room's decoration. This trench also drew our attention to the possibility of another erroneous interpretation. Although we were looking for walls based on the aerial photos, in one case, we could only document the place of the removed walls. This highlights also the problem when we see a long, uninterrupted line, even if the line actually breaks. During excavation it became clear that the original aerial photo did not lie. We opened Trench F to define the wall more precisely, and we could in fact document the traces (fig. 4).

Trench D was opened because we could not get evaluable data on the division of rooms within the building on any of the aerial photos. Our hypothesis was that the remains were destroyed and the stones removed, and only debris would be found in the area. Fortunately, the opposite was found: the vegetation did not signal the remains because we found an undisturbed *terrazzo* floor in the whole area of the trench except for the walls, which provided a similarly disadvantageous environment for growth. The walls were also covered with plaster and the rubble contained numerous fragments of the wall paintings. Thanks to this exploration, the state of preservation of the site can also be assessed with the help of the terrain model, the depth measurements of the excavation, the geophysical survey and the aerial photos (fig. 5).

Trench E was opened on a strongly eroded slope in the hope that we could survey the *villa*'s bathhouse. Unfortunately, only the wall foundations have survived, with the traces of parallel carved lines of deep ploughing.

During the excavation, we prepared photo 3D documentation. The photos were taken in accordance with the phases of documentation, thus they can be used together with our other measurements. Their processing, integration into GIS and transformation into a coordinate system is in progress. After the test of their accuracy, the models will provide great help in the processing of the excavation documentation, especially when combined with measurements at the level of finds.

Parallel to the excavation, we also surveyed the site's environment. Even though the site has been known to amateur collectors and treasure hunters, the field survey and metal detector survey yielded numerous finds. We also succeeded in identifying the intensively cultivated area of the *villa*, which

[7] I would here like to thank Gábor Bertók and Csilla Gáti for their help.

[8] http://index.hu/video/2012/08/20/legiregeszet

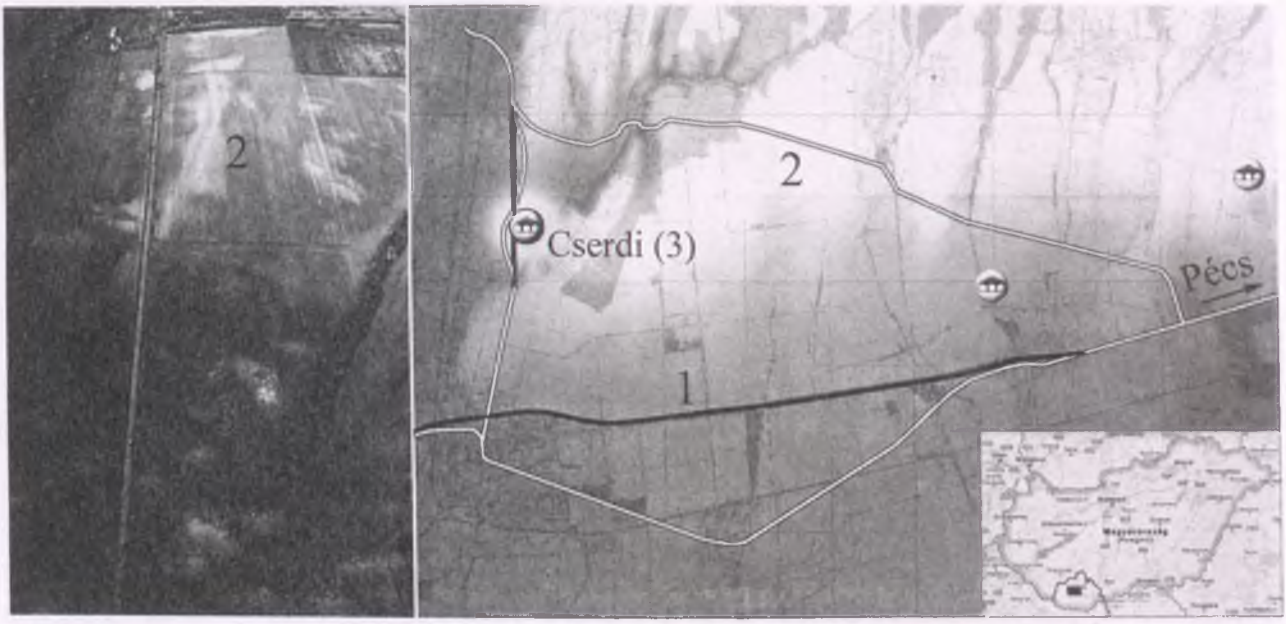


Fig. 6. Soil marks indicate the earlier road (2) and field plot system with the remains of the *villa* (3) (left), and the modern (1) and assumed Roman roads (2) with the known *villas*, west of Pécs (right) (photo: M. Szabó, PLT 30359)

were aligned along an earlier road indicated by soil marks (fig. 6). Based on the examination of available older maps, survey data and certain elements of local folklore, it seems likely that there were more Roman roads west of Pécs. In the light of our knowledge of *villa*s, their study will be important from the point of view of landscape archaeology, just like the documentation of the location and size of other estates.

In contrast to the modern road system, previously two main roads ran west of Pécs (Radnóti 1939–40, Fülep–Burger 1979). One of these roughly followed the line of Road 6. The other one now only exists as a dirt track: it left Pécs to the west, turned to the north-west and headed towards the western end of Lake Balaton. The *villa* of Cserdi is located in the area between these two main roads. Based on the analysis of maps from the 18th century and recent aerial photos, we could detect an old field system here and a road belonging to it. The track of the latter changed during the 19th century, when it was straightened. Further investigation is needed to determine the age of the earlier road, but the results of our survey are promising from the point of view of landscape archaeology as well (fig. 6).

The non-invasive investigation of the *villa* and its area, as well as the trial excavation yielded a wealth of new data for the better understanding of the site and its environs. The finds suggest that the site was occupied during all four centuries of the province's existence, even if the aerial photos clearly indicate that it attained its greatest importance during the last centuries of the Roman period. The pre-Roman occupation and the causes leading to the *villa*'s destruction raise several questions. The promising results of the site's research definitely encourages us to continue the exploration of the region's Roman sites and, also, to study the Roman land use.

Aerial archaeological investigation of Árpádian Age earthen forts and castles in Hungary (12th–13th centuries)

Zsuzsa Miklós

Keywords: Árpádian Age (12th–13th centuries), earthen fort, aerial archaeology, castle research

The earthen forts of the 12th–13th centuries can be found in hilly and mountainous regions, and on plain land and on floodplains alike. Their geographic location obviously determined the mode of fortification. The forts were adapted to the local terrain: in hilly and mountainous regions, the inner ditch and outer rampart were usually accompanied by multiple cuts across the ridge and the hillside was often carved even steeper. On the plainland, the residential area of the earthen forts was often protected by a circular ditch and an outer rampart. Very often, the stream flowing nearby was incorporated into the defences: the fort was protected by the watercourse on one side, with the semicircular or horseshoe shaped ditch and rampart extending to the stream. The earthen forts usually cover an area ranging between 0.03 and 0.24 hectares. Whenever possible, simple, undefended villages were established near an earthen fort, although the distance between them was often as much as 1–1.5 kilometres. Our research indicates that only the landowner and his family, his servants and his animals lived in the protected area, which accommodated a single, tower-like structure and perhaps one or two economic buildings. The tower was constructed from various materials: brick and wood in regions lacking stone and stone where it was readily available.

History of research

After World War 2, aerial photographs were exclusively made for military cartographic purposes. Copies of these photos could be examined with a special permission from the 1970s. While these photos are certainly useful for identifying earthen forts, a few millimetres large light or dark coloured ring is all that indicates a possible medieval ditch or rampart owing to their scale (usually 1:20,000). Aerial archaeological reconnaissance became possible from the late 1980s and the early 1990s, although the procedure for obtaining permission remained rather complicated. Since 2000, it is no longer necessary to request a permit from the military and the aviation authorities for aerial archaeological prospecting.

The geographic environment

As has been mentioned in the above, these small forts are found among hills and mountains, on plain land and on floodplains alike. The likelihood of their detection largely depends on their location. Earthen forts constructed in mountainous regions are usually surrounded by woodland and they can best be photographed when covered with snow and in low raking sunshine. At the same time, these forts have generally survived in a fairly good state of preservation owing to the protection afforded by the woodland around them. The hilly regions are generally intensively cultivated, although earlier cultivated, but later abandoned fields tend to be covered by shrub. Agricultural cultivation is in part advantageous because it clears the terrain and the vegetation itself can indicate the presence of fortifications, but at the same time, ramparts are often levelled and ditches are filled up. Very often, nothing remains of the defence works on the surface and thus the remains of these earthen forts can only be detected from the air. This is especially true of earthen forts located on plains where the defence works have been ploughed away. The single exceptions are floodplain areas where the outlines of a former fort, as well as its ditches and ramparts can sometimes be made out, as for example at Resznek–Várhely in County Zala. In larger stream valleys, where the stream itself was incorporated into the defences, the earthen forts were also protected by the woodland flanking the valley.

Fig. 1. Péterhida–Pusztafalusi dűlő, County Somogy (photo: Zs. Miklós)

Dating

The date of the photographed feature usually cannot (and should not) be determined from the aerial archaeological photos alone – this is doubly true for earthen forts. No far-reaching conclusions can be drawn from the simple fact that a smaller area or a hill is enclosed by a ditch and rampart because monuments of this type can date from various periods such as the Árpádian Age, the Late Middle Ages (14th–16th centuries) or even the Ottoman Period. It is therefore necessary to inspect the site by field surveys where surface finds can be of aid in dating. Obviously, mistakes can be made even in these cases: in some cases, archaic-looking pottery sherds can suggest an earlier date. One case in point is the earthen fort by the Báta Stream at Őcsény–Oltovány in southern Transdanubia. Aerial photos and the finds collected during field surveying both suggested a date in the Árpádian Age, although the fort's size was larger than customary in that period. The surface finds included pieces that appeared to date from the Árpádian Age and from the late medieval period. Only the site's excavation made it clear that the vessel fragments that appeared to date from the Árpádian Age were in fact late medieval pieces.

Very often, we did not encounter any surface finds in the area of smaller earthen forts which, judging from their size, could date from the Árpádian Age. In these cases, at least a small sounding excavation should be performed.

Experiences in aerial archaeological prospecting

I have been engaged in aerial archaeological prospecting and photography since 1990, principally in Counties Tolna, Somogy and Pest.[1] I first flew with a PZL 101, later a Z-142, and now a Cessna plane. The PZL 101 had a very small window, unsuited to making photos and thus we usually flew with the door removed. Photos from the Z-142 could only be made through the cover and thus

[1] Aerial archaeological research during the past few years has been generously funded by OTKA grants T48318, K72231, K78316.

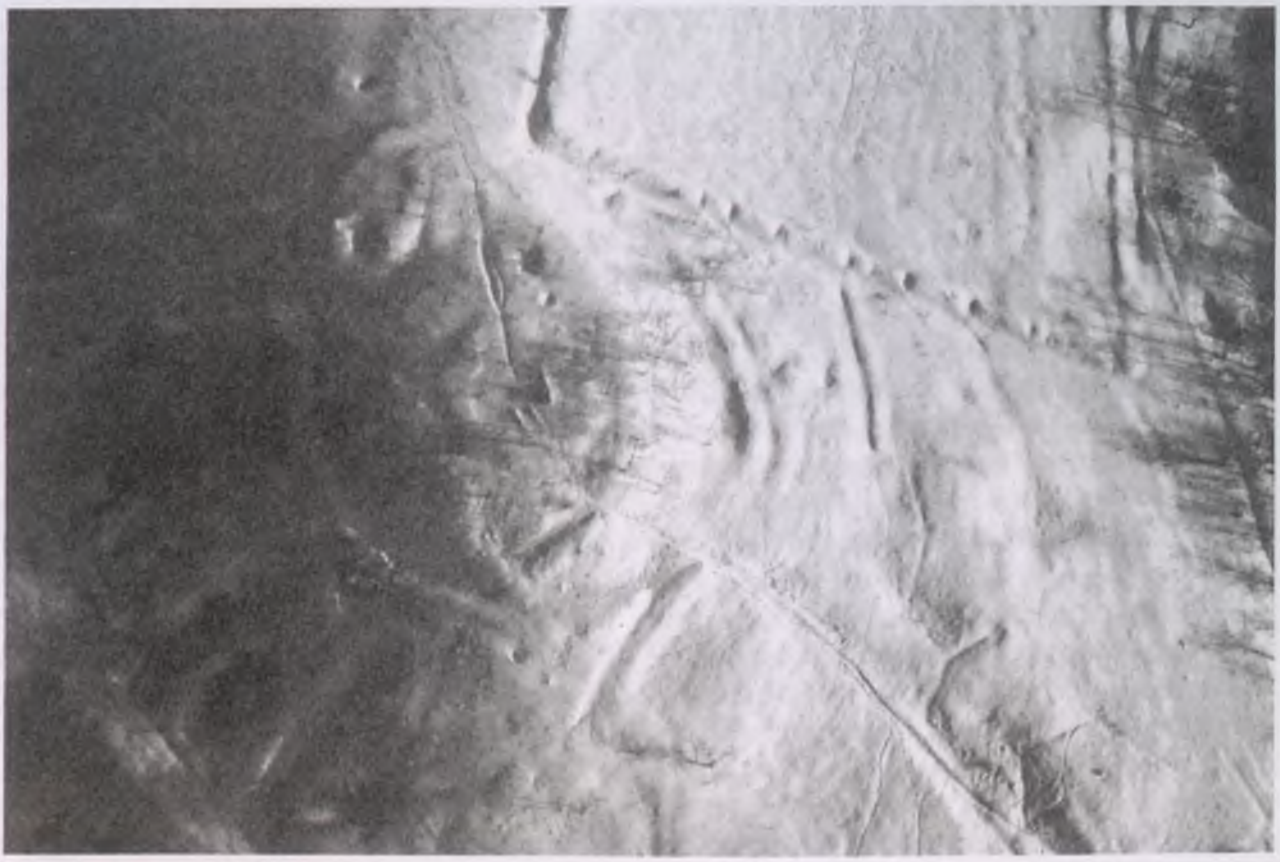


Fig. 2. Kerepes–Kálvária, County Pest (photo: Zs. Miklós)

the plane first had to be manoeuvred into a knife-edge position, which was rather cumbersome. Depending on its type, the window can usually be opened in Cessna planes. Even so, we usually fly without a door in order to make better photos and more accurate observations.

The best time for flights

Frost marks

In Hungary, the snow cover is most suitable for aerial photography in December and in January/February. In my experience, the ideal condition is when the top of the snow freezes and there is sunshine. Without sunshine, ideally low raking sunshine, the snow cover does not reveal much. In fortunate cases, even an eroded rampart and ditch become visible in the landscape, as in the case of Bikács–Belső sziget in County Tolna. Very often, the remains that are not visible on the surface, are clearly outlined by the frost and the shadow marks on the snow and can complement the geodesic survey (fig. 1). On sites of former villages, the shadow marks often indicate the presence of sites ringed by one or multiple ditches. While these sites often conform to the formal traits of Árpádian Age earthen forts, their function is often elusive even after the inspection of the site in the field. Despite the similarities in form, these sites may have been corrals. However, this can only be established by excavating the site and cutting through the features (Nagykarácsony–Ménesmajor, County Fejér).

Snow and shadow marks cast when the sun is low can be of great aid in areas covered by woodland and shrub. Archaeological monuments are not readily visible in these areas when inspected in the field. The outlines and the layout of the fort are clearly outlined on aerial photos (fig. 2, pl. 15.3).

Soil marks

Depending on the weather, deep ploughing is usually performed in November/December, after the autumn harvest, a time theoretically suitable for aerial archaeological reconnaissance. However, the air is usually damp and thus ideal circumstances for photography are very rare.

Spring is much more suitable because soil marks can be more clearly seen in freshly ploughed land. This situation lasts until mid-May. Knowing that maize has to be planted until May 1 by the latest, it starts growing in the first two weeks of that month, depending on the amount of rainfall. From mid-May to the month's end, its height is not as high as to disturb photography, and the green background actually accentuates potential archaeological features. Bronze and Árpádian Age defence works can be clearly made out in these environments. A dark band usually indicates the location of former ditches in ploughed fields, while ramparts appear as light bands, if they have not been obliterated by ploughing (pl. 14.1). At first sight, the Zsámbok site appeared to be an earthen fort of the Árpádian Age. However, the brick and stone rubble, the human bone fragments and the pottery sherds found during the site's inspection in the field suggested a church and a graveyard. Further aerial photos are therefore necessary for clarifying the exact nature of the site, as well as its investigation with a trial trench cutting through the ditch encircling the small hill.

Crop marks

In Hungary, crop marks can be observed from March onward, once the late snow has melted. However, fields sown with autumn wheat and pasturelands are not suitable at this early date for indicating the presence of former earthen forts. Aerial archaeological photography can be performed with better results in late April and early May, when autumn wheat has grown high enough to outline ramparts and ditches with its colour and growth anomalies. Former houses, pits, ramparts and ditches can be clearly seen in fields sown with autumn wheat by this time (pl. 14.2). Interestingly enough, the ditch of Bronze Age hillforts is not always visible, either among the green crops, or when the crop has ripened, at the time before harvesting.

Árpádian Age earthen forts can best be observed in areas sown with cereals (especially fields with autumn wheat): their presence is indicated by growth anomalies and by the crop's colour. The shades of yellow are usually darker in the area of former ditches, rich in humus, than in the surrounding land (pl. 14.3).

In fortunate cases, shrubs and trees can also signal the presence of archaeological monuments: during the vegetation period, the different shades of green outline the one-time defence works (pl. 15.2).

The crop marks indicating remains of Bronze Age forts are usually similar to the ones signalling the earthen forts of the Árpádian Age, the single difference being one of size (pl. 15.1). This is one of the reasons that the sites must be inspected in the field in order to determine their age.

Aerial archaeological photography and reconnaissance thus play an important role in research: the survey of a geographic region can hardly be complete without recourse to this prospecting technique.

Ramparts in the Görgényi, Hargita and Persányi Mountains

András Sófalvi

Keywords: Eastern Transylvania, ramparts, radiocarbon dates, aerial archaeological photography

The ramparts in eastern Transylvania constitute a territorially distinct and independent class among the similar monuments in the Carpathian Basin. Earlier known as the Szeklerland ramparts, these earthworks extend across the volcanic plateau of the Görgényi/Gurghiu and Hargita/Harghita Mountains, part of the eastern Carpathians, and the ridge of the Persányi/Perşani Mountains from north-west to south-east and north to south, from the headwater of the Kis-Nyárád/Niraju Mic to the Bogata Pass south of the Rákos Gorges of the Olt (pl. 16). Several theories have been proposed for their date and function during the past 150 years. This study presents the findings of my archaeological research on these earthworks, especially regarding their date, which can now be determined more accurately as a result of archaeometric analyses. The Homárka rampart in the Háromszék/Trei Scaune Basin and the Papok sánca rampart in the Barcaság/Ţara Bârsei region are not discussed here.

The first scientific description of the eastern Transylvanian ramparts was written by Balázs Orbán (Orbán 1868–1873), who believed that they had been defenceworks which, together with the stone castles near them, had protected the eastern confines of the Hungarian Kingdom. In the late 19th century, Gábor Téglás contended that the ramparts had been part of the eastern Dacian *limes* (Téglás 1895). The systematic investigation of the eastern Transylvanian ramparts was only begun in the 1970s. They were mapped in detail by István Dénes, a geologist and amateur archaeologist, who surveyed the earthworks and cut through them in several locations (Dénes 2001, Dénes 2003, Dénes 2007). In his interpretation of the ramparts, Dénes accepted the theory proposed by the archaeologists Géza Ferenczi and István Ferenczi that at the turn of the 11th and 12th centuries, the borders of the medieval Hungarian Kingdom had been defended by a sophisticated system of stone castles and ramparts (Ferenczi–Dénes 1994). A new chapter was opened in the research of the ramparts after 2000. Together with Antal Kosza, I mapped their exact course using GPS and began the systematic aerial archaeological photography of these monuments. The charcoal samples taken from the burnt wooden structure of the ramparts were submitted to radiocarbon analysis – the dates thus gained set these earthworks in an entirely new perspective.

Lying at 600–900 m a.s.l., the ramparts in the Görgényi, Hargita and Persányi Mountains can be divided into two main types in terms of their formal traits; as shall be shown below, these formal divergences can be traced to chronological and, presumably, functional differences.

The Ördög útja rampart extending west–north-west to east–south-east across the Görgényi–Hargita upland (fig. 1) is an earthwork whose line can be traced for several kilometres. Its line is only interrupted by river and stream valleys. The 0.5–1.5 m high, 4–8 m wide rampart has a trapezoidal or rounded section and is flanked by shallow ditches. It was used as a road during the past few centuries. Although the rampart is strongly eroded, its perished sections can be securely identified from the specks of burnt earth. The Ördögbarázda rampart running perpendicular to the former, starts from the eastern side of the Hargita Mountains. Its first section was constructed from stone, while the other sections were raised from earth. A ditch flanks its eastern side. In the south, the rampart extends across the Lövéte/Lueta Plateu along the western edge of the deep valley of the Vargyas/Vârghiş Stream. The width of the alternately convex and flattish earthwork ranges between 7 and 12 metres, while its height exceeds 1.5 m in some spots. Following a gap of several kilometres, the rampart continues in the Rika Woods south of the Vargyas Pass, its line following the watershed ridge of the Persányi Mountains. The earthwork known as the Kakasbarázda rampart is perhaps the most impressive earthwork among the eastern Transylvanian monuments of this type. The 2 m high rampart, whose width exceeds 10 m in some spots and is flanked by a ditch on the eastern side, is in some areas complemented by a double and, occasionally, a triple rampart (together with the

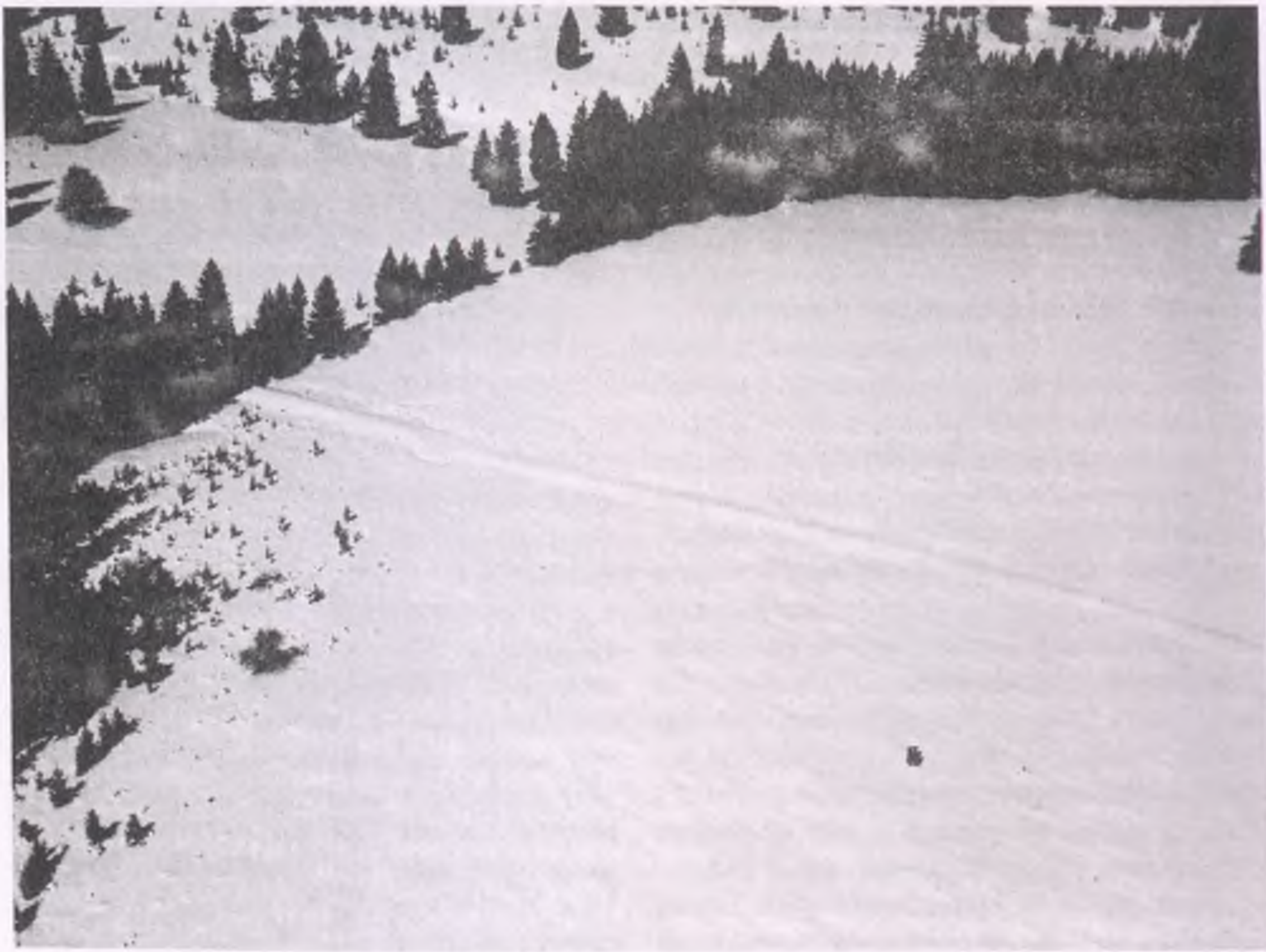


Fig. 1. The Ördögútja rampart in the Zetelaki/Zetea upland (photo: A. Sófalvi)

ditches). The rampart is interrupted by larger river and stream valleys. The section of the Kakasbarázda rampart running south of the Olt is virtually identical with the northern section (fig. 2). The documented length of the rampart in its current form is 43.2 km, and neither its initial, northern section, nor its final, southern section can be associated with any natural formation such as a mountain or a valley, suggesting that its construction was not completed. The gateways enabling passage through the rampart had probably been located at the junction of the earthwork and the roads leading through the river valleys. The rampart's line is marked by specks of burnt earth along its entire length, indicating that it had a wooden structure which had been torched in several locations (it seems unlikely that a conflagration had run its course along the rampart's entire length because no traces of burning were observed in its vicinity). The soundings and the sections cut across the rampart confirmed the initial observations: the charred timber remains and the thick layer of burnt earth both testify to the existence of a wooden structure and the intensity of the fire. However, the small soundings did not enable a reconstruction of the rampart's exact structure: horizontal and vertical timbers were both found in the trenches.

The dating and the function of the Ördög útja, Ördögbarázda and Kakasbarázda ramparts was earlier in part based on various historical reconstructions and in part on observations made in the field. In the lack of any dating materials, a date in the Roman Age and the Middle Ages was both proposed. The breakthrough came after 2005, when charcoal samples from the timber structures were collected and submitted to laboratory analyses. The samples were in all cases taken from the closed layer sequence of the perished timber structure in the course of smaller sounding excavations. One sample from the Ördög útja rampart and five

Fig. 2. The Kakasbarázda rampart south of the Olt (photo: A. Sófalvi)

samples from various sections of the Kakasbarázda rampart have so far been analysed. The radiocarbon measurements[1] gave dates in the 7th–9th centuries, with a smaller scatter (see Table 1; Sófalvi 2012). The dates would suggest that the rampart system was constructed over a longer period of time and that it was constructed from south to north.

The dendrochronological analyses have only yielded a floating chronology so far.

The other group of ramparts in the region is made up by the few hundred metres long earthworks and ditches running north-west (Sóvidék/Ținutul Ocnelor) and west (Küküllő mente/Depresiunea Târnavelor) of the ramparts described in the above and in the Rika Woods near the Kakasbarázda rampart. Some of these earthworks lie near medieval castles (Parajd–Rapsóné vára/Praid–Cetatea Rapsóné and Firtosváralja–Firtosvár/Firtușu–Cetatea Firtușu) or other monuments (Homoródalmás–Tatársánc/ Merești–Sanțul Tătarilor (fig. 3). The topographical location of these

	Sample code	Sample no.	$\delta^{13}C$(PDB) ± 0.2 [‰]	Conventional radiocarbon date (BP)	Calendar date (cal AD, 1 δ)
1	deb-13396	Székelyföld 011	- 26.7	1205 +/- 40	773–880 AD
2	deb-13402	Székelyföld 012	- 24.5	1250 +/- 35	689–789 AD
3	deb-13403	Székelyföld 013	- 27.3	1280 +/- 40	681–766 AD

Table 1. Radiocarbon dates for the Kakasbarázda rampart

[1] The charcoal samples were analysed in the Institute for Nuclear Research in Debrecen, as part of the research project led by Elek Benkő, funded by OTKA grant no. K-48577. The measurements were performed by Éva Svingor, Magdolna Mogyorósi and Sándor Sudár.

Fig. 3. The Tatársánc rampart above the Vargyas Pass (photo: András Sófalvi)

earthworks suggests that they are medieval establishments in an integral unity with the castles. The 13th–14th century archaeological finds from the Tatársánc rampart provide a post quem date for this earthwork. The radiocarbon measurements for a part of the smaller ramparts with a wooden structure near the Kakasbarázda rampart gave a date in the 8th–9th centuries, while the Országhatár rampart, originally constructed in the late Roman Age, was renewed and also used during the late Middle Ages, in the 15th century.

The topographic survey of the eastern Transylvanian ramparts and the application of archaeometric procedures in their dating have yielded a host of new data that shed fresh light on a virtually unknown episode in the region's early medieval history. The Ördög útja–Ördögbarázda–Kakasbarázda ramparts represent the built heritage of a period (7th–9th centuries), about which very little is known. Few settlements or cemeteries are known and thus the archaeological record is rather patchy, and neither are there any direct correlations between the ramparts and the data contained in the historical sources. The surviving remnant of the rampart system is but a torso of the original monument, and even though we do not have any numerical data on its one-time dimensions (its length probably exceeded the sum length of the currently known sections), it seems likely that its construction called for immense labour, which in turn implies the existence of a large population. The campsites or settlements of the population constructing and/or performing the maintenance of the ramparts still await discovery. The above clearly show that we are only at the initial phase of this research.

The names of the ramparts reveal that local lore associated their construction with supernatural powers (fairies, devils, magical roosters), meaning that the earthworks were part of a mythical world in the imagination of the Hungarian-Szekler population. It is noteworthy that the word "borozda", one element in the name given to the ramparts, has a Slavic ancestry (VISY 2011b, 225).

The topographical location of the rampart system's different sections and the one-time landscape provide important clues for the function of the ramparts. The Ördögútja rampart constructed across the flat Görgényi–Hargita upland, south-west of the high mountains, was no more than a symbolic boundary at the most. The rampart sections extending behind a high ridge, such as the few hundred metres long section of the Kakasbarázda rampart in the Rika Woods south of the Nádas Stream, or the rampart sections running along a stream bank were obviously unsuited to a military function. The reconstruction of the one-time vegetation in the direct environs of the ramparts through palaeobotanical sampling can yield fresh insights in this respect. The earthworks in a woodland environment could hardly have fulfilled a military function owing to poor visibility conditions, and it therefore seems more likely that they can be associated with economic and/or commercial activities, such as directing the flow of trade along certain routes or to particular gateways. In this case, the system could be maintained by a smaller population too.

Research on the eastern Transylvanian ramparts should focus on the sections in the southern part of the Persányi Mountains and the Görgényi upland because the determination of the exact spatial extent of these earthworks can be crucial for determining their function. Aerial archaeological reconnaissance will continue to play an important role in the research of these monuments. Obviously, our findings will remain incomplete without a study of the region's early medieval settlement history, while a comparison with the other Eastern and South-East European rampart system from this period can also contribute to elucidating their function.

References

AGACHE 1978 Agache, R., *La Somme pré-romaine et romaine d'après les prospections aériennes à basse altitude. Mémoires de la Société des Antiquaires de Picardie. Amiens*, 1978.

ALDRED–SEKEDAT 2010 Aldred, O. – Sekedat, B., Part 1 of Moving on to Mobility: Archaeological Ambulations on the Mobile World. Archaeolog (2010). http://traumwerk.stanford.edu/archaeolog/2010/12/moving_on_to_mobility_archaeol.html

ALDRED–SEKEDAT 2011a Aldred, O. – Sekedat, B., Part 2 of Moving on to Mobility: Archaeological ambulations on the mobile world. Archaeolog (2011). http://traumwerk.stanford.edu/archaeolog/2011/01/part_2_of_moving_on_to_mobilit.html

ALDRED–SEKEDAT 2011b Aldred, O. – Sekedat, B., Part 3 of Moving on to Mobility: Archaeological ambulations on the mobile world. Archaeolog (2011). http://traumwerk.stanford.edu/archaeolog/2011/02/part_3_of_moving_on_to_mobilit.html

ALDRED–SEKEDAT 2011c Aldred, O. – Sekedat, B., Part 4 of Moving on to Mobility: Archaeological ambulations on the mobile world. Archaeolog (2011). http://traumwerk.stanford.edu/archaeolog/2011/05/part_4_of_moving_on_to_mobilit.html

APORTA 2004 Aporta, C., Routes, trails and tracks: Trail breaking among the Inuit of Igloolik', *Études/Inuit/Studies*, 28/2 (2004), 9–38.

ARNUP 1998 Arnup, R. W., *The extent, effect and management of forestry-related soil disturbance, with reference to implications for the Clay Belt: a literature review.* Ottawa, 1998.

B. THOMAS 1964 B. Thomas, E., Römische Villen in Pannonien. Beiträge zur römischen Siedlungsgeschichte. Budapest, 1964.

BAJUSZ 2005 Bajusz, I., Téglás István jegyzetei. Régészeti feljegyzések 1/2, Kolozsvár, 2005.

BANASZEK–RĄCZKOWSKI 2010 Banaszek, Ł. – Rączkowski, W., Archeologia w lesie. O identyfikacji stanowisk archeologicznych w gminie Polanów (i nie tylko). In: Rączkowski, W. – Sroka, J. (eds), *Historia i kultura Ziemi Sławieńskiej. Tom X. Miasto i gmina Polanów. Fundacja Dziedzictwo.* Sławno–Polanów 2010, 117–132.

BĂRBULESCU 1987 Bărbulescu, M., *Din istoria militară a Daciei Romane. Legiunea V Macedonica şi castrul de la Potaissa*, Cluj-Napoca, 1987.

BĂRBULESCU 1994 Bărbulescu, M., Potaissa. Studiu monografic, Turda, 1994.

BARKÓCZI 1949 Barkóczi, L., A brigetiói tábor és canabae topográfiája (Nouvelles donées pour la topographie de Brigetio). *Antiquitas Hungarica* III (1949) 67–72.

BARKÓCZI 1951 Barkóczi, L., Brigetio. *Dissertationes Pannonicae Ser. 2, No. 22*, Budapest, 1951.

BARNA 2005 Barna, J. P., Sormás – Török-földek településtörténeti áttekintése. A középső neolitikum (The history of a settlement at Sormás–Török-földek. Middle Neolithic). *Zalai Múzeum* 14 (2005) 17–37.

BAUCON *et al.* 2008 Baucon, A. – Privitera, S. – Morandi Bonacossi, D. – Canci, A. – Neto de Carvalho, C. – Kyriazi, E. – Loborel, J. – Loaborel-Deguen, F. – Morhange, C. – Marriner, N., Principles of Ichnoarchaeology: new frontiers for studying past times. Studi Trentini di scienze naturali. *Acta Geologica* 83 (2008) 43–72.

BELLA 1891 Bella, L., A Sopron melletti Purgstall földvára és urnatemetője. *Archaeologiai Értesítő* 11 (1891) 313–320.

BENDER 2002 Bender, B., Time and Landscape. *Current Anthropology* 43 (2002) 103–102.

BERKOVICS-BOROTHA 1886 Berkovics-Borotha, M., Ásatásom az ó-szőnyi római táborban. *Archaeologiai Értesítő* 6 (1886) 392–397.

BERTÓK *et al.* 2008a Bertók, G. – Gáti, Cs. – Lóki, R., Előzetes jelentés a Belvárdgyula határában (Baranya megye) talált késő neolitikus település és körárok kutatásáról (Vorbericht über den Forschungstand der spätneolithischen Siedlung und Kreisgrabenanlage in der Gemarkung von Belvárdgyula (Komitat Baranya)). *Ősrégészeti Levelek* 10 (2008) 5–17.

BERTÓK *et al.* 2008b Bertók, G. – Gáti, Cs. – Vajda, O., Előzetes jelentés a Szemely-Hegyes lelőhelyen (Baranya megye) található neolitikus körárokrendszer kutatásáról (Preliminary report on the research at the neolithic Kreisgrabenanlage at Szemely-Hegyes, Baranya county, Hungary). *Archaeologiai Értesítő* 133 (2008) 85–106.

BERTÓK–GÁTI 2011 Bertók, G. – Gáti, Cs., Neue angaben zur spätneolithischen Siedlunsstruktur in Südostransdanubien. *Acta Archaeologica Academiae Scientiarum Hungaricae* 62 (2011) 1–28.

BÍRÓ 1974 Bíró, M., Roman Villas in Pannonia. *Acta Archaeologica Academiae Scientiarum Hungaricae* 26 (1974) 23–57.

BÍRÓ 2006 Bíró, Sz., Római villához tartozó temető Szombathely-Zanat határából. *Savaria. A Vas Megyei Múzeumok Értesítője* 29 (2005) [2006] 53–61.

BÓNA 1975 Bóna, I., Die mittlere Bronzezeit Ungarns und ihre südöstlichen Beziehungen. Archaeologia Hungarica Series Nova 49. Budapest, 1975.

BORHY 2006 Borhy, L., Brigetio/Komárom-szőny, Komárno. In: Humer, F. (hrsg.), *Legionsadler und Druidenstab. Vom Legionslager zur Donaumetropole.* Textband, Carnuntum-Wien, 2006, 152–153.

BORHY *et al.* 2011 Borhy, L. – Bartus, D. – Czajlik, Z. – Rupnik, L. – Számadó, E., Brigetio (Komárom/Szőny): Tábor – város a Duna mellett. Brigetio (Komárom/Szőny) – Fortress/City next to the Danube. In: Visy, Zs. (ed.), *Rómaiak a Dunánál. A Ripa Pannonica Magyarországon mint világörökségi helyszín. – Romans on the Danube. The Ripa Pannonica in Hungary as a World Heritage Site.* Pécs, 2011. 42–51.

BÖDŐCS 2008 Bödőcs, A., *A római kori úthálózat térinformatikai vizsgálata a mai Magyarország területén / A study of the roman road network in Hungary using GIS.* PhD dissertation. Eötvös Loránd University. Budapest, 2008.

BÖDŐCS 2009 Bödőcs, A., *A római kori Savaria környéki centuriatio területének vizsgálata térinformatikai eszközökkel / The analysis of the centuriatio around the Roman Savaria using GIS.* Thesis. Budapest University of Technology and Economics. Budapest, 2009.

BÖDŐCS–KOVÁCS 2011 Bödőcs, A. – Kovács, G., A római kori birtokrendszer kialakítása és tájformáló hatása Pannoniában. *Geodézia és kartográfia* 63/3 (2011) 20–25.

BRAASCH 2003 Braasch, O., Die Donau hinab – archäologische Flüge in Ungarn. In: Visy, Zs. (ed.), *Régészeti műemlékek kutatása és gondozása a 3. évezred küszöbén.* Pécs, 2003, 41–65.

BRAASCH 2007 Braasch, O., Gallipoli ahead – Air survey between the Baltic and Mediterranean. *Študijné zvesti Archeologického ústavu Slovenskej akadémii vied* 41 (2007) 84–96.

BRADFORD 1957 Bradford, J., *Ancient landscapes.* Studies in Field Archaeology. London, 1957.

BRZOZOWSKI–SIEMASZKO 2009 Brzozowski, J. – Siemaszko, J., Dwa nowe grodziska na Suwalszczyźnie. In: Bitner-Wróblewska, A. – Iwanowska, G., *Bałto-*

wie i ich sąsiedzi. Marian Kaczyński in Memoriam, Seminarium Bałtyjskie II. Warszawa, 2009, 637–642.*

Buatois–Mangano 2011 — Buatois, L. A. – Mangano G. M., *Ichnology. Organism–Substrate Interactions in Space and Time.* Cambridge, 2011.

Budziszewski–Wysocki 2012 — Budziszewski, J. – Wysocki, J., Nowe możliwości detekcji materialnych śladów historii terenów leśnych – lotnicze skanowani laserowe (LiDAR). In: Kobyliński, Z. – Wysocki, J. (eds), *Archaeologica Hereditas. Konserwacja Zapobiegawcza Środowiska 1.* Instytut Archeologii UKSW. Warszawa-Zielona Góra, 2012, 117–126.

Challis 2006 — Challis, K., Airborne Laser Altimetry in Alluviated Landscapes. *Archaeological Prospection* 13 (2006) 103–127.

Cordier 2012 — Cordier, A., Archéologie aérienne en Côte-d'Or en 2011: les aléas d'une sécheresse précoce, *Revue Archéologique de l'Est* 61 (2012) 371–383.

Corns–Shaw 2009 — Corns, A., Shaw, R., High resolution 3-dimensional documentation of archaeological monuments and landscapes using airborne LiDAR. *Journal of Cultural Heritage* 10 Sup. 1. (2009) 72–77.

Crawford 1929 — Crawford, O.G.S., Air-Photography for Archaeologists, London, 1929.

Crescioli *et al.* 2000 — Crescioli, M. – D'Andrea, A. – Niccolucci, F., A GIS-based analysis of the etruscan cemetery of Pontecagnano using fuzzy logic. In: Lock, G. R. (ed.), *Beyond the Map: Archaeology and Spatial Technologies, European University Centre for Cultural Heritage, Ravello, Italy, October 1–2 1999.* Amsterdam, 2000, 157–179.

Crişan *et al.* 1992 — Crişan, I. H. – Bărbulescu, M. – Chirilă, E. – Vasiliev, V. – Winkler, I., *Repertoriul arheologic al județului Cluj,* Cluj-Napoca, 1992.

Crutchley 2006 — Crutchley, S., Light Detection and Ranging (LiDAR) in the Witham Valley, Lincolnshire: an Assessment of New Remote Sensing Techniques. *Archaeological Prospection* 13/4 (2006) 251–57.

Czajlik 2004 — Czajlik, Z., Aerial archaeological investigations in Hungary in 2003. In: Kisfaludi, J. (ed.), *Archaeological Investigations in Hungary 2003.* Budapest, 2004, 111–125.

Czajlik 2007 — Czajlik, Z., Aerial archaeological prospection and documentation. The aerial archaeological archive of the Institute of Archaéological Sciences of the Eötvös Loránd University of Budapest (Summary of the activity in 1993–2005), *Archeometriai Műhely* 4 (2007) 1–10.

Czajlik 2008 — Czajlik, Z., Aerial archaeology in the research of burial tumuli in Hungary. *Communicationes Archaeologicae Hungariae* 28 (2008) 95–107.

Czajlik 2010 — Czajlik, Z., Les possibilités de la prospection aérienne conventionnelle en Hongrie, In: Borhy, L. (ed.), *Studia Celtica Classica et Romana Nicolae Szabó septuagesimo dedicata,* Budapest, 2010, 80–96.

Czajlik *et al.* 2012a — Czajlik, Z. – Király, G. – Czövek, A. – Puszta, S. – Holl, B. – Brolly, G., The Application of Remote Sensing Technology and Geophysical Methods in the Topographic Survey of Early Iron Age Burial Tumuli in Transdanubia. In: Berecki, S. (ed.) *Iron Age Rites and Rituals in the Carpathian basin. Proceedings of the International Colloquium from Târgu Mureş, 7–9 October 2011.* Târgu Mureş, 2012, 65–76.

Czajlik *et al.* 2012b — Czajlik, Z. – Bödőcs, A. – Rupnik, L., Légi fényképezéses régészeti kutatások Magyarországon 2010-ben. In: Kisfaludi, J. (ed.), Aerial photographic archaeological investigations in Hungary in 2010. *Régészeti kutatások Magyarországon.* Budapest, 2012, 111–132.

Dawkins 1989 — Dawkins, R., *The Extended Phenotype.* Oxford, 1989.

De Man *et al.* 2005 — De Man, J. – Cordemans, K., – Verkeyn, J. – Mestdagh, H., A Laser Based Digital Elevation Model. New Possibilities for Flemish Archaeologists. In: Bourgeois, J. – Meganck, M. (eds), *Aerial Photography and Archaeology 2003. A Century of Information. Conference held at the Ghent University, December 10th–12th, 2003.* Academia Press. Ghent 2005, 151–161.

Dénes 2001 — Dénes, I., Székelyföldi töltésvonulatok 1. *ACTA – A Csíki Székely Múzeum és a Székely Nemzeti Múzeum Évkönyve* 2000, 215–236.

Dénes 2003 — Dénes, I., Székelyföldi töltésvonulatok 2. *ACTA – A Csíki Székely Múzeum és a Székely Nemzeti Múzeum Évkönyve* 2003, 99–110.

Dénes 2007 — Dénes, I., Székelyföldi töltésvonulatok 3. *Acta Siculica – A Székely Nemzeti Múzeum Évkönyve* 2007, 253–285.

Devereux *et al.* 2008 — Devereux, B.J. – Amable, G.S. – Crow, P., Visualisation of LiDAR terrain models for archaeological feature detection. *Antiquity* 82 (2008) 470–79.

Dombay 1939 — Dombay, J., *A zengővárkonyi őskori telep és temető (The prehistoric settlement and cemetery at Zengővárkony). Archaeologia Hungarica* 23, Budapest, 1939.

Dombay 1960a — Dombay, J., Próbaásatás a villánykövesdi kőrézkori lakótelepen (Probegrabung in der aeneolithischen Ansiedlung bei Villánykövesd, Kom. Baranya). *Janus Pannonius Múzeum Évkönyve* 1959 (1960) 55–75.

Dombay 1960b — Dombay, J., *Die Siedlung und das Gräberfeld von Zengővárkony. Archaeologia Hungarica 37.* Budapest, 1960.

Doneus 2004 — Doneus, M., Aerial Archaeology in the Landscape of Carnuntum. *Archaeologia Aerea. Studi di Aerotopografia Archaeologica*, No. I, Libreria dello Stato, Istituto Poligrafico e Zecca dello Stato, Roma, 2004, 215–234.

Doneus 2006 — Doneus, M., Luftbildarchäologie in Carnuntum. In: Humer, F. (hrsg.), *Legionsadler und Druidenstab. Vom Legionslager zur Donaumetropole. Textband*, Carnuntum–Wien, 2006, 23–32.

Doneus–Briese 2006 — Doneus, M. – Briese, C., Full-waveform airborne laser scanning as a tool for archaeological reconnaissance. In: Campana, S. – Forte, M. (eds), *From Space to Place. 2. International Conference on Remote Sensing in Archaeology. Archaeopress.* Oxford 2006, 99–106.

Doneus–Briese 2010 — Doneus, M. – Briese, C., Airborne Laser Scanning in forested areas – potential and limitation of an archaeological prospection technique. In: Cowley, D. C. (ed.), *Remote Sensing for Archaeological Heritage Management. Proceedings of the 11th EAC Heritage Management Symposium, Reykjavik, Iceland, 24-27 March 2010*, EAC Occasional Paper No. 5, Occasional Publication of the Aerial Archaeology Research Group No. 3, Budapest 2011, 59–76.

Edgeworth 2011 — Edgeworth, M., *Fluid Pasts. Archaeology of flow.* Bristol, 2011.

Engel *et al.* 2009 — Engel, M. – Okulicz–Kozaryn, J. – Sobczak, C., Warowna siedziba jaćwieskiego nobila Шюрпы? Architektura obronna kompleksu osadniczego w Szurpiłach. In: Bitner–Wróblewska, A. – Iwanowska, G. (eds), *Bałtowie i ich sąsiedzi. Marian Kaczyński in Memoriam, Seminarium Bałtyjskie II. Warszawa 2009*, 517–544.

Ferenczi–Dénes 1994 — Ferenczi, I. – Dénes, I., Udvarhelyszéki töltésvonulatokról. Adalék Erdély Szent-László kori határvédelmének kérdéséhez. In: *A Zürichi*

	Magyar Történelmi Egyesület Első (Székelyudvarhelyi) Övezeti Történész-találkozó Előadásai és Iratai. Zürichi Magyar Történelmi Egyesület Kiadványa. Budapest – Zürich, 1994. 85–106.
FODOREAN 2006	Fodorean, F., *Drumurile din Dacia romană.* Cluj-Napoca, 2006.
FODOREAN 2011a	Fodorean, F., The aqueducts of Potaissa. Frontinus-Schriftenreihe *(Internationale Gesellschaft für Wasser und Energie zur Förderung der Wissenschaft, Forschung und Bildung auf dem Gebiet der Geschichte der Rohrleitungs-, Energie- und Wassertechnik sowie der rohrleitungstechnischen Fachausbildung)* 28 (2011) 95–108.
FODOREAN 2011b	Fodorean, F., The Bridges of Roman Dacia. In: *Archäologie der Brücken. Vorgeschichte. Antike. Mittelalter. Neuzeit (Archaeology of Bridges. Prehistory. Antiquity. Middle Ages. Modern Era).* Bayerische Gesellschaft für Unterwasserarchäologie (Herausgeber), in Verbindung mit dem Bayerischen landesamt für Denkmalpflege, Verlag Friedrich Pustet, Regensburg, 2011, 143–147.
FODOREAN 2012	Fodorean, F., Die Strassen des Römischen Dakiens. Forschungsstand, neue Entdeckungen und Perspektiven der Forschung. Gymnasium. *Zeitschrift für Kultur der Antike und Humanistische Bildung* 119 (2012) 255–279.
FÜLEP – BURGER 1979	Fülep, F. – Burger, A., Baranya megye a római korban (Baranya County in the Roman Age). In: Bándi, G. (ed.), *Baranya megye története az őskortól a honfoglalásig (The history of Baranya County from the Prehistoric period to the Hungarian Conquest).* Pécs 1979, 223–317.
GABLER 1994	Gabler, D., Die ländliche Besiedlung Oberpannoniens. In: Bender, H. – Wolff, H. (eds), *Ländliche Besiedlung und Landwirtschaft in den Rhein – Donau – Provinzien des Römischen Reiches,* Band 2. Passauer Universitätsschriften zur Archäologie. Espelkamp, 1994, 377–419.
GALLAGHER–JOSEPHS 2008	Gallagher, J.M. – Josephs, R.L., Using LiDAR to Detect Cultural Resources in a Forest Environment: an Example from Isle Royale National Park, Michigan, USA. *Archaeological Prospection* 15 (2008) 187–206.
GARBACZ 2009	Garbacz, K., *Osadnictwo kultury przeworskiej we wschodniej części Niecki Nidziańskiej,* Warsaw, 2009
GLAVAŠ 2011	Glavaš, V., Problems of reconnaissance of the karst landscape – an example of the north sub-Velebit littoral. Croatia, *AARGnews* 43 (2011) 24–30.
GOGÂLTAN 2002	Gogâltan, F., Die Tells der Bronzezeit im Karpatenbecken. Terminologische Fragen. In: Rustoiu, A. – Ursuţiu, A. (eds), *Interregionale und Kulturelle Beziehungen im Karpatenraum (2. Jahrtausend v. Chr.–1. Jahrtausend n. Chr.) – Interferenţe etnice şi culturale în mileniile I a. Chr.–I. p. Chr. Vol. IV — Ethnische und Kulturelle Interferenzen im 1. Jahrtausend v. Chr.–1. Jahrtausend n. Chr. Band 4.,* Cluj-Napoca, 2002, 11–45.
GOGUEY 1966	Goguey, R., Recherches sur l'influence des dates et des conditions techniques des prises de vues dans la détection aérienne des indices d'origine archéologique, In: *Archives Internationales de Photogrammétrie, vol. XVI, Actes du IIe Symposium International de Photo-Interprétation,* Paris, 1966, 3–12.
GOGUEY 1968	Goguey, R., *De l'aviation à l'archéologie : recherches sur les techniques et les méthodes de l'archéologie aérienne,* Thèse de l'Ecole Pratique des Hautes Etudes, Paris, 1968.

GOGUEY 1969 Goguey, R., Archéologie aérienne, In: Kodeko, Paris, XXI^e numéro spécial, janv. 1969, 30–31.

GOGUEY 1972 Goguey, R., Mirebeau: les fouilles de 1970 sur les thermes, In: *Mémoires de la Commission des Antiquités de la Côte d'Or*, t. XXVII, 1970–1971, Dijon, 1972, 14–20.

GOGUEY 1991 Goguey, R., Alésia: les travaux de César sur la Montagne de Bussy d'après les dernières révélations de la photographie aérienne, *Académie des Inscriptions et Belles Lettres* (1991), 43–51.

GOGUEY 1997 Goguey, R., Vix: les données de l'archéologie aérienne sur le site et son environnement, In: Brun, P. – Chaume, B. (dir.), *Vix et les éphémères principautés celtiques. Les VI^e et V^e siècles avant J.-C. en Europe centre-occidentale, Actes du colloque de Châtillon-sur-Seine (27-29 octobre 1993)*, Paris, 1997, 179–200.

GOGUEY 1999 Goguey, R. – Violot A., Recherches d'archéologie aérienne sur le siège d'Alésia (1959–1999), In: *Le siège d'Alésia, Académie des Inscriptions et Belles Lettres*, 1999.

GOGUEY 2000 Goguey, R., Sur la route de Dijon… au limes romain de Pannonie, In: *Hommage à Charles Léva, Centre Interdisciplinaire de recherches aériennes. Bruxelles, 23*, 30–31.

GOGUEY 2005 Goguey, R., Un exemple de recherches diachroniques: l'archéologie aérienne en Hongrie, In: *Archéologies: 20 ans de recherches françaises dans le monde - Ministère des Affaires Etrangères, Paris, 2005*, 111–112.

GOGUEY–REDDÉ 1995 Goguey, R. - Reddé, M., Le camp légionnaire de Mirebeau, Mayence, Römisch–Germanisches Zentralmuseum, 1995

GOGUEY–SZABÓ 1995 Goguey, R. – Szabó, M., *L'histoire vue du ciel – A történelem madártávlatból : photographie aérienne et archéologie en France et en Hongrie*, Catalogue d'exposition, Budapest, 1995.

GUGL *et al.* 2006 Gugl, Ch. - Humer, F. - Klein, M. - Pregesbauer, M., Versuch einer Wiederherstellung des antiken Carnuntum auf virtuellem Wege. In: Humer, F. (ed.), *Legionsadler und Druidenstab. Vom Legions-lager zur Donaumetropole. Textband, Carnuntum-Wien 2006*, 33–42.

H. KELEMEN 2010 H. Kelemen, M., Adatok egy új római objektumról Tokodon (Results from a newly identified building from Roman Tokod). In: Tari, E. - Tóth, E. (ed.), *Tanulmánykötet Horváth István 70 éves születésnapjára. Esztergom-Budapest 2010* (2012) 69–93.

HANNAM *et al.* 2006 Hannam, K. - Sheller, M. - Urry, J. Editorial, Mobilities, Immobilities and Moorings. *Mobilities* 1 (2006) 1–22.

HESSE 2010 Hesse, R., LiDAR-derived Local Relief Models – a new tool for archaeological prospection. *Archaeological Prospection* 17 (2010) 67–72.

HINDLE 2001 Hindle, P., Roads and Tracks for Historians. Chichester, 2001.

HOLDEN *et al.* 2002 Holden, N. - Horne, P. - Bewley, R.H., High-resolution digital airborne mapping and archaeology. In: Bewley, R.H. - Rączkowski, W. (eds), *Aerial Archaeology: Developing Future Practice. Proceedings of the NATO Advanced Research Workshop on Aerial Archaeology – Developing Future Practice. Leszno, Poland 15–17 November 2000.* IOS Press. Amsterdam, 2002, 173–80.

ILON 2001 Ilon, G., Egy valódi „via rustica" Savaria territoriumán. *Savaria. A Vas Megyei Múzeumok Értesítője* 25/3 (2000–2001) 69–80.

INGOLD 2004 Ingold, T., Culture on the ground: The world perceived through the feet. *Journal of Material Culture* 9(3) (2004) 315–40.

INGOLD 2007 Ingold, T., Lines: *A brief history*. London and New York, 2007.

INGOLD 2011 Ingołd, T., *Being Alive: Essays on movement, knowledge and description*. London and New York, 2011.

JASKANIS 1996 Jaskanis, D., Próba oceny metody Archeologicznego Zdjęcia Polski na podstawie doświadczeń ogólnokrajowego koordynatora. In: Jaskanis D., *Archeologiczne Zdjęcie Polski – metoda i doświadczenia. Próba oceny. MKiS*. Warszawa, 1996, 9–38.

KALICZ 1983–84 Kalicz, N., Übersicht über den Forschungsstand der Entwicklung der Lengyel-*Kultur* und die ältesten "Wehranlagen" in Ungarn. Mitteilungen der Österreichischen Arbeitsgemeinschaft für Ur- und Frühgeschichte 33–34 (1983–84) 271–293.

KOBYLIŃSKI *et al.* 2012 Kobyliński, Z. – Borowski, M. – Budziszewski, J. – Herbich, T. – Kobyliński, Ł. – Sławik, Ł. – Wach, D. – Wysocki, J. – Jaszewska, A., Kompleksowe, niedestrukcyjne rozpoznanie zasobów archeologicznych Starego Kraju w województwie lubuskim. *Archeologia Środkowego Nadodrza* 9 (2012) 11–42.

KOŁAKOWSKI 1972 Kolakowski, L., Obecność mitu, Paris, 1972.

KOVÁCS 1969 Kovács, T., A százhalombattai bronzkori telep (The Bronze-Age Settlement at Százhalombatta). *Archaeologiai Értesítő* 96 (1969) 161–169.

KOVÁCS 1984 Kovács, T., Die Vatya–Kultur. In: Tasić, N. *(ed.), Kulturen der Frühbronzezeit des Karpatenbeckens und Nordbalkans*. Beograd, 1984, 217–233.

KUZMA 1995 Kuzma, I., Luftbildarchäologie in der Slowakei. In: Kunow, J. (ed.), *Luftbildarchäologie in Ost- und Mitteleuropa. Forschungen zur Archäologie im Land Brandenburg 3. Berlin*, 251–258.

KWINTER 2001 Kwinter, S., *Architectures of time: Towards a theory of Event in Modernist Architecture*. Cambridge, 2001.

LÁNG 1941 Láng, F., Das Dolichenum von Brigetio. In: Alföldi, A. (hrsg.), *Laureae Aquincenses Memoriae valentini Kuzsinszky dicatae II. Dissertationes Pannonicae Ser. 2, No. 11*, Budapest, 1941, 165–181.

LASAPONARA *et al.* 2010 Lasaponara, R., Coluzzi, R., Gizzi, F.T., Masini, N., On the LiDAR contribution for the archaeological and geomorphological study of a deserted medieval village in Southern Italy. *Journal of Geophysics and Engineering* 7 (2010), 155–63.

LEFEBVRE 1991 Lefebvre, H., The Production of Space. Oxford, 1991.

ŁOSIŃSKI *et al.* 1971 Łosiński, W. – Olczak, J. – Siuchniński K., Źródła archeologiczne do studiów nad wczesnośredniowiecznym osadnictwem grodowym na terenie województwa koszalińskiego, T. IV, Poznań, 1971.

MÁTYÁS 2007 Mátyás, Sz., Egy kora római település Savaria territóriumáról. *Savaria. A Vas Megyei Múzeumok Értesítője* 30 (2006) 2007, 159–198.

MELVIN *et al.* 2004 Melvin, G. R. – Larsen, R. E. – McDouglald, N. K. – Tate, K. W. – Gerlach, J, D. – Fulgham, K. O. Cattle grazing has varying impact on stream-channel erosion in oak woodlands. *California agriculture* 58/3 (2004) 138–143.

MILCH 1910 Milch, Á., A bregetiumi Jupiter-dolichenus szentély. A *Komárommármegyei és Városi Muzeum-Egyesület 1900. évi értesítője* 14 (1901) 28–35.

MLEKUŽ 2012 Mlekuž, D., Messy landscapes manifesto. *AARG News* 44 (2012) 22–23.

MLEKUŽ 2013 Mlekuž, D., Messy landscapes: lidar and the practice of landscaping. In: Opitz, R. S – Cowley, D. C., *Interpreting Archaeological Topography: 3D, Visualization and Observation*. Oxford, 2013, 88–99.

Mócsy 1965	Mócsy, A., Savaria utcarendszerének rekonstrukciójához. *Archaeologiai Értesítő* 92 (1965) 27–36.
Mócsy 1974	Mócsy, A., *Pannonia and Upper Moesia (The Provinces of the Roman Empire)*. London and Boston, 1974.
Mócsy 1990	Mócsy, A., Földbirtok. In: Mócsy, A.–Fitz, J., *Pannonia Régészeti Kézikönyve*. Budapest, 1990. 125–127.
Muir 2000	Muir, R., *The New Reading The Landscape: Fieldwork in Landscape History.* Exeter, 2000.
MRT 4	Dax, M. – Éri, I. – Mithay, S., Veszprém megye régészeti topográfiája. A pápai és zirci járás. Magyarország régészeti topográfiája 4. Budapest, 1972.
MRT 7	Dinnyés, I. – Kővári, K. – Lovag, Zs. – Tettamanti, S. – Topál, J. – Torma, I., Magyarország Régészeti Topográfiája 7. Pest megye régészeti topográfiája. A Budai és Szentendrei járás. Budapest, 1986.
Neogrády 1948–50	Neogrády, S., A légifénykép és az archaeológiai kutatások. *Térképészeti Közlöny* 7 (1948–50) 283–332.
Nestupný 2006	E. Nestupný., Enclosures and fortifications in Central Europe. In: Harding, A. – Sievers, S. – Venclová, N. (eds), *Enclosing the Past: inside aind outside in the prehistory. Sheffield Archaeological Monographs* 15 (2006) 1–4.
Olwig 2007	Olwig, K. R., Perambulatory Practice, Sight and the Sense of Belonging. In: Ingold, T – Vergunst, J. L. (eds), *Ways of Walking: Ethnography and Practice on Foot.* Farnham, 2007, 81–91.
Orbán 1868–1873	Orbán, B., *A Székelyföld leírása történelmi, régészeti, természetrajzi s népismei szempontból I–VI.* Pest – Budapest, 1868–1873.
Orlicka–Jasnoch 2012	Orlica–Jasnoch, J., Inwentaryzacja wybranych cmentarzysk kurhanowych ludności kultury łużyckiej z terenu województwa lubuskiego przy pomocy lotniczego skaningu laserowego (LiDAR). *Archeologia Środkowego Nadodrza* 9 (2012) 53–80.
Osztás *et al.* 2004	Osztás, A. – Marton, T. – Sófalvi, A., Szólád–Kisaszó. In: Honti, Sz. (ed.), *A tervezett M7-es autópálya Somogy megyei szakaszának megelőző régészeti feltárása III (2002–2003). Somogyi Múzeumok Közleményei* 16 (2004) 61–62.
P. Fischl–Reményi 2007	P. Fischl, K. – Reményi, L., Possibilites of the Bronze Age Tell Sites in the Carpathian Basin. In: Uglešić, A. (ed.), *European Association of Archaeologist 13th Annual meeting. Zadar, Croatia 18th – 23rd September 2007. Abstract Book.* Zadar, 246–247.
Paitier 2012	Paitier, H.–P., Archéologie et photographie : un rendez-vous manqué ? In: *L'archéo-Théma : Les métiers de l'archéologie,* (Hors-Série n°5), 2012.
Parcak 2009	Parcak, S., Satellite Remote Sensing for Archaeology, Abingdon-New York, 2009.
Paulovics 1941	Paulovics, I., Funde und Forschungen in Brigetio (Szőny). In: Alföldi, A. (hrsg.), *Laureae Aquincenses Memoriae valentini Kuzsinszky dicatae II. Dissertationes Pannonicae Ser. 2, No. 11*, Budapest, 1941, 118–164.
Pelisiak 2003	Pelisiak, A., *Osadnictwo. Gospodarka. Społeczeństwo. Studia nad kulturą pucharów lejkowatych na Niżu Polskim,* Rzeszów, 2003.
Pelivan 2007	Pelivan, A., *Velebit,* Donja Lomnica, 2007.
Perica–Orešić 1999	Perica, D. – Orešić, D., Klimatska obilježja Velebita i njihov utjecaj na oblikovanje reljefa. *Senjski Zbornik* 26 (1999) 1–50.
Petrasch 1990a	Petrasch, J., Mittelneolithische Kreisgrabenanlagen in Mitteleuropa.

PETRASCH 2004 *Bericht der Römisch-Germanischen Kommission* 71 (1990) 407–564.
Petrasch, J., Von Menschen und Hunden: Befunde aus Kreisgrabenanlagen der Oberlauterbacher Gruppe und der Lengyel-Kultur und deren Interpretationen. In: Bertemes, F.–Biehl, P.F.,–Meller, H. (Hrsg.), *Neolithische Kreisgrabenanlagen in Europa internationale Arbeitstagung, 7.-9. Mai 2004 in Goseck*, 2004, 295–308.

PLIT 2010 Plit, J., Przestrzenne zmiany zasięgu lasów i gospodarowania w lasach gminy Polanów w ciągu ostatnich 400 lat. In: Rączkowski, W. – Sroka, J. (eds), *Historia i kultura Ziemi Sławieńskiej. Tom X. Miasto i gmina Polanów. Fundacja Dziedzictwo. Sławno-Polanów, 2010*, 269–288.

PODBORSKÝ 1988 Podborský, V., *Těšetice-Kyjovice 4: Rondel osady lidu s moravskou malovanou keramikou (Těšetice-Kyjovice 4: Rondel from a settlement of the Moravian painted pottery culture).* Brno, Czech Republic: Univerzita Jana Evangelisty, 1988.

RĄCZKOWSKI 2003 Rączkowski, W., Wobec mitu naukowego: gród wczesnośredniowieczny w interpretacji archeologicznej. *Biuletyn Historyczny* 23 (2003) 173–188.

RĄCZKOWSKI 2005 Rączkowski, W., Tradition in power: vicious circle(s) of aerial survey in Poland. In: Brophy, K. – Cowley, D. (eds), *From the Air. Understanding Aerial Archaeology.* Tempus. Stroud, 2005, 151–167.

RĄCZKOWSKI 2006 Rączkowski, W., Towards integration: two prospection methods and some thoughts. In: Campana, S. – Forte, M. (eds), *From Space to Place. 2nd International Conference on Remote Sensing in Archaeology. BAR International Series* 1568. Archaeopress. Oxford, 2006, 203–206.

RĄCZKOWSKI 2011 Rączkowski, W., Integrating survey data – the Polish AZP and beyond. In: Cowley, D. C. (ed.), *Remote Sensing for Archaeological Heritage Management. EAC Occasional Paper No. 5. Brussels, 2011*, 153–160.

RĂDEANU–FODOREAN 2011 Rădeanu, V. – Fodorean, F., Archeological structures in Dacia identified on aerial photographs. *Archeologia Aerea* IV–V (2010–2011) 329–332.

RADNÓTI 1939–40 Radnóti, A., Sopianaeból kiinduló római utak (Roman roads starting from Sopianae). *Pécs sz. kir. Város Majorossy Imre Múzeumának Értesítője* 1939–40, 27–39

RADNÓTI 1946–48 Radnóti, A., Bronz Mithrasz-tábla Brigetioból (Le bas-relief Mithriaque de bronze de Brigetio). *Archaeologiai Értesítő* 7–9 (1946–48) 137–146.

REDDÉ–SCHNURBEIN 2001 Reddé, M. – Schnurbein, S. (von) (dir.), Alésia. Fouilles et recherches franco-allemandes sur les travaux militaires romains autour du Mont-Auxois (1991 – 1997), Paris: *Académie des Inscriptions et Belles-Lettres*, 2001, 33–53.

REDŐ 2006 Redő, F., The Kerka Valley in the Roman Age In: Bánffy, E. (ed.) Archaeology and Settlement History in the Kerka Valley, South–West Hungary. *Antaeus* 28 (2006) 101–115.

RIU 1 Barkóczi, L. – Mócsy, A. (eds), *Die römische Inschriften Ungarns.1. Savaria, Scarbantia und die Limes-Strecke ad Flexum–Arrabona.* Budapest, 1972.

RÓMER 1878 Rómer, F., *Résultats généraux du Mouvement Archéologique en Hongrie.* Budapest, 1878.

RYBICKA 1995 Rybicka, M., *Przemiany kulturowe i osadnicze w III tys. przed Chr. na Kujawach: Kultura pucharów lejkowatych i amfor kulistych na Pagórach Radziejowskich.* Łódź, 1995.

SCHIFFER 1987 Schiffer, M.B., *Formation processes of the archaeological record.* Albuquerque, 1987.

SEKULER – BLAKE 1994 Sekuler, R. – Blake, R., *Perception*. New York: Mcgraw-Hill College, 1994.

SHAW–CORNS 2011 Shaw, R. – Corns, A., High resolution LiDAR specifically for archaeology: are we fully exploiting this valuable resource? In: Cowley, D. C. (ed.), *Remote Sensing for Archaeological Heritage Management. EAC Occasional Paper No. 5.* Brussels, 2011, 77–86.

SHELER–URRY 2006 Sheller, M. – Urry, J. The new mobilities paradigm. *Environment and Planning* 38 (2006) 207–222.

SKRZYPEK 2010 Skrzypek, J., Z pradziejów gminy Polanów. In: Rączkowski, W. – Sroka, J. (eds), *Historia i kultura Ziemi Sławieńskiej. Tom X. Miasto i gmina Polanów. Fundacja Dziedzictwo. Sławno-Polanów, 2010*, 39–116.

SÓFALVI 2012 Sófalvi, A., *A székelység határvédelme és önvédelme a középkortól a fejedelemség koráig. Várak és más védelmi objektumok Udvarhelyszék településtörténetében / The Border and Self-defence of the Szeklers from the Medieval Age till the Age of Principality. Castles and other Defence Objects in the Settlement History of Udvarhelyszék.* PhD dissertation. Eötvös Loránd University. Budapest, 2012.

SOMOGYI 2007 Somogyi, K., Die besonderen Grabenanlagen der Lengyel-Kultur in Kaposújlak – Várdomb-dűlő im Komitat Somogy (SW-Ungarn). In: Kozlowski J. K. – Raczky, P. (eds), *The Lengyel, Polgár and Related Cultures in the Middle/Late Neolithic in central Europe. Kraków, 2007*, 329–344.

SZABÓ 2011a Szabó, M., Élet a hadsereg árnyékában – Life in the shadow of the army. In: Visy, Zs. (ed.), *Rómaiak a Dunánál. A Ripa Pannonica Magyarországon mint világörökségi helyszín. – Romans on the Danube. The Ripa Pannonica in Hungary as a World Heritage Site.* Pécs, 2011, 89–93.

SZABÓ 2011b Szabó, M., Régészeti kutatások a Ripa Pannonica polgári településein (Archaeological research on the civilian settlements of the Ripa Pannonica). In: Visy, Zs. – Szabó, M. – Priskin, A. – Lóki, R. (eds), *A Danube Limes program régészeti kutatásai 2008-2011 között (The Danube Limes project archaeological research between 2008-2011)*, Pécs 2011, 147–162.

SZABÓ–VISY 2011 Szabó, M., – Visy, Zs., Menettáborok Brigetio környékén – Marching camps in the vicinity of Brigetio. In: Visy, Zs. – Szabó, M. – Priskin, A. – Lóki, R. (eds), *A Danube limes program régészeti kutatásai 2008–2011 között. Jelentés a Danube Limes Unesco World Heritage Site pályázat keretében a PTE BTK Régészet Tanszékének kutatócsoportja által végzett kutatásokról – The Danube Limes project archaeological research between 2008–2011. Report on the research carried out by the research team of the Department of Archaeology, University of Pécs within the framework of the Danube Limes Unesco World Heritage Site project.* Pécs, 2011, 107–112.

SZÁMADÓ 1997 Számadó, E., Brigetio kutatástörténete (Research History of Brigetio, Forschungsgeschichte Brigetios). *Komárom Megyei Múzeumok Közleményei* 5 (1992/1997) 149–174.

SZÁMADÓ 2010 Számadó, E., Régészeti kutatások Komárom/Szőny területén a római kori Brigetióban, 1990–2010 között (The Archaeological Research at Komárom (Szőny Neighbourhood) on the Territory of the Roman Brigetio, 1990–2010); (Cercetarea archeologica de la Komárom (cartierul Szőny), pe teritoriul Brigetio-ului roman, 1990–2010). *Terra Sebus* 2010/2 (2010) 141–176.

SZÁMADÓ–BORHY 2003 Számadó, E. – Borhy, L., Brigetio Castra Legionis. In: Visy, Zs. (ed.), *The Roman Army in Pannonia. An Archaeological Guide of the Ripa Pannonica.* Pécs, 2003, 75–77.

TÉGLÁS 1895 Téglás, G., A Limes Dacicus két Küküllő és Olt közötti részlete Udvarhelymegye éjszaki és keleti hegységeiben Oroszfalutól Alsó-Rákosig. *Archaeologiai Közlemények* 19 (1895) 5–54.

TOKAI 2008 Tokai, Z.-M., 0711 Nagykanizsa-Palin – Anyagnyerőhely. http://www.zmmi.hu/gm/m7_kiadvany/Htm/031_0711.htm

TÓTH 1977a Tóth, E., Geschichte der Oberen Wart im 1. Jahrtausend. In: Triber, L. (ed.), *Die Obere Wart. Festschrift zum Gedenken an die Wiedererrichtung der Oberen Wart im Jahre 1327.* Innsbruck, 1977, 77–100.

TÓTH 1977b Tóth, E., A Savaria-Bassiana útszakasz. *Archaeologiai Értesítő* 104 (1977) 65–75.

TÓTH 2009 Tóth, E., Studia Valeriana. Az alsóhetényi és ságvári késő római erődök kutatásának eredményei (Results of the research on the Late Roman inner fortresses at Alsóhetény and Ságvár). Dombóvár, 2009

TRNKA 1991 Trnka, G., Studien zu mittelneolithischen Kreisgrabenanlagen. *Mitteilungen der Prähistorischen Kommission* 26 (1991).

URRY 2007 Urry, J. 2007. *Mobilities.* Cambridge, 2007.

VICZIÁN–HORVÁTH 2006 Viczián, I. – Horváth, F., A tatai mocsarak a római korban és Mikoviny Sámuel lecsapoló munkája (Marshes in the environs of Tata at the Roman Age and their draining by Sámuel Mikoviny). *Földrajzi Értesítő* LV/3–4 (2006) 257–272.

VIDA 1996 Vida, T., Külsővat és környékének régészeti emlékei a római kortól az árpád-korig. In: Ilon, G. (ed.), *Tanulmányok Külsővat történetéből.* Külsővat, 1996, 75–104.

VISY 1994 Visy, Zs., Die ländliche Besiedlung und Landwirtschaft in Niederpannonien. In: Bender, H. – Wolff, H. (eds), *Ländliche Besiedlung und Landwirtschaft in den Rhein – Donau – Provinzien des Römischen Reiches, Band 2,* Passauer Universitätsschriften zur Archäologie. Espelkamp, 1994, 421–449.

VISY 1995 Visy, Zs., Luftbildarchäologie am römischen Limes in Ungarn. In: Kunow, J. (ed.), *Luftbildarchäologie in Ost- und Mitteleuropa. Forschungen zur Archäologie im Land Brandenburg 3.* Berlin, 213–218.

VISY 2000 Visy, Zs., *A ripa Pannonica Magyarországon.* Budapest, 2000.

VISY 2003a Visy, Zs., A pécsi légirégészeti műhely. Régészeti kutatások a Ripa Pannonica mentén. In: Visy, Zs. (ed.), *Régészeti műemlékek kutatása és gondozása a 3. évezred küszöbén.* Pécs, 2003, 107–122.

VISY 2003b Visy, Zs., *The ripa Pannonica in Hungary.* Budapest, 2003.

VISY 2011a Visy, Zs. (ed.), *Rómaiak a Dunánál. A Ripa Pannonica Magyarországon mint világörökségi helyszín. – Romans on the Danube. The Ripa Pannonica in Hungary as a World Heritage Site.* Pécs, 2011. 42–51.

VISY 2011b Visy, Zs., Régi sáncok a székely hagyományban. In: Sófalvi, A. – Visy, Zs., (eds), *Tanulmányok a székelység középkori és fejedelemség kori történelméből.* Énlaka–Székelyudvarhely, 2011, 219–232.

VMFN Balogh, L. – Végh, J., Vas megye földrajzi nevei. Szombathely 1982.

WAGNER *et al.* 2006 Wagner, W. – Ullrich, A. – Ducic, V. – Melzer, T. – Studnicka, N., Gaussian decomposition and calibration of a novel small-footprint full-waveform digitising airborne laser scanner. ISPRS *Journal of*

Photogrammetry and Remote Sensing 60 (2006) 100–112.

WEINER 1991 Weiner, J. F., *The Empty Place: Poetry, Space and Being among the Foi of Papua New Guinea.* Bloomington (In), 1991.

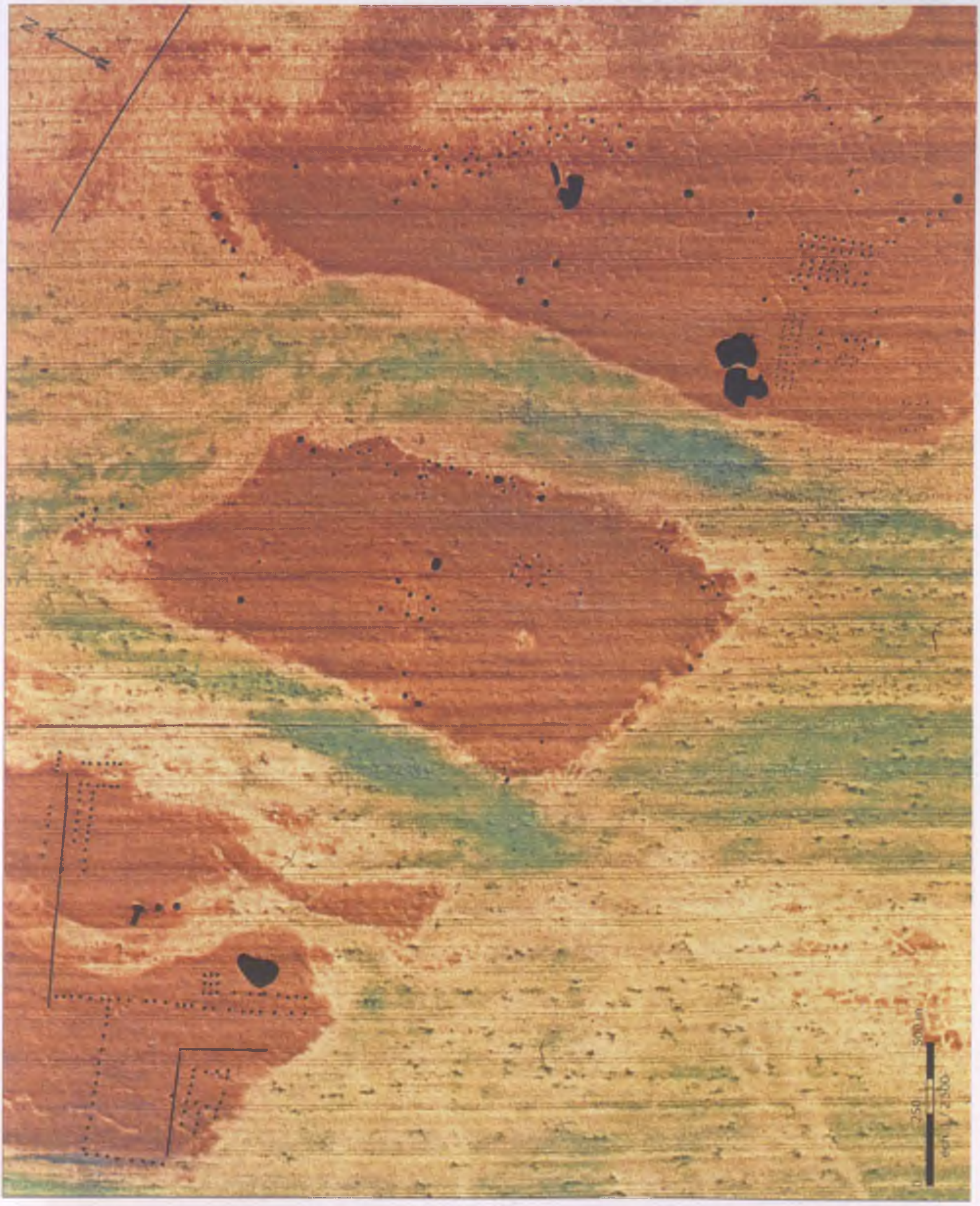
WYCZÓŁKOWSKI 2011 Wyczółkowski, M., *Archeologia leśna. Nowe metody. Nowe perspektywy,* Kętrzyn, 2011.

ZAKŠEK *et al.* 2011 Zakšek, K. – Oštir, K. – Kokalj, Z., Sky-view factor as a relief visualization technique. *Remote Sensing* 3 (2011) 398–415.

ZALAI-GAÁL 1990a Zalai-Gaál, I., Neue Daten zur Erforschung der spätneolithischen Schanzwerke im südlichen Transdaunbien (Újabb adatok a későneolitikus körsáncok kutatásához a Dél-Dunántúlon). *Zalai Múzeum* 2 (1990) 31–46.

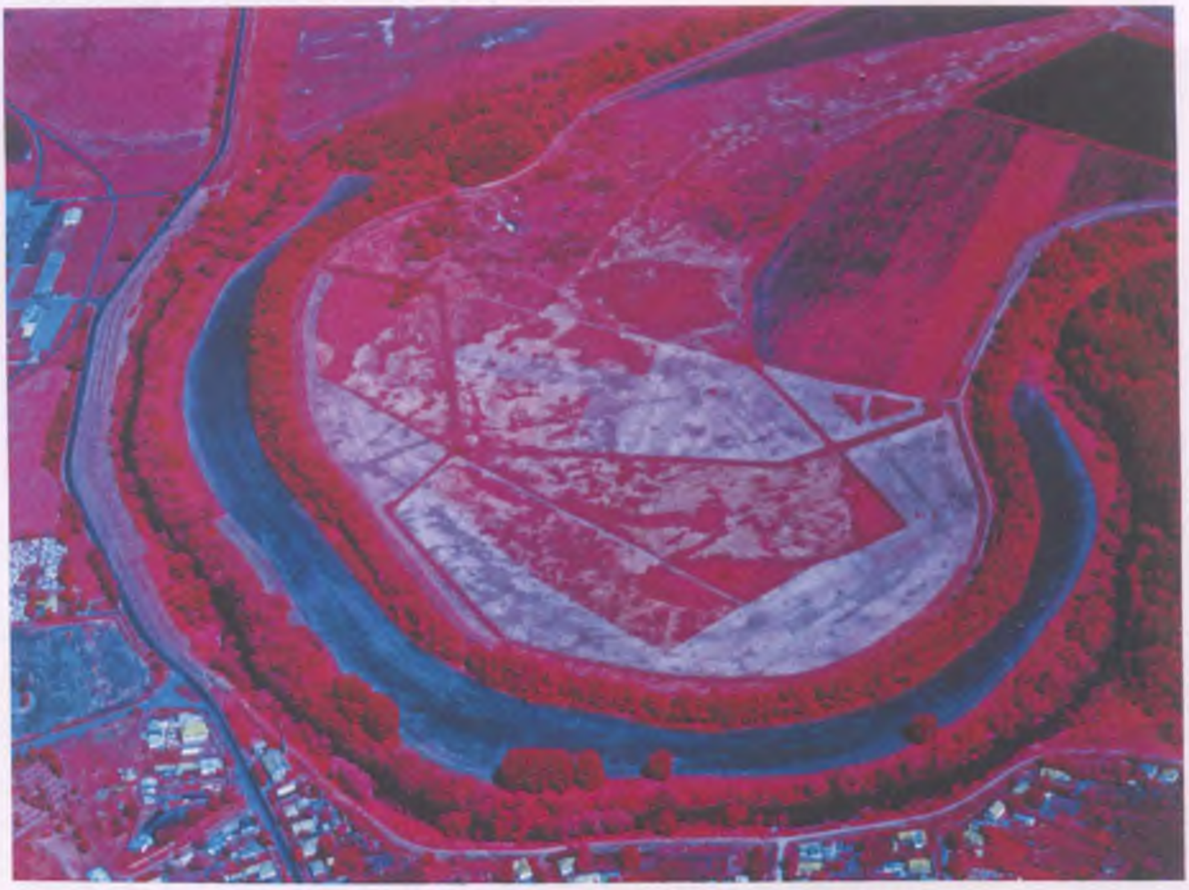
ZALAI-GAÁL 1990b Zalai-Gaál, I., A neolitikus körárokrendszerek kutatása a Dél-Dunántúlon. *Archaeologiai Értesítő* 117 (1990) 3–24.

Plates

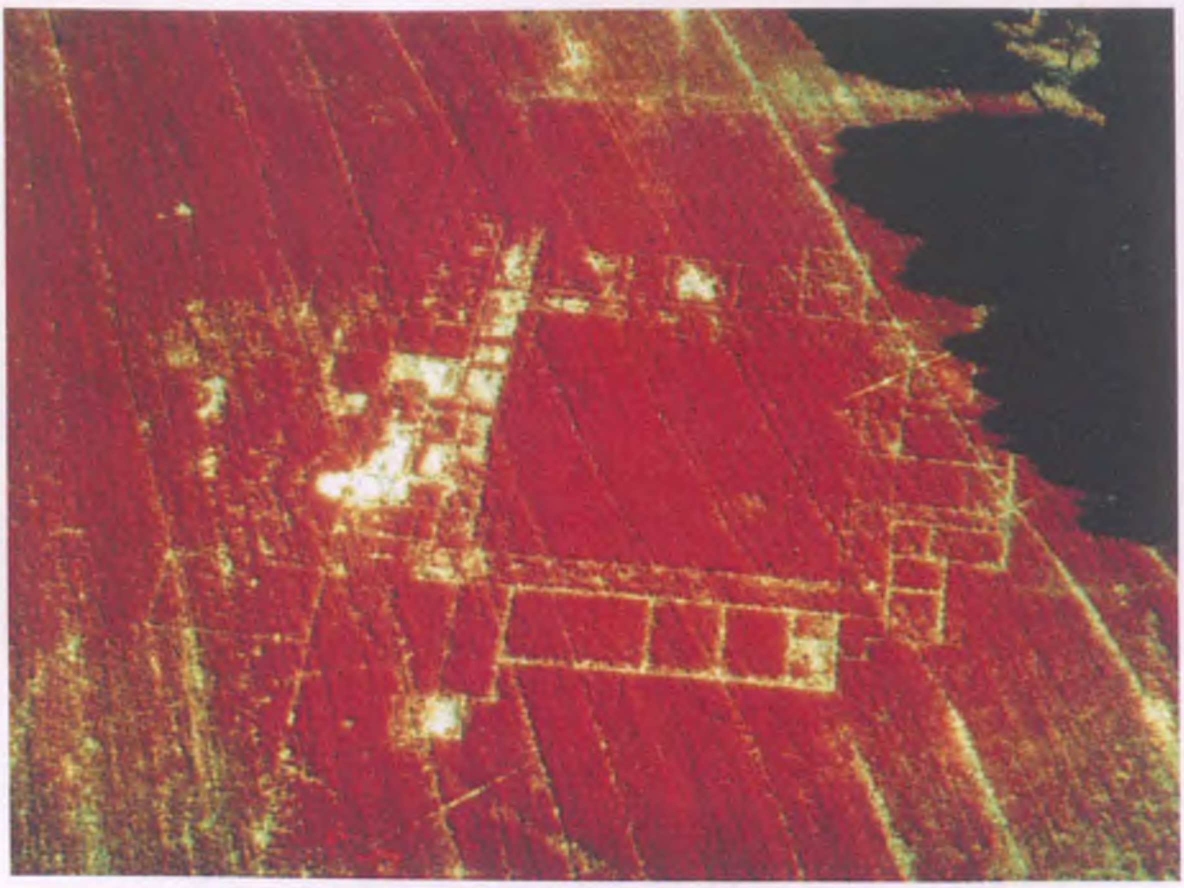


Und (Hongrie), photo verticale (R. Goguey, 09.06.1993 ; Interprétation A. Cordier)

Plate 1



1. Zagyvarékas (Hongrie), photo infra-rouge (photo R. Goguey, 16.06.1996)

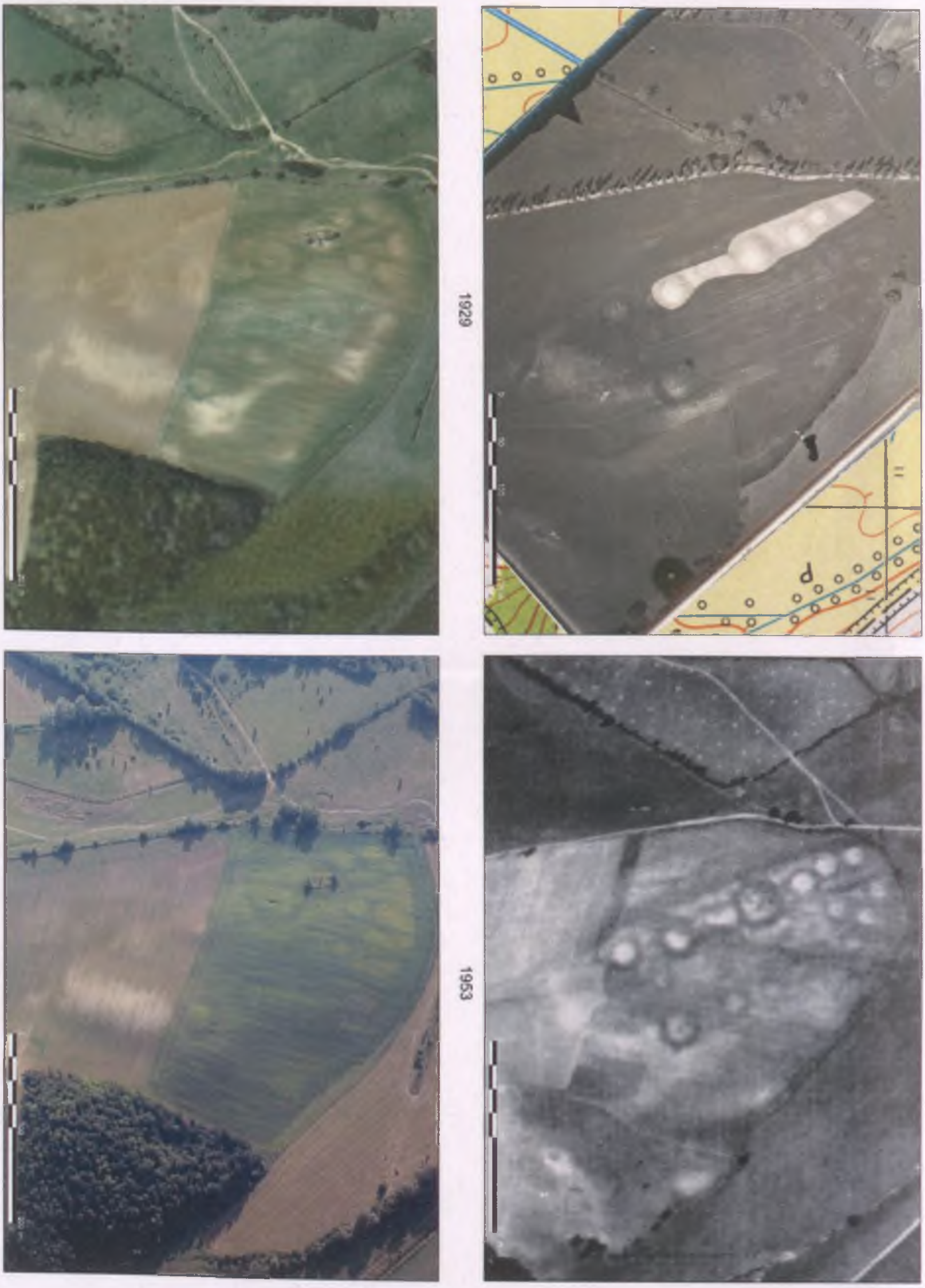


2. Nicey (France), villa à cour péristyle, photo infra-rouge (photo R. Goguey, 01.07.1976)

Plate 2

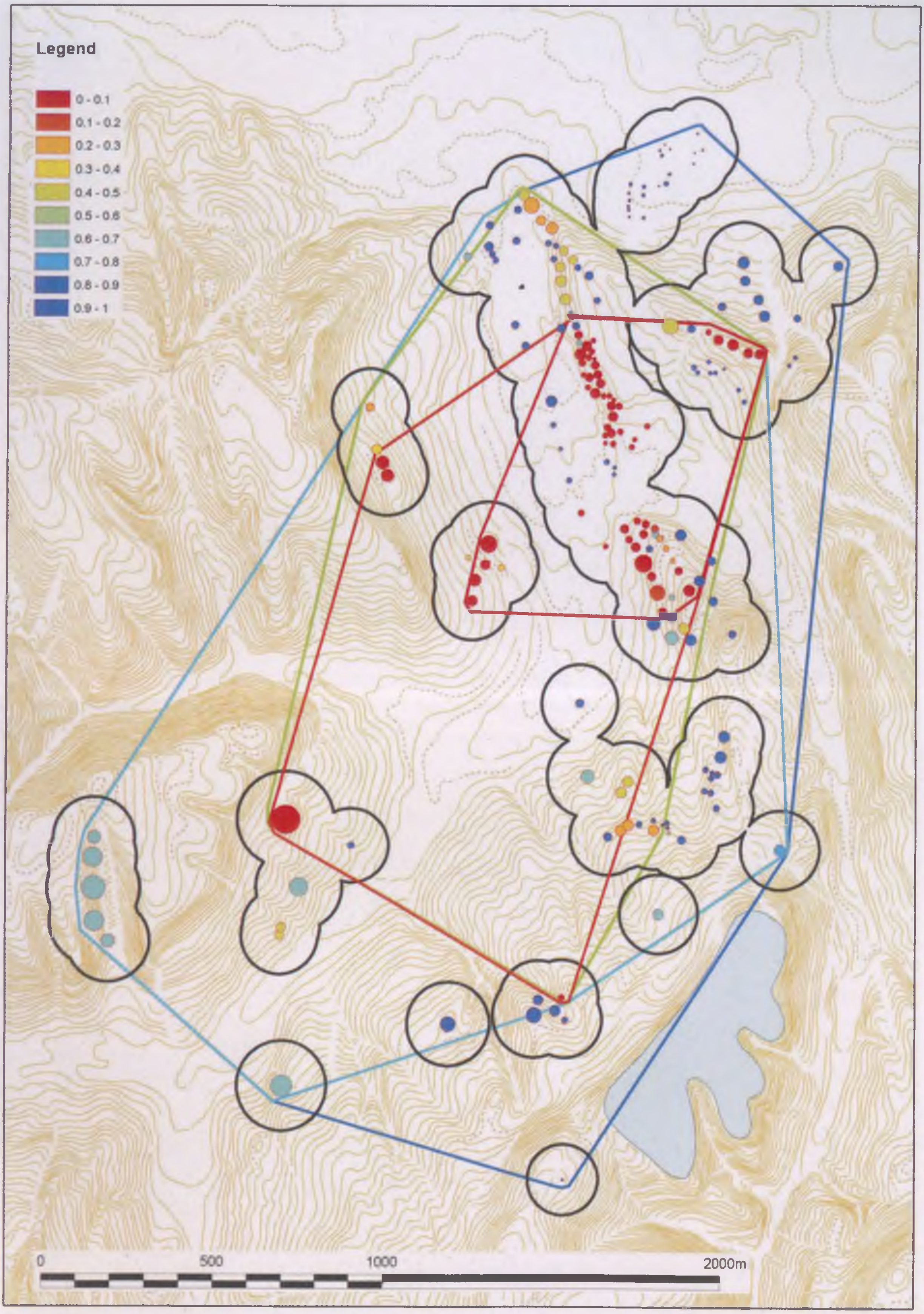
Oblique aerial photo of the Jablanova hillfort and interpretation (photo: V. Glavaš)

Plate 3



1929: Sándor Neogrády's photo made with a photogrammetric camera in July 1929: Fitted to a modern topographic map (Archives of the Hungarian National Museum) 1953: Photo made with a cartographic photogrammetric camera 2000: Large resolution satellite photo (GoogleMap) 2005: Z. Czajlik's photo made with a hand held camera

Plate 4



Determination of the site's boundaries and the location of the Szalacska hillfort. The buffer zone was 100 m. On the map (and on the diagram) we marked the tumuli with different colours, depending on their uncertainty: red marks certain tumuli, blue wholly uncertain ones (in cases when uncertainty is high, the scale increases with the uncertainty). The site boundary is marked accordingly: the red line marks the boundary of securely identifiable tumuli. Intermediate colours (green and yellow) mark tumuli whose former existence was indicated by various sources, but whose presence is nonetheless uncertain.

Plate 5

1. Rondel near Vokány, Baranya County (02.09. 2010, sugar beet, photo: G. Bertók, Cs. Gáti)

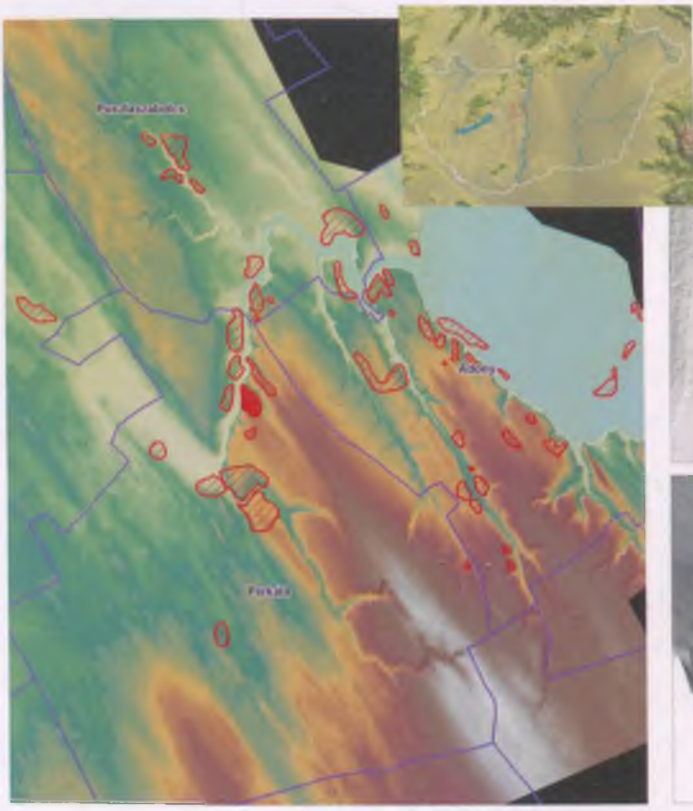
2. Rondels near Szemely (06.08. 2006, sunflower, photo: G. Bertók)

Plate 6

1. Aerial image of the motorway excavation and the nearby rondel near Belvárdgyula (31.05. 2007, wheat, photo: G. Bertók)

2. Aerial photo of the Villánykövesd rondel (06.12. 2006, growning wheat, photo: G. Bertók))

Plate 7



1

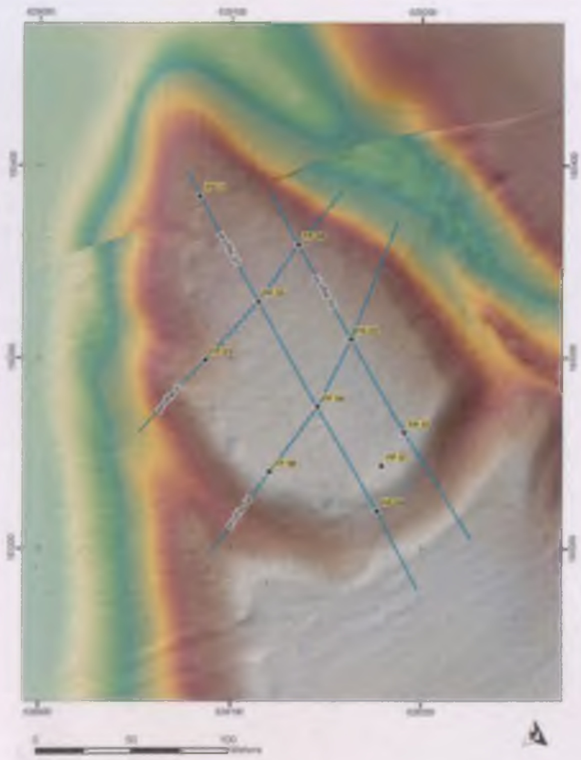
2

3

4

1. Location of the Perkáta–Forrás-dűlő site, 2. the terrain model generated from the LiDAR survey, 3. orthophoto, 4. the grid of the systematically sampled area

Plate 8



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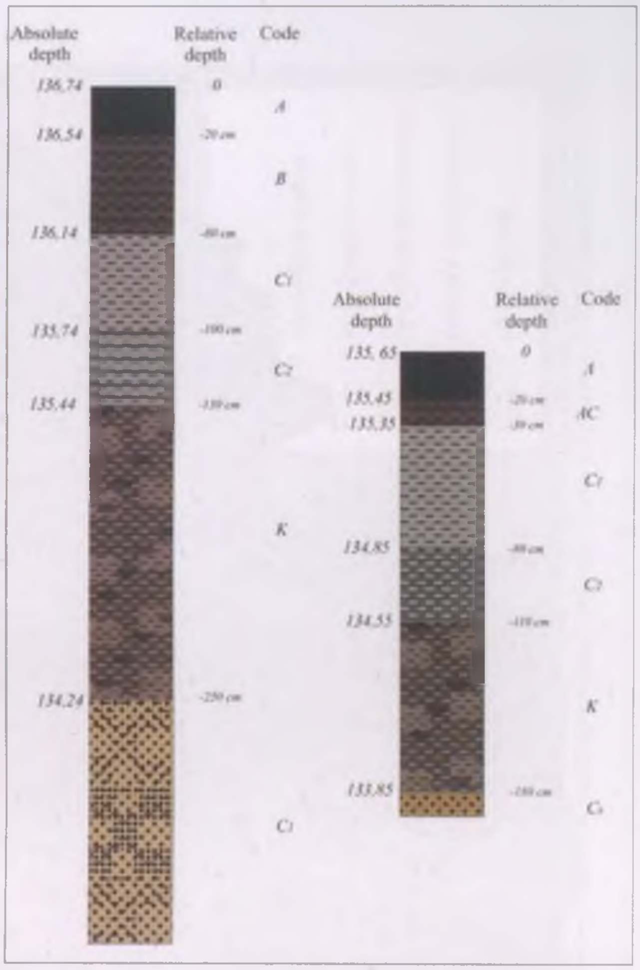
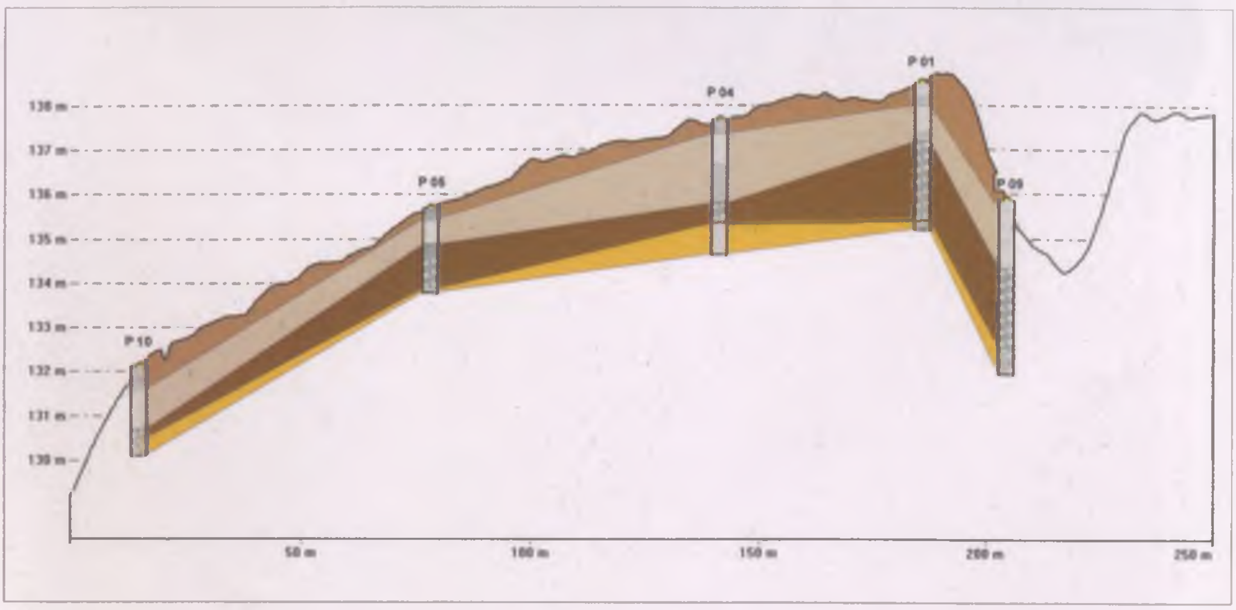


2



3

1. The locations of the gridded borings at the Perkáta–Forrás-dűlő site, 2. stratigraphy of the site based on the cores from drilling locations PK05 and PK07, with absolute elevations and relative depth, 3. section of the hillfort at Perkáta–Forrás-dűlő with the most important stratigraphic units: yellow: bedrock, dark brown: occupation deposit, greyish-brown: recent soil parent material, brown: chernozem-like modern soil formation.

Plate 9

Map of Roman Dacia (authors: F. Fodorean, C. Moldovan)

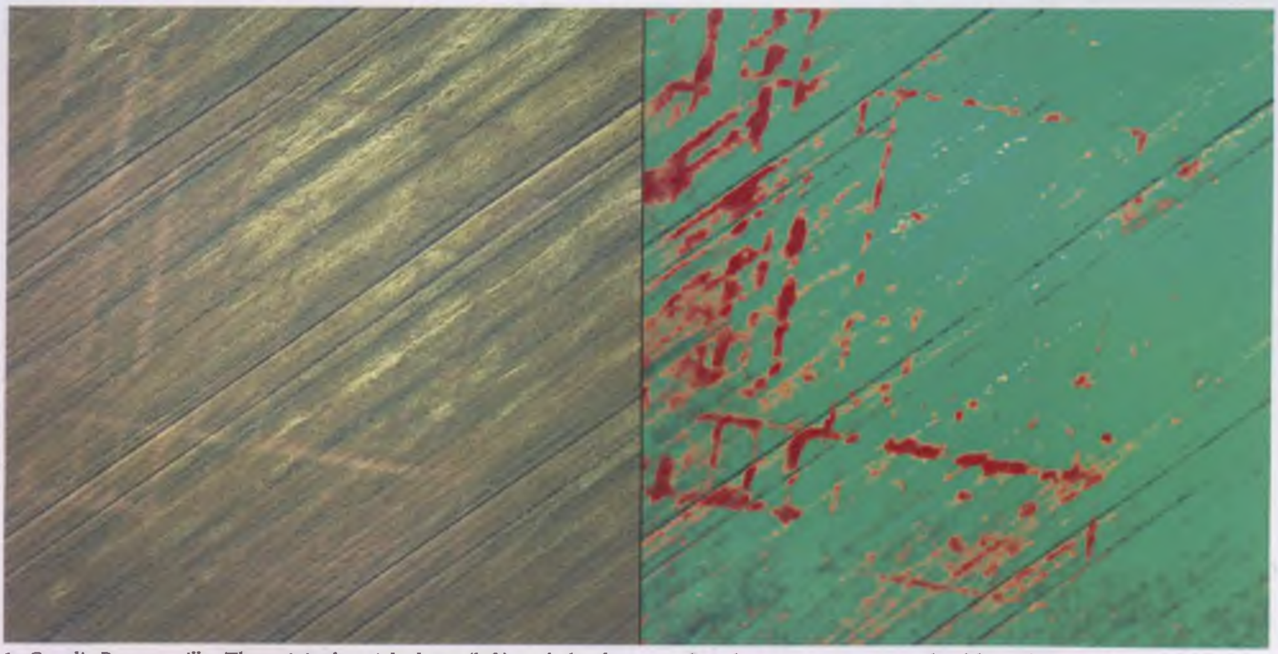
Plate 10

Brigetio and its surroundings. The map of the site based on the interpretation of aerial photos and topographical data provided by earlier publications. (map: L. Rupnik)

Plate 11

Details of the military settlement. Crop marks of road sections, stone buildings, pits, ditches and sunken floored houses are visible. (photos: Z. Czajlik, 21.06. 2012–above, 14.06. 2012–below)

Plate 12



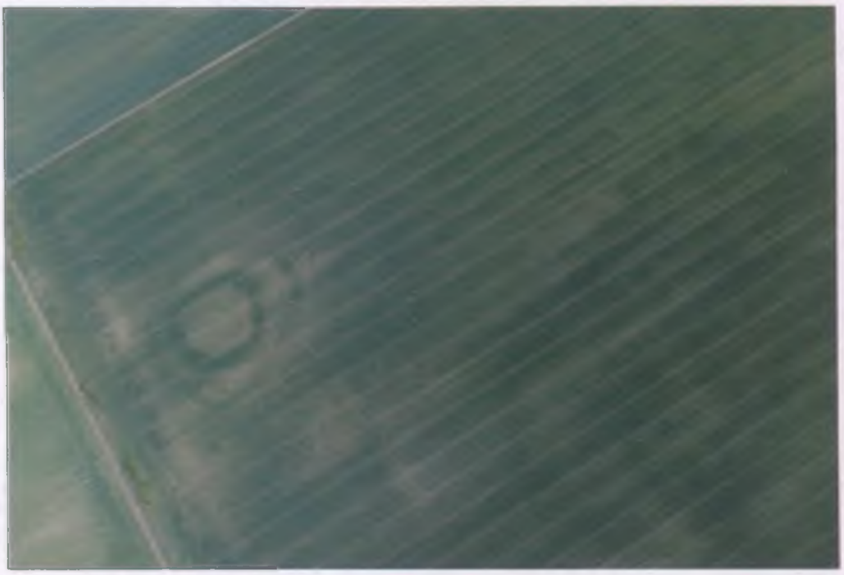
1. Cserdi, Roman *villa*. The original aerial photo (left) and the features after the segmentation on the false coloured image on the right (PLT 31582, Máté Szabó)

2. Cserdi, Roman *villa*. Geodetic survey of crop marks and the increased accuracy

3. Cserdi, Roman *villa*. High detailed aerial photo of the multirotor copter

Plate 13

1. Zsámbok–Köpűs kút, County Pest (photo: Zs. Miklós)



2. Hantos, County Fejér (photo: Zs. Miklós)

3. Bikács–Belső sziget, County Tolna (photo: Zs. Miklós)

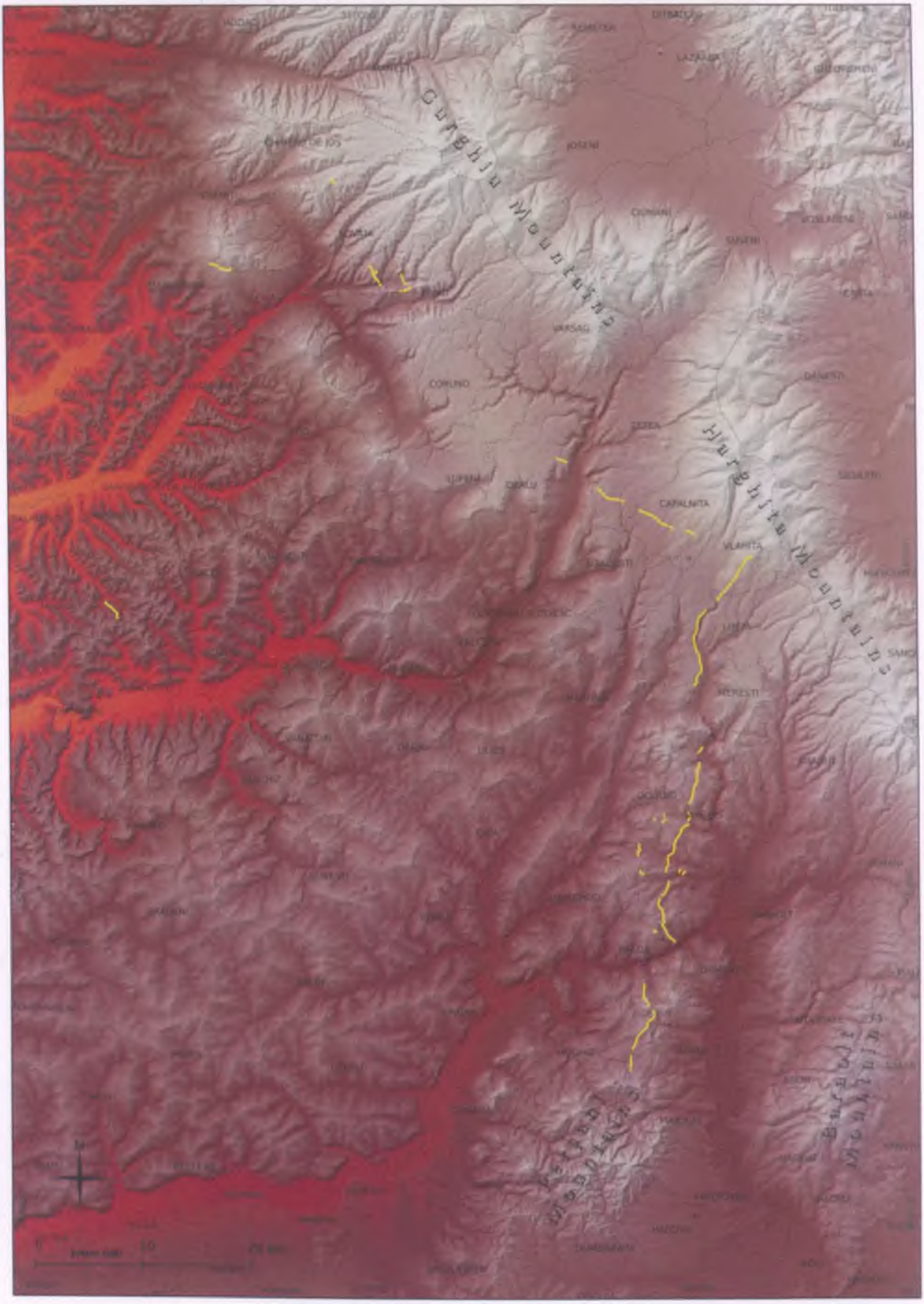
Plate 14

1. Dabas–Dabasi szőlők, County Pest (photo: Zs. Miklós)

2. Váralja–Várfő, County Tolna (photo: Zs. Miklós)

3. Bélavár–Bocskádi erdő, County Somogy (photo: Zs. Miklós)

Plate 15



Ramparts in the Görgényi, Hargita and Persányi Mountains (map: Antal Kosza)

Plate 16

Authors

BAKLANOV, Szandra
Hungarian National Museum, Centre for National Heritage
H-1113 Budapest, Daróci u. 3.
baklanov.szandra@mnm-nok.gov.hu

BANASZEK, Łukasz
Institute of Prehistory, Adam Miczkiewicz University
PL-61-809 Poznań, ul. Św. Marcin 78
lukas.banaszek@wp.pl

BERTÓK, Gábor
Department of Archaeology, Janus Pannonius Museum
H-7621 Pécs, Kăptalan u. 5.
bertokgabor@yahoo.co.uk

BÖDŐCS, András
Institute of Archaeological Sciences, Faculty of Humanities, Eötvös Loránd University
H-1088 Budapest, Múzeum krt. 4/B
bodocs.andras@btk.elte.hu

CORDIER, Alexandra
Université de Bourgogne, UMR 6298 ARTEHIS
F-21000 Dijon, 6 Boulevard Gabriel
alexandra.cordier@sfr.fr

CZAJLIK, Zoltán
Institute of Archaeological Sciences, Faculty of Humanities Eötvös Loránd University
H-1088 Budapest, Múzeum krt. 4/B
czajlik.zoltan@btk.elte.hu

FODOREAN, Florin
Department of Ancient History and Archaeology, Babeş-Bolyai University
RO-400084 Cluj-Napoca, Str. Mihail Kogălniceanu 1
fodorean_f@yahoo.com

GÁTI, Csilla
Department of Archaeology, Janus Pannonius Museum
H-7621 Pécs, Káptalan u. 5.
gatics@gmail.com

GLAVAŠ, Vedrana
Department of Archaeology, University of Zadar
CR-23000 Zadar, Obala Kralja Petra Krešimira IV., 2
vedrana.glavas@gmail.com

GOGUEY, René
F-21240 Talant, 4 rue Colonel Marcaire
rene.goguey@orange.fr

KENÉZ, Árpád
Centre for National Heritage, Hungarian National Museum
H-1113 Budapest, Daróci u. 3.
kenezarpad@gmail.com

MIKLÓS, Zsuzsa
Institute of Archaeology, Research Centre for the Humanities, Hungarian Academy of Sciences
H-1014 Budapest, Uri u. 49.
miklos.zsuzsa@btk.mta.hu

MLEKUZ, Dimitrij
Department of Archaeology, Faculty of Arts, University of Ljubljana
SL-1000 Ljubljana, Aškerčeva 2
dmlekuz@gmail.com

PALMER, Rog
Air Photo Services
21 Gunhild Way Cambridge CB1 8QZ, UK
rog.palmer@ntlworld.com

PETŐ, Ákos
Centre for National Heritage, Hungarian National Museum
H-1113 Budapest, Daróci u. 3.
peto.akos@mnm-nok.gov.hu

REMÉNYI, László
Centre for National Heritage, Hungarian National Museum
H-1113 Budapest, Daróci u. 3.
remenyi.laszlo@mnm-nok.gov.hu

RUPNIK, László
MTA-ELTE Research Group for Interdisciplinary Archaeology, Eötvös Loránd University
H-1088 Budapest, Múzeum krt. 4/B
rupnik.laszlo@gmail.com

SOBCZAK, Cezary
State Archaeological Museum in Warsaw
PL-00-241 Warsaw, ul. Długa 52
cezarysobczak@gmail.com

SÓFALVI, András
Muzeul Haáz Rezső / Haáz Rezső Múzeum
RO-535600 Odorheiu Secuesc / Székelyudvarhely
str. Kossuth Lajos 29
sofalvi@hotmail.com

SZABÓ, Máté
Department of Archaeology, University of Pécs
H-7624 Pécs, Rókus u. 2
szabo.mate@pte.hu

Conference Programme

PROGRAMME DETAILS, 13th September, 2012 - Day 1

Local session Carpathian Basin

11.00–11.20	The Application of Remote Sensing Technology and Geophysical Methods in the Topographic Survey of Early Iron Age Burial Tumuli in Transdanubia *Zoltán Czajlik, Géza Király, Attila Czövek, Sándor Puszta, Balázs Holl and Gábor Brolly*
11.25–11.45	Using Remote Sensing and Non–destructive Archaeological Methods in the Research of Roman Villas and the Ancient Landscape of Pannonia *Máté Szabó*
11.50–12.10	Roman Potaissa and its Surroundings. A view from above *Florin Fodorean*
12.15–12.35	Archaeological and Geoarchaeological Investigations at Perkáta, Forrás–dűlő Bronze Age Fortified Settlement *László Reményi, Ákos Pető and Árpád Kenéz*

Knowledge production

13.50 -14.10	Turning Hyperspectral Pixels into Archaeological Information – *Geert Verhoeven, Michael Doneus, Christian Briese and Clement Atzberger*
14.15–14.35	ALB – Airborne Laser Bathymetry: Surveying Underwater Topography *Michael Doneus, Michael Pregesbauer, Christian Briese and Nives Doneus*
14.40–15.00	Image Processing at the Service of Archaeological Survey: a Progress Report from the Silvretta Archaeological Project *Karsten Lambers and Igor Zingman*
15.05–15.25	Beyond 3D Modeling in Archaeology – Metadata, Reliability and Scientific Visualization *Sorin Hermon*

YAARG (Young AARG) session

15.50–16.20	Irish Early Medieval Settlement from the Air: A LiDAR Study of Counties Roscommon and Leitrim *Susan Curran*
16.20–16.40	Google Earth and Silk Road. Satellite Reconnaissance in Xinjiang *Emilia Smagur and Kasper Hanus*
16.40 -16.50	First Results of Aerial Archaeology in Harghita County (Romania) *András Sófalvi*
16.50–17.10	Remote Sensing Imagery in Archaeology: the Case Study of Heslington East *Jitka Jizerova*
17.10–17.30	Troubles with Everything: Flying over Velebit *Vedrana Glavaš*

PROGRAMME DETAILS, 14th September, 2012 - Day 2

Interpretation

9.00–9.20	Interpreting Remote Sensing Data in a Glaciated, Karst Lowland Landscape; What Lies in and around Rathcroghan Mound,Tulsk, County Roscommon, Ireland? *Kevin Barton and Ralf Hesse*
9.25–9.45	Roads to Nowhere? Disentangling Meshworks of Holloways *Dimitrij Mlekuž*
9.50–10.10	The Saint, a Mound and the Flame on the Hill: Integration of Remote Sensing Techniques on The Hill of Slane Archaeological Project *Conor Brady, Kevin Barton, and Matthew Seaver*

Applications

10.55–11.15	Borders: The Problems of the Aerial Archaeological Research of the Roman Limitation in Pannonia *András Bödőcs*
11.20–11.50	Archaeological Three-Dimensional Recording and Reconstruction of Pharaonic and Christian Features of the Quarry Complex of Dayr Abu Hinnis (Middle Egypt) *G. J.M. van Loon, V. De Laet, A. Van der Perre, M. Hendrickx, R. Goossens and H. Willems*
11.55–12.15	An Experimental Application of Airborne Laser Scanning for Landscape Archaeology in Northeastern Poland *Cezary Sobczak*
13.30–14.30	Poster session

Discussion session: AARG, aerial archaeology and remote sensing – time for a change?

14.30–15.00	Position paper 1: A Geoarchaeologist's View of Aerial Archaeology *David Jordan*
15.00–15.30	Responses *Wlodek Raczkowski, David Stott, Simon Crutchley*
15.45–16.15	Position paper 2: What Next? Aerial Archaeology as Landscape Archaeology *Rachel Opitz and Steve Davis*
16.15–16.45	Responses *Rog Palmer, Dave Cowley, Michael Doneus*

AARG Field trip, 15th September, 2012 - Day 3

Field trip to Százhalombatta (visit to the 'Matrica' Museum and the Archaeological Park as well as to the Iron Age *tumulus* site and the Bronz Age and Iron Age hillfort).

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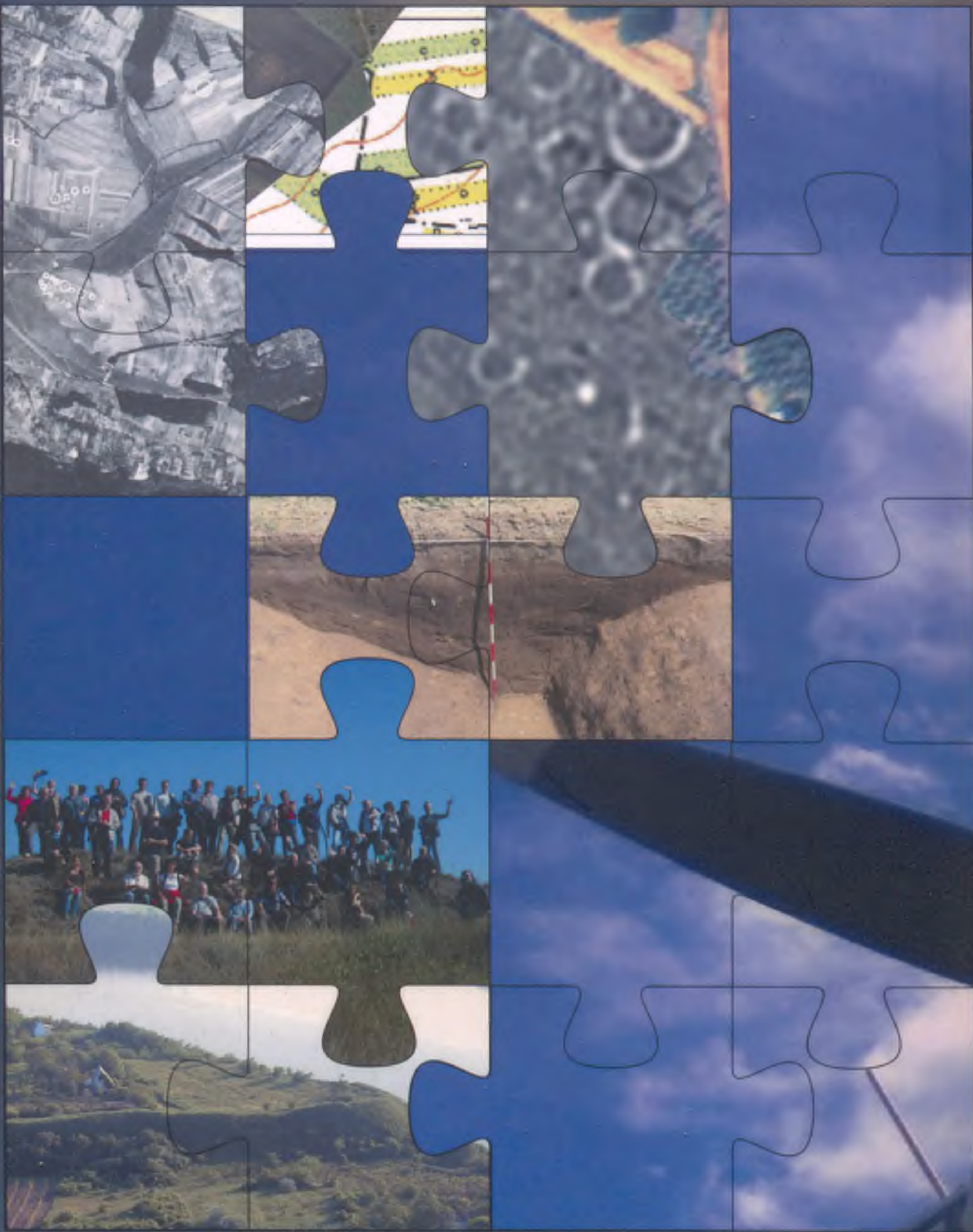

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