



EAC Occasional Paper No. 5



# Remote Sensing for Archaeological Heritage Management

Edited by David C Cowley

Remote sensing is one of the main foundations of archaeological data, underpinning knowledge and understanding of the historic environment. The volume, arising from a symposium organised by the Europae Archaeologiae Consilium (EAC) and the Aerial Archaeology Research Group (AARG), provides up to date expert statements on the methodologies, achievements and potential of remote sensing with a particular focus on archaeological heritage management. Well-established approaches and techniques are set alongside new technologies and data-sources, with discussion covering relative merits and applicability, and the need for integrated approaches to understanding and managing the landscape. Discussions cover aerial photography, both modern and historic, LiDAR, satellite imagery, multi-and hyper-spectral data, sonar and geophysical survey, addressing both terrestrial and maritime contexts. Case studies drawn from the contrasting landscapes of Europe illustrate best practice and innovative projects.

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Occasional Publication of the Aerial Archaeology Research Group No. 3

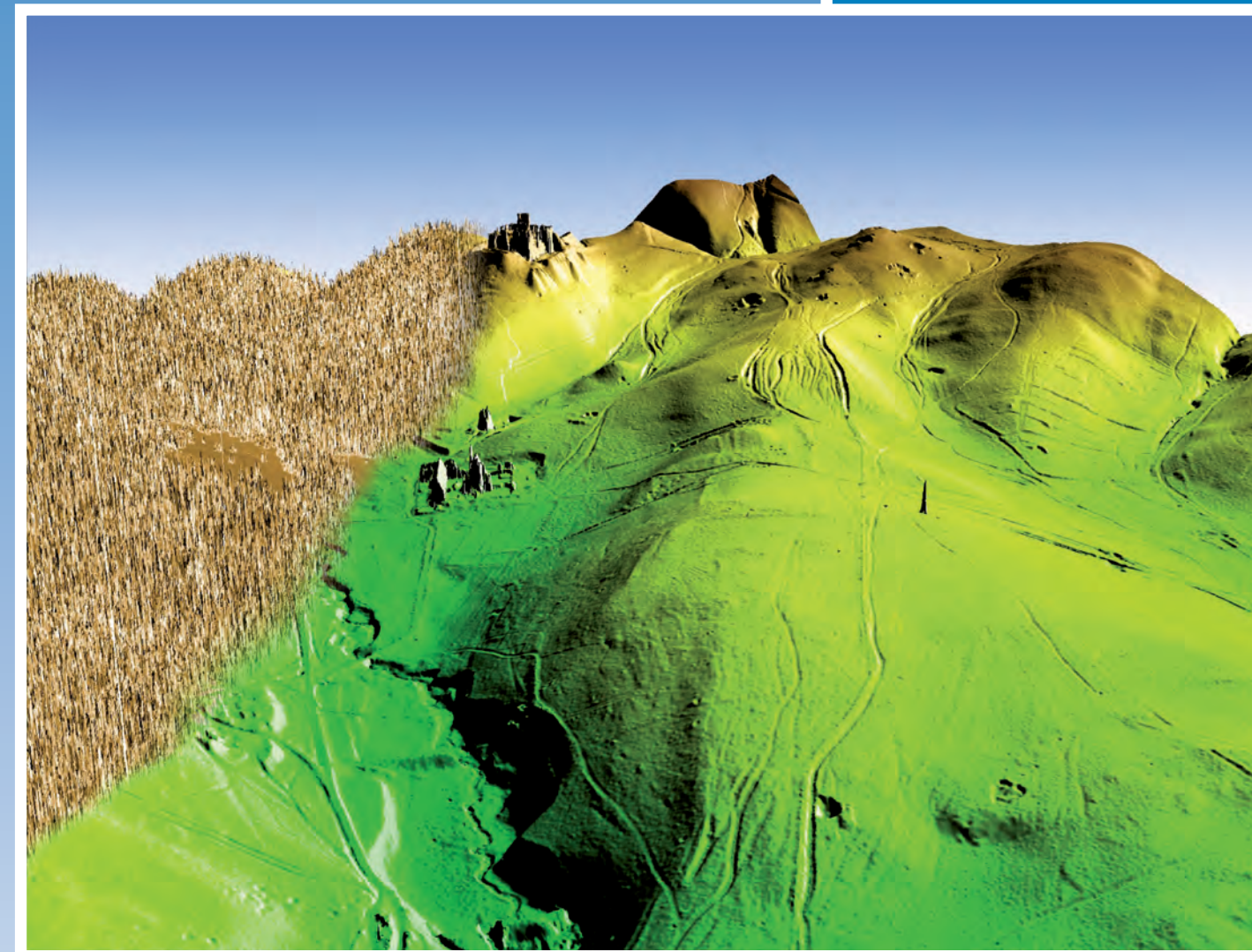
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## **Remote Sensing for Archaeological Heritage Management**

Edited by David C Cowley

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Airborne Laser Scan (LiDAR) of a forested area before and after filtering

(St. Anna in der Wüste, Austria). © *Michael Doneus and Klaus Löcker, LBI-ARCHPRO, Vienna*

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# 17 | Remote sensing for the integrated study and management of sites and monuments – a Central European perspective and Czech case study

Martin Gojda

**Abstract:** Recent innovations in remote sensing techniques have been profoundly changing the possibilities of what is traditionally termed aerial archaeology. These changes are discussed and reflected not only in the West but also in Central European countries, most of which entered aerial archaeology as late as the 1990s after the pan-European collapse of communist regimes. Legal and administrative barriers on flying, taking and publishing aerial photographs for whatever purpose in most of them were responsible for the delay in launching continuous aerial survey programmes in that part of Europe. In spite of this delay activities in remote sensing during the last two decades have enormously enriched the cognitive and methodological capacity of archaeology in the study of past human settlements and landscapes, and also helped to open discussion on theoretical issues. This contribution illustrates how an ongoing aerial archaeology programme in Bohemia has influenced ideas on past settlement forms and dynamics, and how important aerial photography is for the monitoring and documentation of Czech cultural heritage. For the future in Bohemia testing of ALS potential for a large-scale mapping of archaeological landscapes will be of major importance (state-funded pilot project 2010–11) and subsequent acquisition of LiDAR of the whole Czech Republic.

## Introduction

Current archaeological practice in Central European countries of the former Soviet bloc has been influenced by progressive acceleration of social processes caused by the collapse of communism. One of the most important consequences of this is large-scale impact on both urban environments and rural landscapes through a boom in construction activity, which represents an unparalleled threat to archaeological heritage. As a result developments in archaeology in the heart of Europe at the end of the 20<sup>th</sup> century have been largely driven by factors external to the professional community, and in many cases beyond their control. As a result archaeologists are forced to choose research themes, approaches and strategies with account to these external factors – not only in field-project strategies but also in data management and storage, their use, analysis, interpretation, and, last but not least, in making them available by publications to the wider public.

In the face of the continuing large-scale threats to the archaeological heritage since the 1970s methodologies have had to develop in a dynamic way. Problems concerning the strategy of rescue projects and approaches to the most effective evaluation of limited time and budget were particularly pressing. Increasingly, field projects (excavations) of threatened sites have applied probability and sampling strategies. The necessity of implementing sampling strategies in excavations has been greatly assisted by increasing support of non-invasive methods. Although the application of non-destructive methods for data collection is widely understood as currently the most

effective means of generating archaeological heritage protection policy, as well as a useful tool for research in some sub-disciplines (such as spatial- and landscape archaeology), it is excavation which continues to dominate archaeological fieldwork in the post-communist era throughout former Soviet bloc countries.

At the same time large-scale improvements in science and technology have influenced cognitive process and archaeological methods, especially in survey techniques. In the last two decades a huge increase in the quantity and quality of data for archaeological study of the human past is largely due to progress in what is generally termed *remote sensing (of the Earth)*. As a result one of the most effective survey disciplines ever applied in archaeology – aerial survey (reconnaissance) and photography, most commonly aerial archaeology – has been influenced dramatically, up to the point that even the term is now considered inappropriate by some scholars.

Thus, the questions to be answered in this paper are: how has the application of aerial survey in Central Europe, specifically in Bohemia, contributed to the current view of ancient settlement dynamics on the one hand and, how has this discipline supported the process of monitoring and documentation of sites and monuments? To begin answering these questions, this paper will open with a brief overview of development from traditional aerial archaeology to more complex remote sensing applications in current archaeology and past landscape studies.

## Early developments: who set the agenda for aerial archaeology?

In addressing the issue of the origins of aerial archaeology, it is appropriate to ask three questions:

1. Which part of the world saw the first aerial survey campaign aimed at identifying unknown buried archaeological sites?
2. Who most markedly shaped the content of the field in its beginnings and who influenced most seriously the form of aerial archaeology from the theoretical and methodological point of view?
3. Who, using aerial survey, collected information that had a fundamental impact on the archaeological knowledge of a historical landscape and peoples living there in the past?

The answers to these questions establish that, in its beginnings, the field was formed by several personalities whose general contribution to aerial archaeology was, besides their own abilities and knowledge, influenced significantly by the technical potential of their equipment (especially aircraft and cameras) as well as by geographical characteristics of the landscapes in which they worked. Thus, two very different and distant geographical areas became the cradle of aerial archaeology: the desert and dry steppe landscapes of the Near East (especially East Mediterranean, Sinai, Levant, Mesopotamia), later also the more distant areas of the Middle East (Iran) and North Africa on the one hand, and Western Europe (England) on the other (Bewley 2005; Deuel 1969; Downey 1980; Rączkowski 2002, 28–42; Musson 2005).

A figure with undeniable primacy in the practice of aerial archaeology was O. G. S. Crawford, the founder of *Antiquity*. He was the first to publish his discoveries and to define through them the principles underlying the identification of archaeological sites and features in the field. Simultaneously, he introduced to specialized literature the procedures of gaining and processing field data (especially Crawford 1924; Crawford & Keiller 1928; for analytical evaluation of Crawford by a non-British scholar see Rączkowski 2002, 42–61). However, this happened about twenty years after aerial imaging had begun to take an important part in the discovery and photographic documentation of architectural and archaeological monuments. The development of methodological owes much to the French scholar P.A. Poidebard. The first chapter of his 1934 work is vitally important as it is devoted to the methods of aerial survey in archaeology as he developed them in the specific environment of the arid desert in which he had been working (e.g. the technique of backlight imaging from low altitudes or ground survey of sites immediately after their identification, Poidebard 1934). Crawford himself considered Poidebard the first to have made a creative contribution to the general development of the methodology of aerial archaeology (Kennedy & Riley 1990, 51–63).

In Central European countries (such as Hungary, Poland, Germany and former Czechoslovakia – Czech and Slovak Republics since 1993) aerial archaeology in the period between World War I and World War II

was limited to aerial photography of prehistoric earthworks (such as hillforts), medieval standing and ruined buildings, and sites under excavation (i.e. Biskupin in Poland, which was photographed regularly from balloons in 1935–9). In Germany systematic aerial photography of sites and monuments had been taken since 1928 by the Hansa Luftbild company and since 1935 by the Luftwaffe (Braasch 1997; Kobylinski 2005; Krasnodębski 2005).

A promising turning point for large-scale inclusion of aerial survey into central European archaeologies could have been an invitation in 1938 to Crawford by the German Lilienthal Company to Berlin. His lecture became a basis for a book *Luftbild und Vorgeschichte* in which Crawford's achievements (and early German photographs) had the potential to greatly influence scholars in Central Europe who, at that time, were much more aware of German journals and books rather than English. Unfortunately, the start of World War II terminated any potential in this area. In Austria too attempts were made in the 1920s and 1930s to photograph and interpret aerial images and transform sites documented on them into maps (Doneus *et al.* 2001, 12–3). The very first aerial photos taken by Czech archaeologists are of sites excavated by themselves and by American expedition between 1929 and 1932. Although there were a few attempts to undertake airborne archaeological prospection it took six decades until Soviet bloc countries were able to embark on regular aerial survey.

## The last two decades: new challenges

Central Europe witnessed the beginnings of systematic long-term aerial reconnaissance and photography for archaeology in Germany (I. Scollar) and in Austria (G. Spitzer and H. Friesinger) in the early 1960s (Deuel 1969; Doneus *et al.* 2001). A few attempts to organize survey flights are detectable also in former Czechoslovakia, but pilot projects – one in Moravia and one in Slovakia – were not launched until as late as mid-1980s (Bálek 1995; Kovárník 1995; Kuzma *et al.* 1996; Visy 1997).

When the Soviet bloc collapsed in 1989/90 a new era in the history of aerial archaeology started. Large territories became the target of local scholars who wanted to explore potential of these 'virgin' areas for the identification of buried sites and landscapes by means of aerial prospection. Some of them soon invited specialists from western countries (UK, Germany, France) in which the discipline had a long tradition to assist in this development. Of special importance for Central European beginners was the assistance of former military pilot and aerial prospector/photographer Otto Braasch from Germany (winner of the 2004 EAA's annual Heritage Prize). Communication between scholars from all over Europe has proved extremely fruitful (Gojda 1997), and there has been an almost continuous chain of international projects supported mostly by EU programmes (such as RAPHAEEL and Culture 2000) over the last fifteen years. Summer courses in aerial archaeology, seminars, workshops and exhibitions have been regularly organised, publications produced (Bewley & Rączkowski 2002; Burgeois &



Meganck 2005; Gojda 2007; Nowakowski *et al.* 2005) and a documentary film produced (<http://www.kar.zcu.cz/videoarchiv.php>). These have all helped to spread aerial archaeology among professionals, university students and the wider public.

Also significant for the development and spread of aerial archaeology in Europe during this period have been efforts to encourage (through the Aerial Archaeology Research Group (AARG) and European Association of Archaeologists (EAA) the lifting of restrictions on flying and aerial photography (Braasch 2002).

Apart from the many aerial archaeological projects in Central European countries focused on the identification of unknown features, sites and landscapes, on increasing their number in national sites and monuments records, and on detecting new site types (for a high-standard project of this type see Schwarz 2003), a few more complex projects were carried out. These have testified the potential of combining various non-destructive and traditional field methods, including small-scale excavations of sites detected via aerial survey, and study of vertical aerial/satellite photographs. This methodology has usually been applied to projects studying regional settlement history, structure and dynamics (for Bohemia see next section). Finally, theoretical issues of aerial archaeology cannot be omitted. In the past this was an under explored area, but currently, theory is being discussed more frequently. This is most significantly due to Polish scholars from the University of Poznań, especially W. Rączkowski, author of the only monograph on methodology and theory in aerial archaeology (Rączkowski 2002, see also 2005; Zuk 2005; Palmer 1989; Brophy 2005; Brophy & Cowley 2005).

Thus, over the last two decades the hopes of professional communities in the wake of the fall of the Iron Curtain seem to have been fulfilled. In the meantime new possibilities for the discipline arrived. They relate to improved technology (availability of satellite data with very high – sub meter – resolution, mostly from private satellite systems, such as IKONOS and QuickBird; Airborne Laser Scanning (ALS/LiDAR – see Doneus & Briese this volume); airborne thermal infrared scanning) and with current possibilities to study satellite and aerial images freely on internet servers (such as Google Earth™) where they are usually presented in the form of (geo-referenced) orthophotomaps. Also of importance are Global Positioning Systems (GPS), which since early the 1990s have helped in low altitude aerial survey by enabling digital recording of photographed sites into a GPS station, to record flight tracks, and not to lose time (very expensive in flying aircraft) by paper map navigation. Finally, aerial/satellite data processing has also been very much improved, especially through the introduction of GIS into past landscape and environmental studies. Digital photography, another innovation of the last two decades, allows quick and effective processing of aerial photographs immediately after landing. It offers also other advantages, such as quick copying of images in original quality and the storage of photographs in large numbers in digital databases and archives.

### Aerial photographs and other remotely sensed data

During the last twenty years or so European archaeology has been strongly linked with natural sciences and technology innovations. GIS, GPS, high resolution satellite images, hyperspectral scans, aerial orthophotos and LiDAR/ALS data (to name only those linked to the detection and record of data from remote distance) are just the most important tools and products devised for use in disciplines other than archaeology, but applied extensively in current archaeological practice (most recently e.g. Parcak 2009; Lasaponara & Masini 2008). Apart from archaeology there is hardly any discipline among human sciences that cooperates so widely with natural sciences, and this is a factor obviously in the favour of archaeology amongst both research communities and the wider public.

However, the extremely dynamic development of sophisticated instruments, operating today preferably in a digital environment, is not free of danger. Metal detector heritage looters, able to identify sites with buried artefacts quickly even from rough locations, represent just one side of the problem. The other side is our incapacity to protect heritage effectively. Moreover, a strict demand to publish excavated and surveyed sites and features with high spatial accuracy, so that GIS spatial analyses, mathematical and statistical procedures can be applied in data processing, is counter-productive as well.

Since the early 1970s a new kind of dataset started to be accessible for the study of the Earth's surface, including archaeology. These are images captured by the first satellite systems operating for civilian purposes (Fowler 2010). In 1960 a term *remote sensing* was used for this kind of continuous photography and scanning of the complete surface of Earth (Hnojil 2005). This term was later introduced also to archaeological terminology as more or less equivalent to *satellite archaeology* (Parcak 2009). Later, since the 1990s the term remote sensing started to be used in a wider sense, to include both images sensed from a great distance (space) and photographs taken from aircraft flying at high altitude. Recently, the term is being used even more broadly to refer to all techniques for archaeological prospection where there is no physical contact with sensed (measured) archaeological situations (features, artefacts, layers etc.). Consequently, geophysical survey is included into remote sensing to name the most frequently used method (see Gaffney & Gaffney this volume).

In fact, the difference between various sensors which record land surface as image data sets is just technical and for archaeology most products of remote sensing are photographs and panchromatic images which are to be analysed and interpreted visually (but see Beck and Bennett *et al.* this volume, and Hanson 2008). This raises two issues to be addressed. Firstly, comparison of the value of vertical images and oblique photographs in terms of their spatial accuracy and the transcription of interpreted data into plans/maps, and secondly the methodological problems associated with different archaeological approaches to the land surface. These

can be divided between approaches where specialist aerial reconnaissance in a low altitude aircraft produces hand-held photographs only of those sites/areas/features which the observer considers important – an approach that is biased by time pressures, changing light conditions during flight and also by the personal interests/experience of the prospector (see Palmer 2005 for a discussion of these issues). On the other hand there is the interpreter working on the ground with images – both vertical and oblique, aerial or satellite – which were taken for many reasons, rarely specifically for archaeology and ancient landscape study. While there is no space here to list advantages and limitations of the

two approaches, they certainly both are valuable in their own way and it would be unreasonable to exclude one in favour of the other. They can be combined in a useful way and, at the same time, they are each specific enough so that one cannot replace fully the other. For example, oblique photography of historical monuments, ruined or semi-ruined architectural remains and earthworks carried out in very specific winter conditions (i.e. late afternoon long shadows, slight snow cover, trees free of leaves) has no equivalent in high altitude vertical photographs taken with no respect to the specific season and time of day necessary for achieving the desired result.

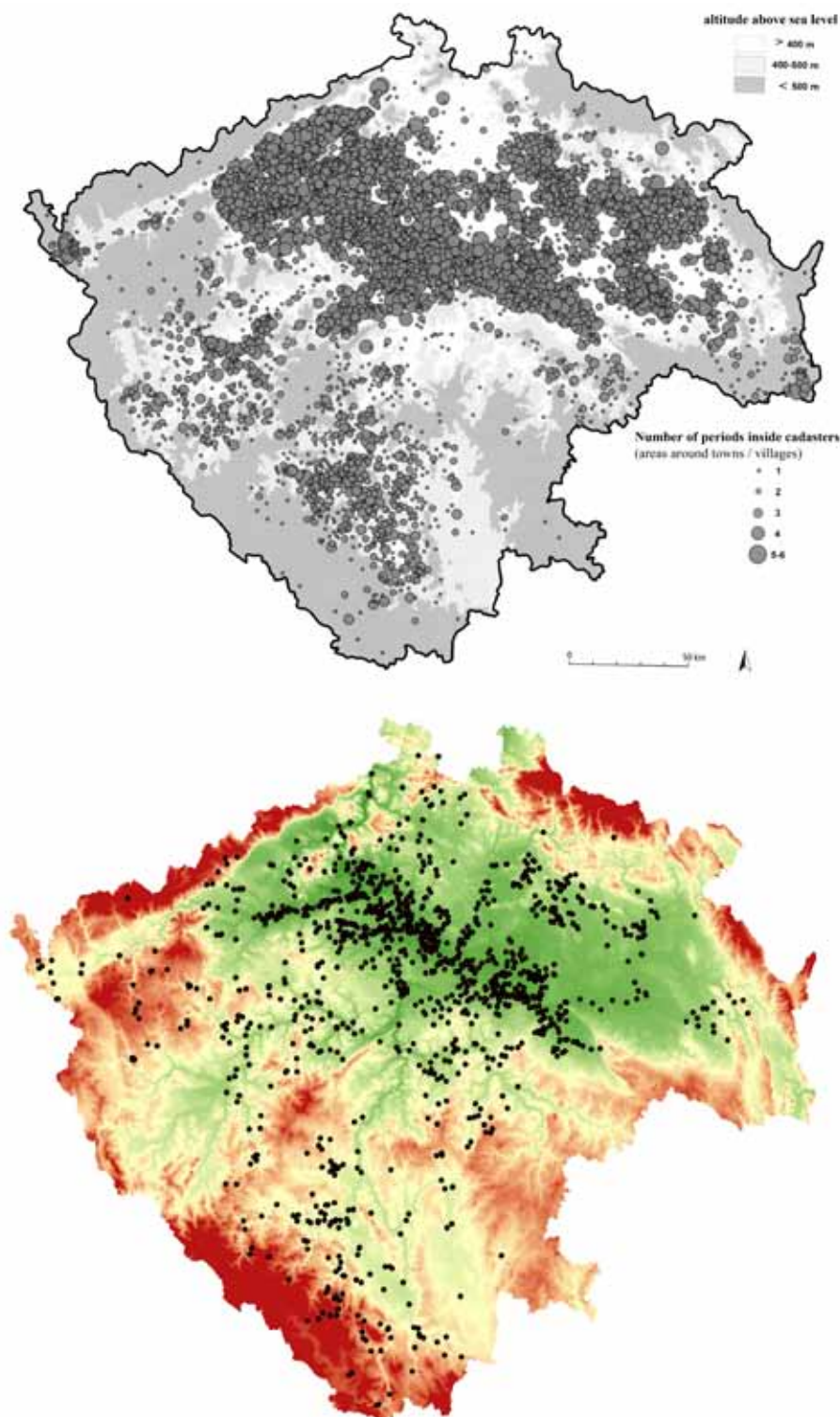


Figure 17.1: Map of prehistoric sites in Bohemia, western part of the Czech Republic. The distribution reflects both settlement activities traditionally based in the environmentally most fertile lowlands and large river valleys in northern half of the country, and the intensity of regional archaeological fieldwork (a); map of sites and monuments in Bohemia documented by aerial photographs (project of the Institute of Archaeology, Czech Academy of Sciences). The dots represent both identified prehistoric to medieval sites (about 70%), and architectural monuments and urban units. The map shows that most aerial-surveyed sites have been recorded in the same territory as those identified previously on the ground. This is understandable as – in terms of environmental conditions – cropmarks territories generally corresponding to zones preferably settled by past populations. © *Institute of Archaeology, Czech Academy of Sciences.*

Figure 17.2: Ctiněves, northwest Bohemia. Part of a large late Bronze Age settlement displayed through hundreds of cropmarked pits. Clearly visible is also a large rectangular enclosure and a small one placed inside, and a central pit. Black arrows indicate a set of small enclosures, and in a black frame (bottom right) there is a ring ditch. Most prehistoric sites identified in Bohemia from the air so far include large numbers (10s to 100s) of sunken features such as pits and houses, and a few enclosures and linear ditches.  
© Institute of Archaeology, Czech Academy of Sciences.



All the data sources discussed above are the basis for identifying archaeological meaning and interpreting the Earth's surface recorded by various sensors. All such data, no matter whether performed from low altitude (aerial photographs, LiDAR) or from space (satellite) can be described under the comprehensive term of *remote sensing for archaeology*, including aerial archaeology (aerial survey, aerial reconnaissance and oblique photography), interpretation of vertical (orthorectified) photographs, panchromatic, multispectral and hyperspectral images and LiDAR image data (one can ask if the Aerial Archaeology Research Group will change its name accordingly, or whether will keep it forever, with respect to tradition).

### Bohemia as a case study: retrospective overview

The vast majority of traces of past human activities in Central Europe are levelled by cultivation and in general terms a much smaller number of sites, mainly hillforts, have been preserved as earthworks; of the earthworks many are in woodland. Thus, since most archaeology is buried under the surface the only way to trace individual features, and especially large sites, without very expensive and time-consuming large-scale excavations or geophysical survey, is to identify and record them during observer-directed aerial survey or to detect them on existing aerial photographs deposited in archives, and available on the internet (orthophotographs) – simply because they show almost exclusively as cropmarks.

Since the beginning of the study of Bohemia reported on here, carried out by the Institute of Archaeology, Czech Academy of Sciences, Prague, since 1992 and since 2005 in cooperation with the University of West Bohemia, specialists have tended to include results of aerial survey into research on settlement development and dynamics in study areas and on

the investigation of settlement structure in specific periods. The presence of specialists and a high standard equipment in the Institute allowed the development of an approach combining non-invasive methods (those operating both in large spatial units and on a site level) and sample excavations, which has turned out to be very effective. This approach has helped to create chronological frameworks for study areas, which is of primary significance for the study of complex settlement processes, underpinning better understanding of settlement strategies, the processes of stability and change in settlement history and preferences for site location and setting (for environmental and/or symbolic reasons). The programme also has been focused on developing the methodology of aerial archaeology. Some sites have been observed annually, and in individual phases of the year, informing an understanding of the role of climate, site geomorphology and plant types in the processes through which features are made visible as cropmarks and soilmarks (see also Czajlik *et al.* this volume). In addition, the effectiveness of aerial reconnaissance from quantitative and qualitative aspects (number and types of archaeological sites and features) has been compared to existing records on sites discovered in the same area over much longer periods by ground methods (Figure 17.1; for principal results of this approach see Gojda 2004a & 2004b).

Annual aerial survey campaigns over Bohemia have revealed about 1,000 sites of past settlement (and many hundreds of marks which were discarded as of either geological or recent origin during after post-reconnaissance aerial photo interpretation). Many of the archaeological remains are of otherwise unknown or rare types of sites and features. Most of them include non-linear features, such as pits and sunken houses which may be the only features detected on site or they are accompanied by linear ditches or enclosures (Figures 17.2 & 17.3).



Figure 17.3: Ctiněves, northwest Bohemia. Large enclosure mapped from an orthophotomap (a, b - both files available at [www.mapy.cz](http://www.mapy.cz)) and the setting of the enclosure shown in an elevation model (c) of the landscape around the Hill of Říp. This shows the site position on a local promontory facing a lowland area climbing slightly up the mountain's lower edge  
© University of West Bohemia.

In several cases large settlement areas, accumulations of residential and burial sites, spread over a few square kilometres have been identified through systematic annual reconnaissance over 10 to 15 years. These sites, which have been further investigated by extensive geophysical survey and small-scale sampling excavations, include some that have a range of remains indicative of a long settlement history. This has been confirmed by extensive analytical ploughed field-walking campaigns (surface artefact collections) in the 1990s, which demonstrated that in prehistory (i.e. from the Neolithic/Eneolithic to Roman periods) many of them were continuously settled (Kuna 2000). Evidence of multiphase prehistoric sites where use has varied between residential and funeral/ritual practice demonstrate the dynamics of settlement and illustrate the meaning of *genius loci* in the past. These areas occur both on terrace edges close to large river courses (Figures 17.4 & 17.5) and on plateaus several kilometres from the major rivers. In the past, however,

these plateaus were crossed by minor watercourses which have since disappeared due to various factors, especially intensive agricultural practice. Systematic aerial survey of selected river basins and small stream valleys (few to few tens kilometres long) have led to the discovery of dense linear concentrations of settlement areas situated a couple of kilometres apart. Some of them produced pollen data for environmental reconstruction of past landscapes (Figure 17.9).

Recently attention has also been focused on the analysis and interpretation of vertical aerial images (orthophotographs) and on the rectification and transformation of data identified on them into plans and maps. Progress has been made in 3-D analysis of verticals (Šmejda 2009), and also satellite images and their potential for Czech landscape and settlement study are now being evaluated (Figure 17.7b; Gojda & John 2009).

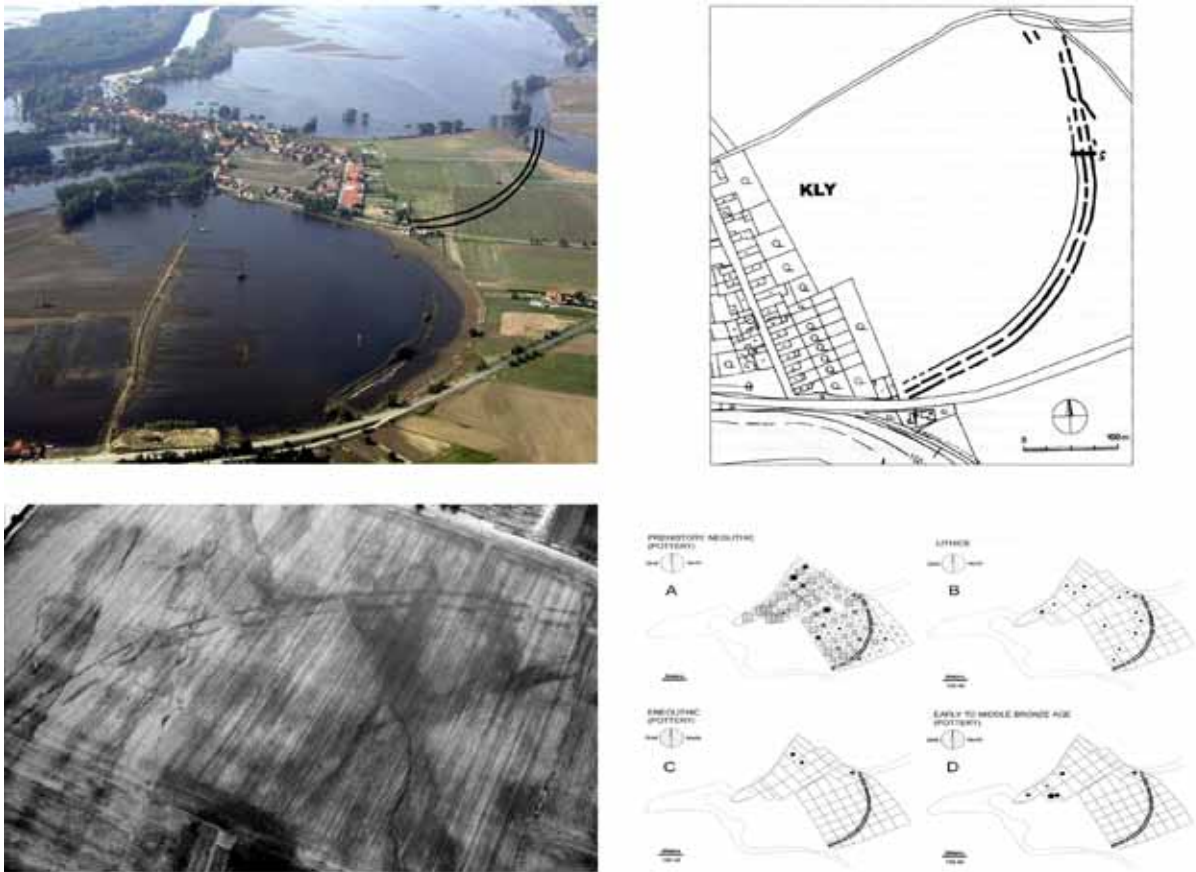


Figure 17.4: Kly, Central Bohemia. Many sites discovered from the air have become a target of fieldwork and research. A typical example of this approach is the site of Kly, an area enclosed by a double ditch and palisade trench placed on a low promontory raised above the alluvial zone of the River Labe (*Top left* – taken in August 2002 during flooding). The plan of the site (*Top right*) is based on interpreted aerial photographs and a magnetic survey, which has supplemented information on the northern end of the double ditch. A further part of the enclosing ditch system (almost 500m long) can be seen in a second aerial view (*Bottom left*). The site was also ploughed-walked, producing artefacts enabling its dating. Although the ditches date from to the early Eneolithic (Michelsberg culture, around 4000 BC) most pottery fragments (*Bottom right*) come from an earlier period (late Neolithic in Czech chronology scheme, second half of 5<sup>th</sup> millennium BC; see plan A). This very probably documents settlement continuity on the site from the Neolithic to the Eneolithic. A small excavation (section through the ditches – see letter S on *Top right*) produced in-situ artefacts dating the ditch system precisely. © *Institute of Archaeology, Czech Academy of Sciences.*

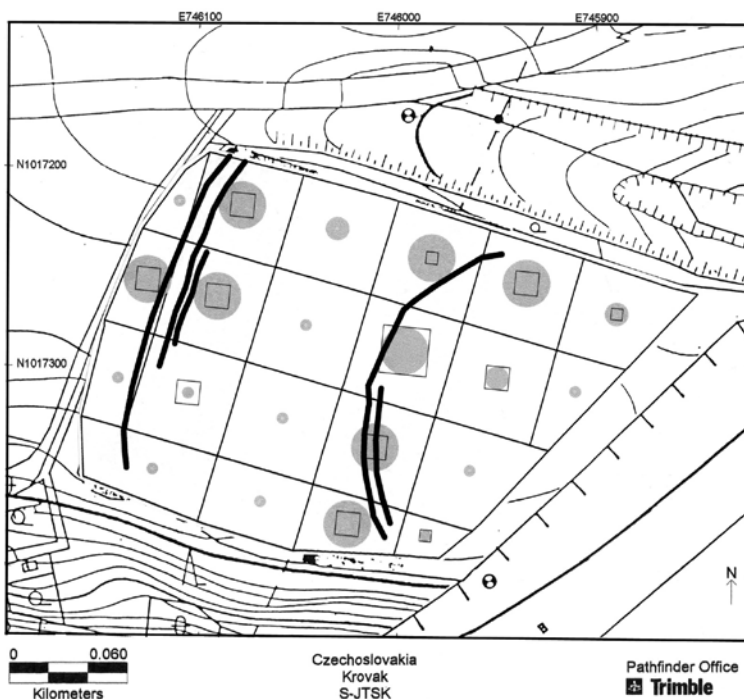


Figure 17.5: Vepřek, central Bohemia. Plan of a site placed on a strategic hilltop above the Labe. Three non-destructive methods have been applied to its study: aerial reconnaissance and geophysical survey identified two multiple ditched systems (black lines), and surface artefact collection (ploughed-field walking) produced data on the age of settlement activity (several prehistoric periods) and the distribution of artefacts on the surface. None of the field methods (including small-scale excavation) brought information about the exact age of the ditches. © *Institute of Archaeology, Czech Academy of Sciences.*



Figure 17.6: Nechanice, eastern Bohemia. Most of the late medieval to post-medieval earthworks in Bohemia lie in woodland, an environment more likely to allow the preservation of earthworks than open fields. The image shows a moated site enclosed by multiple ditch-and-bank system. The ditches are almost completely silted up and the banks largely levelled; unlike a few decades ago when the site was an earthwork and recordable as shadow marks it is now mainly visible as cropmarks. © *Institute of Archaeology, Czech Academy of Sciences*.

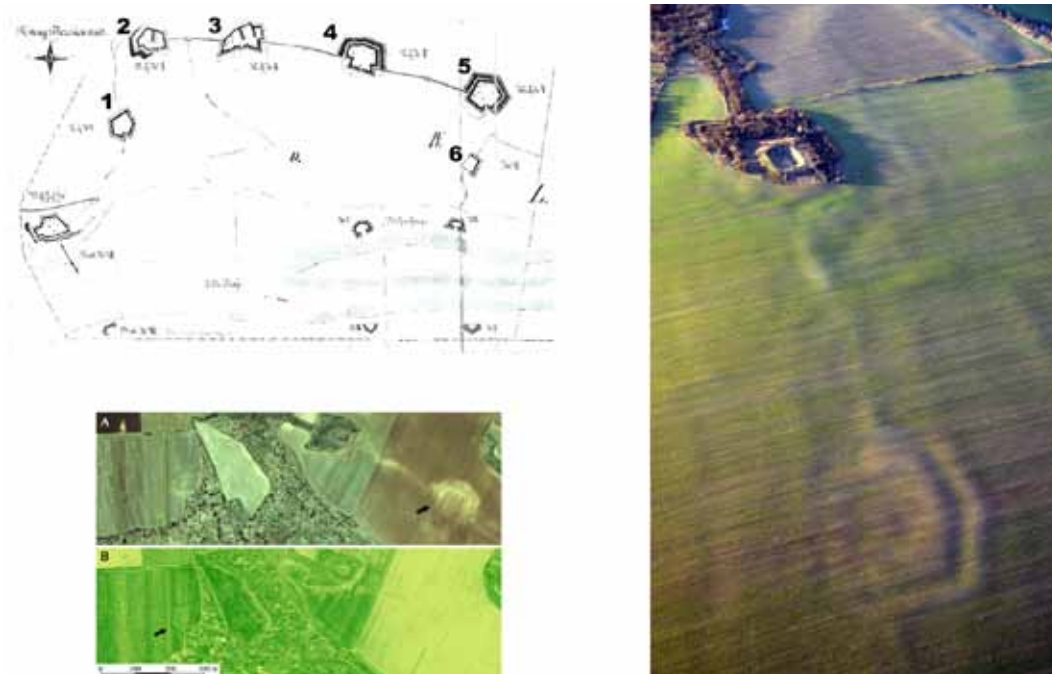


Figure 17.7: Treboutice, northwest Bohemia. Recently orthophotographs and satellite images have been applied in Bohemia as an important remotely sensed data source for past landscape and settlement study and protection. The potential of satellite data has been tested at an early modern (mid-19<sup>th</sup> century) military installation near a large brick-walled 18<sup>th</sup> century fortress. The original plan of the fortification system (Top left) shows the layout, parts of which has also been recorded on QuickBird satellite imagery (Bottom left) of forts 1, 3 & 4: A = combination of multi-spectral images in the visible parts of the spectrum R+G+B, corrected by pan-sharpening; B = vegetation index NRVI, also corrected by pan-sharpening. ; Forts 3 & 4 have also been recorded on oblique views (Right). A late autumn aerial campaign in 2009 produced evidence, from slight shadows recorded in the late afternoon, that the site survives as a very low earthwork, in spite of lying in a regularly cultivated field. © *University of West Bohemia*.



Figure 17.8: Louny, northwest Bohemia. Crop-marked small polygonal fort, a part of temporary field defences constructed in 1813 in response to the threat of military attack of Napoleonic troops from Saxony into Bohemia. Like many other prehistoric, ancient and later buried features and monuments this was identified during low altitude aerial survey, but has not been recorded on available satellite images and orthophotographs yet. The small point features are pits of prehistoric origin. © *Institute of Archaeology, Czech Academy of Sciences*.

### Aerial monitoring and photography of cultural heritage: earthworks, architectural monuments and urban areas

Integrated into the aerial survey programme of the Institute since the beginning is also aerial photography of cultural heritage and monitoring changes and destructive processes, such as agriculture and construction. Systematic attention has been focused on sites and monuments in those parts of Bohemia over which annual aerial reconnaissance has been organized to identify past settlement through crop- and soilmarks. Consequently, documentation has been primarily in the most fertile lowland areas of central and northwest Bohemia (and which, in spite of continuous pressures from farming, industrial and



Figure 17.9: Mastiřovice, northwest Bohemia. In some settlement areas recorded by remote sensing, environmental samples have been taken for pollen analysis where suitable soil layers exist, providing evidence for reconstruction of past land use. The photograph shows a hand auger being prepared for sampling sediments in a local stream basin situated close to a Roman period settlement which had been identified from the air through cropmarks. © *University of West Bohemia*.

construction activities, have a wide range of standing monuments and extremely well preserved medieval village cores and historic town centres). In these areas we have photographed various categories of cultural landscape, such as archaeological earthworks (e.g. Figures 17.6, 17.7 & 17.8), architectural monuments (e.g. Figure 17.10) and historic urban units.

Unfortunately, the repeated offer by the Institute to the institutions responsible for these aspects of cultural heritage for cooperation in systematic aerial photographic documentation of listed sites, for example, has not led to regular collaboration. Only in the 1990s was a collection of aerial oblique photographs of listed archaeological sites deposited in the Sites and Monuments Record of the National Heritage Office. Recently, however, an agreement between the Institute and Prague City Council has allowed a transfer of data. A complete set of high resolution digital orthophotos of Greater Prague, consisting of periods of imagery taken between the late 1930s and the present, has been deposited in the Institute's Archive of Aerial Photographs (see below), while the Council obtained all oblique photographs taken since 1992 over both the city centre and the suburbs.

As the Institute is also one of the country's most active bodies in terms of large-scale rescue fieldwork, aerial photography of sites excavated in advance of developments, such as motorway constructions and aggregate extraction, is of great importance. It is a highly effective way of recording the work across the site as the fieldwork progresses (Figure 17.11).

The Institute's collection of aerial photographs of Czech historical landscapes and monuments – one

of the largest in the country – is open to any kind of research and heritage management carried out on a professional basis. Its value will certainly be recognized in future as a source of information documenting the major changes that took place in the post-communist era in both rural and urban landscapes.

#### Data storage

All the available remotely sensed data has been deposited in the Archive of Aerial Photographs at the Institute. The traditional (analogue) collection includes negatives (6,500), slides (5,700) and printed enlargements filed by a town/village area and accompanied by maps and other relevant papers (850 files altogether). There are also 175 vertical images taken by Czech air forces between the late 1920s and the 1990s. The digital collection comprises photographs taken since 2002 (about 9,000 images), 15 hours of footage taken by semi-professional camcorder (12 hours in Bohemia, 3 hours abroad), and scans of the slide collection.

#### Perspectives for the future and conclusion

Undoubtedly the way forward in understanding past landscapes by remote sensing techniques will be through combinations of all methods mentioned above. Each of them can be used in specific conditions and consequently, their potential can be fully evaluated when they are integrated. While archaeological field methods will probably never be totally non-destructive, in the near future excavation will probably only be applied in rescue situations, and research projects on sites that are not threatened will focus completely on



Figure 17.10: Bezděz castle, northern Bohemia. Monitoring sites and documenting them with aerial photographs repeatedly since the early 1990s provides a good opportunity to record their state of preservation and to identify changes. This listed 13<sup>th</sup> century royal castle has been partly excavated during large-scale restoration, and the images show landscape setting and varying details of the monument. © *Institute of Archaeology, Czech Academy of Sciences.*





Figure 17.11: Documentation of large rescue projects in Bohemia is an important component of the aerial archaeology programme. Most rescue excavations take place during construction of new roads and motorways, such as that near the district town of Kolín, central Bohemia where a large single-ditched and part of a double-ditched enclosure are visible (Top), and during sand/gravel extraction, for example at Vliněves, central Bohemia where a Bronze Age burial site is being excavated (Bottom). © Institute of Archaeology, Czech Academy of Sciences.

non-invasive field methods. This will ensure that sites will be preserved relatively undamaged for future generations of archaeologists, whose methods and equipment will be much better than ours and will be able to reveal details we can hardly imagine.

For Bohemia the potential of ALS (LiDAR) for large-scale mapping of archaeological landscapes is of major importance. During 2010/11 a state-funded pilot project at the University of West Bohemia will scan a sample area, filter and classify the data, and finally evaluate the results against research objectives on the one hand, and of the requirements for sites and monuments record/management on the other. In the Czech Republic, and certainly also in other central European post-communist countries, a significant focus will be on the large-scale inclusion of LiDAR data into the mapping, study and management of archaeological (landscape) heritage. An ALS programme for the whole Czech Republic started in autumn 2009 and should be finished by 2012, although the primary unprocessed data from scanned regions will probably be available more or less immediately). It is the authors firm belief that a specialist centre for LiDAR data processing, mapping and subsequent ground-observation should be established, perhaps as a part of a university archaeological institute/department to fully exploit the potential of this technique (see Bofinger & Hesse this volume).

Finally, there are a number of theoretical and methodological issues to be addressed. Principle among them are the issues of the interpretation and

classification of the vast amount of information on high resolution orthophotos and satellite data. These highlight the difficulties of interpreting the large number of features recorded as natural or cultural, and their integration into subsequent synthesis.

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