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Researching Archaeological Landscapes Across Borders

Strategies, Methods and Decisions for the 21st Century

Edited by Zoltán Czajlik, Matija Črešnar, Michael Doneus, Martin Fera, Anja Hellmuth Kramberger and Marko Mele

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Iron Age and Roman Age tumuli at Vaskeresztes-Felsőcsatár – Burg im Burgenland – Schandorf/Čemba, at the Austrian-Hungarian border, visualised from Airborne Laserscanning data
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Table of Contents

PART I

I.1 Foreword – purpose of the tool

Marko Mele

Archaeology with its methodology is currently undergoing massive changes. While until recently, “archaeology” generally had the connotation of “digging” and the making of individual precious archaeological finds, non-invasive research methods are gaining more and more importance and have begun to challenge archaeological excavations as the primary archaeological information source. Moreover, today’s widespread use of large scale archaeological prospection has shifted the focus from single sites and finds to a more comprehensive approach into the research of cultural landscapes.

The shift of the research focus was reinforced by an accelerated development of new and enhanced technologies, such as airborne laser scanning (ALS) or advanced and motorized archaeological geophysics. Technological development is being accompanied by new methodological approaches in (archaeological) landscape research, theoretical approaches in understanding cultural landscapes, as well as adaption of legislative frameworks for monument protection on various levels and the establishment of preventive archaeology.

The changing archaeological research landscape makes it necessary to rethink our approaches towards landscape research. This is true to an even greater extent, as the European Cultural Heritage Strategy for the 21st Century (Strategy 21) will require us to widen our future archaeological project applications towards an assessment of their social, economic, territorial and educational impacts.

This publication is attempting a first step in the direction of a comprehensive examination of the changing world of archaeological methodology. It is an attempt by the international partnership of the Iron Age Danube Project involving professionals from Austria, Croatia, Hungary, Slovakia and Slovenia to create an easy-to-read guidebook for a comprehensive approach to archaeological landscape research in the light of Strategy 21. Its concept is not to produce yet another methodological manual for archaeologists already working in landscape research. It should be seen rather as a guidebook, a methodological tool for cultural heritage managers involved with the archaeological heritage and also for the new generation of upcoming archaeologists facing their first challenges in the research and preservation of the archaeological heritage. In this respect, the publication connects practical guidelines for the use of state-of-the-art research methods with theoretical and legislative necessities at the European level.

The starting point of the tool is the newly introduced European Cultural Heritage Strategy for the 21st Century (Strategy 21), which created a new system of evaluating approaches to the aspects of research, preservation and presentation of our cultural heritage. The evaluation procedure in the strategy tackles three major fields (1. social, 2. economic and territorial and 3. knowledge and education), with a set of challenges and recommendations in order to find the overlapping points for single actions. Given that we see the publication in hand as a methodological tool, it should guide the reader from the strategic to the applicative level in archaeological research of landscapes. To achieve this aim we offer a matrix as an aid in the selection of the most appropriate methods for a planned project.

The publication is divided into two parts and pursues three major questions which must be faced during archaeological project planning:

1. What is the contribution of the project in the field of archaeological research?
2. What is the potential audience, who are the potential users and who should benefit of the planned archaeological research?
3. What is the best methodology to reach the goals of archaeological landscape research?

The first two questions mostly concern Part 1 of the book, which aims at an evaluation of any project according to the challenges and recommendations identified in Strategy 21. The third question is mostly approached in the Part 2, where readers can gain a better insight into the available methods and their implementation in various environments of the collaborating countries. Additionally, an overview of the legal framework for the implementation of the methods in Austria, Croatia, Hungary and Slovenia and tips for using the different methods should make the book relevant and useful in many situations. A glossary shedding light on much not always easily understood archaeological terminology is intended to support communication between the archaeological community and non-archaeologists, primarily among heritage managers, at the legislative level and of course potential financing partners for archaeological projects.

I.2 Landscape as an archaeological heritage

Dimitrij Mlekuž

Introduction

Landscape archaeology explores how human communities in the past have related to space, i.e. their environment, how they structured their activities in space, transformed their environment and imbued it with meaning through cultural practices. Landscape archaeology is a varied and heterogeneous field of archaeological research that shares a common interest: the spatial dimension of the past human activity revealed through the study of material traces and remains.

The central concept of landscape archaeology is the 'landscape' itself. The landscape is a very open-ended concept, used in many different ways. The meaning ranges from the landscape as purely material space, a piece of Earth's surface to an idea or way of seeing and depicting the world to a way of experiencing the world, from thing to representation and experience. These tensions are productive as they animate the discussions which in return create new understandings of the landscape.

The tensions stem from the intense discussion focusing on the diverse and sometimes exclusive aspects that human societies spread and organise in space as they establish a relationship with the environment. Landscape archaeology accommodates different ways of understanding and dealing with space that have been developed not only within archaeology but borrowed and adopted from disciplines such as geography or anthropology.

Landscape archaeology today is a very wide-ranging field that employs diverse and often contradictory theoretical perspectives in its approach to landscapes of the past.

From space to place and landscape

The landscape could be a physical environment, a more or less stable stage that provides resources, potentials and sets limitations. In some cases, it can be seen as an ultimate determinant that guides the progress of human societies, cultures and civilizations. Thus the physical environment could be seen as a proxy for understanding the development and diversity of cultures that populate it.

From the 1960s and especially 1970s onwards, with the revolution brought about by processual archaeology, an interest in the spatial dimension of the archaeological record flourished. Processual movement, with its strong emphasis on methodology and environmental archaeology aimed at the scientific study of past and incorporated methods and techniques developed in other disciplines. All of these developments were aimed at systematically approaching the relationship between human societies and their environments through ecological, evolutionary, economic and social perspectives.

Concepts such as space or the environment became central to archaeological research at that time. Study of "settlement patterns", or the locational regularities became useful tools that allowed an understanding of the functioning of past cultures through the study of the spatial organisation of their activities, mainly in settlements and subsistence.

An important innovation was the idea of the systematic sampling of archaeological entities within the 'region'. The region was proposed as a suitable sample area for a study of cultural systems. New techniques, such as analytical field surveys have been developed in order to systematically sample large areas. Landscape archaeology thus developed as a distinct part of the discipline that systematically gathers a variety of data from large regions with various methods and seeks to explain site interrelationships and cultural development within a given region focusing on ecological conditions, population levels, climate, land use patterns, technology, settlement patterns and the organisation of sites.

Processual approaches that equated landscape simply with an abstract space populated with sites, artefacts or resources, as an ecosystem or as a region, a sampling universe, have failed to address all aspects of the human experience involved fully and comprehensively. The concept of space, as an empirically neutral series of relationships between objects and the environment was replaced (or complemented) with the concept of 'place', which is the meaningfully constituted and culturally constructed space that people dwell in.

Thus, landscapes become a network of culturally constructed and experienced 'places' created through cultural and social practices based on the common but also contested understandings that people have of them. Places have meaning, cultural and social experiences in space reconstitute spaces as places through experience. This approach focused on lived experience, symbolic aspects, meaning, power, and the emphasis given on symbolic and sacred landscapes.

The landscape is therefore studied in relation to time, space, place, memory, movement, continuity and perception. The landscape is inhabited with people who charge it with meaning over and over again. There are different ways of making landscape depending on when and by whom it is inhabited. And there are also distinctions between inhabiting and interpreting the landscape. Contradiction and conflict are seen as embedded in the landscape. The landscape becomes both medium and arena for power struggles and social and political tensions.

These discussions have explicitly addressed the meaning of the landscape, the variability of perceptions of it and also the ways meaning is produced, negotiated and contested in a landscape. A piece of Earth's surface is not one single landscape, but can be many, at the same time. Landscapes may be termed ritual, symbolic, sacred, burial, mythical, urban or aesthetic.

Archaeological approaches to landscapes

The specific way landscape archaeology approaches landscape is archaeological, as it is concerned with the material, durable remains of the past activities. However, past landscapes can be tackled in broadly three different ways, which can be complementary to each other or mutually exclusive. First, the landscape can be seen as a context to understand the spatial patterning of the material record, as a space for artefacts and traces. This is a common approach in the study of settlement patterns or off-site archaeology. This approach sees the landscape as naturally or humanly created features that exist 'objectively' across space. Landscape thus consists of features within their natural context.

On the other hand, past landscapes can be seen as a setting that existed at a specific moment in time. These can be 'reconstructed' by creating representations – images, maps, accounts – of the past landscapes at different moments using different methods and approaches, for example, environmental reconstruction, mapping of archaeological features using remote sensing, dating techniques etc. This approach aims at bringing together fragments of the past into a structural whole.

Last but not least, a modern landscape can be seen as an artefact, a cumulative result of past human cultural practices from Palaeolithic times through until today. Modern landscape is a research object in itself, the landscapes we see today should themselves be considered as an archaeological record as a whole. This approach is focused on time-depth of landscapes and sees archaeology as its constitutive part. The landscape is seen (and treated) as a heritage, and special focus is on the ways the past is incorporated, used and reused in the present.

Archaeological analysis operates on a continuum of scale, from the microscopic analysis of a single artefact to regional or even global long-term cultural change. A common assumption is that shifting from one scale to another in space and time is a seamless process. Scale in this sense is invisible, a mere mathematical abstraction. However, issues of scale exist at the fundamental level of archaeological interpretation. The scale can be understood as the level of conceptual abstraction of processes and phenomena in space. Therefore, scale addresses the ways in which space is produced, reproduced, and structured into places. Scales exist as material products. Artefacts, structures, sites, landscapes are not merely arbitrary scales of analysis, but their scale is related to social and natural processes that structure the archaeological record. Thus, scale tells us something about reality. The landscape is not simply a unit of analysis over and above the site or a scale of analysis, but an object in its own right.

Spatial technologies

One of the key aspects of modern archaeological landscape studies is the use of spatial technologies. Archaeological traces are, by definition, often fragmented, buried and invisible. They require specialised tools and approaches to detect, record and imagine past landscapes.

Information technology has been of increasing importance in recent times for data manipulation, mapping, and analysis. The use of spatial technologies in archaeological research has enhanced our ability to collect, store, analyse and imagine archaeological data. Remote sensing has helped us detect archaeological remains systematically over large areas. Remotely sensed images of the Earth's surface have increased in quality, availability, and potential for being integrated in a GIS environments. New technologies such as lidar (light detection and ranging) or ALS (airborne laser scanning), create remarkably detailed models of ground topography, which can be used for archaeological prospection. Advances in GIS and remote sensing have resulted in the development of spatial databases, which now regularly include thousands of individual features extending over the broadest areas of study.

Spatial technology has had an immense impact on our ability to create, manage and analyse data sets and share our findings with other professionals and the public. Geographic information systems have gradually become the platforms archaeologists use to store large sets of information. These changes have been especially important in heritage management and influence how archaeologists approach the study of past landscapes. The results include not only the discovery and protection of new sites and the complete survey of known sites but also allow for non-invasive or minimally destructive field archaeology. They play a key role in the development of preventive (or development led) archaeology, where archaeological remains are seen as a limited resource that has to be managed in a sustainable way, and this mainly through spatial planning.

Spatial analysis continues to be a central part of archaeology, with geographical information systems (GIS) providing a powerful tool in regional studies of settlement patterns, location analyses and modelling. Specialised studies focus on intrasite analysis (for example space syntax analyses), predictive modelling, modelling of cost surfaces and models of landscape perception. One of the most common modelling applications using spatial technology explores the role of visibility in spatial practices and construction of meaning in the landscape.

The productive engagement with information systems in archaeology opens new paradigms and research venues. Spatial technologies have been conceived as useful tools, which can be applied to the working processes in archaeology that are already well established. But information systems are not only representation tools, they also allow for a productive engagement with landscapes of the past. The construction and analysis of digital models of past landscapes is not only a way of reproducing the real world but also a new framework of reference for approaching and exploring it in novel ways, while also identifying new conceptual and theoretical problems.

The integration of spatial technology within archaeology has brought to the fore new conceptions of archaeological data. This is especially true in the field of Big Data. Big data is a broad term for datasets so large and complex that they become awkward to work with using only the database management tools currently on-hand. Challenges in working with big data include analysis, capture, data curation, search, sharing, storage, transfer, visualisation and querying. These issues deal explicitly with scale and complexity in the archaeological record. The real question with big data is not the management of large quantities of data, but how to deal with a new quality that emerges from this vast quantity. Big data requires new modes of using data for knowledge production that extend and complement the traditional scientific method, such as deep learning, hierarchical representation, neural networks, and information visualisation. It also allows us a glimpse into the large-scale historical and spatial patterns for the first time.

Modern landscape as a historical artefact or historical landscape

Another set of approaches deals with the modern landscape as material culture. The present-day landscape is seen as a historical artefact and the main object of study is focused on to how the past survives and makes the present landscape. Modern landscape is understood as a heritage, a cultural asset and a resource. The goal of these approaches is to provide structured understanding to inform planning and management decisions across a wide range of options that affect the landscape. This understanding is rooted in principles and aspirations of the European Landscape Convention and has developed tools such as historical landscape characterisation (HLC) or "landscape biography".

These approaches were developed to provide an understanding of the historical dimension of the modern landscape. HLC provides a context for appreciating how archaeological sites fit into the historic landscape. It focuses on time-depth of the landscape, treating landscape as a matter of history rather than geography. Everything in the landscape has historical roots, and even the most recent examples of landscape features are part of a long chain of events that stretches back across centuries or millennia.

The main element of analysis are contiguous areas, not isolated locations or sites. HLC addresses the landscape as a whole, not just isolated sites. All aspects of the landscape are important and part of landscape character, no matter how modern, ordinary, unattractive or degraded they may be. HLC is concerned with the degree and extent of human agency and intervention, since all natural and living features (e.g., woodland, land cover or hedges) are as much a part of landscape character as are archaeological features or buildings.

Characterisation of the landscape is understood as a matter of interpretation, where perceptions and opinions, ideologies, past and present, are an important aspect of the landscape.

Conclusions

Modern landscape archaeology attempts to encompass almost all previous approaches in a more cohesive and complete framework combining methodological correctness and interpretative complexity.

The landscape is a concept with no fixed definition and can be many things. Some archaeological studies focus on the geometry of the landscape, some on environmental properties, others focus on the personal and symbolic experience; some are interested in patterns of stability, others in patterns of change, some seek to identify systems, while others might look for the divergences from patterns and individual experiences.

The approaches developed or adopted by landscape archaeology, such as settlement pattern analyses, locational analyses, regional analyses, the archaeology of places or phenomenological approaches, all can contribute towards the building of a landscape approach. Each offers a partial answer to the larger questions the landscape paradigm enables us to ask. They all examine different facets of a key issue of landscape archaeology: a concern with the human experience of the world around them.

I.3 European Heritage Strategy for the 21st Century – *Strategy 21*

Jelka Pirkovič

What is the European Cultural Heritage Strategy for the 21st Century about?

Our heritage is rooted in the human environment and cultural landscape by its very nature and the archaeological heritage as an integral part of it is a perfect example of this. The heritage represents an important factor in the formation of cultural values and the identity of individuals and their constituent communities regardless of their provenience and social status. If properly managed, heritage also becomes a sustainable development resource, significantly benefiting the local community. Furthermore, the archaeological heritage is a non-renewable source of knowledge with an immeasurable potential for scientific and educational interpretation.

In the last decade, the Council of Europe and the European Union[1] have adopted a series of political documents confirming the importance of heritage for Europe's future. Among these the *Council of Europe's Framework Convention on the Value of Cultural Heritage for So*ciety (Faro, 2005)[2] most firmly defines the new international framework for action regarding the social role of our heritage.

The *Faro Convention* defines, among others, the right to heritage as one of the universally accepted human rights and relates heritage to heritage communities that value and sustain it.

The main aim of the **Iron Age Danube Project** is to re-evaluate this important part of cultural heritage in its landscape setting, where archaeological research and interpretation deliver a necessary starting point in defining the social value of the specific landscape areas. In the logic of the *Faro Convention*, archaeological teams working in sites are members of the international heritage community whose members are experts working in the field of heritage. At the same time, they need to build an alliance with other heritage communities in the territory. This is also the case in the **Iron Age Danube Project**, where archaeologists define values of archaeological landscapes and their activities in the partner countries in collaboration with other stakeholders.

Objects and sites in themselves cannot in general be valued unless they have a special meaning for the society and communities at different levels. The relation between heritage and heritage communities gives a solid basis for participatory governance and therewith opens new perspectives for the strengthening of bottom-up democracy in the wider field of heritage management.

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1 *Council conclusions of 21 May 2014 on cultural heritage as a strategic resource for a sustainable Europe, Council conclusions of 25 November 2014 on participatory governance of cultural heritage, European Parliament resolution of 8 September 2015 towards an integrated approach to cultural heritage for Europe, Council conclusions of 27 May 2015 on cultural and creative crossovers to stimulate innovation, economic sustainability and social inclusion, and* ***Council conclusions of 22 May 2018 on the need to bring cultural heritage to the fore across policies in the EU.***

2 https://www.coe.int/en/web/conventions/full-list/-/conventions/treaty/199

Until now, eighteen Member States of the Council of Europe have ratified the *Faro Convention.* In comparison to other international heritage treaties, a relatively small number of ratifications may look like a disadvantage. However, it is worth noting that the great majority of states, which are members of the convention are from the so-called "new Europe", while only five belong to the "old Europe" core. If we consider the EU Member States that co-operate in the **Danube Transnational Programme**, only four out of the total (Germany, Czech Republic, Romania and Bulgaria) have not yet ratified the *Faro Convention*. It is important to mention that all five countries, participating in the **Iron Age Danube Project** partnership, have already ratified the convention.

In order to accelerate the introduction of Faro principles in heritage policies and practice, the Belgian Presidency of the Committee of Ministers of the Council of Europe organised a conference in Namur, Belgium in 2015, summoning the ministers responsible for cultural heritage. At the end of the conference, the ministers adopted the so-called *Namur Declaration*[3] calling upon the Council of Europe to develop a European Cultural Heritage Strategy and to involve all relevant stakeholders in this process: the Member States, European institutions, experts, and "civil society actors and organisations active in the heritage field". In fact, the process of developing the strategy was an example of a participatory approach where European non-governmental organisations (among them notably the *Europeae Archaeologiae Consilium EAC* and *European Association of Archaeologists*) contributed an important part to the content and structure of the draft. The Committee of Ministers of the Council of Europe adopted the **European Cultural Heritage Strategy for the 21st Century** (hereafter: **Strategy 21**) in the form of recommendations for the Member States.[4]

It is of great importance that all the policy sectors implement their interventions on the grounds of strategic, evidence-based decisions. This is even more the case for heritage policy because the sector is relatively deficient in terms of financial capacities. On top of this, heritage concerns depend on and at the same time influence activities in other sectors. To cope with heritage challenges, the sector needs to justify how heritage-led interventions have wider societal and development impacts and not only those related to the cultural sector or science.

The heritage authorities have in most cases until now, planned and implemented heritage interventions following a vertical, sector-based approach with a linear intervention logic. This kind of intervention logic is conducted in the following steps: first, we define an intervention challenge relevant to a heritage problem; then we formulate goals, allocate resources from the heritage sector alone, and focus on actions that produce results on targeted heritage concerns in the hope of resolving the initial problem.

An intervention usually produces direct impacts on a policy goal defined by the sector. In reality, there are areas where policy domains overlap and it is impossible to delineate one domain from another. As a result some interventions impact goals in other sectors. If we do not consider this fact in the planning stage, the effects in other sectors may not be accounted for, they may be contra productive or, in the worst case, even damaging.

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[3] https://rm.coe.int/CoERMPublicCommonSearchServices/DisplayDCTMContent?documentId=09000016806a89ae.

[4] *Recommendation of the Committee of Ministers to member States on the European Cultural Heritage Strategy for the 21st century* adopted on 22 February 2017, https://rm.coe.int/16806f6a03.

Strategy 21 pursues the general aim of meeting a higher recognition for heritage in different policies by offering new solutions to the problems modern societies face. Following this aim, it applies a new intervention logic of heritage policy with a new approach to achieving goals. This means that in terms of investment and regulation, policy measures do not exclusively rely on vertical interventions of the heritage sector. On the contrary, **Strategy 21** proposes that core heritage stakeholders (horizontally) engage in cross-sectoral cooperation. In this respect, heritage interventions should integrate other concerns, such as social and employment policy, spatial planning and environment, regional and rural development, education, research, innovation, and technological development, and of course, economic development and tourism. This also means that heritage policy planning and implementation at national, regional and local levels should involve these sectors, and that heritage interventions should if possible, integrate measures, including financial ones, devised by these sectors.

In order to implement the principles that the *Faro Convention* advocates (right to heritage, relationship between heritage values and heritage communities), **Strategy 21** introduces two sets of principles – the first aims at putting people and democratic values at the centre of each action, and the second proposes an integrated approach with the holistic vertical-horizontal intervention logic aiming at achieving synergic effects from the policy measures in different sectors and administrative levels that are expected to contribute to the well-being of Europeans and to the protection of the environment.

How should we implement Strategy 21?

By its aim, format and remit Strategy 21 belongs to the so-called “soft law” or, better to say, it is a reference document for different heritage stakeholders, in the first place for the Council of Europe’s Member States. The Council of Europe facilitates the implementation of **Strategy 21** and has to this end prepared a user-friendly website presenting components, recommendations and good practice examples that illustrate opportunities the Strategy offers.[5] The list of examples is non-exhaustive and all parties are invited to include new activities illustrating how the recommendations are followed. Among projects including archaeological heritage, we mention some promising ones, e.g., the *John Nurminen Foundation,* Finland, with its online map interpreting maritime heritage,[6] *Rundlingsverein*, Germany, active in supporting the nomination of historical circular villages in the Germanic / Slavic contact zone, dating from the 12th century to the UNESCO World Heritage List; the *Ancient Stadium of Philippopolis*, a project dedicated to the development of an underground archaeological museum in Plovdiv, Bulgaria,[7] *Academy of Heritage - post-graduate studies*, Poland, where academic institutions covering different disciplines (humanities, economics, spatial planning and the like) offer an integrated curriculum,[8] Historic England project *Heritage Schools*, Great Britain, Slovenian project *Cultural Heritage Week*, and Estonian project *Teaching materials for teachers about local heritage*

5 A section of Strategy 21 website is dedicated to the short explanation about the strategy, heritage policy evaluation ”in less than 1000 words“. https://rm.coe.int/strategy-21-impact-evaluation-basics-in-less-than-1000-words-/16808e9906. Recently, the topic of archaeological heritage management in Europe has been added.

6 http://www.lokistories.fi/.

7 http://ancient-stadium-plovdiv.eu/?p=39&l=2ancient-stadium-plovdiv.eu.

8 http://mck.krakow.pl/a-post-graduate-studies.

represent three similar initiatives aiming at bringing everyday heritage closer to teachers and children.[9]

Another important element is that **Strategy 21** aims to "…enable citizens to develop or regain a sense of ownership of heritage; pursue actions in the spirit of Faro; engage in dialogue and establish partnerships with national and international institutions, and with NGOs" (*Namur declaration*). In the *2018 European Year of Cultural Heritage*, the European Union and the Council of Europe agreed to jointly promote the *Faro Convention*. It is obvious that **Strategy 21** could be considered as a part of the Faro principles promotion.

It is expected that the Council of Europe Member States will implement **Strategy 21** mainly using it as a model facilitating their task of seeking agreements among different stakeholders on national heritage policy goals, to establish an effective relationship between strategic goals and operational objectives, translating these into policy measures and ultimately evaluating the policy results. If we foster the holistic approach and stakeholders reach a broader consensus on common goals, inputs and results, heritage and other sectors can achieve a higher level of synergy. The final outcome of wisely developed heritage interventions produces impacts across different sectors of society and proves that heritage-oriented activities benefit not only the heritage sector but also society at large.

Why should the Strategy 21 process benefit the European Union?

Strategy 21 considers European Union documents adopted since 2014, especially those defining the role of heritage as a strategic resource for a sustainable Europe, on the benefits of participatory governance of heritage, and on heritage as one of the catalysts stimulating innovation, economic sustainability and social inclusion. Several strategic challenges and recommendations underline these topics. Without going into all the details, we will here mention only two topics relevant for designing the strategy of the **Iron Age Danube Project.** The first, the participatory governance is presented briefly in the following paragraph. The second - heritage interpretation is presented in more detail in a separate chapter.

In **Strategy 21,** the term "participatory governance" is used alternatively with the term "participatory management"[10] Almost all challenges and recommendations involve the participation of wider public which is considered as one of the major tools for strengthening the relationship between heritage and society, citizenship and also the transmission and sharing of democratic values (Component S of **Strategy 21**). The Strategy dedicates one of the strategic goals (challenge S 6) to the promotion of participatory management. We can reach this goal by applying recommendations for the involvement of citizens and local authorities in heritage management and for making heritage more accessible (challenges S). On the other hand, practising participatory heritage management contributes to reaching territorial and economic development strategic goals (challenges D), as well as those that **Strategy 21** sets in the field of knowledge and education (challenges K).

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[9] https://historicengland.org.uk/services-skills/education/heritage-schools/, http://www.zvkds.si/sl/dekd/dekd-tkd, http://www.eays.edu.ee/aja/index.php/ajalooopetus/ajalugu/126-eestikultuuriloo-oppematerjal-eaus-2013.

[10] **Strategy 21** defines participatory management as "openness to the needs and expectations of stakeholders, the readiness of the holders of public authority to listen to them and provide responses to their expectations or queries, delivering public policies in a spirit of openness, accountability and shared ownership."

In short, **Strategy 21** offers national authorities and other partners practical tools for how to use the socioeconomic and identification potential of heritage resources. From the EU neighbourhood policy point of view, **Strategy 21** can contribute to the cooperation with countries beyond EU in the form of shared heritage projects. Interreg **Danube Transnational Programme** offers an excellent example of such a cooperation.

What is the innovative concept of Strategy 21 about?

The starting points of **Strategy 21** can be briefly described in the following statements.

1. The Strategy proposes the new heritage governance which marks the shift from material heritage objects to people.
2. It offers practical tools to foster shared responsibility and cross-sectoral approach.
3. It integrates different administrative levels and combines them with the needs and expectations of the civil society, experts, academia and other interested parties.

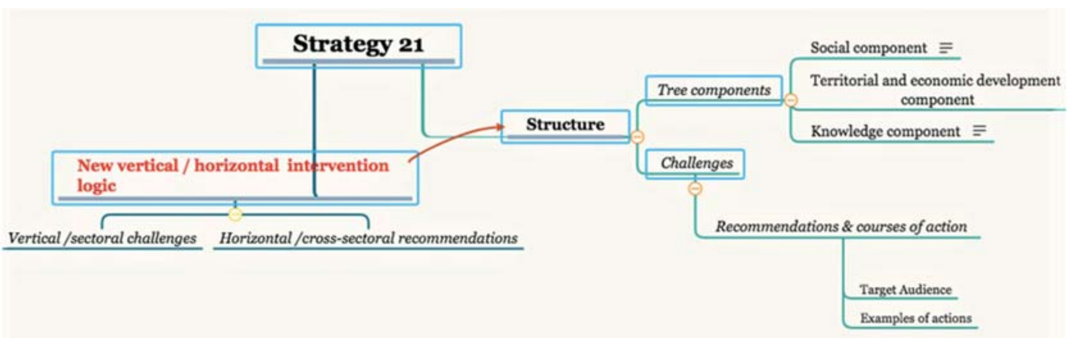
In order to take on board the integrative approach, **Strategy 21** adopts the holistic vertical-horizontal intervention logic. The approach has been developed by Bojan Radej and Jelka Pirkovič (see Annex 2 of **Strategy 21**).[11]

The structure of the document is adjusted to the general scope of Council of Europe's actions which is directed to help other partners in performing their tasks.

When a Member State or another entity wants to follow **Strategy 21** logical structure it needs to refine it in the following way:

- **Strategy 21** challenges should be specified in the form of strategic goals,
- **Strategy 21** recommendations should be specified in the form of development priorities,
- **Strategy 21** courses of action should be specified in the form of measures, and
- **Strategy 21** examples of action should be translated into priority activities (Figure 1).

Strategy 21 introduces three policy domains: Society (S), Economic and Territorial Development (D) and Knowledge and Education (K). They represent vertical, sectoral approach of the Strategy. Challenges bring to the Strategy a specific sectoral perspective,



I.3 Figure 1: Logical structure of Strategy 21 (J. Pirković)

[11] See also Radej, Bojan, Pirkovič, Jelka, Paquet, Pierre. Smart heritage policy. *Innovative issues and approaches in social sciences*, ISSN 1855-0541, Jan 2018, vol. 11, no. 1, pp. 57-70, http://www.iiass.com/pdf/IIASS-2018-no1-art4.pdf.

while the horizontal perspective takes the form of recommendations (development priorities with corresponding measures that reflect the cross-sectoral approach).

Strategy 21 acknowledges that several sectors share common goals, measures, and impacts horizontally and we need to accommodate them. The aim is to connect vertical heritage concerns with horizontal ones. **Strategy 21** defines on one hand challenges in three vertical priority components (policy domains) and on the other hand recommendations on how these challenges are addressed. **Strategy 21** also indicates which courses of actions (measures) target specific challenges (goals).

The overlaps of policy domains in **Strategy 21** are called areas of convergence or interfaces. In technology, especially in computing, an interface is a tool that enables cognitive transfer of knowledge from one knowledge domain to another.[12] From the social systems point of

Challenges** / Recommen-dations*		Social								Development								Knowledge							
		S1	S2	S3	S4	S5	S6	S7	S8	D1	D2	D3	D4	D5	D6	D7	D8	K1	K2	K3	K4	K5	K6	K7	K8
S1	Social		X		X		X		X	X		X						X		X					
S2		X	X			X		X		X		X						X		X					
S3		X	X	X	X	X	X	X	X	X								X		X			X		
S4		X	X	X	X	X	X	X	X									X	X	X					
S5		X		X		X	X	X	X	X						X		X						X	
S6		X	X		X	X	X	X		X						X		X					X		
S7			X		X	X	X	X	X			X						X	X	X					
S8			X	X	X	X	X		X	X			X					X	X	X					X
S9		X		X	X	X	X		X	X		X							X		X				
S10		X	X		X	X	X	X	X	X				X		X									
D1	Development		X								X	X	X	X	X	X									
D2									X	X	X	X		X		X			X			X			
D3					X					X		X		X				X	X		X	X			X
D4											X	X	X	X	X							X			
D5									X	X	X	X	X	X	X	X				X					
D6								X		X	X	X	X	X	X	X					X		X		
D7					X		X		X	X	X	X	X	X	X					X				X	X
D8											X		X		X		X					X	X	X	
D9												X	X	X											
D10										X	X	X	X	X	X				X	X			X		
D11							X		X	X	X	X	X		X									X	
K1	Knowledge				X													X	X	X					X
K2																			X	X					
K3																		X	X	X	X				
K4																		X	X	X	X	X			
K5																		X	X	X	X	X			
K6					X						X					X			X	X	X				
K7					X													X	X	X	X				X
K8																		X	X	X	X	X			
K9																			X	X	X	X			
K10																		X	X	X	X	X			
K11																		X	X	X	X	X			

*I.3 Figure 2: **Strategy 21**– Leopold matrix of interfaces with recommendations impacting challenges in three policy domains (Source: European Cultural Heritage Strategy for the 21st century,* https://rm.coe.int/european-heritage-strategy-for-the-21st-century-strategy-21-full-text/16808ae270*, p. 55.56.)*

12 Masoud Yazani, Phillip Baker (eds) (2000): *Iconic Communication*. Intellect Books: Bristol, p. 144.

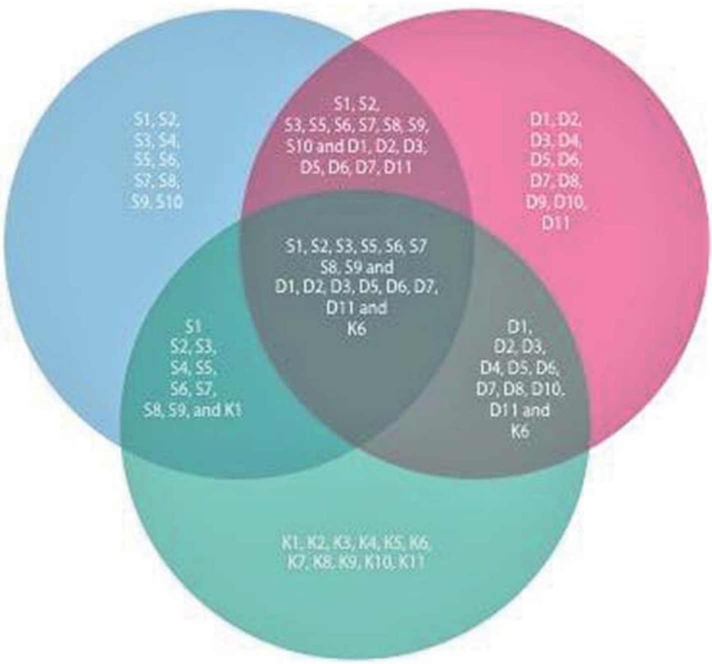
view, each function system is self-referential and "...reproduces itself by applying distinct codes, thereby maintaining a boundary vis-à-vis other function systems." By this means the system prevents outside agents from imposing change on how the system functions. This is why it is so important to define the overlaps among heritage policy domains and to build into the strategy interfaces as practical tools for enabling horizontal interaction with sectors outside the heritage one.

The Leopold matrix usually maps the distribution of measures and their impact on goals. **Strategy 21** foresees that a number of recommendations through their courses of actions (measures) produce impacts in two or even three policy domains. In our case, the Leopold matrix portrays the distribution of planned impacts on **Strategy 21** challenges (Figure 2).

Besides the three diagonal areas (S-S, D-D, and K-K) where measures target to impact challenges from their own policy domain, there are three areas of interfaces where measures from one domain are planned to indirectly impact challenges in another domain (and vice versa). Such occurrences are placed in pairs on two opposite sides of the diagonal grey areas (in the intersections of S-D and D-S, of D-K and K-D, and of K-S and S-K).

The so-called Venn diagram clearly visualises the overlaps between domains. The diagram below illustrates the intersection of all three domains in the central, triple interface (Figure 3).

The diagram illustrates the relationship between recommendations with their courses of actions and challenges S, D, G in terms of the potential impacts on three policy domains.



*I.3 Figure 3: Venn diagram of **Strategy 21** degree of integration (Source: European Cultural Heritage Strategy for the 21st century,* https://rm.coe.int/european-heritage-strategy-for-the-21st-century-strategy-21-full-text/16808ae270*, p. 59)*

The central, triple interface represents the selection of recommendations and their courses of actions with the highest potential to achieve impacts in all three policy domains.

The description of **Strategy 21** structural elements would not be complete if we omit to note that each course of action designates stakeholders that should be involved in the development of these actions and be responsible for the implementation. Due to the highly indicative role, **Strategy 21** suggests neither the financial resources needed for the implementation of planned activities, nor indicators for monitoring and evaluation purposes. It is expected that the parties implementing Strategy **21** will define indicators in accordance with their specific goals and strategic priorities. If these are linked to **Strategy 21** challenges and recommendations, it is realistic to arrive at an overall comparison of how **Strategy 21** challenges are met.

How can the Strategy 21 model benefit the Iron Age Danube Project strategy?

The last chapter illustrates how **Strategy 21** innovative approach can be used as a model and an input for the **Iron Age Danube Project** strategy. We have selected the subject of archaeological landscape interpretation as an example in order to make a general point.

Strategy 21 links heritage interpretation to all three strategic domains and formulates a large number of related recommendations. The following tables quote **Strategy 21** challenges in order to facilitate the possible evaluation of how the **Iron Age Danube Project** strategy fulfils the overall European strategic goals. As far as strategy components are concerned, we have kept the naming conventions in **Strategy 21**, complementing these with more narrow terms suitable for designing a strategy at the project level. Names of recommendations and courses of action derive from **Strategy 21**, but their actual wording has been adapted to serve the needs of the **Iron Age Danube Project** strategy (Tables 1-3).

I.3 Table 1: Adaptation of ***Strategy 21*** *Social component to the needs of the* ***Iron Age Danube Project*** *strategy (“interpretation” topic)*

SOCIAL COMPONENT (S) **Stakeholders’ participation in archaeological landscape interpretation**	
Recommendations and courses of action	**Challenges**
S1 **Encourage the involvement of citizens and local authorities in capitalising on the archaeological landscapes as a valuable part of their environment** Courses of action: - Identify people’s expectations, interests, likes and dislikes (young people, pensioners, newcomers, etc.) - Organise discovery visits to archaeological landscape run by local inhabitants and heritage professionals. S2 **Make archaeological landscape more accessible** Course of action: - Devise interactive, fun, creative presentation methods. S4 **Promote archaeological landscape as a meeting place and vehicle for intercultural dialogue, peace and tolerance** Course of action: - Develop narratives highlighting the intercultural values to be found in the archaeological landscape. S5 **Encourage and assess citizen participation practices and procedures** Course of action: - Implement new participatory approaches to archaeological landscape interpretation as a vital part of heritage management. S7 **Develop and promote participatory archaeological landscape identification programmes** Course of action: - Promote projects fostering the contextualisation of items that have been identified as archaeological heritage, making sure that by classifying them they are not divorced from their natural setting and context.	S1 Living in peace S2 Improving quality of life S4 Preserving the collective memory S6 Promoting participatory management S8 Promoting an inclusive approach to heritage

*I.3 Table 2: Adaptation of **Strategy 21** Territorial and economic development component to the needs of the **Iron Age Danube Project** strategy ("interpretation" topic)*

TERRITORIAL AND ECONOMIC DEVELOPMENT COMPONENT (D) **Archaeological landscape interpretation as a driver of local/regional development**	
Recommendations and courses of action	**Challenges**
D2 **Support and promote the heritage sector as a means of creating jobs and business opportunities** Course of action: - Inform the public and taxpayers, elected representatives and decision-makers about the economic and social impacts of archaeological landscape interpretation as a part of good management practice. D3 **Promote heritage skills and professionals** Course of action: - Open excavation and other works on archaeological sites to the public. D7 **Consider archaeological landscapes in tourism development policies** Courses of action: - Participate in drawing up tourism strategies at national and regional level. - Organise consultations with the local population to promote sustainable and responsible tourism, based on the values of archaeological landscapes and other heritage in the area. - Jointly devise material for tourists (guidebooks, virtual tourist guides, local visitor guides, etc.) D9 **Use innovative techniques to present archaeological landscape to the public while preserving its integrity** Course of action: - Present a space or an object in the archaeological landscape that has disappeared, is inaccessible, vulnerable or disconnected from its context. D10 **Use archaeological landscapes as means of giving the region a distinctive character and making it more attractive and better known** Courses of action: - Identify the most representative archaeological landscapes of the region. - Promote ethical branding (image management) with due regard for archaeological landscape values.	D1 Building a more inclusive and cohesive society D3 Ensuring that Europeans enjoy a high quality of life, in harmony with their cultural and natural environment D4 Implementing the principle of integrated conservation D6 Developing the ability of public services to address sustainable spatial development issues by means of better-using heritage D7 Preserving and developing the ability of public services to address heritage issues

*I.3 Table 3: Adaptation of **Strategy 21** Knowledge and education component to the needs of the **Iron Age Danube Project** strategy ("interpretation" topic)*

KNOWLEDGE AND EDUCATION COMPONENT **Synergy in the field of knowledge, education and interpretation**	
Recommendations and courses of action	**Challenges**
K2 **Implement measures to encourage young people to practise heritage** Course of action: - Organise targeted events about archaeological landscape interpretation for young people prepared in consultation with them. K3 **Encourage creativity to capture the attention of the heritage audience** Courses of action: - Highlight the interrelations between archaeological landscapes and state-of-the-art technologies in the fields of archaeology, conservation and restoration. - Encourage the creation of games focusing on archaeological landscapes and their values. - Organise multidisciplinary events based on and expressing the value of archaeological landscapes. K4 **Provide optimum training for non-professional players and for professionals from other sectors with a connection to archaeological landscape** Courses of action: - Introduce training for owners, local guides, seasonal workers, trainees, service providers. - Encourage heritage discovery with professionals. K5 **Diversify training systems for heritage professionals** Courses of action: - Enhance co-operation between universities, schools and training centres in the field of archaeological heritage interpretation. - Organise in-house training of heritage professionals with a view to enhancing archaeological heritage interpretation. K9 **Develop study and research programmes that reflect the needs of the heritage sector and share the findings**. Course of action: - Develop an interdisciplinary and international approach to archaeological landscape interpretation.	K1 Helping to foster a shared knowledge society K3 Raising awareness of the values conveyed by heritage K5 Guaranteeing a high technical level for all heritage trades and crafts K7 Encouraging heritage research K8 Enlisting the commitment of young people to heritage

After listing the recommendations relevant for archaeological landscape interpretation, we proceed by mapping the probable impacts of individual recommendations on challenges.

Impacts are marked with an “X” in the Leopold matrix. Fields running diagonally from top left to bottom right correspond to supposed recommendation impacts on challenges pertaining to the same components (Table 4).

To reach the final representation depicted by the Venn diagram, we need to proceed in two steps, first by filling in the so-called input-output matrix (Table 5), and then to

I.3 Table 4: Leopold matrix of interfaces between recommendations of the ***Iron Age Danube Project*** *(“interpretation” topic) and* ***Strategy 21*** *challenges*

Challenges		SOCIETY					DEVELOPMENT					KNOWLEDGE				
Recommendations		S1	S2	S4	S6	S8	D1	D3	D4	D6	D7	K1	K3	K5	K7	K8
SOCIETY	S1		X	X	X	X	X	X				X	X			
	S2	X	X				X	X				X	X			
	S4	X	X	X	X	X						X	X			
	S5	X			X	X	X				X	X			X	
	S7	X		X	X	X		X				X	X			
DEVELOPMENT	D2					X	X	X			X			X		
	D3			X			X	X				X		X		X
	D7			X	X	X	X	X					X		X	X
	D9							X								
	D10						X	X					X			
KNOWLEDGE	K2				X	X	X						X			X
	K3								X	X		X	X			
	K4											X	X	X		
	K5											X	X	X		
	K9												X	X		

I.3 Table 5: Input-output matrix articulating impacts of "interpretation" recommendations on challenges in components S, D, and K on scale of 1 to 5

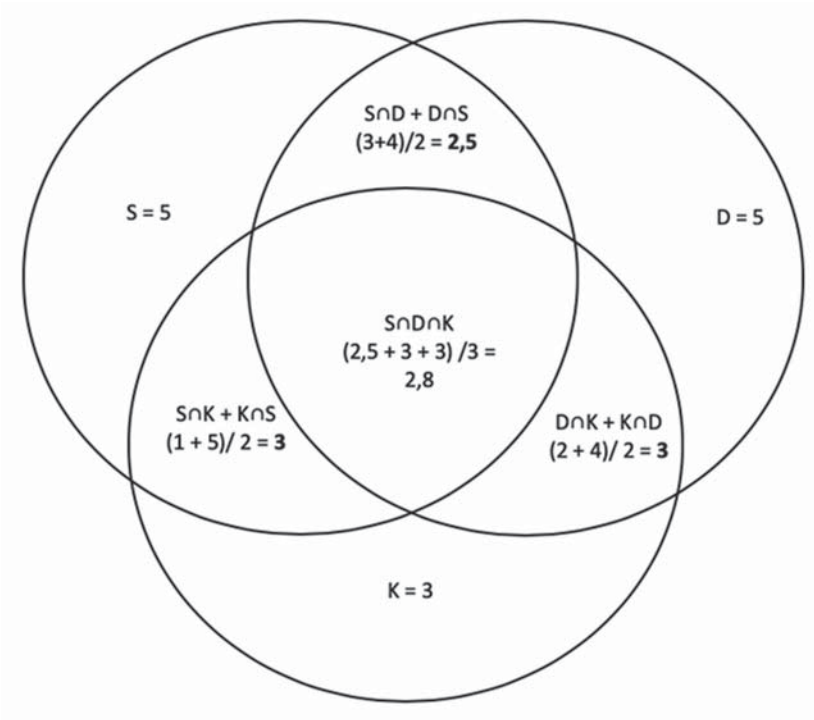
CHALLENGES / RECOMMENDATIONS	Challenges S	Challenges D	Challenges K
Recommendations S	S1–2, S4-5, S7 = 5	S 1–2, S 5, S7 = 4	S 1-2, S4-5, S7 = 5
Recommendations D	D2 –3, D7 = 3	D2 – 3, D7, D9 – 10 = 5	D2–3, D7, D10 = 4
Recommendations K	K1 =1	K1-2 = 2	K1–5, K9 = 3

I.3 Table 6: Correlation matrix showing overlaps of impacts related to "interpretation" on scale of 1 to 5

CHALLENGES / RECOMMENDATIONS	Challenges S	Challenges D	Challenges K
Recommendations S	5	D∩S (3 + 4)/2 = 2,5	K∩S (1 + 5)/2 = 3
Recommendations D	-	5	K∩D (2 + 4)/2 = 3
Recommendations K	-	-	3

calculate the result of the input-output matrix (the calculation procedure is visualised with corresponding double arrows) and then fill in the correlation matrix (Table 6).

The last step is the Venn diagram. In the case of correlating recommendation related to "interpretation" that could be used for the purpose of the **Iron Age Danube Project** strategy, we see a strong correlation of recommendations "S" impacts on challenges "S", and recommendations "D" impacts on challenges "D". The degree of integration is also quite high when considering recommendations "S" impacts on challenges "K", and vice versa, and recommendations "D" on challenges "K", and vice versa. It is encouraging that the analysis shows a very positive degree of integration inside the central, triple interface where all three strategy domains intersect (Figure 4).



I.3 Figure 4: Venn diagram illustrating the degree of integration of topic "interpretation"

Conclusion

The matrices and the diagrams have proved to be a useful tool for the presentation of holistic vertical-horizontal intervention logics employed in **Strategy 21**. This method further provides arguments for developing the **Iron Age Danube Project** strategy, because the method is useful for convincing decision makers about the cross-sectoral character of the strategy, and what is even more important, it paves the way to building alliances with other sectors for an integrated approach. If a strategy defines specific and relevant indicators, evaluation can assess cross-sectoral impacts and provide additional evidence of wider social and economic results of planned interventions.

The vertical-horizontal intervention logic also enables a more refined and realistic prognosis of cross-sectoral impacts: we can consider the magnitude of the potential impacts, i.e. the number of their occurrence which indicates the quality of their expected (ex-ante) and actual (ex-post) results. We can evaluate the efficiency (financial resources per unit of outcome), effectiveness (benefit for end users), relevance (meeting social needs, solving problems), and consistency of the intervention logic (problem definition, goal setting, planning activities and resources, setting a monitoring system and performance indicators – outputs, outcomes, impacts). When designing the **Iron Age Danube Project** strategy, it would be possible to prioritise recommendations that have the highest potential for achieving synergic impacts and thus benefit not only archaeological and landscape heritage but also other policy domains.

Strategy 21 success depends upon the application of its philosophy in strategic heritage documents in European countries, as well as in other strategic documents developed by national and international organisations and other players. Long-term benefits of good heritage governance are diverse and multi-dimensional, especially if governance addresses landscape management. Scientific evidence of positive effects from heritage and landscape management ranges from documenting the therapeutic benefits in people when they engage in heritage activities, to macroeconomic data on the profitability of heritage and landscape-related services including tourism, upkeep and management. Heritage and landscapes are not only "national" – at the same time they are European and local – even more, they are a source of our culture and a depository of our collective memory. International documents provide standards of sustainable heritage management. Strategy 21 methodology adds to these policy and technical standards another, holistic dimension – it provides an important mechanism to address not only sectoral needs but also trans-sectoral and transnational ones by strengthening dialogue and cooperation among heritage experts, authorities, local business, civil society and local population and through this, opening new avenues for creativity and innovation.

I.4 From Strategy 21 to archaeological methods

Marko Mele, Martin Fera

In general, strategies create frames for diverse actions on multiple levels – international, national, regional, local or person-based, which should enable us to follow a joint agenda to reach common goals. Strategy 21 introduced a new intervention logic for future heritage management in Europe. It opens new viewpoints on cultural heritage, enforcing a strategic thinking towards the end-user of any research output by including social (S), development (D) and knowledge (K) components into research agendas.

Its main aim seems to be to break up the ivory-tower of scientific research by putting a focus on research impacts going beyond the merely scientific output. Therefore, this chapter puts an emphasis on potential impacts of archaeological projects on common heritage policies. This is important, as the understanding of the role of the project/action in the frame of a bigger strategy might also influence the choice of applied methods.

As an example of the connection between scientific research and the S-D-K impact of Strategy 21, we can think about an archaeological landscape project based on remote sensing (mainly using aerial photography). Scientifically, the project has to produce new aerial photographic evidence of a region's archaeological landscape. In a "classical" approach, the project team would select the most efficient way of flying in order to get the best photos to investigate the proposed research question. However, evaluating the S-D-K impact, the project leader might also consider creating an economy-development impact in the research region, since the project results could secure further funding of the heritage research. The development impact in that region could for example be achieved in the field of tourism, by promoting nature with a series of spectacular photos from the air. The researcher has two similarly efficient possibilities in flying, by plane or a small helicopter. Considering the development impact, he might invite a professional photographer and a journalist to join him on the flight. Consequently, he would decide to go by plane, where he can additionally take two more persons with him.

Considerations as shown in the example above are often part of the preparation of our projects and part of many "science-to-public" initiatives. Still, we think that in many projects the considerations on S-D-K impacts are not always fully comprehended and lack a long-term perspective. Strategy 21 has systematically gathered challenges and recommendations for heritage management and could be used as a supporting evaluation tool for the development of future projects. In the following, we will try to show the practical way of evaluating projects on the example of the Iron Age Danube Project.

I.4a Consideration 1 – "Scale" of the research project

Marko Mele

Scale not only plays an important role in the understanding and perceiving of landscapes, as already mentioned in the chapter I.2, but has also been considered in Strategy 21. Different recommendations of the Strategy have different scale impacts. Some recommendations target only local or regional audiences and some have a national or European impact. For an archaeological project scale is also a significant factor, since archaeological research in general can range from exploring single objects under a microscope to trying to study the changes in different landscapes on a wider trans-regional scale, as in the case of the Iron Age Danube Project. Knowing the scale of a project in a geographic sense and its material resources makes it easier to evaluate its impact in the sense of Strategy 21 and can be useful in the selection of appropriate methods. Most archaeological projects could be divided into the following levels:

Level 1 – primarily single object research (feature, archaeological find)
Level 2 – primarily single site research
Level 3 – primarily regional research
Level 4 – primarily trans-regional research

The aim of the consideration is not to put a project in "a box", but rather to stimulate researchers to clarify what scale the fundamental results of their project have and consequently how much of an impact can they achieve. For example, an excavation of a single archaeological site, which can be classified as a level 2 project, has a big impact on the local community, local business in the vicinity and new knowledge about the location, but has mostly a relatively small impact on the heritage protection policies at state level, as it is only another excavation project. In our guidebook the main focus is placed on the research of archaeological landscapes and through this on level 3 and 4 projects.

I.4b Consideration 2 – "Goals" with respect to the components S – D – K of Strategy 21

Marko Mele

Strategy 21 has identified 24 challenges of the cultural heritage, which define three major components: social (S), economic and territorial development (D) and knowledge and education (K). Further to this, Strategy 21 also introduces 32 recommendations for tackling these challenges, which are also divided in the 3 components (S, D and K) and are interconnected with the challenges in form of a Leopold matrix of interfaces. A project leader can use the matrix to integrate the recommendations, which his project could follow in order to tackle challenges in the heritage sector. The matrix could also be used for the evaluation of the impact of an existing project on challenges in the heritage sector. At the project level, an evaluation made using the proposed methodology of the challenges and recommendations mostly ends by identifying the main focus in one of the components or even in one of the four main interfaces, which need to be considered in conceptualising heritage management:

- between S and D
- between D and K
- between K and S
- between S, D and K.

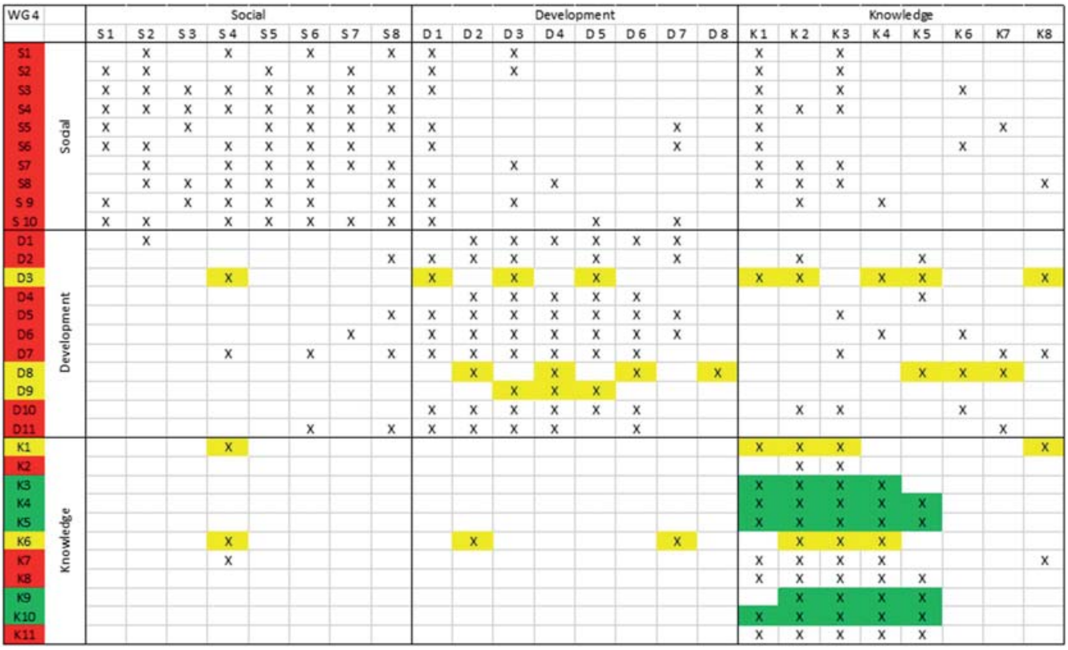
In the following we would like to present the evaluation procedure for three different working packages of our Iron Age Danube Project, with the full title "Monumentalized Early Iron Age Landscapes in the Danube river basin". This is one of the Interreg projects of the Danube transnational programme, which connects the cultural (archaeological) heritage with the tourism of the region. The project focuses on monumental archaeological landscapes of the Early Iron Age, characterized by, e.g. fortified hilltop settlements and large tumulus cemeteries, roughly from the era between the 9th and 4th century BC (also known as Hallstatt period). It builds joint approaches for the research and management of complex (pre)historic landscapes and their integration into sustainable tourism. The project's major innovation is the methodological shift of dealing with complex prehistoric landscapes rather than individual sites. Therefore, the partnership develops new strategies and methodological tools for their research, protection, presentation and promotion. Since the project as a whole is too complex for a presentation of its evaluation in one book chapter, our analyses are focused on three work packages, holistic enough to be isolated and considered as functional single projects:

- Work package 4: (Pre)historic landscapes
- Work package 5: Landscapes field research
- Work package 6: Landscapes revitalisation

Work package 4:

In work package 4 the partners had to develop a joint methodological tool with multilingual terminology, to be able to compare and connect different micro-regions to joint research agendas and create a common presentation of the ancient landscape. The tool and a joint approach should be used in nine micro-regions (Großklein (AT), Strettweg (AT), Poštela (SI), Dolenjske Toplice (SI), Jalžabet (CRO), Kaptol (CRO), Százhalombatta (HU), Süttő (HU-SK) and Sopron (HU-AT)) to create nine landscape studies, which will be combined into one common publication. The goal of the WP 4 is not only to research the micro-regions but also to digitally visualise some of the most important Early Iron Age landscapes in Europe by using modern technologies like ALS (airborne laser scanning) and geophysics.

The major outputs of work package 4 are: "Tool for landscape research" and "Landscape studies with digital visualisations" (Figure 1).



WG4		Social								Development								Knowledge							
		S1	S2	S3	S4	S5	S6	S7	S8	D1	D2	D3	D4	D5	D6	D7	D8	K1	K2	K3	K4	K5	K6	K7	K8
S1			X		X		X		X	X		X						X		X					
S2		X	X			X		X		X		X						X		X					
S3		X	X	X	X	X	X	X	X	X								X		X			X		
S4		X	X	X	X	X	X	X	X									X	X	X					
S5	Social	X		X		X	X	X	X	X						X		X						X	
S6		X	X		X	X	X	X		X						X		X					X		
S7			X		X	X	X	X	X			X						X	X	X					
S8			X	X	X	X	X		X	X			X					X	X	X					X
S 9		X		X	X	X	X		X	X		X							X		X				
S 10		X	X		X	X	X	X	X	X				X		X									
D1			X								X	X	X	X	X	X									
D2									X	X	X	X		X		X			X			X			
D3					X					X		X		X				X	X		X	X			X
D4											X	X	X	X	X							X			
D5									X	X	X	X	X	X	X	X				X					
D6	Development							X		X	X	X	X	X	X	X					X		X		
D7					X		X		X	X	X	X	X	X	X					X				X	X
D8											X		X		X		X					X	X	X	
D9												X	X	X											
D10										X	X	X	X	X	X				X	X			X		
D11							X		X	X	X	X	X		X									X	
K1					X													X	X	X					X
K2																			X	X					
K3																		X	X	X	X				
K4																		X	X	X	X	X			
K5																		X	X	X	X	X			
K6	Knowledge				X						X					X			X	X	X				
K7					X													X	X	X	X				X
K8																		X	X	X	X	X			
K9																			X	X	X	X			
K10																		X	X	X	X	X			
K11																		X	X	X	X	X			

I.4b Figure 1: Evaluation of the work package 4 according to the matrix presented in the Strategy 21

The evaluation of the work package according to the matrix presented in Strategy 21 shows that the it fully integrates recommendations K3, K4, K5, K9 and K10 (see Figure 1: green) and also partly recommendations D3, D8, D9, K1 and K6 (see Figure 1: yellow). The recommendations referred to have an impact on challenges in the social, development and knowledge field. The evaluation shows that the activities of work package 4 have the biggest impact in the knowledge sector challenges, where fully or partly positive correlations take 42% of the 91 possible correlations. Much smaller are the impacts on the challenges in the development sector, where the fully or partly positive impacts of our activities present 16% of all possible correlations. The impact on the social sector is insignificant but present with 4% of partly positive correlations (Figure 2).

I.4b Figure 2: Evaluation of activities of the work package 4 in percentages

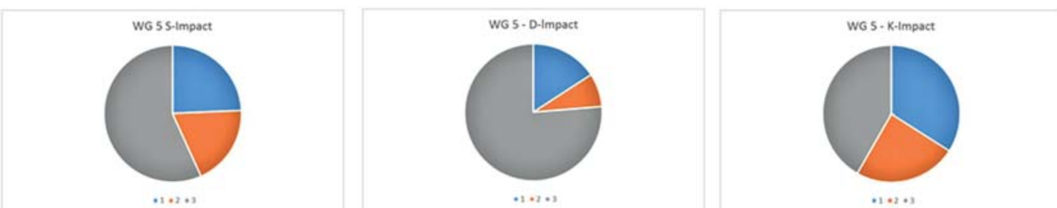
Work package 5:

The main output of work package 5 is the organization of four joint international camps with a duration of from 4 to 6 weeks. During the duration of these camps the project partners conducted field research in 9 micro-regions in order to develop and test new methods and research strategies under realistic circumstances. Apart from research work, the camps will include partner meetings, public events and discussions with different stakeholders. The first camp was organized in Austria at sites Großklein and Strettweg in May and June 2017, the second was in Croatia at Jalžabet and Kaptol in August and September 2017, a third was in Slovenia at Poštela and Dolenjske Toplice in May and June 2018 and the fourth was in Hungary at Százhalombatta, Süttő and Sopron from August to October 2018 (Figure 3).

WG 5		Social								Development								Knowledge							
		S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 8	D 1	D 2	D 3	D 4	D 5	D 6	D 7	D 8	K 1	K 2	K 3	K 4	K 5	K 6	K7	K8
S1	Social		X		X		X		X	X		X						X		X					
S2		X	X			X		X		X		X						X		X					
S3		X	X	X	X	X	X	X	X	X								X		X			X		
S4		X	X	X	X	X	X	X	X									X	X	X					
S5		X		X		X	X	X	X	X						X		X						X	
S6		X	X		X	X	X	X		X						X		X					X		
S7			X		X	X	X	X	X			X						X	X	X					
S8			X	X	X	X	X		X	X			X					X	X	X					X
S 9		X		X	X	X	X		X	X		X							X		X				
S 10		X	X		X	X	X	X	X	X				X		X									
D1	Development		X								X	X	X	X	X	X									
D2									X	X	X	X		X		X			X			X			
D3					X					X		X		X				X	X		X	X			X
D4											X	X	X	X	X							X			
D5									X	X	X	X	X	X	X	X				X					
D6								X		X	X	X	X	X	X	X					X		X		
D7					X		X		X	X	X	X	X	X	X					X				X	X
D8											X		X		X		X					X	X	X	
D 9												X	X	X											
D 10										X	X	X	X	X	X				X	X			X		
D 11							X		X	X	X	X	X		X									X	
K1	Knowledge				X													X	X	X					X
K2																			X	X					
K3																		X	X	X	X				
K4																		X	X	X	X	X			
K5																		X	X	X	X	X			
K6					X						X					X			X	X	X				
K7					X													X	X	X	X				X
K8																		X	X	X	X	X			
K9																			X	X	X	X			
K10																		X	X	X	X	X			
K11																		X	X	X	X	X			

I.4b Figure 3: Evaluation of the work package 5 according to the matrix presented in the Strategy 21

Since the international archaeological camps were planned as a combination of research activities and actions for raising awareness of the heritage plus public promotion events, the evaluation also shows a variety of impacts. In each of the S-D-K fields there are at least two recommendations which are followed in full and further ones which are partly followed. So in this case the impact is widely dispersed, with a slightly higher impact on the knowledge and social challenges. In the social field the fully or partly positive correlations account for 43% of all the correlations, in the development field 24% and in the knowledge field 58% (Figure 4).



I.4b Figure 4: Evaluation of activities of the work package 5 in percentages

Work package 6:

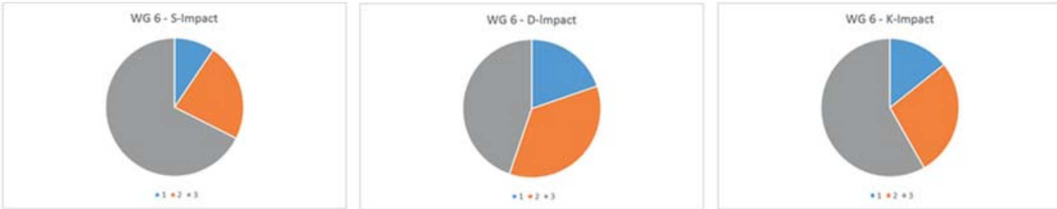
The aim of work package 6 is to initiate the revitalisation and presentation of prehistoric landscapes by starting regional initiatives in all participating countries. For this purpose new approaches for the presentation of landscapes in the micro-regions were developed. The proposed solutions will include a major consideration focus on the possibilities of imbedding the products into an existing tourist infrastructure. Some of the new revitalisation solutions proposed in the plans were already implemented during the project as pilot actions in the form of small scale investments. In addition to the on-site presentations, a high-tech app for visitors was developed. The app functions as a digital guide, connecting the researched micro-regions with single sites and monumentalized landscapes on the one hand and a transnational thematic route on the other. This high-tech software enables a new digital experience of the Iron Age archaeological heritage in the Danube region with e-learning tools, interactive 3D objects, visualisations and augmented reality.

The evaluation of work package 6 shows that our activities mostly concern the challenges in the development field, followed by the knowledge and social fields (Figure 5). The development field accounts for 55% of the fully or partly positive correlations. In the knowledge field the impact presents 42% of positive correlations and in the social field the positive correlations reach 32% (Figure 6).

Since the evaluation of the correspondence between project activities and recommendations of Strategy 21 depends largely on the personal experience of the evaluator, the goal of the evaluation is not an exact statistical analysis of the project. This kind of evaluation can have two major impacts: 1. People preparing different projects in the heritage sector are encouraged to consider ways of tackling the major challenges represented by the sector.

WG 6		Social								Development								Knowledge							
		S1	S2	S3	S4	S5	S6	S7	S8	D1	D2	D3	D4	D5	D6	D7	D8	K1	K2	K3	K4	K5	K6	K7	K8
S1	Social		X		X		X		X	X		X						X		X					
S2		X	X			X		X		X		X						X		X					
S3		X	X	X	X	X	X	X	X	X								X		X			X		
S4		X	X	X	X	X	X	X	X									X	X	X					
S5		X		X		X	X	X	X	X						X		X						X	
S6		X	X		X	X	X	X		X						X		X					X		
S7			X		X	X	X	X	X			X						X	X	X					
S8			X	X	X	X	X		X	X			X					X	X	X					X
S 9		X		X	X	X	X		X	X		X							X		X				
S 10		X	X		X	X	X	X	X	X				X		X									
D1	Development		X								X	X	X	X	X	X									
D2									X	X	X	X		X		X			X			X			
D3					X					X		X		X				X	X		X	X			X
D4											X	X	X	X	X							X			
D5									X	X	X	X	X	X	X	X				X					
D6								X		X	X	X	X	X	X	X					X		X		
D7					X		X		X	X	X	X	X	X	X					X				X	X
D8											X		X		X		X					X	X	X	
D 9												X	X	X											
D 10										X	X	X	X	X	X				X	X			X		
D 11							X		X	X	X	X	X		X									X	
K1	Knowledge				X													X	X	X					X
K2																			X	X					
K3																		X	X	X	X				
K4																		X	X	X	X	X			
K5																		X	X	X	X	X			
K6					X						X					X			X	X	X				
K7					X													X	X	X	X				X
K8																		X	X	X	X	X			
K9																			X	X	X	X			
K10																		X	X	X	X	X			
K11																		X	X	X	X	X			

I.4b Figure 5: Evaluation of the work package 6 according to the matrix presented in the Strategy 21



I.4b Figure 6: Evaluation of activities of the work package 6 in percentages

2. It supports the selection procedures for EU-funding of heritage projects in different EU-programmes. Consequently, the scarce resources of the often underfinanced culture and heritage sector can be better channelled and utilised in tackling common European challenges.

I.4c Consideration 3 – "Methods" for the landscape research

Martin Fera

Once the evaluation according to recommendations of Strategy 21 is completed and shows, for example, that a project´s main focus is knowledge, then the project leader can use a matrix introduced in this chapter for obtaining recommendations for the most efficient archaeological methods when conducting landscape research and thereby the basic aim of the presented tool is fulfilled.

Decision matrix

Over the past 150 years theoretical and practical developments in the field of scientific archaeological approaches to past and present landscapes have led to the development of a variety of methods and tools. Spatial technologies form an important part of the methodological inventory of the discipline since its formalization at the beginning of the 19th century. Aerial photographs from cameras mounted on kites or in balloons or aircraft showed their potential for the recognition, recording and visualisation of archaeological traces in the landscape at a very early stage. The technical developments of the past few decades have brought further technologies into the method pool of archaeological prospection. In the area of remote sensing, these have largely been in the fields of space-based imaging and airborne laser scanning, by means of which forested areas are now also revealing their wealth of material on traces of human activities. Within the domain of ground-based sensorial equipment, the range of geophysical methods has been extended and newly developed motorised systems can now be used to examine entire portions of the landscape quickly and in high resolution. These methods thus enable us to investigate large areas systematically and in combination with more traditional methods such as surface surveys and excavations.

It is not possible, however, to apply all of these methods with equal success to all landscapes. Many factors, such as the research question, accessibility, natural background, land cover and other parameters, influence the suitability of different methods significantly. In the following chapters the different methods are described and their applicability in different areas is discussed in detail. These chapters are thus intended to serve as a tool for parties interested in landscape archaeological investigations.

The following table represents an interactive tool and shows some of the aspects that can help in choosing the most appropriate methods. The tool is formed as a decision matrix with yes/no answers to the questions concerning the planned research project. The presented methods are weighted according to their suitability for the project in question. The end result is a recommended mix of methods serving as a decision-making aid for the early stage researchers. Since basic methods such as desktop assessment and the use of available historic maps, aerial photographs and previous research documentation should always be a first step of a research design, these will always be high weighting level. The tool is also helpful for the exclusion of non/least appropriate methods, e.g. if physical impact on the ground is not intended or allowed, the excavation will be eliminated straight away.

The tool should also fulfil the task of highlighting the importance of a multi method approach, counteracting some of the unavoidable bias when dealing with single methods only. The integration of complementary data sources in a common geoinformatic framework enables researchers to collect data, extract information and finally gain knowledge about human activities in the targeted areas.

In order to reach its full potential, however, the tool must be seen only as a first step in the layout phase of the project and as a general hint pointing in the optimal direction. Further detailed assessment of the circumstances with the help of experts in the fields will always be necessary and will help to make the best use of every single method in any planned project (Figure 7).

	Considerations	Auxiliary Questions	Methods Yes	No	General Methods: Heritage Assesment: Written sources	General Methods: Heritage Assesment: Aerial Photographs	General Methods: Field Survey: Surface Survey	Specific Methods: Soil Surveys: Soil Sampling	Specific Methods: Geophysics: Geomagnetic	Specific Methods: Geophysics: Georadar	Specific Methods: Geophysics: ERT	Specific Methods: Geophysics: Motorized	Specific Methods: Remote Sensing: Aerial Arch. Phot.	Specific Methods: Remote Sensing: ALS	Specific Methods: Paleoenv.: PE Research	Specific Methods: Excavation: Area Excavation
Level of Research	Prospection /	Is your focus on the investigation of a whole region?			3	3	2	2	1	1	1	2	3	3	3	1
	Delineation /	Is your focus on the investigation of a single site?			3	3	3	3	3	3	3	3	3	3	3	2
	Characterisation	Is the focus on the investigation of a single distinct feature?			1	3	2	2	3	3	3	3	3	2	3	3
Environment. Impact	Non intrusive	Has the research to be non intrusive?			3	3	2	1	3	3	3	3	3	3	2	0
	Destructive	Can the research be intrusive?			3	3	3	3	3	3	3	3	3	3	3	3
	Sampling	Can you take samples in the region?			3	3	2	0	3	3	3	3	3	3	0	1
Cultural History	Chronology	Do you want chronological information on sites/features?			2	2	2	1	1	2	1	1	1	2	1	3
	Cultural contacts	Do you want to investigate material cultural aspects?			2	1	2	1	1	1	1	1	1	1	1	3
Baseline Assesment 1	Cost	Is the investigation part of a funded research project?			3	3	3	3	3	3	3	3	3	3	3	3
		Can additional funding be provided?			3	3	2	2	2	2	2	1	1	1	1	1
		Can the support of an established institution be sought?			3	3	3	3	2	2	2	2	2	3	2	2
	Time	Does it have to be a very short investigation?			3	3	3	3	2	2	2	2	2	2	2	2
		Can the investigation be done for one season?			3	3	3	3	3	3	3	3	2	3	3	3
		Can the investigation be done in many seasons?			3	3	3	3	3	3	3	3	3	3	3	3
		Can it be done in the vegetation period?			3	3	2	2	2	2	2	2	3	2	2	1
		Can it be done in the vegetation free period?			3	3	3	3	3	3	3	3	2	3	3	3
	Accessibility	Is the area acessible for vehicles?			3	3	3	3	2	2	2	0	3	3	3	2
		Is the area free of obtrusions for vehicles?			3	3	3	3	2	2	2	1	3	3	3	3
		Can the area be accessed by foot?			3	3	3	1	2	2	2	2	3	3	1	2
		Can equipment be brought to the area?			3	3	3	2	1	1	2	1	3	3	2	1
	Competence	Are specialists for various methods included?			3	2	3	1	1	1	1	1	1	2	1	1
		Can specialists for various methods be consulted?			3	3	3	2	2	2	2	2	2	2	2	2
		Can the data aquisition be done by specialist contractors?			3	3	3	3	3	3	3	3	3	3	3	2
Baseline Assesment 2	Geology and Pedology	Are in the area metamorphosed rocks or igneous geology?			3	3	3	2	2	3	3	2	3	3	3	3
		Are in the area mainly sands and gravels?			3	3	3	3	3	3	2	2	3	3	3	3
		Is the area on alluvial soils?			3	2	3	3	2	3	3	2	2	3	3	3
	Geomorphology	Is it a mainly flat area?			3	3	3	3	3	3	3	3	3	3	3	3
		Is it a mainly hilly area?			3	3	3	3	2	2	3	1	3	3	3	3
		Is it an area with accented relief?			3	3	3	3	2	2	2	1	2	3	3	3
	Land cover	Are there mainly seasonal crops in the area?			3	3	3	3	3	3	3	3	3	3	3	3
		Is the area mainly forested?			3	2	2	3	2	1	2	0	1	3	3	2
		Are there mainly permanent crops?			3	2	2	3	2	1	1	1	1	3	3	1
		Is the area in urban environment?			3	2	0	1	1	2	1	1	1	1	1	3
	Hydrology	Is the area in inland wetlands?			3	2	2	3	1	1	1	1	2	3	3	2
		Is the area in coastal wetlands?			3	2	2	3	1	1	1	1	2	3	3	2

I.4c Figure 7: Decision matrix

Part II

II.1 Introduction

Martin Fera

Archaeological research in the 21st century continues to focus on the material legacy of humans as a source for understanding historical social, economic and political developments. Their depiction in the landscape makes these traces important objects of investigation.

Contrary to the common belief of non-archaeologists, traditional approaches such as archaeological excavation represent a relatively small part of archaeological research. A significantly higher portion is formed by methods that enable investigation of an area on a larger, landscape appropriate scale. Non-destructive, large scale investigations thus became a common tool in archaeological research, and also a foundation and a guide when considering the inclusion of the destructive methods.

The multi-layered nature of the data acquired employing different sensors and methods also makes it possible to obtain a better grip on the disadvantages and limitations of individual methods, which lead to bias in the data, and furthermore to arrive at a far more sustainable interpretation of the object of investigation by integrating independent measured values.

The focus on the research of entire landscapes is also represented in the selection of methods in the following chapter. As in any well-planned project, the collection of basic data in the first phase of the investigation of archaeological landscapes plays an important role in the selection and effective use of more targeted investigative methods. Both internal factors (such as the research question and the objectives) and external factors (such as natural conditions and historical and contemporary cultural use) play a major role in the applicability of these different methods. A basic aid to decision-making was presented in the previous chapter with the decision matrix, which is intended to provide an overview of focal points and exclusion criteria for the use of individual methods.

In the second part, the individual methods are summarized according to application-specific criteria and explained in detail. The basics for all methods are summarized briefly and concisely here, extending from the basic study of archived sources, remote sensing methods that can be used over a wide area, geophysical methods that can be applied more specifically and down to targeted excavations. Extracting the richness of experiences pooled from the international multidisciplinary team of authors, typical work processes for the use of each method are presented and questions and considerations about their advantages and limitations are discussed. Furthermore, their application is demonstrated through the research on Iron Age landscapes and sites from various regions of the project area.

When focusing on the investigation of landscapes, methods for prospecting, identification and delimitation of traces of human activity are in the foreground. Targeted interventions in the soil, such as excavations, are seen here especially in this context. They are a valuable aid for the characterisation of prospection results and provide additional insights into the temporal and cultural classification, but must always be regarded as being integrated into a more comprehensive research package.

II.2 Baseline-Assessment
Zoltán Czajlik

II.2a Costs, time, accessibility

Introduction
Designing, organizing and implementing landscape archaeology research is a process that – similar to agricultural work – is highly influenced, even determined by the changing of seasons and the weather. For generations of archaeologists the right time for field work in the continental Europe was clearly the summer, or perhaps late spring and early autumn. With the spread of large-scale rescue excavations, it has become increasingly common for field work also to be done as much as possible during bad weather, but this is always and everywhere a contingency solution.

On the other hand, experiences for the increasing the number of ground surveys, which are the most common tools of landscape archaeology, show that better results can be achieved outside the vegetation period. It thus became not only a preference to work in early spring / late autumn, but rather the field implementation of these tools at that time became a necessity. We must often thus follow the limitations and strengths of the given method, which are mostly dependent on the season and the weather conditions. In the today's landscape archaeology we have in hand a method that is effective almost for any period (except for wet days in winter).

One of the major tasks of archaeological work has become the organization of the use of each method at the right time. It is also essential to maintain close contact with the authorities and in many cases the owners / users of the fields to be investigated, which, besides the correct application of the methods, determines the effectiveness, success and cost of the research. Of course, the quantity and flexibility of the available resources are decisive, but one can say with confidence that persistent good results cannot be achieved without adequate training and motivated specialists.

Basics
At the beginning of almost any archaeological research stands the acquaintance with the selected research area, what mostly begins with the analysis of published scientific literature, available databases and geospatial data. On today's level of digitization it is possible for the greater part of Europe, for a well-trained researcher to be capable of producing GIS-layers with this data in a period of a few months, which helps this researcher to determine the further research strategy. Project plans can be built on this, as well as specific field research steps. The latter steps – both from a theoretical and an organizational perspective – are worth dividing into two large groups: remote sensing methods and instrumental / find collecting works involving engagement in the field. While the organization of the former requires administrative cooperation only with the authorities alone, the latter should be adjusted to the broader interests of the users of the area.

The constraints of adaptation and flexibility are not only applicable for field work organization; continuous background work with swift primary processing of new data can greatly increase efficiency. An experienced team of researchers, with a good technical background, can often gather and evaluate more information in a season, than could be expected from multiannual excavations. However, this does not mean that individual researchers or smaller teams cannot work efficiently and to a very high standard. There is no need for large numbers of people to collect data, or even for aerial archaeological photography, the identification of sites, or the occasional geodetic survey. Only in the case of larger work stages, systematic ground surveys and archaeological geophysical research (except for multi-channel mechanized systems) need broader support be brought in, at least with the help of enthusiastic volunteers. It is, however, an absolutely iron rule that the more methods that are to be practiced, the more specialists (geodesist, geophysicist, ALS specialist, etc.) will that be needed.

Workflow

The depth of laboratory preparation depends to a very great extent on the prior knowledge of the micro-region to be researched. The less archaeological knowledge that is available, the greater the need will be to gather other field data as soon as possible in order to develop a good research strategy. It is worthwhile extending the work to the following types of data: old and new topographic maps, covered and uncovered geological data, archive aerial photographs, GE/satellite-imagery, ALS-models, archaeological site data / collections, bibliographic data collection. It is useful to build at least GIS information layers and simpler databases from this information.

In parallel with the data collection, the administrative preparation of active remote sensing research should be started. Contacting authorities is usually not difficult, but sometimes the time factor of the multi-step authorisation (1 week - 2 months) requires serious foresight.

Active, independent remote sensing research that can follow the data collection is not cheap and requires the participation of experts, but a targeted survey with the right time / resolution / intensity often results in information that is unlikely to be acquired in other ways. The elaboration of the ALS-models is strongly influenced by their resolution and the fact that data collection was carried out during or outside the vegetation period – accordingly, for landscape archaeological purposes, a new and more subtle, survey is often needed. It is also worthwhile to launch aerial archaeological research at an early stage, since good, uniform and, in many cases, results that would otherwise be unavailable can only be expected from aerial archaeological flights carried out over a long time interval, during different seasons and vegetation conditions.

Field work is usually a thorough research of important zones that can be identified based on laboratory data collection and the subsequent remote sensing research. A complete geophysical research or systematic ground survey of an entire micro-region can only be done in very exceptional cases at high cost / time commitment. After defining the areas selected for detailed research, negotiations should start immediately with the owners / users. Due to crop rotation, an area can often be surveyed only in a narrow time window, or the field work can only be done piece by piece, so this work phase determines the success of the entire research project. During multiannual research on larger agricultural areas, the adaptation of all field (and aerial archaeological photography) activity to the crop rotation is a worthwhile endeavour.

From the array of geophysical methods, magnetic measurements can be performed throughout the year, provided access to the area and movement of the instruments can be assured in dependence on the state of the vegetation. The water and humic acid content of the soil are important constraints on the application of ground penetrating radar (GPR), which means that field work can mostly be done only in dry seasons (e.g. after harvest), possibly in winter, with frozen soil conditions. Ground surveys aiming the simple identification of sites can be performed anytime except during snowy, very wet weather, but systematic ground surveys can usually be carried out only outside the vegetation period (late autumn, but preferably in early spring).

Key facts

- The recommended minimum scale for the use of modern topographic maps is M = 1:25.000.
- ALS-surveys have a minimum dot density of 8 points/m^2, but – especially in forested areas – 40 dots/m^2 density may be necessary. Ideally, these should be carried out late in the winter / early spring. The price depends largely on the dot density to be obtained and the size of the area.
- Aerial archaeological photography can be carried out in various seasons depending on the vegetation coverage, and the most favourable period for European continental areas under agricultural cultivation is the early / late summer. On an annual basis, research on a micro-region requires at least 2-3 flights. Site exploration can be either costly or very cost-effective depending on the characteristics of the area (morphology, vegetation coverage, etc.).
- The average performance of the magnetic geophysical research to be performed outside the vegetation period is 1 to 3 hectares per day, but it can be reduced to 0.25 hectares in woody and difficult areas, and can be over 10 hectares with multi-channel or motorized devices. In any case, it requires serious investment.
- The effectiveness of ground surveys involving simple site identification depends heavily on the terrain and vegetation coverage, with proper organization and vehicle assistance, 1 to 10 sites per day can be identified even by one well-trained researcher. A systematic surface survey is much less effective and a group of 4-5 people can deal with approx. 5-6 hectares per day.
- The data should be collected to the greatest extent possible in databases supported in GIS systems. Combining information layers is not only synergistic, but in many cases decisive in determining further research strategy. It should also be emphasized that this is usually the information interface through which the results of the landscape archaeological research can be most easily evaluated, compared with other research, or utilized for other purposes (e.g. predictive modelling, heritage protection and management, preparation of investments, etc.).

II.2b The environmental context

Introduction

The natural elements of the landscape (geology, geomorphology, land coverage, pedology, hydrology), are decisive for the strategy development and possibilities of the landscape archaeological research, whether or not their current state is the same or very different from what it was in the past. It is crucial to know the non-changing or archaic elements and to recognize the degree of transformation of each element.

Some of today's landscape elements affect the research possibilities in a very different way, they can either make it difficult or even help to recognize the former image of the landscape and the archaeological phenomena in it.

While the recognition of modern human interventions seems to be obvious, dating the traces of earlier human activity is far from being so clear. It is not enough to have an exhaustive knowledge of a time period; the deeper the research moves back in time, the more it is necessary to have at least a sketchy knowledge of "intermediate states". There are human interventions in the landscape that have been well-known for millennia, thus posterior land use has adapted to them. These monumental structures that can still define the image of a landscape (e.g. Iron Age tumulus fields, fortifications) may have significance beyond landscape archaeology.

Basics

The most permanent element of the landscape is the geological background. The basic geological structures/rocks are necessarily older than the dates of surface changes, vegetation cover and human interventions. Their effect on the emerging morphology, soils and hydrological elements is significant, and they also have an impact on the possibilities of human interventions. The terraced surfaces of the Iron Age settlements or the huge tumulus-necropolises were probably easier to build on softer rocks, and the simple flat graves were often dug into sandy/pebbly subsoil areas.

Although it might seem that the geomorphologic background is constant through historical and archaeological periods, this can actually be unjustified. In the mountains, landslides and rock falls can cause serious changes in the landscape, and the role of erosion in almost every milieu is also very significant. Similar processes are also taking place in less intensive and spectacular ways on hilly landscapes and in alluvial areas, where filling up (alluviation) in particular has enormous relevance.

Changes in the hydrological system are directly related to the morphological processes and the rainfall conditions. Even in the short term, streams can disappear (e.g. in a karst landscape), there may be a significant changes in the course of waterways, so understanding and dating the changes in the hydrological system is one of the most exciting areas of the landscape archaeological research.

As far as the vegetation cover is concerned, the natural vegetation conditions of the Carpathian Basin have an ever-increasing but still reversible human intervention up until the Early Iron Age. Irreversible, definitive changes can only be detected from the Celtic Age, especially in the hilly areas.

Before airborne laser scanning (ALS) technology, the archaeological exploration of forested areas was much more difficult and recognizing the correlations involved required much work. Thanks to the application of this method, a great number of archaeological phenomena did become identifiable. Since exposure to continuous human activity (e.g. arable cultivation) is generally less in these areas, the ramparts, terraces or tumuli encountered are generally in a much better state, the terrain is "more contrasting", which helps the interpretation. A good example of this is provided by the 3 sites from Hungary in the project. While the tumuli of Százhalombatta and Süttő is becoming more and more flat and eroded due to agricultural cultivation, the ALS-survey from 2007 of the tumuli in the woods of Sopron-Várhely shows it is in the same conditions as seen on the 1982 map.

Aerial photography is most successful in alluvial or hilly areas where grain monocultures are currently practised. With properly selected flights, systematic archaeological reconnaissance can provide much information on archaeological phenomena. Unfortunately, the most recognizable features are usually the ones that are already in a state of decay due to arable land cultivation. If the burial chamber of an Iron Age tumulus becomes recognizable in a photograph, this usually means that the mantle of the mound is in a barely recognizable, eroding state.

Today's increasingly widespread, multi-channel, high-capacity geophysical methods can also be used primarily in flat and hilly areas under agricultural cultivation. On terrains with more accentuated relief and/or wooded areas, they cannot be moved, therefore traditional handheld devices are the solution. Of course, the capacity of the latter is at least one order of magnitude below the multi-channel devices.

The possibilities and limitations of an archaeological surface survey are similar to geophysical methods, since they also depend on the terrain and vegetation cover. It should be emphasized in both methods that while in remote sensing, the terrain and vegetation coverage do not affect the usability of the GPS-devices and thus the collection of precise coordinates and the organization of the work, field surveys may well encounter problems with them. In wet, hilly areas and especially in mountains, it is often difficult to move the research team and equipment, and in forested areas, much work may be required to capture any geospatial data accurately due to the lack of or to an inappropriate satellite connection.

Workflow

Based on the above, it is obvious that the significance of the basic methods and their mutual support depends on the terrain and surface coverage. Mountainous and forested areas can no longer be easily researched without terrain models based on airborne laser scanning. In these areas, when scanning at the right resolution, the importance of aerial photography is greatly diminished. Detailed field research areas should be selected based on the terrain model.

However, in areas under agricultural cultivation, ALS has less significance, it can be replaced with photogrammetry-based terrain modelling using drones, modern aircraft or archive aerial photographic material (orthophotos). In view of the variation in the terrain due to cultivation, the possible lower resolution of the latter model does not necessarily represent a disadvantage. In areas under grain crop cultivation, aerial photography has priority and magnetic geophysical research and ground surveys should be based upon it.

The terrain and land cover conditions are also decisive in terms of work organization. Depending on the vegetation coverage, the organization and/or application of specific research processes can be combined. In the snow period, for example, connecting laser scanning with orthophotography in mountainous areas is recommended, as was the case with Sopron-Várhely.

In areas where the movement of the research team and equipment requires serious logistics background (watercourse areas, hills and mountains that difficult to reach), it is worthwhile to organize some works in parallel (e.g. microrelief survey, magnetometric geophysical research, and ground surveys). During the joint work, the participants can choose between various activities, which is a solution to the problem of monotony in field research.

Recording accurate geospatial data in the field is a top priority. For structures appearing on terrain models, in aerial photographs or from measurements, it is very important to accurately determine the location of surface archaeological finds for their dating and correct interpretation. In open areas, this can be done quickly and efficiently with GPS devices. In woody/bushy areas, however, it may be necessary to use theodolites with a laser distance meter or to combine them with GPS even outside the vegetation period. Theodolite surveys are a much slower working procedure and they require more participants.

Key facts

- The weight, role, and significance of each method is different depending on the terrain and land cover conditions. Systematic field research can be built on archaeological phenomena that can be determined using an ALS-model in mountainous/forested areas.
- Aerial archaeological photography and large-area magnetic geophysical research are effective in flat or non-sloping areas under agricultural cultivation. The two methods can be used in a comparative manner, but when time is lacking for this the latter method is preferred. An archaeological surface survey can also be performed based on the aerial photograph map and the magnetic map.
- Research in areas that are difficult to access for any reason (e.g. highland zones, forests, hilly areas without modern roads, wetlands) are a time consuming and labour-intensive task, requiring experienced participants and much organization work.

II.2b Table 1: The applicability of major non-destructive methods of landscape archaeological research depending on the current surface coverage. While arable lands can be researched in many ways, many methods are useless in bushy areas, scrublands. Among the methods, the ALS-based DEM is the least sensitive to the type of surface cover, while geophysical surveys are not available in arable lands during the vegetation period and in bushy areas, scrublands.

land use / method	arable land, outside vegetation period	pasture	orchard, vineyard, etc.	arable land, within vegetation period	forest	bush, scrub
DEM, using ALS	good	excellent	excellent	problematic	excellent	possible
aerial archaeology	possible	possible	problematic	excellent	problematic	difficult
surface survey	excellent	problematic	good	problematic	difficult	impossible
geophysical survey	excellent	excellent	possible	impossible	possible	impossible
DSM, using aerial photos	good	good	problematic	impossible	impossible	impossible
notation	excellent	good	possible	prob-lematic	diffi-cult	impos-sible

The role of land cover in landscape archaeological research

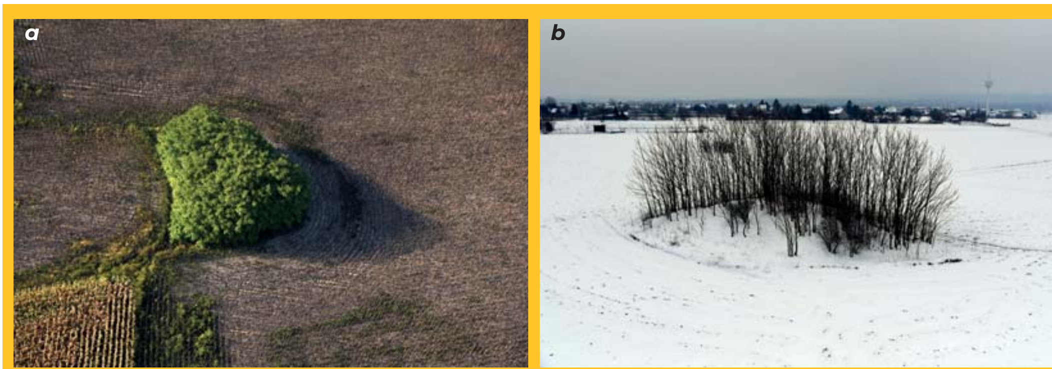
II.2b Figure 1: Research potential of arable lands

II.2b Figure 1.a: Snow covered fields at Győrújbarát. The extant mound appears as a dark hill, with the traces of the geophysical survey in the snow to the east (Zoltán Czajlik, Győrújbarát, March 1, 2018). ALS can be performed, surface finds cannot be collected under these conditions.

II.2b Figure 1.b: Arable land with little snow at Százhalombatta. Dark rings indicate the location of the mounds. (Zoltán Czajlik, Százhalombatta, January 25, 2018). ALS is possible. If there is no frost, surface find collection can be conducted.

II.2b Figure 1.c: Arable land in early spring at Százhalombatta. Dark rings indicate the location of the mounds. (Zoltán Czajlik, Százhalombatta, March 11, 2014). ALS is possible. Geophysical survey and surface find collecting cannot be conducted due to the protection of sowing.

II.2b Figure 1.d: Arable land with autumn sown grain. Rings indicate the location of the former mounds(?). (Zoltán Czajlik, Veszkény, June 22, 2003). During this vegetation period, only aerial photography can be conducted.



II.2b Figure 2: Research potential of bushy areas

II.2b Figure 2.a: Unidentified mound in the bush at Százhalombatta (Zoltán Czajlik, September 10, 2018). Under the given vegetational conditions, the area cannot be studied effectively

II.2b Figure 2.b: Burial mound in the same bush with snow, photographed from extremely low altitude (Zoltán Czajlik, March 1, 2018). Successful ALS can be conducted

II.2b Figure 3: Research potential of forested areas

II.2b Figure 3.a: Well identifiable fortification during leafless period, in the snow at Sopron–Sánchegy (Zoltán Czajlik, March 1, 2018). Surface find collection cannot, but a successful ALS, and, with some limitations, geophysical survey can be conducted

II.2b Figure 3.b: Well identifiable rampart during the leafless period, in the snow at Sopron-Várhely. The fortification cannot be identified among the evergreen pines on the aerial photograph (Zoltán Czajlik, March 1, 2018). Surface find collection cannot, but a successful ALS, and, with some limitations, geophysical survey can be conducted

II.2b Figure 4: Research potential of orchards and vines (aerial archaeology)

II.2b Figure 4.a: Mound traces in the orchards during the leafless period, after rainfall, at Százhalombatta (Zoltán Czajlik, March 11, 2014). Surface find collection, ALS and, with some limitations, geophysical survey can be conducted

II.2b Figure 4.b: In the early autumn, only the largest mounds can be detected in the orchards (Zoltán Czajlik, September 10, 2018). Surface collection, ALS and, with strong limitations, geophysical survey can be conducted

II.3 Practical considerations and legal framework

Martina Jurišić, Susanne Tiefengraber, Katalin Wollák, Katharina Zanier, Matija Črešnar, Martin Fera

II.3.1 General Introduction

The following chapter has the goal of presenting useful information that is needed for planning archaeological landscape research. In addition, it introduces regulations needed to be followed before, during and after field research and provides practical help regarding the following issues:

- responsible Institutions for issuing the needed research permits
- information regarding private or public ownership of a plot, where an archaeological site is located and on which is planned to conduct research
- country-specific archaeological standards
- obligations after completion of research.

Additionally, this text provides information about things to consider while planning archaeological landscape research using both invasive (e.g. archaeological excavation) and non-invasive research methods (remote sensing, ground based geophysical methods). Different procedures and regulations are in force that need to be followed in each country before and after archaeological landscape research. The information presented in the following country review applies to the our project partner countries Austria, Croatia, Hungary and Slovenia that are involved in the Iron Age Danube Project.

Author's note: The information given in the following country review reflects the situation at the preparation time of this tool. Since constant modifications are probable by the nature of these issues, the reader is advised to check for possible changes.

AUSTRIA

Essential requirements for all methods of archaeological research in Austria

In Austria a permit of the Federal Monuments Authority Austria is necessary for almost every archaeological research method. The legal provisions were defined in the Federal Act on the Protection of Monuments due to their historic, artistic or other cultural significance[13] (Monument Protection Act – MPA).[14]

Article 11 of the mentioned Federal Act refers to the permits and obligations relating to excavations of archaeological monuments.

An investigation entailing alterations to the surface of the earth or ground under water (excavation) and other on-site Investigations for the purposes of discovering and examining movable and immovable monuments beneath the surface of the earth or water may only be carried out with the permission of the Federal Monuments Authority. Such permission may only be granted to persons with proper qualifications, e.g. completed a course of a relevant university study. Permission may only be granted to natural persons and for concrete excavation plans, which must be clearly defined in the application and the permission granted.

In addition to this Federal Act, it is necessary to follow all terms and conditions published in Guidelines for Archaeological Interventions.[15] All monuments and sites under a preservation order are published on the homepage of the Federal Monuments Authority.[16] Table 1 for Austria lists all the necessary references and links. Furthermore, permission from the landowner(s) is necessary for each kind of archaeological research method that requires entry to their property, especially if a ground intervention is to be made. In some cases, additional permits from other Institutions are required, for example from the aeronautical authority Austro Control for aerial images and airborne laser scans. Moreover, additional permits are also necessary if it is planned to carry out investigations in protected natural landscape areas.

CROATIA

Protection, preservation and research of the cultural heritage in Croatia are under the jurisdiction of the Directorate for the Protection of the Cultural Heritage in the Ministry of Culture of the Republic of Croatia, with its 22 regional units and conservation departments responsible for each of the areas in which the archaeological site or finding is located. Protection and preservation of the cultural heritage is maintained in accordance with

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13 BDA Bundesdenkmalamt: Federal Act on the Protection of Monuments Due to Their Historic, Artistic or Other Cultural Significance (Monument Protection Act – MPA https://bda.gv.at/fileadmin/Medien/bda.gv.at/SERVICE_RECHT_DOWNLOAD/Monument_Protection_Art.pdf

14 BDA Bundesdenkmalamt: Federal Act on the Protection of Monuments Due to Their Historic, Artistic or Other Cultural Significance (Monument Protection Act – MPA https://www.ris.bka.gv.at/GeltendeFassung/Bundesnormen/10009184/DMSG%2c%20Fassung%20vom%2014.12.2017.pdf

15 BDA: https://bda.gv.at/fileadmin/Medien/bda.gv.at/SERVICE_RECHT_DOWNLOAD/Richtlinien_fuer_archaeologische_Massnahmen_2018.pdf; https://bda.gv.at/fileadmin/Dokumente/bda.gv.at/Publikationen/Richtlinien/Richtlinien/Guidelines2017_Download_20171115.pdf

16 https://bda.gv.at/de/denkmalverzeichnis/#oesterreich-gesamt

the *Act on the Protection and Preservation of Cultural Heritage*.[17] In a case of non-invasive research methods, such as an aerial survey, procedures are more complicated, because it is necessary to obtain various different permits for these from a several state agencies. An approval and authorisation for flight from the Croatian Civil Aviation Agency (CCAA) is first required. This approval is the essential prerequisite for the provision of approvals from other agencies. Croatia Control Ltd. (CCL) issues the flight permits. Next in line is the Geodetic State Administration (DGU), which issues permits for aerial imaging. After submitting a request for an aerial imaging permit with all the required supporting documents, when foreign operators or experts are part of the team, the waiting time for the permit if approved, is approximately 45-50 days (i.e. as soon as the Ministry of Defence of Croatia gives its approval). The permit waiting time for Croatian operators is approximately 15 days. Within eight days after the end of the aerial survey, it is necessary to submit all recorded material for a review and an approval for permission to use to DGU. Lastly the Croatian Regulatory Authority for Network Industries (HAKOM) must licence the use of a radio frequency spectrum on an aircraft. An important issue for consideration while planning the research is also, whether the site is positioned in protected natural landscape areas, Ecological Network Natura 2000 or forested areas. When this is the case an approval is needed from the responsible Croatian Ministry of Environment and Energy and the provincial authority (where the site is located), which depends on the kind of protected natural area in which the site is located. A very important issue is the ownership of the site, and whether it is private or public. It is obligatory to submit an owner's consent for conducting an archaeological excavation. An owner's consent is not necessary for conducting archaeological fieldwalking or other non-invasive research methods, but it is advisable to notify the owner of the land, where the site is located, regarding the planned research. The research leader must submit an expert report with research results to the Conservation Departments and other institutions responsible for research within three months of the completion of archaeological invasive research or non-invasive research methods.

HUNGARY

In Hungary the exploration, evaluation, inventarisation, site registration, protection and preservation of archaeological heritage is regulated by the Heritage Act and its accompanying regulations.[18] The other relevant law is the Museum Act,[19] which covers the activities of the public collections concerning particular the tasks of the museums in the field of the acquisition, research, preservation and public access of the cultural goods. According to current legislation all types of archaeological activity can be conducted either by obtaining an official excavation licence or by a preliminary obligatory notice. For conducting archaeological excavations it is always necessary to provide a licence, but there are certain activities which may be pursued only with a preliminary notice: non-Invasive site/find exploration, watching brief, fieldwalking, test excavation in the frame of preliminary archaeological documentation (heritage assessment), and rescue excavation.

[17] Act on the Protection and Preservation of Cultural Heritage, Official gazette "*Narodne novine*" 69/99, 151/03, 157/03, 100/04, 87/09, 88/10, 61/11, 25/12, 136/12, 157/13, 152/14 , 98/15, 44/17; https://www.zakon.hr/z/340/Zakon-o-za%C5%A1titi-i-o%C4%8Duvanju-kulturnih-dobara

[18] Act LXIV of 2001 on the Protection of Cultural Heritage; Governmental Decree 68/2018. (IV. 9.) on the rules for the protection of the cultural heritage

[19] Act CXL of 1997 on Protection of Museum Institutions, Public Library Services and Community Culture

The competent licensing authorities are the designated district offices of the government offices (one in every county plus two in the capital and thus 21 offices in total). They examine each request for an archaeological excavation, whether the chief archaeologist has enough field experience and the financial background would cover all the archaeological duties. In the case of compound sites or scientifically planned excavations they call upon the expert opinion of the scientific body named by the excavation committee. The request for the excavation licence can be submitted only by Institutions which are eligible for conducting archaeological excavations (museums, research institutions, universities and heritage institutions). The chief of the excavation can only be an archaeologist possessing an appropriate university degree and specialized knowledge with appropriate experience employed by one of the above-mentioned institutions. It is also necessary for the archaeologist to submit a preliminary obligatory report of his/her previous excavations. The institutions should also attach the receiving notice by the relevant museum on the findings, this guarantees that the finds will be stored at the local museum. In case of invasive archaeological interventions the permission of the land owner (or whoever is entitled to dispose of the property) is also required. When the property involved is in state ownership, then special authorisation is needed (see Table 4 for Hungary).

In the event of archaeological excavations intended within a designated protected area on national level, the applicant must provide additional documents, demonstrating that the authority for the protection of nature has authorized the exploration (in the case of a protected area on a local level the local government public notary issues the permission). When the archaeological activity is planned on the outskirts of a protected natural area, in an area with unique landscape value or on a Natura 2000 territory, the authority examines whether the activity complies with the national and EU legal requirements for nature conservation from the nature conservation perspective. In the procedure for authorizing archaeological activity on arable land, the authority requires a soil protection plan.

The excavation license is valid for two years applies for the named chief archaeologist and institution, under the relevant legislation and it also defines the professional requirements for the project under the professional guidelines on archaeological exploration.[20] A separate permit is required for any earthworks, landscaping, depot creations, fillings, or dams more than 30 centimetres in depth at an archaeological site designated as protected. A special regulation is applied for the use of metal detectors. In the case that an eligible institution wishes to use metal detectors, a preliminary notice is required to the district office of the government office. Metal detector users who have relevant contracts with museums can request an individual license for using a metal detector, although searching on registered archaeological sites is prohibited.

Aerial surveys (including different types of aerial photography/remote sensing for archaeological purposes) are subject to licensing, which the service provider must authorize.

Special permission is required in the case of forested land (see Table 3 for Hungary). This permission is required from the forest authority since intended archaeological activity will means a potential recourse to the forest causing a temporary or permanent withdrawal from forest production.[21]

20 http://www.kormany.hu/download/0/8e/21000/r%C3%A9g%C3%A9szeti%20felt%C3%A1r%C3%A1s%20szakmai%20ir%C3%A1nyelvei%202017.pdf; http://oroksegvedelem.kormany.hu/regeszeti-feltarasok-szakmai-iranyelvei

21 Act XXXVII of 2009 on Forestry, Forest Protection and Forest Farming

Thirty days after the intervention is concluded the chief archaeologist must prepare a preliminary report. Within a year a complex documentation (in Hungarian) must be compiled and sent to the relevant central and local organisations including the central database (managed by the Prime Minister's Offices) and archaeological archive (managed by the Hungarian National Museum). If the intervention affected a protected area on a national or local level, the documentation must also be submitted to the nature protection authority. While the finds during the restoration and elaboration may be retained for five years by the excavating institution, all finds must ultimately be deposited in the Regional Museum responsible for the area (in absence of recipient in the Hungarian National Museum), where a copy of the documentation is also deposited.

SLOVENIA

Protection, preservation and research of the cultural heritage are regulated in Slovenia by the Cultural Heritage Protection Act[22] and fall under the competences of the Directorate for Cultural Heritage of the Ministry of Culture and the Institute for the Protection of Cultural Heritage of Slovenia, an authority which has seven regional units in addition to its central office. Archaeological research is regulated in detail by the Archaeological Research Rules.[23]

Furthermore, there are rules on the search for archaeological remains and on the technical means that may be used for this purpose[24]: searching for archaeological remains should not encroach directly on archaeological remains and can be carried out by the use of search devices, but only outside of registered archaeological sites and upon the prior acquisition of a "search authorization".

It should be noted that all methods implying the use of airspace are generally regulated by the Aviation Act[25] and also by the Decree on unmanned aircraft systems.[26] LiDAR/ALS data for the whole territory of Slovenia are freely available on the web-site of the Slovenian Environmental Agency.[27]

Within protected nature areas[28] an authorisation from the Environment Agency of the Republic of Slovenia is required for all interventions, which could affect environmental protection or specific protected natural values[29] (e.g. use of noisy machineries, removal of protected plants and habitat types). Within woodland areas, approval from the Slovenia Forest Service is necessary for all interventions, which imply the deterioration of forests or their exploitation[30] (e.g. tree falling, long-term disposal of excavated material on the surface).

22 Cultural Heritage Protection Act (Official gazette RS, nos. 16/08, 123/08, 8/11, 90/12, 111/13, 32/16).
23 Rules on archaeological research (Official gazette RS, no. 3/13).
24 Rules on the search for archaeological remains and on technical means for this purpose (Official gazette RS, no. 49/14).
25 Aviation Act (Official gazette RS, no. 81/10).
26 Decree on unmanned aircraft systems (Offical gazette RS, no. 52/2016 and no. 81/16).
27 Cf. http://gis.arso.gov.si/evode/profile.aspx?id=atlas_voda_LIDAR@Arso&culture=en-US .
28 For identification of the areas cf. http://gis.arso.gov.si/atlasokolja/profile.aspx?id=Atlas_Okolja_AXL@Arso.
29 Cf. Nature Conservation Act (Official gazette RS, no. 96/04, 61/06, 8/10, 46/14).
30 Cf. Act on Forests (Official gazette RS, no. 30/93, 56/99, 67/02, 110/02, 115/06, 110/07, 106/10, 63/13, 101/13, 17/14, 24/15, 9/16, 77/16).

In Slovenia owner consent is not needed for non-invasive archaeological research (remote sensing, geophysical survey, metal detector survey,[31] surface survey/field walking, structural survey), but nevertheless it is of course, strongly recommended. On the other hand owner consent is necessary for weakly invasive (sub-surface survey, building analysis with surface cleaning and/or sampling, core drilling, soil analysis) and invasive research (trial-trenching, test excavation and excavation, supervision during construction, archaeological documentation of destruction). In this regard, private or public ownership makes no difference. In the case of areas in state ownership, special management agreements will need to be checked, as the owner's consent must be issued by the managing authority for the property (e.g. by the Farmland and Forest Fund of the Republic of Slovenia or by the Slovenian State Forests Company, by the ministry in charge of the property or by the responsible national park).

Within two months of the completion of the archaeological research, the research leader must submit a preliminary report to the responsible regional unit of the Institute for the Protection of Cultural Heritage of Slovenia, which will check the report: the responsible conservator can approve it or ask for supplements. In case of research of minor extension, the preliminary report can also be validated as the final report. At least two years after the end of the archaeological research, the leader is namely obliged to submit a peer-reviewed final report to the Ministry of Culture, the Institute for Protection of Cultural Heritage of Slovenia and the responsible museum. The latter will be in charge of archiving the documentation and finds of the research. The research leader has the exclusive right to publish the results of the research within five years from the date of completion. The same deadline is valid for submitting the entire and original archive of the archaeological site to the responsible museum. The archive of the archaeological site is the property of the state and documentation must be in the Slovenian language.

II.3.2 Permits for archaeological research

II.3.2a General requirements

When planning to conduct any archaeological research there are certain requirements you have to take into consideration and procedures which need to be followed. Different procedures and regulations are in force that need to be followed in each country, which are described below. There are also national institutions that are responsible for issuing research permits. These also validate who is legally allowed to carry out the research and is able to satisfy the required conditions for researchers (local and foreign).

AUSTRIA

All invasive and some non-invasive research methods require a permit of the Federal Monuments Authority. In addition, it is necessary for all archaeological invasive and non-invasive research methods to follow all terms and conditions published in guidelines for archaeological interventions.[32]

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[31] Admissible as a complementary method in relation to other research procedures.

[32] BDA: https://bda.gv.at/fileadmin/Medien/bda.gv.at/SERVICE_RECHT_DOWNLOAD/Richtlinien_fuer_archaeologische_Massnahmen_2018.pdf ; https://bda.gv.at/fileadmin/Dokumente/bda.gv.at/Publikationen/Richtlinien/Richtlinien/Guidelines2017_Download_20171115.pdf

Furthermore, permission of the landowners is necessary for each kind of archaeological research method that requires the entering of their land, especially if a ground intervention is intended.

In some cases, it will be essential to obtain permits from other Institutions too (see Table 1 for Austria).

In the guidelines for archaeological interventions all the necessary steps to get an application for the issue of a permit according to § 11 DMSG are listed.[33] The project manager (applicant) is responsible to follow these guidelines before, during and after an archaeological intervention. At the homepage of the Federal Monuments Authority all necessary forms can be downloaded.[34]

The application together with the following additional documents must be submitted to the Federal Monuments Authority in order to obtain a permit:

- concept for the implementation of the intervention
- plan of the intervention area(s) on the basis of the cadastral plan
- up-to-date extracts from the land register must be included for all plots affected by the proposed intervention
- the applicant must suggest a clear and brief title for the intervention

Subsequently the Federal Monuments Authority will inform the applicant in the approval notification of an intervention number. This intervention number and title should afterwards be included in or on all prepared documents.

Three days before and immediately before the end of the fieldwork the Federal Monuments Authority must be informed. Features or finds which were fully unexpected before the excavation, or are of outstanding importance, must be reported in the terms of § 8 DMSG. All notifications must be in German.

A report should be submitted to the Federal Monuments Authority no more than three months after the completion of fieldwork. The report must consist of two parts: part A (results), part B (comprehensive intervention report) and the site record.

Furthermore, the applicant is required to submit to the Federal Monuments Authority[35] the following documents:

- plans
- written documentation
- photographic documentation
- data backup

For notes and links to the competent authorities, see Table 1 and 2 for Austria.

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33 https://bda.gv.at/fileadmin/Dokumente/bda.gv.at/Publikationen/Richtlinien/Richtlinien/Guidelines2017_Download_20171115.pdf

34 https://bda.gv.at/de/publikationen/standards-leitfaeden-richtlinien/richtlinien-fuer-archaeologische-massnahmen/

35 For detailed information concerning the report and the excavation record please refer to the following link: https://bda.gv.at/fileadmin/Dokumente/bda.gv.at/Publikationen/Richtlinien/Richtlinien/Guidelines2017_Download_20171115.pdf

CROATIA

The Conservation Departments issue approvals for archaeological invasive and non-invasive research methods in accordance to the ordinance on archaeological research, in which archaeological activities, licensing requirements and the conditions for conducting archaeological research are defined.

In general, there a separation is made between two basic methods:

1. Archaeological fieldwalking methods (non-invasive): intensive fieldwalking survey, non-intensive fieldwalking survey, undetermined fieldwalking survey, shovel test.
2. Archaeological excavations (invasive): systematic excavation, rescue excavation, review excavation, test excavation, archaeological supervision.

An archaeological surface survey and an archaeological excavation can be conducted based on an approval issued by the competent Conservation Department (see Table 1 for Croatia). An important issue before planning an archaeological excavation is a consent from the owner of the land, which needs to be submitted with a request for approval of the research. The ownership could be either private or public (see Table 4 for Croatia). The applicant for approval can be a legal entity registered in Croatia or a private person and citizen of Croatia. The expert leader must be a citizen of Croatia (who must be an archaeologist with at least 24 months of experience gained by participating in archaeological excavations. Foreign experts and foreign legal entities can participate only based on the approval of the Conservation Department. Foreign experts or foreign legal entities may participate in research if they have permits issued by special regulations and when these are subject to reciprocity.[36]

HUNGARY

No basic distinction is made in licencing between the different forms of archaeological research. As mentioned above in the case of an archaeological surface survey and watching brief there is no licensing procedure, but only obligatory preliminary reporting to the authority.[37] The procedure in case of rescue investigation is similar. In case of non-invasive archaeological interventions such as fieldwalking, remote sensing, geophysical surveys, metal detector surveys and other activities for which reporting is obligatory, the owner's consent is not needed, but it is strongly recommended. In Hungary, any system of research agendas or research framework applied e.g. in the UK or in the Netherlands, has not been introduced yet, nevertheless, the national database(s) and the Central Archaeological Archive can provide information for the research plans. A distinction is made between preventive / investment led excavation and planned / systematic excavation. Nevertheless, in both cases the preparation of a project-plan is required, but in the case of preventive intervention for a large scale project the project-plan concentrates on the applicable methods and the coverage of the area to be explored. A detailed project-plan is required for systematic excavation (as attachment of the request) in which the description of the research program, its scientific justification and the planned source for excavation budget are presented. The professional program of the project-plan is evaluated by the advisory

[36] The Ministry of Culture of the Republic of Croatia, Ordinance on Archaeological research: Official gazette "*Narodne novine*" no. 102/2010 https://narodne-novine.nn.hr/clanci/sluzbeni/2010_08_102_2798.html

[37] 21 District Offices of the Government Offices Construction and Heritage Department see details in Table 1 for Hungary.

body, the excavation committee. When the applicant wants to excavate on a site with enhanced protection the reasons must be explained thoroughly, as the excavation itself can demolish part of the protected site.

The expertise required for a researcher has already been presented in the general Introduction.

Foreign researchers can participate as collaborators of Hungarian institutions, or in the case of Hungarian institutions commissioning the person (having the required background and experience) with the work.

SLOVENIA

Archaeological research

Archaeological activities, licensing requirements and the conditions for conducting archaeological research are defined by the Archaeological Research Rules.[38]

Archaeological research is defined as work affecting archaeological remains or archaeological heritage for the purpose of their protection, in order to determine their presence, study their elements, obtain information about their existence, importance, state of conservation and threats to them. The research includes "historical analysis" or preparation for the intervention, field research and post-excavation or post-field research procedures aimed at the preparation of the final report and at the delivery of the archive of the archaeological site to the responsible museum. Research procedures are divided into:

- Non-invasive archaeological research procedures: archaeological evaluation of resources/desktop assessment, remote sensing, geophysical survey (including metal detector survey), archaeological topography/topographical survey, surface survey (field walking), structural survey,
- Weakly invasive archaeological research procedures: sub-surface survey (with small "shovel-pits" or 1 x 1 m pits), building analysis with surface cleaning and/or sampling, core drilling, geochemical mapping,[39]
- Invasive archaeological research procedures: trial trenching, rescue or research excavation, archaeological supervision during construction, archaeological documentation of destruction.

Archaeological research can be carried out only after acquisition of the research authorisation, issued by the minister responsible for culture, on the basis of the opinion of the Commission for archaeological research, which is the consultative body of the Ministry of Culture in this matter. A mandatory attachment to the application for the research authorization is the "cultural heritage protection conditions" issued by the responsible regional unit of the Institute for the Protection of Cultural Heritage of Slovenia (IPCHS); there are seven regional units of this authority on the territory of the Republic of Slovenia.[40] In the case of weakly invasive and invasive research, the owner's consent is also mandatory in order to submit the application for the research authorization. In certain cases, when field research procedures are not invasive and do not imply the collection of

[38] Rules on archaeological research (Official gazette RS, no. 3/13).

[39] Many of the low-invasive and weakly invasive methods can be executed in an extensive or intensive way, dependant on the stage of research and knowledge about the location under investigation.

[40] Cf. http://www.zvkds.si/sl/obmocne-enote .

samples of finds (archaeological evaluation of resources, remote sensing, archaeological topography, geophysical survey), the ministerial research authorisation is not mandatory, but acquaintance with the responsible regional unit requirements of the IPCHS is strongly recommended (cf. Appendix 1 of the Archaeological Research Rules).

The archaeological research is performed by a professional archaeologist with a university degree; specific conditions have to be fulfilled in order to be eligible as research leader and deputy research leader.[41]

Search for archaeological remains

In accordance to the rules on the search for archaeological remains and on the technical means used for this purpose,[42] search for archaeological remains implies actions on land, in underground spaces and water, which are carried out in order to discover new data on archaeological remains, and can lead to the discovery of archaeological sites and archaeological finds. As long as the search does not encroach directly on archaeological remains, it is not considered to be an archaeological research.

Searching for archaeological remains can be performed with the use of search devices, such as sonar equipment, metal detectors, magnetometers, georadar and other electronic devices. The use of devices for the search of archaeological remains is permissible only outside registered archaeological sites and upon the prior acquisition of the search authorization by the territorial unit of the Institute for the Protection of the Cultural Heritage of Slovenia. Searching for archaeological remains can be performed by persons without an university degree in archaeology (see Table 2 for Slovenia).

II.3.2b Special requirements for remote sensing and geophysics

This sub-chapter includes the descriptions of general country specific obligatory procedures needed for the planning of different non-invasive research methods. In addition it provides information about what permit types are needed for conducting archaeological research, who is legally allowed to perform archaeological research and which responsible Institutions must be addressed for the issue of a research permit.

The non-invasive research methods concerned in this sub-chapter are:

II.3.2b.1 – Remote sensing (see II.4.5)

II.3.2b.2 – Archaeological geophysics (see II.4.4)

AUSTRIA

II.3.2b.1 Remote sensing

Prospection methods such as archive research, aerial imaging, airborne laser scanning (LiDAR) or archaeological-topographic surveys do not require a permit of the Federal Monuments Authority. Further information and advice are published in the guidelines for archaeological interventions.[43] The institution responsible for aerial imaging and airborne lasers caning (LiDAR) in Austria is the aeronautical authority Austro Control.

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41 Consult the Rules on archaeological research (Official gazette RS, no. 3/13)

42 Rules on the search for archaeological remains and on technical means for this purpose (Official gazette RS, no. 49/14).

43 BDA: https://bda.gv.at/fileadmin/Medien/bda.gv.at/SERVICE_RECHT_DOWNLOAD/Richtlinien_fuer_archaeologische_Massnahmen_2018.pdf; https://bda.gv.at/fileadmin/Dokumente/bda.gv.at/

II.3.2b.2 Archaeological geophysics

A permit of the Federal Monuments Authority is required for every type of geophysical measurement, such as geomagnetic survey, ground radar, ground resistance measurement and electromagnetic induction measurement (EMI). Furthermore it is necessary to follow all terms and conditions published in guidelines for archaeological interventions.[44]

Moreover, it is recommended to obtain the permission of the landowner(s) for this kind of archaeological research.

Notes and links to the competent authorities can be found in Table 1 and 2 for Austria.

CROATIA

II.3.2b.1 Remote sensing

Aerial photography and Airborne laser scanning (ALS):

In addition to the conservation department approvals and authorisations, approvals from other responsible agencies are needed (see Table 2 for Croatia). These permits are issued in accordance with following acts and ordinances:

1. Air Traffic Act[45]
2. Ordinance on the rules of the air[46]
3. Ordinance on Approval of Flights of Foreign Aircraft in Croatian Airspace[47]
4. European obligatory insurance for an Air Flights in accordance with Regulation 785/2004[48]
5. Air Safety Order ASO-2012-003[49]
6. Act on Compulsory Insurance within the Transport Sector[50]
7. Ordinance on Conditions for Assignment and Use of the Radio Frequency Spectrum[51]

It is obligatory for flight operators to be registered either in Croatia or their home country. If the flight operators are registered in the European Union or other countries, a court register document must be translated into Croatian and submitted to the Croatian Civil Aviation Agency (CCAA) for issuing approval and flight authorisation.

Publikationen/Richtlinien/Richtlinien/Guidelines2017_Download_20171115.pdf

44 BDA: https://bda.gv.at/fileadmin/Medien/bda.gv.at/SERVICE_RECHT_DOWNLOAD/Richtlinien_fuer_archaeologische_Massnahmen_2018.pdf; https://bda.gv.at/fileadmin/Dokumente/bda.gv.at/Publikationen/Richtlinien/Richtlinien/Guidelines2017_Download_20171115.pdf

45 Croatian Civil Aviation Agency: Air Traffic Act, Official gazette "*Narodne novine*" no.69/09 , 84/11 , 54/13 , 127/13 , 92/14: https://www.zakon.hr/z/177/Zakon-o-zra%C4%8Dnom-prometu

46 Ordinance on the rules of the air, Official gazette"*Narodne novine*", no. 128/14

47 4. Ministry of the Sea, Transport and Infrastructure of the Republic of Croatia, Ordinance on Approval of Flights of Foreign Aircraft in Croatian Airspace Official gazette "*Narodne novine*" no. 50/2017, https://narodne-novine.nn.hr/clanci/sluzbeni/full/2017_05_50_1144.html

48 European obligatory insurance for air flights in accordance with regulation 785/2004 http://eurlex.europa.eu/legalcontent/HR/TXT/PDF/?uri=CELEX:32012R0923&qid=1434534470216&from=EN

49 Croatian Civil Aviation Agency, Air Safety Order ASO-2012-003: http://www.ccaa.hr/hrvatski/naredbe-o-zrakoplovnoj-sigurnosti_298/

50 Act on Compulsory Insurance within the Transport Sector, Official gazette"*Narodne novine*" no. 151/05, 36/09, 75/09, 76/13, 152/14: https://www.zakon.hr/z/370/Zakon-o-obveznim-osiguranjima-u-prometu

51 Ordinance on conditions for assignment and use of the radio frequency spectrum, Official gazette "Narodne novine" no. 45/2012 https://narodne-novine.nn.hr/clanci/sluzbeni/2012_04_45_1134.html

Unmanned aerial systems (UAV) survey:
The unmanned aerial systems (UAV) survey requires approvals from the conservation departments and agencies as in the case of aerial photography and airborne laser scanning (ALS) (see Table 2 for Croatia)

The regulations applicable on unmanned aerial systems (UAS) when operated in Croatia are as follows:

1. Ordinance on Unmanned Aircraft Systems[52]
2. Ordinance on the Rules of the Air[53]
3. Standardized European Rules of the Air (EU) No 923/2012[54]
4. Air Traffic Act[55]

Unmanned aerial systems (UAS) flights must satisfy all conditions as given in the Ordinance on Unmanned Aircraft Systems. In addition, it is necessary to be in possession of an obligatory insurance in accordance with regulation 785/2004.[56]

Satellite imaging, topographical survey:
In the Geodetic State Administration (DGU) services and products can be purchased such as:

1. Official state maps and topographic survey data (aero-photogrammetric recording of Croatia, digital orthophoto map (DOF), Croatian basic chart (HOK), digital model, relief (DMR), topographic maps, Euro Global Map, GIS applications of the protected coastal area and aero-photogrammetric material - 1968
2. cadastre data
3. geodetic data

See also Table 4 for Croatia.

II.3.2b.2 Archaeological geophysics
According to the ordinance on archaeological research, for conducting research using ground based geophysical methods same procedures as for archaeological fieldwalking and archaeological excavation apply (see Table 1 for Croatia).

HUNGARY

II.3.2b.1 Remote sensing
Remote sensing based archaeological research in Hungary can be classified into three categories according to the equipment or method used:

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52 Croatian Civil Aviation Agency: Ordinance on Unmanned Aircraft Systems, Official gazette"*Narodne novine*", no.49/2015,77/2015., courtesy translation: http://www.ccaa.hr/download/documents/read/ordinance-on-unmanned-aircraft-systems_2123

53 Ministry of the Sea, Transport and Infrastructure of the Republic of Croatia, Ordinance on the rules of the air, Official gazette "*Narodne novine*" no. 128/14https://narodne-novine.nn.hr/clanci/sluzbeni/2014_10_128_2433.html

54 Eropean Aviation safety Agency EASA Standardized European Rules of the Air (EU) No 923/2012: https://www.easa.europa.eu/regulation-groups/sera-standardised- european-rules-air

55 Croatian Civil Aviation Agency: Air Traffic Act, Official gazette "*Narodne novine*" no.69/09 , 84/11 , 54/13 , 127/13 , 92/14: https://www.zakon.hr/z/177/Zakon-o-zra%C4%8Dnom-prometu

56 Lex Europa, Obligatory Insurance Regulation 785/2004, http://eur-lex.europa.eu/homepage.html?locale=en

1. drone
2. hand-held oblique aerial photography/ observer directed photography
3. orthophotography/ total coverage or airborne laser scanning (ALS)

Drones can be used by entities with the license for aviation activity if they also have civil liability insurance. They must submit a case-by-case airspace use application to the relevant ministry.

According to the Part-SPO, small aircraft may be operated by air service companies with a license for this activity. The legal requirements for part SPO, i.e. specific operation (technical requirements and administrative procedures for aircraft operations), are set out in the relevant European Parliament and Council Regulation.[57]

Cartographic (orthophoto) and airborne laser scanning (ALS) is a licensed activity. The service provider must request the license by the competent aeronautical authority[58] (see Table 2 for Hungary).

II.3.2b.2 Archaeological geophysics

Conducting any type of geophysical prospection requires similar procedures to archaeological surface survey (see also Table 1 for Hungary).

SLOVENIA

II.3.2b.1 Aerial survey

Use of airspace is regulated by the Aviation Act.[59] The main governing body responsible for this is the Civil Aviation Agency of the Republic of Slovenia. In general, there are no limitations to what can be scanned or photographed. Since 2015, LiDAR data for the whole Slovenian territory are freely available on the site of the Slovenian Environmental Agency.[60]

Drone use is allowed in Slovenia, but is subject to relatively strict regulation by the Decree on unmanned aircraft systems.[61] The use of drones with a take-off weight under 150 kg is regulated by this law. The use of drones for non-commercial purposes does not require permissions and it is assumed, that research falls under this category. There are three categories of drones, under 5 kg, between 5 and 25 kg and between 25 and 150 kg, with increasing restrictions for their use. From a take-off weight of 5 kilograms, you must register your drone by 24 hours at the latest before the flight control. Without a special appointment for your flight, you must keep a safe distance of at least 1.5 kilometres from airports. Flights in densely inhabited areas are prohibited. Drones may only be flown in daylight, not higher than 150 m and not further than 500 meters, or past the visual line of sight, whichever is closer (see also Table 3 for Slovenia).

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57 See Annexes to Regulation EC No 965/2012: III. (*Part-ORO), V. (Part-SPA),VII. (Part-NCO) és VIII. (Part-SPO)* in accordance with Regulation No 216/2008 of the European Parliament and of the Council.

58 Act XLVI of 2012 on Land Surveying and Cartography Activity Par. 38 (1); Governmental Decree *399/2012. (XII. 20.)* on the authorization of aerial remote sensing and the use of remote sensing data Annex 1.

59 Aviation Act (Official gazette RS, no. 81/10).

60 Cf. http://gis.arso.gov.si/evode/profile.aspx?id=atlas_voda_LIDAR@Arso&culture=en-US .

61 Decree on unmanned aircraft systems (Offical gazette RS, no. 52/2016 and no. 81/16).

II.3.2b.2 Ground based geophysical methods

Similar procedures as for other non-invasive methods of archaeological research are required for conducting research with the use of ground based geophysical methods (see Table 1 for Slovenia).

II.3.3 Research in protected natural landscape areas, ecological network Natura 2000 and forested areas

One of the most important issues in research is ownership of a land where the archaeological research will take place. It can be private or public ownership and legal responsibility for a future archaeological site may be in the hands of various public institutions. Information about regulations in force in the different countries, where to find information on sites located in protected natural landscape areas, notes about the ecological Network Natura 2000 and forested areas, as also about institutions which are responsible for issuing approvals and permits for research and more is provided In the following.

AUSTRIA

In addition to the permit from the Federal Monuments authority Austria, additional permits for archaeological interventions in protected natural landscape areas are necessary. The District Administration Department of each Federal State of Austria is responsible for these permits. There are different regulations in the nine Federal States of Austria.[62] Furthermore, it is necessary to follow all terms and conditions published in Guidelines for Archaeological Interventions.[63] Moreover, the obtaining of permission from the landowner(s) for any kind of archaeological research that requires entering their property, especially if it is intended to penetrate the ground, is strongly recommended.

See Tables 1 and 2 for Austria for notes and links to the responsible authorities and to ascertain if the property is located in a nature protected landscape area.

CROATIA

Approvals for conducting research in the protected natural landscape areas, Ecological Network Natura 2000 and forested areas are issued by responsible institutions, in accordance with regulation in dependence on what kind of protection the area in question is under (see also Table 3 for Croatia).

Protected natural landscape areas The *Nature Protection Act*[64] stipulates nine categories of protected areas, in article 111 protected parts of nature are listed while article 144 and 145 contain directions regarding scientific or expert research in these areas.

Ecological Network Natura 2000 Natura 2000 is an Ecological Network of the European Union, which consists of the most significant areas for conservation of species and habitat

62 http://www.umweltbundesamt.at/umweltsituation/naturschutz/sg/nsg/ ; http://www.umweltbundesamt.at/fileadmin/site/publikationen/M091.pdf

63 https://bda.gv.at/fileadmin/Medien/bda.gv.at/SERVICE_RECHT_DOWNLOAD/Richtlinien_fuer_archaeologische_Massnahmen_2018.pdf

64 Nature Protection Act, Official gazette"*Narodne novine*" no. 80/13: https://www.zakon.hr/z/403/Zakon-o-za%C5%A1titi-prirode

types. By the *Regulation on the ecological network*[65] the ecological network of Croatia was established which is at the same time considered as a Natura 2000 area.

Forested areas. Approval for conducting research in the forests depends on their private or public ownership (State-owned). The *Forest Act*[66] prescribes conditions and directions for a forest-management in Croatia. Information about possible location of an archaeological site within a protected area, responsible institutions for issuing approvals and permits for research and contact persons can be found in Table 3 and 4 for Croatia.

Notes: if the site is not in a protected area, there is no need for a special permit for conducting research. Forest areas are not automatically in the category of protected areas.

HUNGARY

There are two different licensing procedures. In a case where the archaeological research is planned in a nature reserve (in other words in a protected area on the national or local level) the applicant has to obtain the preliminary permit of the designated protection authority (from the responsible District Office or from notary of the local government). In the case of conservational spatial categories where conservational permission is not an obligation nor a Natura 2000 territory the license for archaeological activity may contain special prescriptions for nature conservation as both the heritage and nature conservation officials work in the licence issuing district office.

In the case of forested areas, the procedure is similar to that for the nature reserve. An applicant has to obtain the preliminary permit of the designated protection authority (from the assigned department of the responsible District Office).

In all cases, the consent of the landowner/user should be the first step. For detailed information about licensing procedures see Table 4 for Hungary.

SLOVENIA

In accordance to the Nature Conservation Act,[67] authorisations for activities within protected nature areas are generally needed for all interventions, which affect environment protection or specific protected natural values. Research activities can be limited or prohibited in the case of natural monuments or strict nature reserves, nature reserves, but also of enlarged protected areas, i.e. National, Regional and Landscape Parks, which are additionally regulated by a park specific law or act. Nature 2000 areas are further regulated by the Decree on special protection areas (Natura 2000 areas).[68] Status and extension of protected nature areas can be checked in the online portal Atlas Okolja, i. e. Environmental Atlas.[69] The application for authorisation of interventions must be addressed to the Slovenian Environment Agency.

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65 Regulation on the ecological network, Official gazette „*Narodne novine*“ no. 124/13: https://narodne-novine.nn.hr/clanci/sluzbeni/2013_10_124_2664.html

66 Act on Forests, Official gazette „*Narodne novine*“ no. 140/05, 82/06, 129/08, 80/10, 124/10, 25/12, 68/12, 148/13, 94/14: https://www.zakon.hr/z/294/Zakon-o-%C5%A1umama

67 Cf. Nature Conservation Act (Official gazette RS, no. 96/04, 61/06, 8/10, 46/14).

68 Decree on special protection areas (Natura 2000 areas) (Official gazette RS, no. 49/04, 110/04, 59/07, 43/08, 8/12, 33/13, 35/13, 39/13, 3/14, 21/16)

69 Cf. http://gis.arso.gov.si/atlasokolja/profile.aspx?id=Atlas_Okolja_AXL@Arso.

In compliance with the Forestry Act,[70] approval from the Slovenia Forest Service is necessary for all interventions, which could negatively affect forests, their functions and exploitation. The application for the authorisation must be addressed to the responsible regional unit of the Slovenia Forest Service (there are namely 14 regional units[71]) (see also Table 4 for Slovenia).

II.3.4 National sources of data for permits and approvals and other useful data

The following chapter is composed mainly of tables with useful links to country-specific websites, where information can be found about sites on which the research shall take place. Furthermore, there is useful advice on which institutions should be contacted regarding required permits for different research methods. Also, links to websites with information on cadastre/land division and ownership of the land/plots (private or public), links for ecological Network Natura 2000, register of protected cultural heritage, where aerial images important for the site can be purchased and more.

Authors note: The information given in the following text reflects the situation at the time of preparation of this tool. Since the constant modifications are probable by the nature of these issues, the reader is advised to check for possible changes.

AUSTRIA

The following Tables (1-2) contain useful information regarding the institutions responsible for archaeological research methods, aerial imaging (LiDAR) and ground-based geophysical methods as well as sources of data in Austria.

AUSTRIA TABLE 1: INSTITUTIONS RESPONSIBLE FOR ARCHAEOLOGICAL RESEARCH METHODS, ARIAL IMAGING (LiDAR) AND ARCHAEOLOGICAL GEOPHYSICS IN AUSTRIA		
METHOD OF RESEARCH	**INSTITUTIONS RESPONSIBLE FOR THE PERMISSION**	**WEB LINKS**
FIELD WALKING Undetermined field walking survey, linewalking survey grid-survey, surface survey	Permit of the Federal Monuments Authority	Additional web links for each federal state of Austria: https://bda.gv.at/de/ueber-uns/abteilungen-in-den-bundeslaendern/
	Permit of the land owner	
ARCHAEOLOGICAL-TOPOGRAPHICAL MEASUREMENTS	Permit of the land owner	

[70] Cf. Act on Forests (Official gazette RS, no. 30/93, 56/99, 67/02, 110/02, 115/06, 110/07, 106/10, 63/13, 101/13, 17/14, 24/15, 9/16, 77/16).

[71] Cf. http://www.zgs.si/obmocne_enote/index.html.

ARCHAEOLOGICAL GEOPHYSICS Magnetometer measurements, low-frequency EM, geophysical measurements, electrical resistivity tomography (ERT), resistivity mapping (twin probe array), ground penetrating radar measurements	Permit of the Federal Monuments authority	Additional web links for each federal state of Austria: https://bda.gv.at/de/ueber-uns/abteilungen-in-den-bundeslaendern/
	Permit of the land owner	
DRIVING CORE WELL RESEARCH TEST PIT RESEARCH METAL DETECTOR	Permit of the Federal Monuments authority	Additional web links for each federal state of Austria: https://bda.gv.at/de/ueber-uns/abteilungen-in-den-bundeslaendern/
	Permit of the land owner	
ARCHAEOLOGICAL EXCAVATION Research excavation, rescue excavation, underwater excavation, mine excavation	Permit of the Federal Monuments Authority	Additional web links for each federal state of Austria: https://bda.gv.at/de/ueber-uns/abteilungen-in-den-bundeslaendern/
	Permit of the land owner	
AERIAL PHOTOGRAPHY	Permit of the aeronautical authority Austro Control	https://www.austrocontrol.at/luftfahrtbehoerde/lizenzen__bewilligungen/flugbewilligungen
UAV (DRONE) SURVEY	Permit of the aeronautical authority Austro Control	https://www.austrocontrol.at/luftfahrtbehoerde/lizenzen_bewilligungen/flugbewilligungen http://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=10011306
AIRBORNE LASER SCANNING (ALS)	Permit of the aeronautical authority Austro Control	https://www.austrocontrol.at/luftfahrtbehoerde/lizenzen__bewilligungen/flugbewilligungen

AUSTRIA TABLE 2: SOURCES OF BASIC DATA		
INSTITUTION	**TYPE OF DATA**	**LINK TO WEBSITE**
LAND REGISTER AUSTRIA	Land ownership	https://grundbuchauszug.info/ https://www.a1.net/business/produkte-loesungen/grundstuecksdatenbank https://grundbuchplus.com/ http://www.grundbuchauszug-online.at/antrag/
THE FEDERAL OFFICE FOR CALIBRATION AND MEASUREMENT	Cadastre, survey points and coordinates	http://www.bev.gv.at/portal/page?_pageid=713,1604790&_dad=portal&_schema=PORTAL http://www.geoland.at/
THE FEDERAL MONUMENTS AUTHORITY	Information about monument protection and protected areas in Austria	https://bda.gv.at/de/denkmalverzeichnis/#oesterreich-gesamt https://bda.gv.at/de/denkmalverzeichnis/#denkmalliste-gemaess-3-dmsg https://bda.gv.at/de/denkmalverzeichnis/#verordnungen-gemaess-2a-dmsg-ueber-denkmale-im-oeffentlichen-eigentum https://bda.gv.at/de/denkmalverzeichnis/#kulturgueterschutzliste
THE FEDERAL MONUMENTS AUTHORITY	Information about the legal basis responsible for Austria	https://bda.gv.at/de/rechtliche-grundlagen/internationale-uebereinkuenfte/ https://bda.gv.at/de/rechtliche-grundlagen/gesetze-und-verordnungen/ https://bda.gv.at/de/service/download/ https://bda.gv.at/de/english/
THE FEDERAL MONUMENTS AUTHORITY	Information about the regulations for archaeological actions	https://bda.gv.at/fileadmin/Medien/bda.gv.at/SERVICE_RECHT_DOWNLOAD/Richtlinien_fuer_archaeologische_Massnahmen_2018.pdf https://bda.gv.at/fileadmin/Dokumente/bda.gv.at/Publikationen/Richtlinien/Richtlinien/Guidelines2017_Download_20171115.pdf

THE FEDERAL ENVIRONMENT AGENCY	Permits and information about protected natural landscape areas	http://www.umweltbundesamt.at/umweltsituation/naturschutz/sg/nsg/ http://www.umweltbundesamt.at/fileadmin/site/publikationen/M091.pdf

CROATIA

Useful information about the institutions responsible for archaeological research methods and ground-based geophysical methods, institutions responsible for the aerial survey permits, data for research in the protected natural landscape areas, Natura 2000 and forested areas as well as sources of data for permits and approvals will be presented in the following Tables (1-4).

CROATIA TABLE 1: INSTITUTIONS RESPONSIBLE FOR ARCHAEOLOGICAL RESEARCH METHODS AND ARCHAEOLOGICAL GEOPHYSICS		
METHOD OF RESEARCH	**INSTITUTIONS RESPONSIBLE FOR THE PERMITS**	**WEB LINKS**
ARCHAEOLOGICAL FIELDWALKING Intensive fieldwalking survey, non-intensive fieldwalking survey, undetermined fieldwalking survey, shovel test, surface survey	The Ministry of Culture of the Republic of Croatia: Conservation Departments in the provincial administrative district where the research site is located	http://www.min-kulture.hr/default.aspx?id=18877
ARCHAEOLOGICAL EXCAVATION Systematic excavation, rescue excavation, test excavation, review excavation and archaeological supervision	The Ministry of Culture of the Republic of Croatia: Conservation Departments in the provincial administrative district where the research site is located	http://www.min-kulture.hr/default.aspx?id=18877
ARCHAEOLOGICAL GEOPHYSICS Magnetometer measurements, low-frequency EM, geophysical measurements, electrical resistivity tomography (ERT), resistivity mapping (twin probe array), ground penetrating radar measurements), metal detecting	The Ministry of Culture of the Republic of Croatia: Conservation Departments in the provincial administrative district where the research site is located	http://www.min-kulture.hr/default.aspx?id=18877

METHOD OF RESEARCH	CROATIA TABLE 2: INSTITUTIONS RESPONSIBLE FOR AERIAL SURVEY PERMITS (for research and aerial imaging)				
AERIAL SURVEY	**THE MINISTRY OF CULTURE OF THE REPUBLIC OF CROATIA** CONSERVATION DEPARTMENTS IN THE COUNTY where the research site is located	**GEODETIC STATE ADMINISTRATION (DGU)**	**CROATIAN CIVIL AVIATION AGENCY (CCAA)**	**CROATIAN CONTROL**	**CROATIAN REGULATORY AUTHORITY FOR NETWORK INDUSTRIES (HAKOM) FOR RADIO FREQUENCY**
AERIAL PHOTOGRAPHY UNMANNED AERIAL VEHICLE (UAV) SURVEY; AIRBORNE LASER SCANNING (ALS)	Links for 22 Conservation Departments in Croatia: http://www.min-kulture.hr/default.aspx?id=18877 Approval for archaeological research	https://www.dgu.hr/ Permit for Issuance of an Aerial Imaging and Aerial Imagery Use	http://www.ccaa.hr/english/flight-authorisation_23/ Approval and Authorization for Flight	http://www.crocontrol.hr/default.aspx?id=3505 Approval and Authorization for Flight	https://www.hakom.hr/default.aspx?id=7
SATELLITE IMAGING; TOPOGRAPHICAL SURVEY		http://www.dgu.hr/proizvodi-i-usluge/ Purchase of images, maps and data in DGU			

CROATIA TABLE 3: RESEARCH IN PROTECTED NATURAL LANDSCAPE AREAS, NATURA 2000 AND FORESTED AREAS		
RESEARCH PLACE		
PROTECTION CATEGORY PURPOSE	**INSTITUTIONS RESPONSIBLE FOR THE PERMITS**	**WEB LINK:**
STRICT RESERVE	The provincial administrative district (where the site is located)	Lists with links for each of the 22 Croatian counties http://www.croatia.eu/article.php?lang=2&id=30
NATIONAL PARK	The Ministry of Environment and Energy	The Ministry of Environment and Energy Directorate for Nature Protection http://www.mzoip.hr/en/contacts.html
SPECIAL RESERVE	County (where the site is located)	Lists with links from every 22 Croatian Counties http://www.croatia.eu/article.php?lang=2&id=30
NATURE PARK	The Ministry of Environment and Energy	The Ministry of Environment and Energy Directorate for Nature Protection http://www.mzoip.hr/en/contacts.html
REGIONAL PARK	The provincial administrative district (where the site is located)	Lists with links from every 22 Croatian Counties http://www.croatia.eu/article.php?lang=2&id=30
NATURE MONUMENT	The provincial administrative district (where the site is located)	Lists with links from every 22 Croatian Counties http://www.croatia.eu/article.php?lang=2&id=30
SIGNIFICANT LANDSCAPE	The provincial administrative district (where the site is located)	Lists with links from every 22 Croatian Counties http://www.croatia.eu/article.php?lang=2&id=30
PARK FOREST	The provincial administrative district (where the site is located)	Lists with links from every 22 Croatian Counties http://www.croatia.eu/article.php?lang=2&id=30
HORTICULTURAL MONUMENT	The provincial administrative district (where the site is located)	Lists with links from every 22 Croatian Counties http://www.croatia.eu/article.php?lang=2&id=30
ECOLOGICAL NETWORK NATURA 2000	The Ministry of Environment and Energy	The Ministry of Environment and Energy Directorate for Nature Protection http://www.mzoip.hr/en/contacts.html
FORESTED AREAS	Croatian forests (Hrvatske šume d.o.o.)	“HRVATSKE ŠUME” d.o.o. Headquarters, Zagreb http://portal.hrsume.hr/index.php/en/contact

CROATIA TABLE 4 : SOURCES OF BASIC DATA FOR THE PERMITS AND APPROVALS - 1		
INSTITUTION	**TYPE OF DATA**	**LINK TO WEBSITE**
THE MINISTRY OF CULTURE OF THE REPUBLIC OF CROATIA	Home page	http://www.min-kulture.hr/
	Register of the protected cultural heritage	http://www.min-kulture.hr/default.aspx?id=6212
	Links for 22 conservation departments in Croatia	http://www.min-kulture.hr/default.aspx?id=18877
	Request for Approval for Archaeological Research	http://www.min-kulture.hr/default.aspx?id=3
GEODETIC STATE ADMINISTRATION (DGU)	Home page	https://www.dgu.hr/
	Cadastral data Information about ownership of cadastral parcels numbers	http://www.katastar.hr/dgu/pretrazivac#
	National spatial data Infrastructure (NIPP) Information about site and place of research, including parcels numbers that you can use at link at Cadastral data website regarding ownership information.	http://geoportal.nipp.hr/hr/application/view
	Request for Permit for Issuance of an Aerial Imaging and Aerial Imagery Use. https://www.dgu.hr/assets/uploads/Dokumenti/Zahtjevi/Fotogrametrijski%20podaci/Request%20-%20Issuance%20of%20an%20aerial%20imaging%20and%20areial%20imagery%20use%20-%202017.pdf	
	Purchase of images, maps and data in DGU	http://www.dgu.hr/proizvodi-i-usluge/
CROATIAN CIVIL AVIATION AGENCY (CCAA)	Home page	http://www.ccaa.hr/english/naslovnica_1/
	Contact for the information regarding flight operations (UAV, LiDAR, and Aerial Photography).	http://www.ccaa.hr/english/letacke-operacije-kontakti_27/
	Information regarding Flight Authorisation	http://www.ccaa.hr/english/odobravanje-letova_23/
	Forms and publications (Application for approval, Operator's Declaration, Summarized requirements etc.)	http://www.ccaa.hr/english/forms-and-publications_416/

CROATIA TABLE 4 : SOURCES OF DATA FOR PERMITS AND APPROVALS - 2		
MINISTRY OF STATE PROPERTY	Home page	https://imovina.gov.hr/
	Information about ownership of the state properties that includes land where archaeological research can be conducted as well as where to require permit for research.	https://imovina.gov.hr/pristup-informacijama/16
	State Property Register	http://registar-imovina.gov.hr/
CROATIAN ENVIRONMENT AND NATURE AGENCY	Home page	http://www.iszp.hr/
	Bioportal-Nature protection information system web portal (Nature 2000) Map where you can find information if the site of research is located in ecological network Natura 2000 or protected natural landscape areas.	http://www.iszp.hr/gis/?lang=en&theme=neptune
MINISTRY OF ENVIRONMENT AND ENERGY (Directorate for nature protection)	Home page	http://www.mzoip.hr/
	NATURE PROTECTION MANAGEMENT Request for permissions for research if the site is located in ecological network Natura 2000 or protected natural landscape areas. Submit request for permissions for research as official letter in Word format (No Form available on the website)	http://www.mzoip.hr/en/nature.html
“HRVATSKE ŠUME” d.o.o. (Croatian forests)	Home page	http://portal.hrsume.hr/index.php/en/
	If the land is in the ownership of the “HRVATSKE ŠUME” d.o.o. (Croatian forests) Submit request for permissions for research as official letter in Word format (No Form available on the website)	http://portal.hrsume.hr/index.php/en/catalogue-of-information
	Area of forests and forestland in Croatia	http://javni-podaci-karta.hrsume.hr/

HUNGARY

The following Tables (1-4) contain useful information regarding institutions responsible for archaeological research methods, aerial imaging, ground-based geophysical methods, institutions responsible for permits, data for research in protected natural landscape areas, Natura 2000 and forested areas as well as sources of data for permits and approvals in Hungary.

HUNGARY TABLE 1: INSTITUTIONS RESPONSIBLE FOR ARCHAEOLOGICAL RESEARCH METHODS, AERIAL IMAGING (LIDAR) AND ARCHAEOLOGICAL GEOPHYSICS IN HUNGARY		
METHOD OF RESEARCH	**INSTITUTIONS RESPONSIBLE FOR THE PERMISSION**	**WEB LINKS**
FIELDWALKING Any type, surface survey	No permission, but preliminary notice to the Construction and Heritage Department of the District Bureau Offices is required. E.g. Baranya Megyei Kormányhivatal Pécsi Járási Hivatal Hatósági Főosztály Építésügyi és Örökségvédelmi Osztály	Separate web links for each Department (there are 21 in Hungary) Central link: http://www.kormanyhivatal.hu/hu/rolunk-about-us http://www.kormanyhivatal.hu/hu/baranya/jarasok/pecsi-jarasi-hivatal-hatosagi-foosztaly
ARCHAEOLOGICAL GEOPHYSICS Magnetometer surveys, low-frequency EM, geophysical surveys, electrical resistivity tomography (ERT), resistivity mapping (twin probe array), ground penetrating radar surveys	See above	See above
DRIVING CORE TEST PIT RESEARCH	Being a destructive intervention, a permit by the Construction and Heritage Department of the District Bureau Offices is required.	See above

METAL DETECTING	When conducting research, professional institutions do not need to obtain a permit, but are required to submit a preliminary notice to the Construction and Heritage Department of the District Bureau Offices. Unaffiliated research is prohibited on registered archaeological sites. Any individual conducting metal detecting is required to have a permit from the Construction and Heritage Department of the District Bureau Offices.	See above
TEST PIT (in the frame **of preliminary archaeological documentation / heritage assessment)**	Requires no permit, but a preliminary notice to the Construction and Heritage Department of the District Bureau Offices is required.	See above
ARCHAEOLOGICAL EXCAVATION • Rescue excavation • Research excavation • Underwater excavation	Permit by the District Offices of the Government Offices Construction and Heritage Department	See above
ARCHAEOLOGICAL EXCAVATION • Watching brief • Rescue excavation	No permission, but preliminary notice to the District Offices of the Government Offices Construction and Heritage Department is required.	See above

HUNGARY TABLE 2: INSTITUTIONS RESPONSIBLE FOR PERMITS FOR AERIAL SURVEY		
METHOD OF RESEARCH	**INSTITUTION**	**WEB LINK**
AERIAL SURVEY	In terms of archaeological heritage protection process no permission, but preliminary notice is required to the District Offices of the Government Offices Construction and Heritage Department.	Separate web links for each Department (there are 21 in Hungary) Central link: http://www.kormanyhivatal.hu/hu/rolunk-about-us

	For aeronautical authorisation: Ministry of Defence State Aviation Department	http://acrsa.org/hu/index.php/jogszabalyi-koernyezet; https://legter.hu/letoltesek/
DRONE	Ministry of Defence State Aviation Department. Entities with a license for aviation activity should request license for case-by-case airspace use from the State Aviation Department.	Email address: hm.alf@hm.gov.hu
HAND-HELD, OBLIQUE AERIAL PHOTOGRAPHY	Ministry of Innovation and Technology Aviation Office. Small airplanes can be operated by air service companies with license for this activity.	http://www.nkh.gov.hu/web/legugyi-hivatal/egyedi-muveletek-spo-
ORTOPHOTOGRAPHY OR AIRBORNE LASER SCANNING (ALS)	Hungarian Armed Forces Geoinformation Service. The service provider should request the license for ortophotography or airborne laser scanning.	https://www.ket.hm.gov.hu/mhgeosz/SitePages/legitav.aspx

HUNGARY TABLE 3: RESEARCH IN PROTECTED NATURAL LANDSCAPE AREAS, NATURA 2000 AND FORESTED AREAS		
PROTECTION CATEGORY	**INSTITUTIONS RESPONSIBLE FOR THE PERMITS**	**WEB LINK**
ARCHAEOLOGICAL EXCAVATION ON NATURE RESERVE • On areas protected on the national level	District Offices of the Government Offices Department of Environmental Protection and Nature Conservation	Separate web links for each Department (there are 21 in Hungary) Central link: http://www.kormanyhivatal.hu/hu/rolunk-about-us
• On areas under local protection	Notary of the local government.	Web link of the related local government
ARCHAEOLOGICAL EXCAVATION ON Arable lands	No special permission, but soil protection plan should be attached to the request.	Separate web links for each Department (there are 21 in Hungary)

ARCHAEOLOGICAL EXCAVATION ON • Territorial conservational categories where conservational permission is not an obligation Natura 2000 territories	District offices of the Government Construction and Heritage Department with current special prescriptions of the Department of Environmental Protection and Nature Conservation	See above
ARCHAEOLOGICAL EXCAVATION ON Forested areas	District offices of the Government Department of Agriculture Forestry Department	See above http://kormanyablak.hu/hu/feladatkorok/169/ERDIG00019 http://kormanyablak.hu/hu/feladatkorok/169/ERDIG00020

HUNGARY TABLE 4/1: SOURCES OF DATA FOR THE PERMITS, APPROVALS AND OTHER DATA REQUIREMENTS		
INSTITUTION	**TYPE OF DATA**	**LINK TO WEBSITE**
PRIME MINISTER'S OFFICE Registration Department	Professional Guidelines for Excavations Heritage protection expert register	http://oroksegvedelem.kormany.hu/regeszeti-feltarasok-szakmai-iranyelvei http://oroksegvedelem.kormany.hu/szakertoi-nevjegyzek-osz
	Central database of protected cultural heritage (listed buildings, archaeological sites, protected properties, archaeological interventions with GIS data)	http://ivo.forsterkozpont.hu/ (accessible for registered professional users)
	Central Building Register Register of the protected properties	https://oroksegvedelem.e-epites.hu/
GOVERNMENT OFFICES		Separate web links for each department (there are 21 in Hungary) Central link: http://www.kormanyhivatal.hu/hu/rolunk-about-us

District Offices of the Government Offices Construction and Heritage Department	Request permit for archaeological activity/research	See above
District Offices of the Government Offices Land Register Department	Offline land register data (information about ownership and other data of cadastral parcel numbers)	Addresses: http://www.takarnet.hu/pls/tknet/hivatalok_p.hivatallista
District Offices of the Government Offices Department of Environmental Protection and Nature Conservation	Request for preliminary permit on nature reserve	Separate web links for each Department (there are 21 in Hungary) Central link: http://www.kormanyhivatal.hu/hu/rolunk-about-us
District Offices of the Government Offices Department of Agriculture, Forestry Department	Request for preliminary permit on forested area	See above
Ministry of Finance Documentation and Information Center of Building Affairs of the Lechner Nonprofit Ltd.	National Spatial Planning Plan Presenting the relevant zones (such as landscape protected zones, national ecological network, World Heritage zones, arable lands, forested lands, etc.)	http://www.terport.hu/teruletrendezes/teruletrendezesi-tervek/magyarorszag

HUNGARY TABLE 4/2: SOURCES OF DATA FOR THE PERMITS, APPROVALS AND OTHER DATA REQUIREMENTS		
INSTITUTION	**TYPE OF DATA**	**LINK TO WEBSITE**
HUNGARIAN NATIONAL MUSEUM • Central Archaeological Archive	Offline data on archaeological intervention (reports and documentation)	https://mnm.hu/hu/gyujtemenyek/central-database/regeszeti-adattar
• Department for Archaeological Exploration and Processing	Hungarian National Museum Archaeology Database (developed in the frame of the ARIADNE program) Online catalogue containing fundamental information on archaeological sites. Documentation of the sites is also available.	http://archeodatabase.hnm.hu/en/ (no restriction on browsing and searching, but sensitive data (e.g. GPS coordinates and full documentations) can only be accessed by registered professional users
	Online accessible publication of reports on archaeological excavations 1998-2010.	http://archeodatabase.hnm.hu/en/rkm (no restriction on access)
	Online database on archaeological excavations 2011.	http://archeodatabase.hnm.hu/en/rkm (will be available from July 2018) (no restriction on access)
MUSEUMS • Municipal museum of county competence • Local (municipal) museum	Documentation of archaeological activity conducted in the county. In the event the museum has an archaeological scope: documentation of archaeological activity conducted in the settlement.	Webpage of the museums concerned (there are 19 + 1 /capital/ museums) Webpage of the museums concerned
VÁRKAPITÁNYSÁG KFT.	Data of preliminary archaeological documentations.	Information available via e-mail: regeszetiprojektiroda@forsterkozpont.hu
MŰEMLÉKEM.HU BT. (civil association)	Database of the built heritage (including many sites having protected monument status).	http://www.muemlekem.hu/

MUNICIPALITIES	Local building acts, master development plans, settlement imagery Handbook	Webpage of the given settlement
Documentation and Information Center of Building Affairs of the Lechner Nonprofit Ltd.	Local building acts, master development plans	http://hunteka.lechnerkozpont.hu
HUNGARIAN ACADEMY OF SCIENCES Research Centre for the Humanities, Institute of Archaeology	Hungarian Archaeological Topography database and publication of archaeological sites and findings in four counties 1(1966)-11(2012)	http://www.archeo.mta.hu/en/publications/series/mrt-1966-2012

HUNGARY TABLE 4/3: SOURCES OF DATA FOR THE PERMITS, APPROVALS AND OTHER DATA REQUIREMENTS		
REQUIREMENTS	**TYPE OF DATA**	**LINK TO WEBSITE**
UNIVERSITIES • University of Pécs, Faculty of Humanities	Archive and database of aerial photography	http://btk.pte.hu/szervezeti_egysegek/legiregeszeti_teka
• Faculty of Humanities of Eötvös Loránd University, Budapest Institute of Archaeological Sciences	Archive and Database of Aerial Photography	http://regeszet.elte.hu/wordpress/index.php/2017/03/12/archeometriai-es-regeszetmodszertani-tanszek/
INSTITUTE AND MUSEUM OF MILITARY HISTORY	Military historical map collection with individual and serial maps, atlas, relief, technical book, journal, aerial photo, etc.	http://www.militaria.hu/hadtorteneti-intezet-es-muzeum/terkeptar

MINISTRY OF AGRICULTURE	Online central land register data (TAKARNET) (Information on ownership and other data on cadastral parcel numbers)	http://www.takarnet.hu/main/belepes.htm (accessible for registered users) https://kereses.magyarorszag.hu/portalkereses parcel finder
MINISTRY OF AGRICULTURE	Data on nature reserves (protected areas at national level, on conservational spatial categories, on Natura 2000 territories, on National Parks, etc.) Data on protected area on local level	http://www.termeszetvedelem.hu/ http://www.termeszetvedelem.hu/termeszetvedelmi-adatbazisok Webpage of the given settlement (or request to the local government)
MINISTRY OF AGRICULTURE National Food Chain Safety Agency	Database of forested areas (including the ownership status)	http://erdoterkep.nebih.gov.hu/
HUNGARIAN NATIONAL ASSET MANAGEMENT INC.	Request for consent in case of state property (in case the state property is located on arable land or on settlement outskirts)	http://www.mnvzrt.hu/felso_menu/kapcsolat/alapelerhetosegek/elerhetosegi_adatok.html http://www.nfa.hu/
GOVERNMENT OFFICE OF BUDAPEST Department of Geodesy, Remote Sensing, and Land Registry	• Maps of the territories of Hungary in scales 1:10 000, 1:25 000, 1:100 000, 1:200 000 available (purchasable) in paper and digital form. • Agricultural parcel identification system (national land mapping map system developed for agricultural subsidies)	http://www.ftf.bfkh.gov.hu/portal/index.php/termekeink/terkepek https://www.mepar.hu/mepar/
MINISTRY OF DEFENCE State Aviation Department	Request (by service provider) for case-by-case airspace use	Email address: hm.alf@hm.gov.hu

MINISTRY OF INNOVATION AND TECHNOLOGY Aviation Office	Request (by service provider) for small airplane use	http://www.nkh.gov.hu/web/legugyi-hivatal/egyedi-muveletek-spo-
HUNGARIAN ARMED FORCES Geoinformation Service	Request (by service provider) for conducting ortophotography or airborne laser scannin	https://www.ket.hm.gov.hu/mhgeosz/SitePages/legitav.aspx

SLOVENIA

The following Tables (1-4) contain useful information and web links about data sources, permits for archaeological remains searches and authorisations for archaeological research, specific permits for research methods, which imply the use of airspace, as well as specific permits for interventions within protected nature and forested areas in Slovenia.

SLOVENIA TABLE 1: DATA SOURCES		
DATA TYPE	**RESPONSIBLE INSTITUTION**	**WEB LINK**
Cartographic and topographic material, aero-photogrammetric recordings, Digital Orthophoto Map, digital relief model, cadastre, Euro Global Map	The Surveying and Mapping Authority of the Republic of Slovenia	http://www.e-prostor.gov.si/zbirke-prostorskih-podatkov/topografski-in-kartografski-podatki/
Registry of immovable cultural heritage	Ministry of Culture of the Republic of Slovenia	http://rkd.situla.org/ http://giskd6s.situla.org/giskd/ http://giskd6s.situla.org/evrd/
LiDAR data/ALS data	Slovenian Environment Agency	http://gis.arso.gov.si/evode/profile.aspx?id=atlas_voda_LIDAR@Arso&culture=en-US
Protected nature and woodland areas	Slovenian Environment Agency	http://gis.arso.gov.si/atlasokolja/profile.aspx?id=Atlas_Okolja_AXL@Arso http://gis.arso.gov.si/geoportal/catalog/main/home.page

SLOVENIA TABLE 2: PERMITS FOR SEARCH FOR ARCHAEOLOGICAL REMAINS AND AUTHORISATIONS FOR ARCHAEOLOGICAL RESEARCH		
PERMIT/AUTHORISATION TYPE	**RESPONSIBLE INSTITUTION**	**WEB LINK**
Permit for search for archaeological remains and for use of technical means for this purpose (do not encroach directly on archaeological remains!)	Responsible regional unit (Celje, Kranj, Ljubljana, Maribor, Nova Gorica, Novo mesto, Piran) of the Institute for the Protection of Cultural Heritage of Slovenia	http://www.zvkds.si/sl/obmocne-enote
Cultural heritage protection conditions (mandatory attachment of the application for the authorization for archaeological research)	Responsible regional unit (Celje, Kranj, Ljubljana, Maribor, Nova Gorica, Novo mesto, Piran) of the Institute for the Protection of Cultural Heritage of Slovenia	http://www.zvkds.si/sl/obmocne-enote http://www.zvkds.si/sl/clanek/nasveti-za-lastnike
Authorization for archaeological research	Ministry of Culture of the Republic of Slovenia	http://www.mk.gov.si/si/storitve/postopki/varstvo_kulturne_dediscine/arheoloske_raziskave/

SLOVENIA TABLE 3. SPECIFIC PERMITS FOR RESEARCH METHODS WHICH IMPLY THE USE OF AIRSPACE		
PERMIT/AUTHORISATION TYPE	**RESPONSIBLE INSTITUTION**	**WEB LINK**
Flight permit	Civil Aviation Agency	https://www.caa.si/

SLOVENIA TABLE 4. SPECIFIC PERMITS FOR INTERVENTIONS WITHIN PROTECTED NATURE AND FORESTED AREAS		
PERMIT/AUTHORISATION TYPE	**RESPONSIBLE INSTITUTION**	**WEB LINK**
Nature conservation authorisation	Slovenian Environment Agency	http://www.arso.gov.si/narava/naravovarstveni%20pogoji%20in%20soglasja.html
Authorisation of the Slovenia Forest Service	Responsible regional unit (Bled, Brežice, Celje, Kočevje, Kranj, Ljubljana, Maribor, Murska Sobota, Nazarje, Novo mesto, Postojna, Sežana, Slovenj Gradec, Tolmin) of the Slovenia Forest Service	http://www.zgs.si/obmocne_enote/index.html http://www.zgs.si/delovna_podrocja/gozdnogospodarsko_nacrtovanje/izdaja_soglasij/index.html

II.3.5 International sources of data

The following tables contain links to websites where useful data can be found at international level with sources of information for research or links to European Acts and Conventions regarding archaeological research and Protection of the Archaeological Heritage.

Authors note: The information given in the following tables reflect the situation at the time of preparation of this tool. Since the constant modifications are probable by the nature of these issues, the reader is advised to check for possible changes.

INTERNATIONAL TABLE 1: SOURCES OF DATA: INTERNATIONAL		
INSTITUTION	**TYPE OF DATA**	**LINK TO WEBSITE**
NATIONAL COLLECTION OF AERIAL PHOTOGRAPHY (NCAP)	One of the largest collections of aerial imagery in the world, containing tens of millions of aerial images featuring historic events and places around the world.	http://ncap.org.uk/about-ncap/our-work http://ncap.org.uk/collections http://ncap.org.uk/ACIU
ECOLOGICAL NETWORK NATURA 2000 LINK FOR THE EUROPEAN COUNTRIES	The Birds Directive 2009/147/EC (79/409/EC) Habitats Directive 43/92/EC	http://ec.europa.eu/environment/nature/natura2000/index_en.htm http://natura2000.eea.europa.eu/#
EUR-LEX ACCESS TO EUROPEAN UNION ACTS	Homepage	http://eur-lex.europa.eu/homepage.html
EU	Environmental Impact Assessment The EIA Directive (85/337/EEC)	http://ec.europa.eu/environment/eia/eia-legalcontext.htm
UNESCO	Convention on Wetlands of International Importance especially as Waterfowl Habitat Ramsar 1971	http://portal.unesco.org/en/ev.php-URL_ID=15398&URL_DO=DO_TOPIC&URL_SECTION=201.html
	Biosphere Reserves Man and the Biosphere Programme 1971	http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/biosphere-reserves/
UNESCO	Convention concerning the Protection of the World Cultural and Natural Heritage 1972	http://portal.unesco.org/en/ev.php-URL_ID=13055&URL_DO=DO_TOPIC&URL_SECTION=201.html
COUNCIL OF EUROPE CONVENTIONS	Home page	https://www.coe.int/en/web/conventions/full-list

	European Cultural Convention, Paris, 19.XII.1954	https://rm.coe.int/168007bd25
	European Convention on the Protection of the Archaeological Heritage (Revised), Valetta, 16.I.1992	https://rm.coe.int/1680072318
	European Landscape Convention Florence, 20.X.2000	https://rm.coe.int/1680080621
	Council of Europe Framework Convention on the Value of Cultural Heritage for Society, Faro, 27.X.2005	https://rm.coe.int/1680083746
EUROPEAN ARCHAEOLOGICAL COUNCIL	**EAC Guidelines 2 EAC Guidelines for the Use of Geophysics in Archaeology Questions to Ask and Points to Consider**	https://www.europae-archaeologiae-consilium.org/eac-guidlines

II.3.6 International sources of geodata

A transnational approach towards the European heritage, such as that sought in this project, benefits greatly from the increased availability of various data sets on a regional but also a Pan-European level.

Apart from the data sets in archives and collections of the partner countries that were primarily derived from previous archaeological work or collected in the scope of the project by various methods and tools at the national archaeological camps, the integration of additional data sets plays an important role for many portions of this project. If it is to fulfil all of its goals, the investigation of complex archaeological landscapes together with their protection and promotion and also the sites in the nine micro-regions all need to be put into a broader context.

The rise of availability of digital geographical data sets is based on European initiatives such as INSPIRE. Some national data sets, such as aerial photographs and products of airborne laser scanning, can even be used for the purposes of archaeological prospection and the mapping of cultural landscapes. Many of the data sets provide information on the physical geography of European regions, environmental topics and land cover today. Furthermore a broad selection of these datasets can be successfully utilised for the investigation and contextualisation of archaeological information in a contemporary environmental setting. However, their value also lies in their potential for providing information at the planning phase of archaeological projects, as also for the assessment of risks and threats for remnant archaeological landscapes and the possibilities for their promotion.

Data repositories for downloadable open data sets:

DATA SET	CONTENT	TYPE	PROVIDER	DESCRIPTION	LINK
Nuts Regions	Administrative units and borders	vector	Eurostat portal of the European Commission	Basic data sets for all European countries on multiple levels of Administrative Borders and Statistical Units	http://ec.europa.eu/eurostat/de/web/gisco/geodata/reference-data/administrative-units-statistical-units/nuts
EU DEM	Digital elevation model	raster	Copernicus, Land Monitoring Service	European Digital Elevation Model (EU-DEM), version 1.1; 25m, 1000 x 1000 km tiles, vertical accuracy: +/- 7 meters RMSE	https://land.copernicus.eu/imagery-in-situ/eu-dem/eu-dem-v1.1?tab=download
EU Hydro	Hydrographic data	raster/ vector	Eurostat portal of the European Commission		http://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/elevation/hydrography-laea
CLC	Corine Land Cover data	raster/ vector	European Environment Agency	European inventory of land cover in 44 classes	https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-corine
LUCAS soil	Harmonised topsoil types	vector	European Soil Data Centre	European Soil Database & soil properties	https://esdac.jrc.ec.europa.eu/content/european-soil-database-v20-vector-and-attribute-data
EU Tree	Tree cover density	raster	Copernicus, Land Monitoring Service	Status layers showing the level of tree cover density in a range from 0-100%, 20m	https://land.copernicus.eu/pan-european/high-resolution-layers/forests/tree-cover-density

DATA SET	CONTENT	TYPE	PROVIDER	DESCRIPTION	LINK
EU Forest	Forest types	raster	Copernicus, Land Monitoring Service	FAO forest definition, in its original (20m) resolution	https://land.copernicus.eu/pan-european/high-resolution-layers/forests/forest-type-1
EU Grass	Grassland	raster	Copernicus, Land Monitoring Service	2015 reference year grassland, 20m	https://land.copernicus.eu/pan-european/high-resolution-layers/grassland
EU Water	Water and wetlands	raster	Copernicus, Land Monitoring Service	water and wet surfaces over the period from 2009 to 2015, 20m	https://land.copernicus.eu/pan-european/high-resolution-layers/water-wetness

II.4 Methods

II.4.1 Desktop assessment

II.4.1.1 Investigation of archaeological sites using old maps

András Bödőcs, László Rupnik

Introduction

Data from various sources are available today for use in archaeological topographic research. For example, more and more databases with remote sensing sources are now opening up. These can record a particular segment of the Earth not only at a given time but also with recurring periodicity.

While some of these sources, such as satellite imagery, can provide high resolution information on today's landcover with accurate (often 1m accuracy) positioning, others, including airborne laser scanning (ALS) deliver high accuracy data on the contemporary surface.

The reason, why old records and maps are still of great value for archaeological research can be found only partly in the procedure of the modern protocol of archaeological topography. These maps, which are now categorized as historical maps, have been used as the only visual source data in field-based topographic researches with a modern approach that have been evolving for some 50 years. They are an invaluable source for any projects involving landscape archaeology elements, delivering snapshots of the past, revealing a glimpse of a landscape as it was prior to the massive regulation of rivers and the building of a modern transport infrastructure. Additional information on them, which former map makers thought worthy of note during their work, contained much historical and archaeological-related data. At the same time, without the availability of more precise technology, the data content and the topographical environments depicted in these historical maps have often only been identified either with great difficulty or some inaccuracies, with the result that the conclusions drawn from them often need clarification. However, especially in the process of unravelling the meaning and significance of remnant structures in the landscape revealed by aerial archaeology or airborne laser scanning they can provide essential clues for interpretation and also time depth.

Maps and GIS

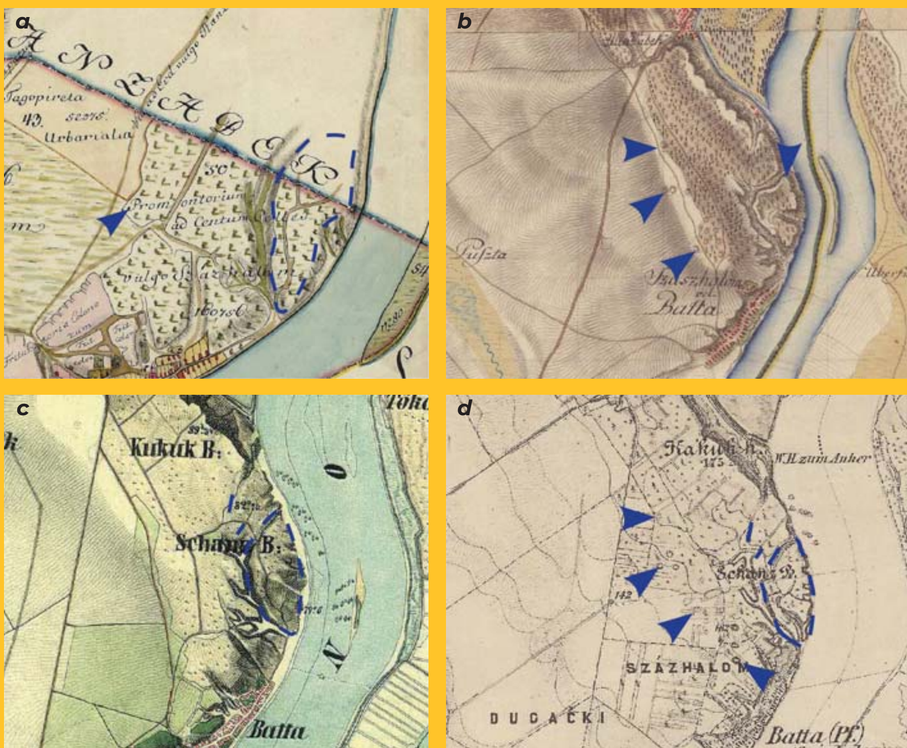
In the world of today with a situation of abundant data sources, the geographical information support and the potentials in the technology used provide much help in utilizing these historical maps. The identification and verification of the data content in these maps can be performed with unprecedented precision, thanks to the research that has been proposed for an interchange between the projections of these maps. Archaeology thus developed the capability to accurately locate objects and locations from old maps by means of modern positioning tools (GPS, Mobile GIS) during a field control. The utilization of historical maps, as mentioned above, is not new in archaeology, since research has already consulted these sources in the past. However, apart the above-mentioned change in quality (data identification), there is also a significant difference in its quantitative application. This is due to geospatial data processing. Those map data files that are available on digital media with appropriate projection and geometry can today be quickly and accurately verified with different GIS tools (given that these databases with continuous coordinate identifiers can manage large surfaces simultaneously, while the details are still available), and their data content can be easily updated on a modern topographic map, or even on other remote sensing data. This technology not only has the capability for comparing topographic environments, but also brings in that which is required for the better identification of the geographic names that are included in the available material. Topographic observations and museum collection trips undertaken since the end of the turn of the 19th and 20th centuries produced several descriptions, periplus-like archaeological guides based on known geographic locations in their own time, possibly still living in the collective memory, due to the non-widespread distribution of topographic maps. However, the results of geographic name identifications in subsequent research often proved to be inaccurate. Fortunately, databases are now available that contain geographically identifiable data on names from the margins of settlements, although this said its use does not allow for rapid control. This kind of utilization of the digital versions of historical maps has also accelerated the field control in this issue – even if not as deeply as the above-mentioned database would call for, because thanks to modern technology and with the help of the usual digital tools, these historical maps have become utilizable in the field in precisely the same way as paper-based topographical maps have been used in recent decades for field topography work.

The comprehensive digitalization and digital publishing work of public collections (e.g. National Archives of Hungary in Hungary) has been a milestone for the extensive use and “re-finding” of historical maps.

Map processing workflow

- Inspection of the digital, georeferenced versions of the Habsburg Military surveys in a GIS environment
- Re-georeference – if it is necessary – these map-sheets
- Seeking historical maps from archives, digitizing and GIS based georeferenced with help of the digital maps of the military surveys, if there are insufficient tie-points with the recent environment
- Resampling the newly processed data based on the maps legends and creating new historical and archaeological interpretation layer

Case study Százhalombatta (Hungary)



II.4.1.1 Figure 1. The burial mounds and the fortified settlement at Százhalombatta, Hungary, have been recorded in different cartographic sources. The cadastre map from 1795 (II.4.1.1 Figure 1a) shows the elevation of the settlement and the Latin name, 'Promontorium de Centum Colles', by the area of the burial mounds. The Josephinian Land Survey (1782-1785) offers an even more detailed picture of the site (II.4.1.1 Figure 1b). The area of the settlement and the round elevations of the mounds are clearly recognizable. According to this map, the site was mainly covered by vineyards at this time. Curiously enough, the engineers of the Second Military Survey (1819-1869) accorded less importance to the mounds; however, the site of the fortified settlement was recorded under its German name, 'Schanz B:(erg)' (II.4.1.1 Figure 1c). The Third Military Survey (1872-1884) depicts the fortified settlement as well as the barrows (II.4.1.1 Figure 1d). One other advantage of this source is the detailed illustration of the field division system of the late 19th century, which clearly influenced the actual situation.

II.4.1.1 Figure 2: The well-preserved mounds of the Early Iron Age site at Süttő, Hungary, were better illustrated on the map of the Second Military Survey (II.4.1.1 Figure 2a), while they are lacking from the map of the First Military Survey. The situation is exactly the opposite as compared with Százhalombatta, which can presumably be explained by the different approach of the drafters. The map of the Third Military Survey is of the quality described above for Süttő (II.4.1.1 Figure 2b).

The uses and limitations of historic maps

The general use of historical maps at archaeological level is unfortunately, limited to a significant extent by the fact that systematic mapping was virtually impossible until the middle of the 18th century. A collection of archaeological sites, resulting from a survey along the Danube conducted by Luigi Ferdinando Marsigli at the end of the 17th century (Danubius Pannonico-mysicus: observationibus geographicis, astronomicis, hydrographicis, historicis, physicis, perlustratus et in sex tomos digestus) is a very important step in the research of the former Danube limes, and the maps showing the Danube sections of the Mappa Generalis from the beginning of the 18th century are worthy of note in regard to the landscape archaeology. Despite the numerous archaeological aspects, the lack of scale resulting from the depiction makes the information difficult to interpret and localize accurately.

Significant archaeological value is represented by the maps from Hungarian regions that were made with the objective of settling land consolidations and border disputes after the expulsion of the Turks from Hungary (Pact of Sremski Karlovci, 1699). Typically, the maps representing the boundaries of a settlement did not contain a completely uniform system of criteria, symbols or colour codes, but these maps nevertheless shared a very similar design. Their scale is typically specified in Viennese fathom and their ratio depends on the size of the plot (1:14,470-1:28,800). In many cases, they contain archaeological information (like "Agger antiquus Kiraly Utya vulgo Kraljev put nuncupatus" or "Promontorium ad centum colles vulgo Százhalom") mainly about old roads and earthworks. A typical characteristic is that the terrain was only indicated in highly pronounced and accentuated areas with shades and colours as a result of the "á la vue" survey method. Different geographical names can be useful for identify the names used in old descriptions. In spite of the absence of projection and precise geometry, geo-correction can be made using GIS tools with the use of better identifiable points of the more or less still existing settlement boundaries, so they can be compared to today's topographic environment.

Digital Habsburg military surveys

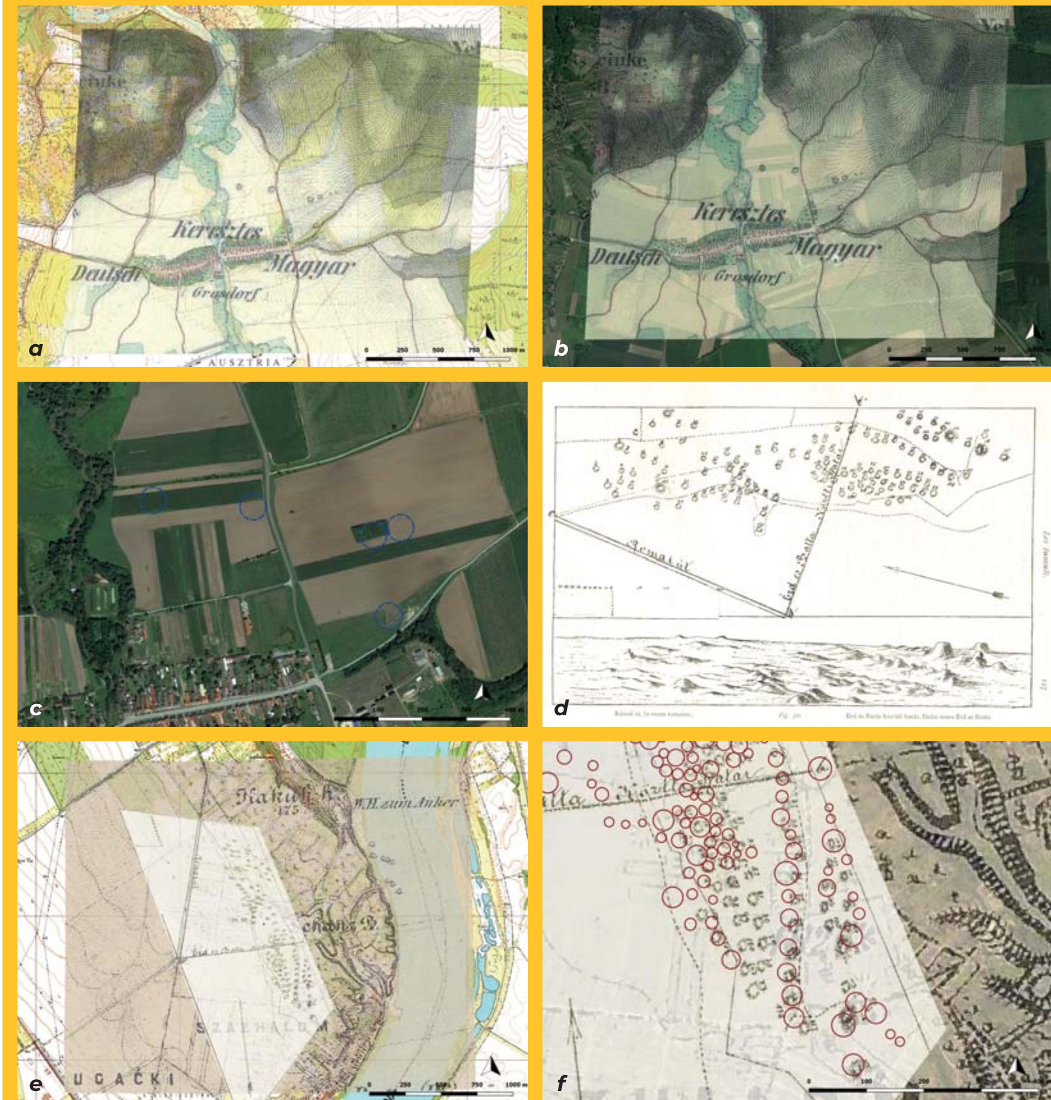
Undoubtedly, one of the most frequently used historical map source is the so-called the First Military Survey (or "Josephinian Land Survey"), which was the result of the military topographic survey in 1763-1787. Approx. 3400 sections were made from the 1:28,800 scale coloured hand-written topographic map covering the Habsburg Empire, which due to its historic extent is available for almost all parts of the countries involved in this project as successor states to the former imperial territories. These sections depict terrain, roads, structures, water networks, names of settlements and geographic formations and, for information purposes, the land use of agricultural areas. While neither altitude measurements nor levelling was done during the survey, with the maps not containing altitude data as a result, the terrain features were nevertheless highlighted and colour shaded on the map sections. In addition, the data content of each section is easily identifiable through the use of a unified signal system. The survey is lacking a projection system; triangulation and internal metering measurements result in a relative accuracy within the sections, but faults of even 200 m may occur at the sections joints.

The individual sections, or their details can be inserted in today's topographic environment with the help of suitable interface points using GIS solutions, but this can be successful mostly in the case of inhabited settlements, or in places where the location of certain features (such as bridges, wells) can be easily identified. Written data referring to archaeological features are rare (like e.g. "Türken hügel" the name Turkish hill used to label a Roman period tumulus). There are unique markings, however, that make the displayed topographical elements recognizable in the case of known archaeological sites (e.g. Érd-Százhalombatta, Vaskeresztes tumulus fields). It is a great help to scrutinize the data that the survey of the entire Habsburg Empire area can now be accessed through a digital database either in Internet or in special publications. In addition, digital data is not simply digitized by sections, but is completed with GIS support, place finders, and the availability of synchronous comparisons with other map files.

Similar to the Josephinian 18th century land survey, archaeological topography and landscape archaeology often involves the maps of the second military survey (or the "Franziszeische Landesaufnahme") in the research work. This survey, which started in 1806 and finished in 1869, used the experience of the previous survey, correcting its errors and re-measuring its areas. The scale of the sections was also based on Viennese fathom (1:28,800). Elevation measurements were also made, although these appear only as metrical elevation points on the map sections and terrain was still marked more or less graphically, with the so-called Lehmann's striping. When designing the map sections, a projection system and a sectioning method (Cassini-Soldner) were used. However, due to distortions, it can be considered to be a projectionless survey. At the same time, due to the methods used during the surveys, several attempts have been made to make coordinate conversions and georeferenced files for GIS applications based on the "pseudo-Cassini" projection of these maps.

As a result of these efforts the joined sections of this survey are now available with a coordinated network of different projections. Using a satisfactory database, one can not only access and read geographic data, but georeferenced quadrangles can be exported into a GIS environment as a base map. This greatly enhances the possibility of extensive use of maps and allows the accurate identification of archaeologically relevant features marked as additional information (e.g. the line of "Alte Römer Strasse" in the borderland of Bögöt/Vas county, Hungary; "Ruine" – in the borderland of Csabrendek/Veszprém county,

Historical maps in Iron Age research



II.4.1.1 Figure 3: A georeferenced version of the military surveys of the Habsburg Monarchy is available from the Arcanum company (https://www.arcanum.hu/en/). The accuracy of the rectification is different in each case, depending on the technical and reference system. The First Military Survey has an imprecision of at least 300-400 meters. This value was decreased to 50-150 meters by the Second Military Survey, which allows better implication regarding archaeological topography. The quality of the original rectification can be improved if we use better ground control points for a limited area. We used this method in the case of the burial mounds at Vaskeresztes in western Hungary. The rectified section of the Second Military Survey can be projected in a GIS environment conferring with modern cadastre maps and satellite images (II.4.1.1 Figure 3a-b). According to the interpretation, the possible location of the mounds can be mapped in order to determine the areas for geophysical surveys for instance (II.4.1.1 Figure 3c). The Third Military Survey was based on better geographical methods, providing an accuracy of approx. 50 meters. This map can be also used as a basis for the geoprocessing of other historical maps such as Sándor Varsányi's hand-drawn map showing the Százhalombatta site in 1847 (II.4.1.1 Figure 3d-e). Although the result is far from accurate, the distortion turned out to be lower than expected in comparison with the modern register of the burial mounds (II.4.1.1 Figure 3f).

Hungary), and for example the documentation of phenomena similar to the representation of the terrain patterns of the known tumulus fields (e.g. Süttő, Vaskeresztes).

Together with the above-mentioned map sources, maps of the so-called third military survey (or the "Franzisco-Josephinische Landesaufnahme") are also available today as a digital database, which can be easily used in digital form, with GIS software. This survey was made after the introduction of the metric system, and a significant difference is that this map is no longer based on the Viennese fathom, but uses a meter-based scale of 1:25,000. Although different from previous surveys, giving less emphasis to plastic representation, it is a very useful source of information, for example in identifying geographic names (parcel names).

Despite the challenges in making the results of the presented mapping events available in a generalized research environment, they provide us with data sets that make historical maps extremely valuable for landscape-archaeological investigations. In the area of the former Habsburg Empire they can be used as (symbolic) depictions of elements in space, helping us to identify and date objects and their development. They can show changes in the topography and hydrology, provide information on historic infrastructure and information on field shapes for the three distinct periods which they record.

Key facts - historical maps in heritage studies

- Coverage:
  - Habsburg Empire wide datasets
  - special local survey data
- Environmental dependency:
  - pre-regulation hydrological conditions
  - monitoring of agricultural land usage
  - visible archaeological phenomena
- Research levels:
  - digitizing
  - georeference
  - resampling
- Social potential:
  - landscape reconstructions
  - useful for education and the environment

II.4.1.2 Archival and cartographic aerial photographs, satellite images

András Bödőcs, László Rupnik, Michael Doneus

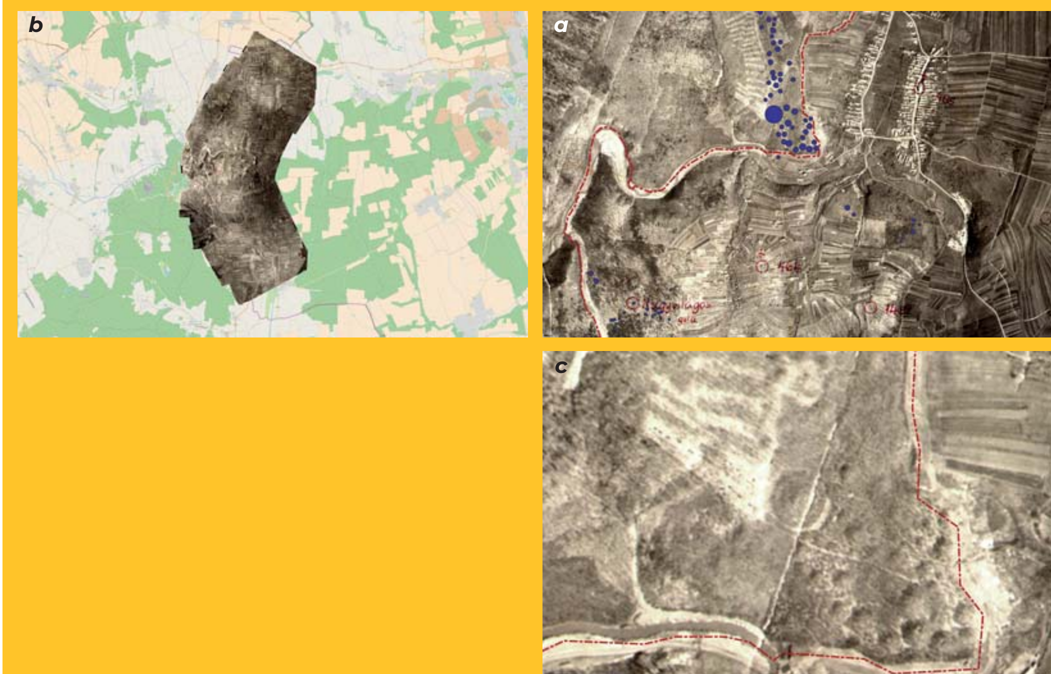
Introduction

The historic maps discussed in chapter II.4.1.1 were all produced from terrestrial surveys. Due to the recognition of its key role in World War I, aerial photography not only became a part of reconnaissance technology, but systematic air photography also moved into its position as an important fixed star in the production of topographic maps during the first decades of the 20th century. The technology (photogrammetry), which can put these pictures in an accurate, undistorted position, making the depicted landscape suitable for mapping, has developed quickly. As a result, national photographic archives usually have large stocks of (vertical) historical aerial photography, often covering significant territorial areas. Following the topographic mapping by the state, the military usually has a large stock of photographs from repeated reconnaissance flights. Additionally, various authorities such as those for water conservancy, forestry, and geodetic companies also often possess image archives. Many of these archives have so far gone unprocessed and it is entirely possible that the may contain an archaeological treasure trove of data.

These archived aerial photographs are an important source for archaeologists and cultural heritage managers, as they depict archaeological sites in their former landscapes and this will be also discussed in the chapter on aerial archaeology below. Environmental changes and transformations of sites and heritage objects during the last century can therefore be assessed. Any information that can be observed on historic aerial photographs can be mapped, including any kind of archaeological sites and features, such as former earthworks, tumuli, old roads, ramparts. Modern methods of image based modelling even make it possible to re-create historic topographic situations and identify topographical change.

It is therefore no surprise, that archaeologists and cultural heritage managers soon realized the archaeological potential of this data source. Unfortunately the majority of

Archive aerial photos



II.4.1.2 Figure 1: Archival aerial photograph series at the Austro/Hungarian border (between Schandorf/Narda and Pornóapáti) created in 1958 during the systematic aerial survey of Hungary's remapping process (II.4.1.2 Figure 1b). Between 1953-1958 the whole territory of the country was photographed. These pictures are valueable for archaeological research. For example in the region of Felsőcsatár (county Vas, Hungary) – Schandorf (Burgenland, Austria), several Iron Age burial mound groups were documented (II.4.1.2 Figure 1a). In 1958 a large tumulus field was still visible from the air due to the lack of the forest that today almost completely covers the surface (II.4.1.2 Figure 1c)

aerial photographs, whether vertical or oblique, that were taken between the two world wars were destroyed and only a handful of exceptions have been preserved from the 1920-1940s. Some of the images made before the World War II – mainly from military archives and rarely from publications – are merely indicators of the valuable resources that have been irrevocably lost.

The significance of those images depicting former terrain surfaces is becoming ever more highly appreciated as the years pass. Advances in digital technologies proved to be a great help in making these photographic images available to a large audience. The digital, or digitizer tools have made it possible to produce very good digital copies of old and vulnerable media, and the development of GIS technologies, including GIS database servers (e.g. Postgis) ensured that theoretically anyone can access these data through the World Wide Web. As a result, the number of people interested in this kind of source material has grown dramatically.

Online catalogues of archival aerial photographs are available, and in many cases, images can be downloaded for free. Wartime reconnaissance photography by the Allied Central Interpretation Unit (ACIU) or the Mediterranean Allied Photo Reconnaissance Wing (MAPRW) is an important resource covering large areas.

The basics of archival and cartographic aerial images

As explained in the chapter on aerial archaeology, flights for vertical photography cover a predetermined territory completely with stereoscopic images. This is achieved by flying routes, where the aircraft used cover the area to be photographed in parallel stripes. Photographs are taken along these lines with a 60% overlap. The overlapping area can be viewed and mapped stereoscopically (i.e. in 3D) with high accuracy (typically an accuracy of less than 10 cm is achievable from vertical photographs at a scale of 1:10.000). The individual stripes have an overlap of 30%, which is important for a photogrammetric restitution of the whole image-block.

Historical aerial photographs are available for each European country. However, the date of the oldest images and the frequency of coverage are different for each country and usually even for each federal state. In Hungary large-scale surveys began in 1953 (continuing until 1959). Detailed aerial photographs (~ 1: 10.000) therefore exist for the whole country. During the communist era, access to these photographs was difficult, but after the 1990s, it was possible to obtain high quality images from this period in the Historical Military Map Collection of the Hungarian Military History Institute and Museum, where this period is also complemented by images from the 1960s and 1980s. In 2012, the Hungarian armed forces allowed free access to almost all the previously concealed photographs. Additional archival photographs can be found on the webpage of the EU-financed Digital Aerial Photograph Archive Project since 2014, where the number of available georeferenced images continues to grow. These photographs were captured in 180 × 180, 210 × 210 or 230 × 230 mm films with black and white technique, which became a standard from the 1950s onward.

As mentioned above, the archaeological utilization of archival aerial photographs is not new. Successful attempts were made in previous centuries to identify archaeological sites such as those along the Danube limes. Today, digital copies of the analogue material are often available: Examination usually reveals even more archaeological traces, as the scans can be subject to image enhancement techniques.

Repeated coverage of an area allows the investigation of topographical changes, to examine the deterioration of some of the known sites, or to clarify information about old excavations.

With the removal of the ban on civil aviation (Open Sky Convention, 1992), opportunity were given to civilian cartographic flights in most parts of Eastern Europe, during which photographs were taken not only in the scales of 1:10.000 – 1:25.000, but also up to 1:5.000. In Hungary and Slovenia, for example, the mapping and archaeological impact studies preceding the construction of motorways have been made using vertical aerial photographs in to this scale. These images have a higher resolution and, due to their polychrome nature, they provide better site identification possibilities based on the discoloration of the vegetation and the soil.

The workflow of archival aerial archaeology

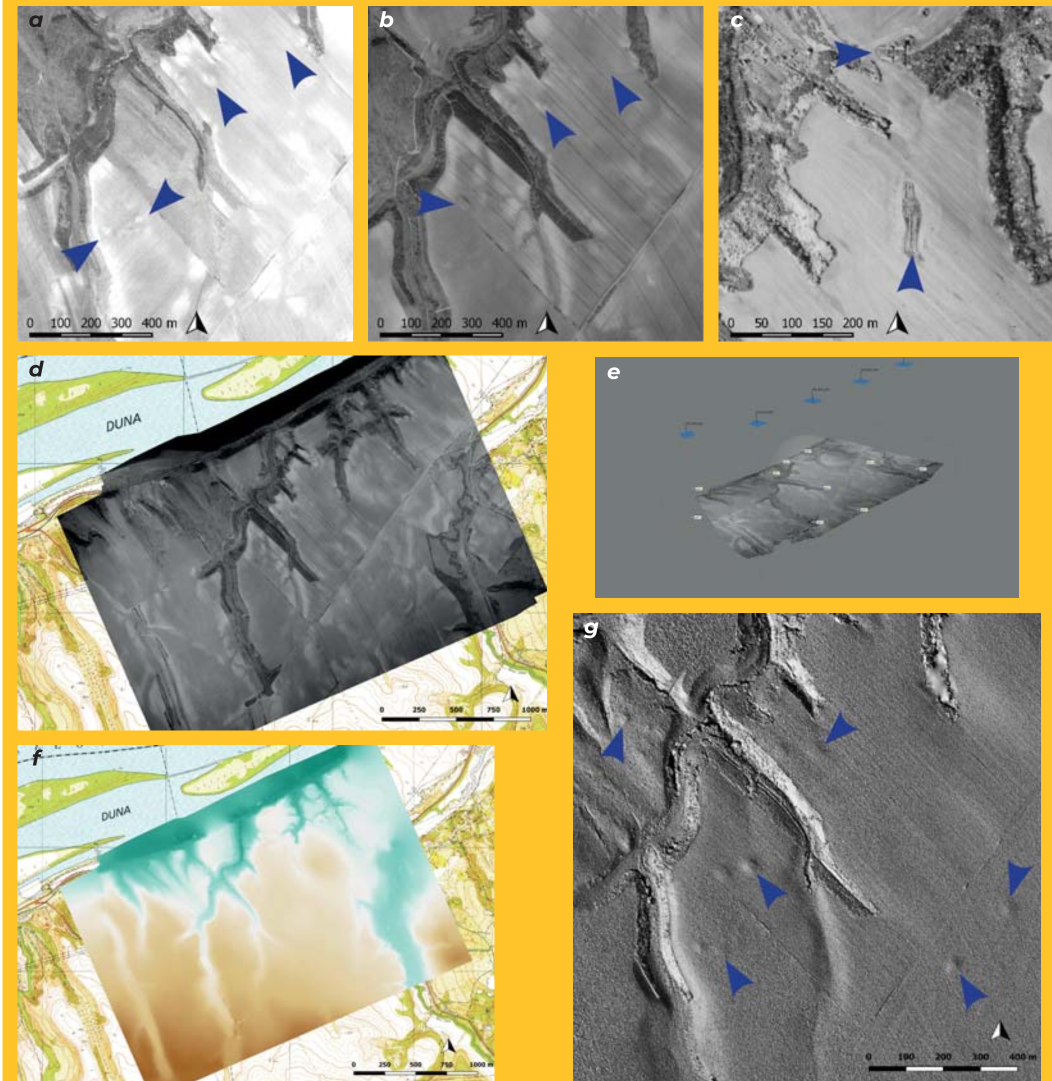
- Archaeological data collecting on archival aerial photographs
- Technical data collecting (camera model, focal length, date of recording, before WW2 flight altitude / barometer value) to achieve accurate results
- Fitting the photographs taken for mapping purposes to exact geographic coordinates and inserting in a suitable location using GIS software
- A more accurate image preparation can provide precise orthophotos, e.g. undistorted images and 3D models
- GIS-based archaeological interpretation

It is important to know that in order to map archaeological traces, historic photographs need to be rectified. Most GIS packages are able to make simple transformations to geo-reference vertical photographs, however, unless the depicted topography is completely flat, the transformed images will still contain considerable displacements.

The photographs need to be processed with specific software using the methods of digital photogrammetry in order to obtain more accurate results. When this is done, however, a few parameters (e.g. the calibration protocol of the used vertical camera including focal length, lens distortion, coordinates of the main point and coordinates of the fiducial marks) have to be known in order to achieve accurate results. Some of the desired parameters are depicted on the margin of each vertical photograph, otherwise it is usually possible to get the calibration protocol from the camera manufacturer based on the camera number (which is also depicted on each photograph). Additionally, image based modelling (often equated with "structure from motion – SfM") software is usually a cheap and adequate solution for the generation of othorphotographs, which are accurate enough for archaeological mapping. All of the mentioned methods need a set of ground control points to be able to establish the relation between image (or image block) and the Earth's surface.

The processed images have the potential to provide a detailed 3D surface model of the date when the source photographs were taken. This helps to provide accurate positioning for the interpreted archaeological features, such as 3D models of ramparts, earthworks and tumuli.

Archive aerial imagery in Iron Age research



II.4.1.2 Figure 2: Although the majority of the archive aerial images were originally made for non-archaeological purposes, they can be very informative for archaeological research in several respects, among which the monitoring of the changes affecting a site is one of the most essential. Sometimes, this is the only way of investigating a site that was subsequently destroyed to some extent. If the capturing was well-timed, the soil marks of the archaeological features can be observed. The burial mounds and some other trenches could be detected under different circumstances at Süttő in 1960 (II.4.1.2 Figure 2a) and 1975 (II.4.1.2 Figure 2b). The series of images from 1987 proved to be very useful in one particular respect. They were taken at the same time as Gábor Vékony and Éva Vadász's excavation of the site (II.4.1.2 Figure 2c). Although the plan of the site is still lacking, the location of the trenches could be reconstructed through the rectification of these images. 3D photogrammetry offers various options such as generating absolute ortophotos (II.4.1.2 Figure 2d-e) and the creation of a digital elevation model (DEM) of the surveyed area (II.4.1.2 Figure 2f). The model can be detailed to the extent that even the elevation of the burial mounds are detected (II.4.1.2 Figure 2g). Its accuracy is limited, among others, by the resolution of the original images, the type of the vegetation and the quality of the ground control points (GCP). Although the effectiveness of this method cannot be compared to airborne laser scanning (ALS), it does provide new possibilities for the archaeologists, especially if the site was destroyed.

Satellites

Although the application of satellites for remote sensing purposes has begun in the 1950s with the start of the Corona programs (officially named KH-1 – KH-4), the launch of the Landsat program (1972) was the beginning of a new era in the relationship of remote sensing and satellites. The resolution of the images produced by multispectral sensors on satellites (initially 60m and then 30m pixel resolution) did not allow their direct utilization in the search for archaeological sites for a long time. This does not mean, however, that results from satellite data analysis, such as environmental reconstructions, have not been used. The best terrestrial resolution has always been provided by the pictures of the panchromatic band and the use of this data source in archaeology began with the utilization of these "aerial photograph-like" images. By the decryption of Corona data in 1995 (February 24, 1995. Executive Order 12951.) for example, archaeology in the Middle East received an enormous potential boost that was also quickly incorporated in publications.

Satellite image analysis tools in GIS software today often provide direct access (E.g. the Semi-Automatic Classification Plugin in QGIS developed) to Landsat data (LS 4 – 8) from the U.S. Geological Survey (USGS) archive, facilitating its broad access. This makes them much simpler for use, for example, in landscape archaeological research. The satellite "site hunt" for archaeological purposes, however, undoubtedly began with the widespread use of the Google Earth program, originally launched under the name EarthViewer by Keyhole Inc., which was purchased by Google in 2004. The software still uses the Keyhole Markup Language (KML) format used by the developer company. The resolution of satellite imagery available within the software has become higher and higher over the past one and a half decades thanks to the images from Ikonos, GeoEye-(1,2), Pleiades (HR-A.B), etc. used in the program. Their field resolution now approximates the accuracy of half a meter, which is close to what is used in aerial archaeological research to identify archaeological sites.

Key facts – archive aerial photos and satellite data in heritage studies

- Coverage:
  - country wide datasets
  - special periods of aerial surveys
- Environmental dependency:
  - very useful in areas, where "dramatic" changes occurred and for monitoring landscape changes
  - interesting results with visible archaeological phenomena
- Research levels:
  - digitizing
  - georeference
  - resampling
- Social potential:
  - landscape reconstructions
  - 3D surface model and data visualisation

II.4.2 Archaeological surface survey

Luka Gruškovnjak, Susanne Tiefengraber, Matija Črešnar

Introduction

Human life with its material culture has always been predominantly played out on the landscape surface. On that surface people have lived and died, travelled and settled, they hunted and gathered and also herded and farmed, they worshipped in the landscape they inhabited and exploited its natural resources. Through such activities, they left traces of their past lives, which we are now discovering as an archaeological record in the present. Through all of their activities, past populations had been creating and using cultural materials, be it in the form of buildings or objects, which constitute an important part of this record. After they reached the end of their useful lives, either through destruction, deposition, discard, abandonment, or from simply being lost, these cultural materials became part of the archaeological record and to a great extent this initially occurred on the surface of the past landscapes. At that moment, these remains began their long and complex post-depositional formation history through which they have been subjected to countless processes, which work to transport, transform and destroy them and often eventually bury them below the surface, where they may remain until archaeologists discover and excavate them in the form of subsurface record. However, many circumstances may also have resulted in cultural materials never being buried and remaining on the surface, or they may have been buried only to be exposed again at a later time in which case archaeologists discover and investigate them as an archaeological surface record.

The principal method to discover and investigate this surface record is an archaeological surface survey, known also as field walking, pedestrian survey, surface collection etc. It is one of the archaeological methods with a long and honourable history since "surface finds and standing structures attracted the attention of the earliest antiquaries before a spade was ever lifted to disinter the past" (S. J. Keay, M. Millet, 1991, 202). Its development started in the 19th century in the form of unsystematic intuitive approaches rooted in the tradition of classical archaeology and archaeological topography. During the 20th century, especially after the World War II new theoretical frameworks, research orientations together with changed social and economic circumstances initiated the development of various systematic approaches and this process of development is still continuing today.

The basics of surface survey

The non-destructive method of surface survey can be applied as an individual research method, but it is even more powerful in combination with any other (non-destructive) prospection method, e.g. aerial photography, airborne laser scanning, geophysics etc., bound in a multi-method research approach, where the weaknesses of one method are surpassed by the strengths of the others.

The principal goals of surface survey traditionally include discerning of settlement patterns and other forms of past human behaviour in the landscape, studying of interactions between past populations and their natural environment, predicting the characteristics of the subsurface record, and discovering the archaeological heritage for purposes of its protection and management in the rapidly developing and changing modern landscape.

There is no universal approach to conducting a surface survey because its use has always been rooted in strong methodological traditions of various regional projects, dealing with different geographical areas, chronological periods, archaeological cultures and research questions. Only a few among many possible approaches used in the past or still in use today include:

The site survey approach uses sites as basic units of observation and thus detection when surveying large areas or entire regions. It is based on traditional antiquarian and topographical approaches and an understanding of the archaeological record as consisting of dots in the landscape, i.e. sites, where large quantities of surface finds and/or features can be found. This approach is based on traditional preconceptions of what a site is and how it should manifest itself on the landscape surface. Consequently, it is biased towards very obtrusive sites but is not capable of detecting less conspicuous, smaller and ephemeral sites, not to mention off-site activities and traces of non-sedentary populations and thus its use is discouraged. The site survey approach should not be confused with intra-site, however, which is a survey within a site and which, especially when combined with other prospection methods (e.g. geophysics), is a strong tool for understanding sites, site formation processes etc. and a good foundation for further research.

The off-site (also distributional, non-site or siteless) survey approach is the very opposite of the site survey approach and sees the archaeological record as being a continuous phenomenon since the activities of past populations were not limited to sites but were performed throughout the landscape. Thus, its goal is to discover sites as well as to investigate the areas in between them. The basic unit of observation in such surveys is the artefact and the quantification of recovered artefacts is used to discern site and off-site distributions. Artefacts of different periods are quantified separately because site and off-site areas of different archaeological periods and cultures will typically manifest themselves with different quantities of surface artefacts. Most prehistoric periods in most regions for example, commonly manifest themselves with very low surface artefact densities and thus, in contrast to the site survey approach, an off-site approach will be capable of detecting a prehistoric site on the basis of very few artefacts, and possibly even on the basis of only one single artefact.

Un-systematic (intuitive) survey, stemming from the topographical tradition, may be used for detecting new find spots or sites (un-systematic site survey), collecting (random) finds, and acquiring very limited information about some basic characteristics of sites (surface conditions, standing features, artefact density, chronology, site type etc.) in a wider area, mostly on pre-targeted locations. The un-systematic approach should be avoided and is only rarely methodologically justifiable, for e.g. during preliminary prospections in order to help in the planning of a systematic survey design.

Probability sampling survey uses one of the statistical sampling designs in order to sample only a certain percent of the region or site. Samples acquired in this way are then used to make statistical statements about the entire sampling universe, which may be as large as an entire region or as small as a single site. Probability sampling was especially promoted and widely used by processual archaeologists, mostly as a regional site survey, but has since been subjected to many critiques and is thus not widely used anymore.

Systematic survey, in contrast to probability sampling, samples the whole survey area, i.e. uses full/total coverage, with the intention of detecting new sites and off-site distributions in the landscape. It may also be used as an intra-site survey in order to acquire additional information about detected (by surface survey or other prospection methods) or previously known sites.

These are only the main approaches, connected to general trends in the methodological history of the surface survey and many more could be mentioned and described (e.g. collection vs. non-collection survey, point sampling survey, discovery vs. property based survey techniques, methodological controls). Despite the multitude of approaches and different trends, emerging throughout the long history of this method's development, a general agreement has mostly been reached about the need for systematic coverage of the whole survey area and quantification of surface artefacts, which are the basic unit of observation. We will thus focus further solely on this approach, while acknowledging that other complementary surface survey strategies, as well as other prospection methods, could and should be used in survey design, the decision making on which ultimately depends on the goals of the survey, the natural and cultural characteristics of the survey area as well as the available for its execution.

In decision making on survey design, the key parameters to be considered are coverage and intensity. Coverage refers to the extent of the area covered by the survey, while intensity refers to the recovery rate of surface artefacts and to the spatial resolution of the data gathered. When speaking of recovery rate, one is dealing with the question of how much is discovered or missed by the survey. The answer to this depends to a great extent on the survey strategy, determined by the shape, size and spatial layout of the survey grid used to cover the survey area. Transects or quadrants are the basic shapes most commonly used. By reducing their size and increasing the search time along transects or within quadrants, the survey and its recovery rate are intensified. Spatial data on artefacts, recovered during the survey, are documented by either aggregate or point provenience. In the case of aggregate provenience, the units of the grid are also used as collection units, meaning that all artefacts recovered within a unit are assigned to it without documenting any other more detailed information on their spatial distribution. In this case, the size and shape of the units greatly affect spatial data resolution, and the smaller the size the greater the resolution. With point provenience, on the other hand, the exact find-spot of every artefact discovered is precisely measured with total station or GPS, thus allowing for full spatial resolution. The key issue to consider, when deciding on appropriate coverage and intensity for reaching the goals of the survey, is that more intensive surveys are more time consuming and consequently do not allow for spatial coverage of large areas. Thus while it is possible to achieve a very high recovery rate and spatial resolution within a smaller area, it can also happen that this area is too small to be representative and useful from a regional point of view. On the other hand greater coverage can be achieved by lowering the intensity and thus increasing the rate at which new data can be of gathered through larger areas of the landscape, while the artefact recovery rate and spatial resolution are much lower.

Another basic but at the same time very complex parameter, crucial for the understanding of any surface survey, is the visibility of the archaeological record on the landscape surface. It is affected by a series of factors, which can be broadly described in five factor groups. They must be considered both in decision making on survey design as well as in the analysis and interpretation of survey results. These factor groups are determined and influenced by (1) geomorphic, pedogenic and other post-depositional formation processes, (2) the nature of the archaeological record, (3) methodological decisions, (4) surface and other environmental conditions during survey and (5) the human factors or fieldworkers themselves (for short descriptions see below).

Workflow

The workflow of a systematic surface survey project consists of several phases, depending on the characteristics of the survey area, the amount of data already available from previous research, the basic goals or research questions of the survey and on resources available.

The preparation phase is dedicated to background research of the survey area. Its goal is to gather the necessary cartographic material and all relevant sets of existing cultural and environmental data about the survey area. The cultural dataset is composed of archaeological, ethnological and historical information as well as data on historic and modern land-use. The environmental dataset is composed of information on geology, pedology, geomorphology, hydrology, meteorology and biology of the area.

What follows is the preparation of the basic survey design. If sufficient data is not available, it may have to consist of preliminary prospections in order to acquire the necessary data. The survey area is divided according to environmental data and data on past and recent land-use, on the basis of the information gathered. Existing archaeological knowledge informs us further about the typical material remains to be expected, the sizes of archaeological sites or other features, in addition to the expected obtrusiveness, clustering and density of archaeological sites, features and artefacts. In dependence on all of these data different parts of the survey area may require different intensities or even strategies in order to reach the desired level of recovery. Some parts may not be appropriate for conducting the surface survey at all and other prospection methods will have to be used.

In this subsequent (fieldwork) phase, the whole survey area should be covered, using the defined strategy. Using transects is usually most appropriate for conducting surveys of large areas of the landscape, whereas quadrants are mostly used for less extensive survey areas. Precise spatial controls of the work done should be used, by measuring coordinates of survey plots with GPS or total station. An essential task during fieldwork is the detailed recording of factors affecting the visibility of the archaeological surface record and of archaeological surface features (e.g. terraces, ramparts, ditches, barrows etc.) in relation to the survey grid. This is achieved by using descriptions, drawing sketches, photography, photogrammetry and/or coordinate measurements as appropriate. After the processing of the retrieved material and other information is completed, the gathered data is analysed and the results are expected to give at least a general picture of the distribution, indicating areas where further investigation is needed. On the basis of these results, at least preliminary answers to the basic research question will probably have emerged and additional more detailed research questions may now be formulated and explored through further phases of research. These are executed in the form of more intensive surface surveys of specific areas and/or with other archaeological research methods in order to answer more detailed research questions, formulated on the basis of previous surface survey phase and/or results of other prospection methods (e.g. remote sensing, geophysics etc.). Usually, the intensified survey is dedicated to research potential sites (intra-site survey) in order to confirm or disprove their presence, and possibly estimate their size, period, type and internal structure. The use of a smaller quadrant grid for aggregate provenience or close interval transects for point provenience is usually most appropriate for such intensive surveys in order to assure the necessary spatial resolution. As further understanding of the natural characteristics and of the nature of the archaeological record in the survey area is being reached during this and further phases, more and more

Workflow surface survey

- Definition of the survey area and of the basic research questions and survey goals
- Background data acquisition and possible preliminary prospections
- Preparation of the basic survey design for total coverage of the survey area
- Preparation of documentation material, technical instruments, survey team
- Execution of total coverage survey
- Processing of retrieved material
- Analysis of the results and comparison with the results of other prospection methods
- Definition of more detailed research questions
- Preparation of survey design for more detailed and intensive resurveys of specific areas
- Execution of more detailed and intensive surveys
- Processing of retrieved material
- Analysis of the results
- Planning and execution of possible further survey phases or application of other research methods
- Comparison with the results of other research methods
- Interpretation and publication of the results

detailed research questions can be formulated and more and more appropriate research strategies designed for answering them.

Application and limitations of a systematic surface survey

The systematic surface survey can be applied on the one hand, to large parts of the landscape or entire regions, defined either naturally or historically, while when conducting development led projects the survey area is limited to the area of the scheduled interventions (e.g. a motorway, railway, airport etc.). The most basic goal of such surveys is discovering new archaeological sites and off-site distributions. On the other hand, it can be applied to already known sites or other archaeological entities in order to gain further insights into their nature and structure. One must bear in mind, however, that covering large areas with systematic surveys can be extremely expensive.

The application of the method in the field is relatively straightforward, while the interpretation of the results can be extraordinarily problematic, because they are full of biases stemming from the wide range of different factors, which determine the visibility of the archaeological record on the surface. Even though these factors are in complex interactions, for the sake of their easier understanding, it is convenient to briefly describe them in groups formed in accordance with their shared characteristics.

The first factor group is determined by post-depositional processes, affecting the visibility, preservation and integrity of the archaeological record. These include natural and anthropogenic processes that bury and expose archaeological remains, move or transport as well as progressively degrade them. Only those parts of the archaeological record, which are exposed on the land surface, can be detected by the surface survey. That is why the method is generally applied much more successfully in arid and semi-arid zones where most of the record is exposed due to erosion or lack of sedimentation, while in temperate zones where most of the record is buried, it is primarily applied to ploughed fields and other areas of exposed and damaged ground surface. Thus, the surface survey is biased towards detecting exposed and damaged parts of the archaeological record and from this perspective, its results do not speak about the full distribution of sites, settlement patterns, past human activities or properties of the subsurface record but primarily about the taphonomy of the landscape. Consequently, archaeological site registers, which are solely based on surface surveys results usually display a strong imbalance between different types of sites, e.g. settlements and burial places. Only in areas where post-depositional processes cause the archaeological record to be visible on the surface can a surface survey be applied in which case further factor groups affecting visibility must be considered.

The second factor group is determined by the nature of archaeological surface record itself, key factors here being obtrusiveness, clustering and density of artefacts. The surface survey is biased towards discovering obtrusive artefacts, high-density distributions and clustered distributions. It is also biased because its main unit of observation is the artefact, which is only one of the main constituents of the archaeological record, others being features, anthropogenic soil horizons, organic remains, chemical and geophysical anomalies as well as other less obvious modifications, caused by past human activities. Furthermore, it is biased because it relies heavily on the quantification of artefacts to interpret the results as sites or off-site distributions, while in different types of sites constituents of the archaeological record are present in different ratios. Thus sites may manifest themselves at lower densities than off-site distributions and some periods and site types may manifest themselves with very few or no artefacts.

The third factor group is determined by methodological decisions made during the survey project and some strategies may not be sufficient to reach the goals of the survey. In addition the precision, reliability and accuracy of the results and the validity of their interpretation is hard to assess when using only standard discovery procedures. Furthermore, the surface survey is a form of sampling, but very little or nothing is usually known about the sampling universe. Thus, when using only the standard discovery procedures described here the size of the sample remains unknown and the validity of statistical procedures used to interpret the results is limited. This could be mended by incorporating very intensive research techniques and methodological controls into some of the phases of survey design. These approaches, a description of which is beyond the scope of this text, can be used to investigate the properties of the sampling universe and to assess the effects of all factors determining visibility on the precision, reliability and accuracy of survey results.

The fourth factor group is comprised of surface conditions, accessibility and other environmental conditions (lighting, weather, flora, fauna etc.) during the survey period. Some surfaces are not accessible due to strong vegetation, difficult terrain, buildings or property owners, who prevent access, and such areas cannot be surveyed. Total coverage of the survey area is almost never possible due to these hindering factors and as a consequence we are always dealing with surface samples or incomplete distributions. Among generally measured aspects of visibility during the survey is the assessment of ground surface exposure in relation to ground cover in order to mathematically correct the biased results during their analysis. However, a variety of other factors also affect visibility which is why simple correction formulae cannot rectify all the biases that differential visibility conditions incorporate into survey results.

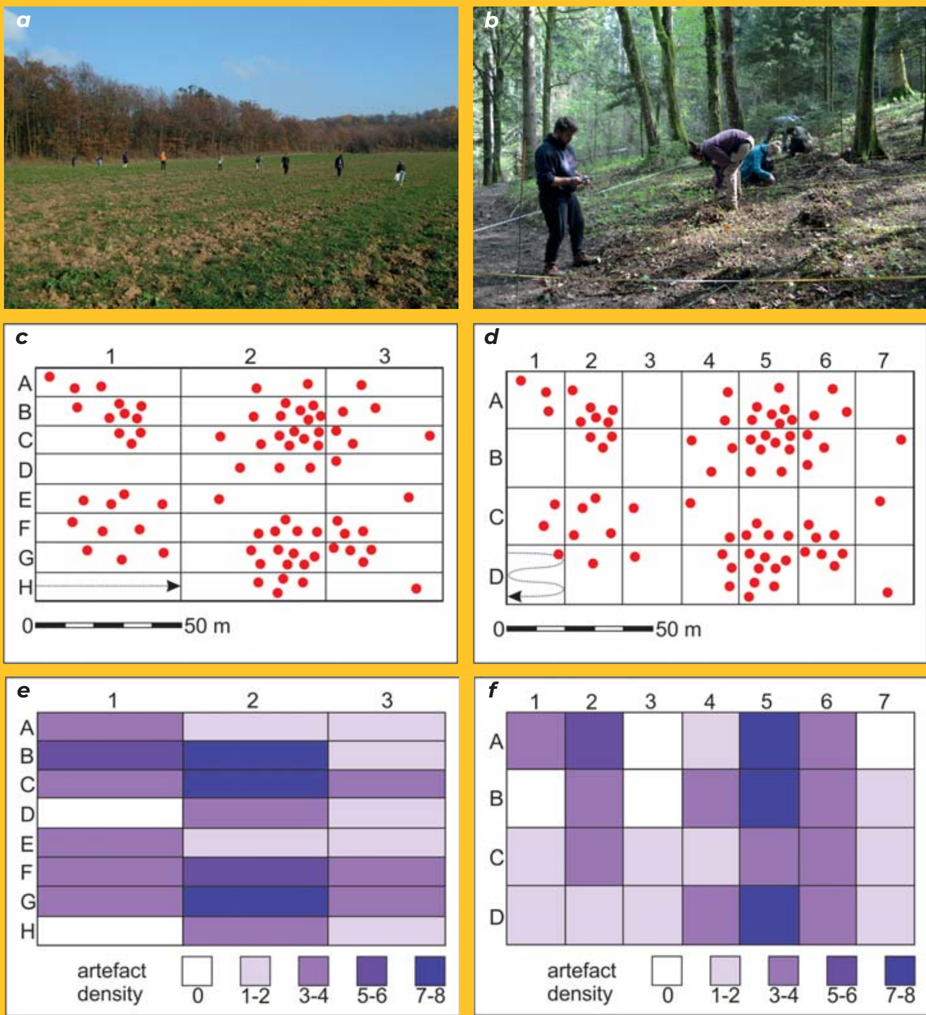
The fifth factor group includes the human factor or fieldworkers ourselves/themselves for ultimately what will actually be detected and collected in the field depends on us/them. The effectiveness of recovery may vary depending on the experience, motivation, mood, visual focus etc. The greatest problem is that in the presence of a mixture of different types, materials and/or colours of artefacts human attention and visual perception becomes unequally distributed and biased towards and/or against certain specific types, materials and/or colours of artefacts.

Taking all of these limitations into consideration surface survey projects should always incorporate other complementary methods and use an interdisciplinary approach both in the survey design and in the interpretation of the results. All archaeological prospection methods will greatly enhance the results since they are designed to detect different constituents of the archaeological record in the landscape in many different ways. Remote sensing methods and geo-/pedo-archaeological or earth science methods, such as fine-scale soil mapping and geomorphological mapping, geophysics, geochemistry etc., incorporated into survey design will prove essential in the assessment of landscape evolution and taphonomy. Such data will help to reveal their effects on the visibility and preservation of archaeological record in the landscape as well as help to gain an understanding of how a past environment affected the interactions of past populations with the landscape they inhabited thus shedding light on those behavioural aspects that archaeology is most concerned with.

Key facts – surface survey in heritage studies

- Coverage:
    - From regional scale to site scale
- Environmental dependency:
    - Very useful on geomorphic surfaces with low sedimentation rates
    - Useful on exposed and damaged surfaces (e.g. ploughed fields, erosional geomorphic surfaces)
    - Very limited use on depositional geomorphic surfaces
    - Highly dependent on vegetation – useful on surfaces with no or low groundcover
- Research levels:
    - Level 1 Prospection
    - Level 2 Delineation
    - Level 3 Characterisation
- Social potential:
    - Cultural heritage management
    - Landscape taphonomy studies

Surface survey



II.4.2 Figure 1a: Walking along a transect grid in the flatlands of Kreuttal/Lower Austria (photo: Joris Coolen)

II.4.2 Figure 1b: Searching within a quadrant grid on the forested hillfort of Cvinger near Dolenjske Toplice/Slovenia (photo: Manca Vinazza).

II.4.2 Figure 1c-d: Examples of a transect (c) and a quadrant (d) survey grid with a dotted arrow-line indicating the walking path followed during the survey. The same hypothetical distribution of artefacts documented with point provenience is shown in both cases. Four clusters of artefacts and a few isolated finds can be seen in full spatial resolution. For reasons of simplification an unrealistic 100 % recovery rate is presumed for both Figures 2 and 3.

II.4.2 Figure 1e-f: Examples of aggregate provenience results for the same hypothetical distribution shown in Figures 1c-d. Both in the case of a transect (c) and a quadrant (d) grid, a smearing effect occurs, disguising spatial patterns and associations of artefact distribution, although the effect is somewhat lessened in the case of quadrant grid. In the analysis of such aggregated data one is always faced with the modifiable aerial unit problem, which arises because arbitrary areal units are used for documenting a continuous space, resulting in arbitrary spatial patterns, which are an artefact of shape and size of units used, thus reducing the validity of interpretations reached using such results.

Surface survey

II.4.2 Figure 2a: Site localization by GPS at Falkenberg, micro-region Strettweg (Styria/Austria) (photo: Susanne Tiefengraber),

II.4.2 Figure 2b: Survey in rough, steep and heavily vegetated zones at Schlossberg Graz (Styria/ Austria) (photo: Susanne Tiefengraber)

The starting point of each archaeological survey is to locate the prospection area. For this reason it is useful to measure the coordinates with GPS or laser tachymeter to fix the plots within a geographical or cadastre system. Aerial photos or ALS-images could provide the support required because these often show a considerable depth of detail, which helps to pin down the location.

If the basic collection unit is a transect grid, each walker must pick up everything that he can see without deviating from the allocated line. Initially it is necessary to determine the survey area, a starting point, respectively a starting line corresponding to the terrain. The survey-crew must be distributed along these starting lines with an appropriate distance maintained between each of the crew members. Subsequently the team members walk in usually straight line transects. They should use compasses in order to stay on course and also run tapes, place stakes or pin-flags. In the case of a survey in a quadrant grid the team members survey entire defined areas in a limited period of time.

Sometimes terrain conditions, such as those in rough, steep and heavily vegetated zones, will not permit walking in straight lines. Under these circumstances it will be useful to divide up the prospection area into small parts, corresponding to topography and mark them for example on cadastre based ALS pictures. When operating with this strategy, however, no assumption about the structure and meaning of artefact distribution is possible. The result will reflect only a general statement about human activity at the survey area. In certain cases the gathered finds, in connection with surface formations such as terraces, ramparts, ditches and barrows enable a more precise interpretation of the site.

In some cases, it is possible to assign the artefacts to activity-based categories. For this reason it is important to obtain information about the distribution of these artefacts by measuring each find spot with a laser tachymeter. Sometimes it is possible to discover remains of architectonic structures or artificial terrain modifications. In such cases it is essential to ensure that these features are carefully recorded by drawing a sketch, description, photo, calibration, photogrammetry, structure from motion (SfM) to obtain a connection to the collected finds.

Surface survey in Iron Age research: micro-region Strettweg (Austria)

II.4.2 Figure 3a: Settlement terraces in the forested area of Falkenberg near Strettweg (ISBE/ Tiefengraber).

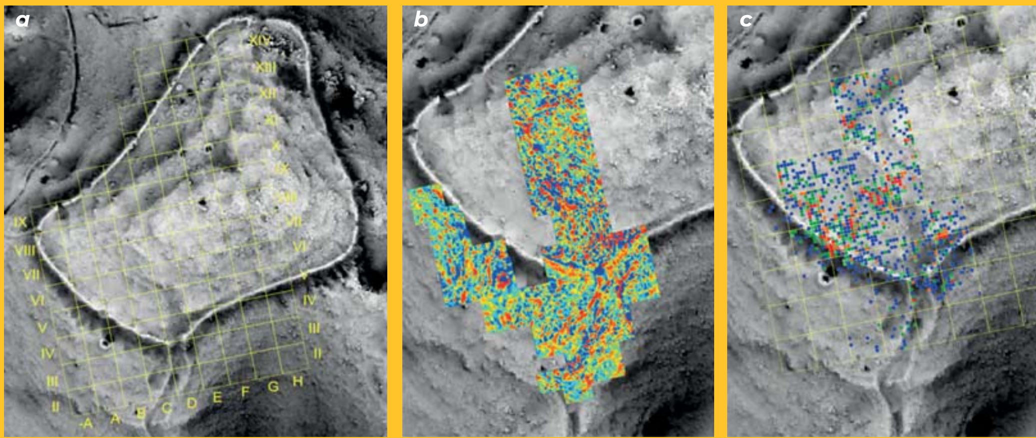
II.4.2 Figure 3b: Artefact and structure location by laser tachymeter, near Strettweg (ISBE/ Tiefengraber).

The micro-region Strettweg, where the famous "Cult Wagon" was discovered in 1851, has a special geographical position within the federal state of Styria in Austria. A very large and fertile inner alpine basin surrounded by wooded mountain ranges and intersected by the rivers Mur and Pöls defines this area. The Iron Age landscape acquired a special imprint with terraced settlements on the hilltops and associated tumuli-groups in the lowlands.

The use of different survey methods is thus mandatory to assess the situation. Formerly it was necessary to conduct several investigations, such as airborne laser scanning (ALS) and aerial image analyses together with a study of written sources. The survey team selected the field walking areas based on the results of this work. The conditions in the settlement zones, such as Falkenberg near Strettweg, were all very similar as a result of their positions on forested hilltops with mostly steep slopes. For this reason, the possibility for surface observation was limited and an unsystematic survey had to be the strategy of choice. Only at places without vegetation on the slopes or under fallen trees and those areas without natural vegetal cover was it possible to detect pottery sherds. Nevertheless, at nearly all of the settlement terraces remains of human activities could be determined and mapped. In the frame of small-scale excavations, conducted at a few of these hilltop settlements, it was possible to confirm the survey results.

The difficult terrain conditions in this area have kept the destruction caused by agriculture and construction work to a minimum. Extensive surface damage has usually been caused only by forestry activities and forest road building, but natural changes of the archaeological record have also to be taken into consideration.

Surface survey in Iron Age research: micro-region Dolenjske Toplice (Slovenia)



II.4.2 Figure 4a: Hillfort area with the basic grid division, a foundation for all the applied prospections.

II.4.2 Figure 4b: Results of the magnetometer survey (preparation: I. Medarić).

II.4.2 Figure 4c: The distribution of slag after surface collection in 2017 (blue / green / red – increasing density).

The systematic surface survey was also a part of the interdisciplinary research conducted at the Cvinger hillfort and its surroundings. The completely forested area of the settlement was divided into a 20 x 20m grid (a), as also used for geophysical measurements (b) and geochemical mapping. For the purpose of surface collection (c), it was further sub-divided into 2 x 2m quadrants, i.e. sampling/collecting units.

After planning the survey in accordance with the already existing results of the structural analysis and the geophysical measurements (e.g. magnetic measurements – b), the survey was carried out in two consecutive campaigns of one month each with a team of up to eight people and sharing the same survey system. The movable grid was also used for the simultaneous mapping of surface magnetic susceptibility (with Kappameter), collecting important information about surface layer condition, and also for a metal detector survey, which was only used, however, for mapping (and not excavating!) of objects containing iron, since the method is an important aid for the analysis and interpretation of magnetic measurements.

After the processing and analysis of all the finds, the results were compared with the results of ALS data and geophysical method analysis. While the interpretation in its entirety is complex, an example can already illustrate the value of interdisciplinary work (a, b, c). A terrace can be recognized (quadrants CVI-DVI), where there is also a clear correlation between the most obvious anomalies in the magnetic map (red marks the strongest detected anomalies), pointing probably to thermo-remanent magnetization and the most dense occurrence of surface iron slag (density: blue<green<red). This correlation points to a possible area of iron production, probably a smithy, where high temperatures were used and slag was produced as waste and discarded. The analysis is not over yet, however, and the preliminary interpretation has to be evaluated in the next steps of our research.

II.4.3 Surveys with soil analysis and archaeological soil chemistry

Roderick B. Salisbury

Introduction

Human activities such as farming, cooking, building, butchering, fertilizing, walking, cleaning, digging, plastering, mixing paints and pigments, stabling animals, and others all change the soil. These changes include elevating or depleting specific elements, raising or lowering the pH values, altering mineral magnetic susceptibility and depositing fats and proteins, all of which leave identifiable chemical traces. Soil chemical surveys can identify variations in the concentration of specific elements that are associated with these various activities. Thus, much as in terrestrial and aerial remote sensing, soil chemistry can be used to locate and interpret traces of human activity that might otherwise not be obvious.

Archaeological soil chemistry is not widely used as a prospection method, although recognition of the method is increasing, and technological advances are making it easier to use in most archaeological projects. Soil phosphate survey has been the most widely used method of chemical prospection in archaeology, but technology has advanced and multi-proxy geochemical methods can now identify many kinds of human activities. Perhaps the most important reason for archaeological soil chemistry prospection is that it provides different kinds of data that are complementary to other methods such as geophysics, aerial photography, or surface collection. For example, we can identify site boundaries based on the distribution and concentration of phosphorus, and we can identify food preparation areas, middens, areas that were kept clean, butchering locations, and even ancient agricultural land use. In many settings, chemical and physical elements in the soil are less prone to post-depositional movement than ceramics, bones or bronzes. As with artefacts and features, sediments exist in patterned relationships that can be identified by scientists, and unless the soil is moved, patterns remain relatively intact and in place. Even if the topsoil moves, for example with erosion, chemical signatures are often retained in the subsoil. Because of this, and because sediments are common to nearly every archaeological setting, soil chemistry has potential for addressing questions about human activities in any landscape.

The basics of archaeological soil chemistry

The premise of archaeological soil chemistry is that human activities generate chemical and physical signatures that can be identified and analysed. All elements fix most easily and persist longest in fine-grained alkaline or acidic soils, although phosphates (P) in particular tend to accumulate most quickly, have low solubility and a strong ability to fix within the soil profile. Archaeological soil chemistry is minimally intrusive, and sample collection is relatively fast and easy. Sample collection for survey typically employs a very small diameter probe, with samples taken at regular intervals across an area of interest. Measurements are taken after chemical digestion of each sample. The methods vary from semi-quantitative approaches such as ring-chromatography tests and colorimeters to more quantitative methods using ICP-MS/OES or pXRF. In all methods, the chemical digestion procedure partly determines how much and in which form an element is released for measurement.

While all elements can potentially be measured, archaeological soil chemistry generally focuses on elements that are known to be elevated or depleted by specific human activities. Aside from the ubiquity of phosphorus (P) in the form of phosphates, typical elements include Ca, Fe, Mg, Mn, K, Cu, Pb, Sr. Elements unlikely to be changed by anthropogenic activities are commonly included as a control; if these control elements do not vary within a sample group, and the anthropogenic elements do vary, the analysis is likely to indicate human activities.

The interpretation of results from the chemical analyses requires comparison with known patterns and chemical signatures of human activities. This in turn requires basic baseline data from the study region, and a compilation of data from experimental and ethno-archaeological research.

Workflow

The workflow for archaeological soil chemistry involves a sampling strategy and an analytical method. The use of an appropriate sampling resolution and sampling depth, as well as an understanding of background soil chemistry, are vital for identifying anthropogenic chemical inputs. Sampling strategies vary according to project objectives. Samples of approximately 100g are sufficient for most inorganic analytical methods. Although the method is applicable for both large scale regional surveys and intra-site surveys, sampling targeted on suspected archaeological phenomena generally yield better results, especially on heavily eroded surfaces. For prospection, samples are collected on a regular grid pattern to study horizontal variations in the concentration of elements. The raster size is dependent on both what is being analysed, and the study questions. Whole sites are often surveyed at a 10m between line and between sample horizontal spacing, while houses or other defined features can be sampled at 50 x 50cm down to 10 x 10cm for high-resolution chemical characterization. Vertical spacing is more dependent on the particularities of any given location, but samples should be taken from each observed soil layer, with thick, undifferentiated layers subdivided into 5 cm or 10 cm levels. At the regional scale, sampling strategies may include samples on 50m interval grids, or sampling along single lines.

Best practice is the collection of background, or off-site, samples to establish the chemical baseline for the area of interest. This can be difficult, however, because it requires an assumption that non-anthropogenic soils can be identified and sampled in the field. Establishing a regional baseline is a better approach.

Laboratory methods again depend on project goals and resources. Phosphates can be analysed alone, using colorimeters or “spot tests” that are relatively simple and inexpensive and can be conducted in field settings. Multi-element chemistry provides a wider range of potential information, but requires more complex chemical methods and instrumentation. Generally, ICP-MS/OES is used, but the use of pXRF is increasing. Extraction of the chemical of interest requires an application of acid to the sediment. This can be anything from very dilute HCl for spot tests to hot nitric and perchloric acids for quasi-total extraction with ICP instruments. Testing the soil pH is highly recommended, as the pH value not only provides information about human activities, but also gives an indication of the likely preservation of both artefacts and chemical signatures.

All samples must be air dried and ground using a mechanical mill or pulverized in a ceramic mortar. For the Pav and pH analyses, samples are then screened through 2mm wire mesh prior to analysis. Multi-element chemistry using ICP-MS/OES benefits from samples screened to analytical fineness, while pXRF works best when performed on pressed pellets.

Workflow soil chemistry

- Sampling of soil layers at regular intervals (for survey) or each stratigraphic unit (excavation)
- Sample preparation (drying, grinding and sieving).
- Chemical digestion.
- Measurement using a colorimeter, ICP-MS/OES, pXRF or other device.
- Data analysis
- GIS-based comparison with other available landscape data (geophysics, aerial-photography, ALS…) or excavation results
- GIS-based archaeological interpretation.

For the Pav spot-test, sub-samples of approximately 50mg are laid out on ashless phosphate-free filter paper. Two drops of a first reagent (HCl, ammonium molybdate, deionized water) are applied to each sample, followed 30 seconds later by two drops of a second reagent (ascorbic acid in deionized water). After standing undisturbed for two minutes, to allow full development of colour and lines, samples are ranked 1–5 (low to high, following a method derived from Eidt 1973 with modification by Bjelajac et al. 1996), where 1 = no colour at all and 5 = very dark blue. This method provides a semi-quantitative result that can be statistically analysed, mapped, and interpolated. Use of a colorimeter requires chemical digestion in a beaker or similar container. The digestion method used is partly determined by local soil conditions (see summary in Holliday and Gartner 2007). In most cases, the result is a blue liquid extractant that can be measured in a colorimeter and then compared to a known curve of the relationship between shade of blue and phosphate content.

Inductively coupled plasma (ICP) spectrometry is the most commonly used method for the analysis of trace and major elements in sediments. Chemical extraction for ICP-MS or ICP-OES is a more complex procedure, requiring laboratories with chemical hoods and other safety equipment. Extraction methods range from weak acids intended to release only the anthropogenic enrichment to boiling samples in strong acids to release all elements in the sample, including those locked in the original geological matrix. Selection of an extraction method requires consultation with the laboratory, specific archaeological questions, and knowledge of local geology. A quasi-total extraction using heated nitric and perchloric acid is currently gaining acceptance in European archaeology, although dilute hydrochloric acid remains common in the Americas.

pXRF does not require chemical digestion. Instead, a pellet is formed by pressing a sample of soil combined with a binder such as wax in a die, using a hydraulic press. For a 40 mm pellet of high silicate material, a soil to wax ratio of 4:1 is pressed in a 40 mm die at 20 tonnes pressure for 20 seconds. Samples can also be packed into open-ended plastic sample cups with polypropylene thin film windows that facilitate the transmittance of X-rays to bulk samples such as soil. Readings are then taken with the XRF device. Each element emits energy at a diagnostic wavelength when exposed to X-ray energy, and XRF identifies and measures the elements present in a sample by measuring the wavelengths of energy that the sample re- emits (fluoresces).

Soil pH is tested using a pH meter and deionized water. Dry, sieved soils are dissolved in deionized water at a 1:1 soil/water solution, agitated twice, and allowed to rest for 60 minutes before measurements are taken.

Data analysis involves the use of multi-variate and spatial statistics to describe spatial patterns and to predict values. Hierarchical Cluster Analysis and Principal Components Analysis reduce the number of variables and identify groups of chemicals that regularly cluster. These clusters generally infer the chemical fingerprint, or signature of specific human activities. Hierarchical cluster analysis gives some indication of which elements are co-related. Principal components analysis (PCA) groups elements that are related under the assumption that related elements co-vary, because they are related to the same input . PCA simplifies and reduces the total number of variables by keeping only the most important information, while retaining most of the variation present, and analyses the structure of the variables and observations. It extracts the important information from the tables and expresses this information as a set of new variables for each test point. The resultant variables – principal components – can then be displayed and further analysed, providing a more accessible picture of spatial patterning than can be achieved by examining each element individually.

The results of the chemical and statistical analyses are interpolated in GIS using one of several algorithms, most commonly IDW (inverse distance weighting) or ordinary kriging. Interpolations can be generated from individual elements and from extracted PCA scores. The generated surfaces display spatial patterning and help to identify areas of enrichment and depletion and easily compare data sets. Kriging, or 'optimal interpolation', produces an estimated surface from a scattered set of points with z-values and is essentially a moving weighted average, where the weights are based on the spatial structure of the data and derived from the variogram model. Various algorithms are available in both commercial and free/open source GIS programs.

The application and its limitations of archaeological soil chemistry

The potential of soil chemistry was recognized and introduced to archaeology in the 1920s when Olaf Arrhenius noticed a correlation between high soil phosphate levels and surface artefact scatters while mapping for sugar beet cultivation in Denmark. Since then, it has been developed sporadically, with greater emphasis in Scandinavia, North America, the U.K. and some regions in Germany. In Central Europe, the method has been used most extensively at Neolithic settlements, but has potential for activity areas analysis and spatial organization at Iron Age settlements and ritual sites.

The methods can be used for prospection across whole landscapes, or for intra-site prospection and spatial interpretation. In addition to locating archaeological phenomena and defining the horizontal and vertical extent of human activities at a given location, multi-element chemistry provides data for exploring activity areas and activity zones at the level of households, settlements, production and ritual sites.

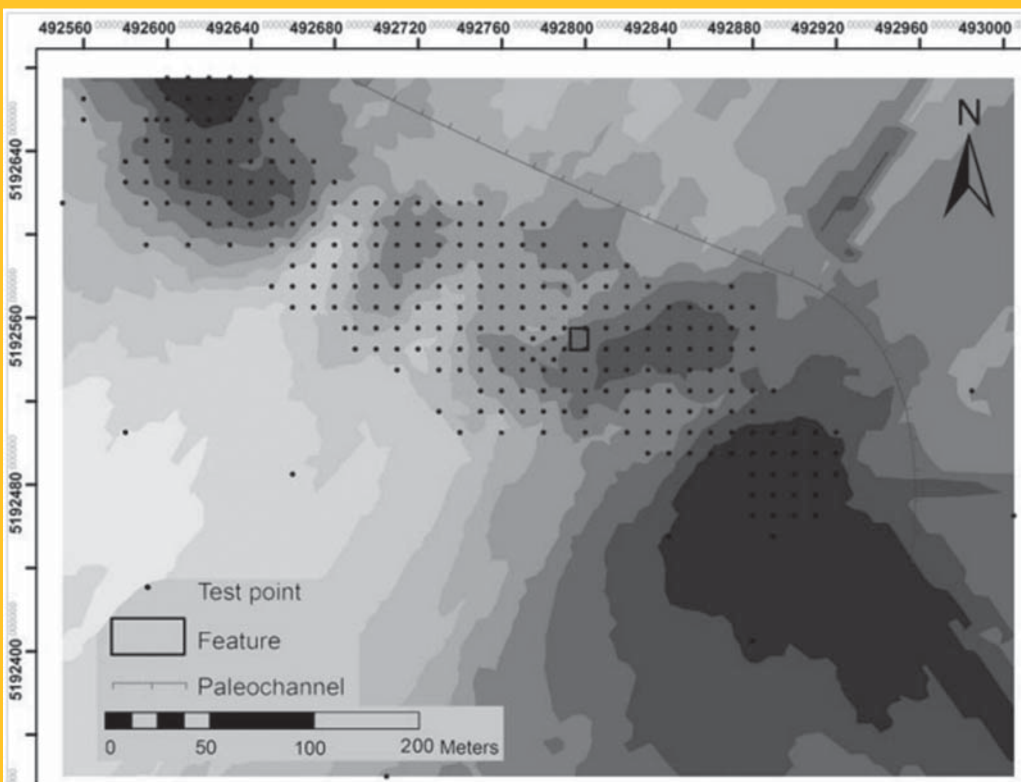
Nevertheless, one needs to be aware of several limitations inherent to soil chemistry. Colorimetric methods of phosphate analysis are semi-quantitative, and compare relative levels of available phosphate. Multi-element methods are more quantitative, but lack a single, universally accepted methodology of chemical digestion and extraction. Different extractions lead to different values measured in terms of parts per million. Furthermore, despite being quantitative, the results from different projects and different regions will be different in terms of regional geology and the intensity and duration of human activity. Therefore, results are comparative in terms of patterning and chemical fingerprints, but not for raw numbers.

These challenges can be resolved by using consistent chemical methods, at least within regions, by understanding how local geology and pedology influences anthropogenic soil enrichment and depletion, and by using soil chemistry in conjunction with other, complimentary prospection methods.

Key facts – archaeological soil chemistry in heritage studies

- Coverage:
  - on demand per project
- Landcover dependency:
  - very useful in farmland
  - good results in woodland
  - limited application in urban areas
- Research levels:
  - Level 1 Prospection
  - Level 2 Delineation
  - Level 3 Patterning of chemical fingerprints
- Dissemination:
  - interpolated surfaces
  - (paleo)landscape reconstruction

Case study Csárdaszállás-Félhalom-dűlő (Hungary)



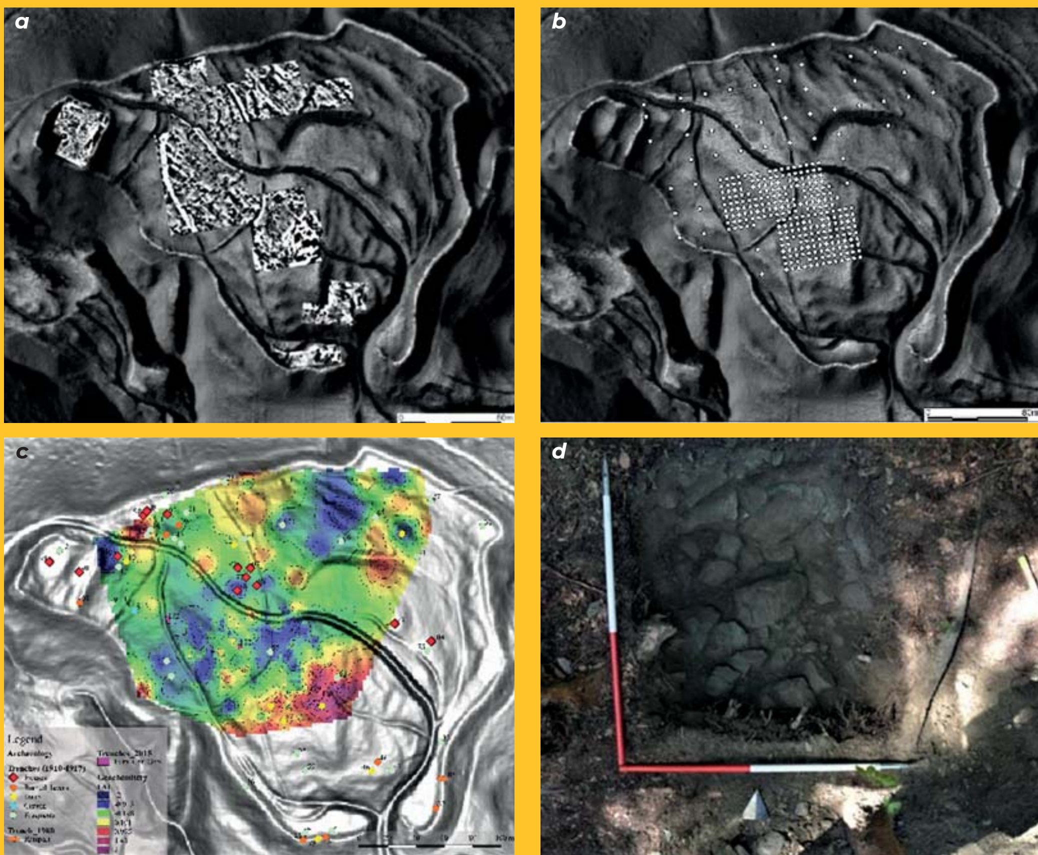
II.4.3 Figure 1: Multi-component Late Neolithic (Tisza) settlement in the Körös Region of eastern Hungary. Spatial distribution of available phosphates based on results of a ring-chromatography test of cultural layer and topsoil samples, delineating several concentrations (by author).

II.4.3.1 Geochemical mapping in hillfort studies

Branko Mušič, Nina Zupančič, Matija Črešnar, Matej Dolenec, Igor Medarić, Barbara Horn

The systematic multidisciplinary work at Poštela near Maribor targeted various parts of the landscape in and around the hillfort and its cemeteries. Following the desk based analysis, the first phase of the hillfort field research consisted of non-invasive geophysical

Case study Poštela near Maribor (Slovenia)



II.4.3.1 Figure 1a: Results of magnetic (pseudo)gradient mapping at the hillfort using caesium Geometrics G-858 magnetometer.

II.4.3.1 Figure 1b: Sampling points at the central part of hillfort for geochemical mapping– coarse grid 20 x 20m, denser grid 5 x 5m

II.4.3.1 Figure 1c: Results of multivariate factor analyses – factors were extracted with principal axis method (PCA) (factor F1 is positively loaded with elements, which can be interpreted as consequence of bedrock weathering and reflects the residue composed of resistant accessory heavy minerals (geogenic factor)

II.4.3.1 Figure 1d: Trench excavated in the south-eastern part of the prospection area, which yielded a high amount of magnetite rocks, visible in the results of the geochemical mapping (see: c) as well as on results of various geophysical methods (see: a)

(a – preparation: I. Medarić, B. Mušič, b – preparation: B. Mušič, c – preparation: N. Zupančič, B. Horn, d – photo: M. Vinazza).

prospections (magnetic method with gradient and single sensors surveys, high resolution ground penetrating radar surveys, electric resistance and surface susceptibility mapping) followed by a minimally invasive top-soil sampling for geochemical mapping. The latter was performed in a broader 20 x 20 m grid in the central part of the settlement, whereas a denser 5 x 5m grid was applied in a selected area, where the results on multi-method geophysical prospection indicated more pronounced archaeologically relevant anomalies (II.4.3.1 Figure 1a-b).

All the over 300 samples were taken from sub-surface horizons immediately below organic horizons at the top part of soil formation sequence. The samples were dried, sieved to 2mm and the homogenised samples were then compressed into pellets. Their chemical composition was measured in a laboratory by X-ray fluorescence (XRF) method with a portable analyser NITON XL3t GOLDD 900S-He.

A multivariate statistical approach of cluster and factor analysis (FA) was used for extracting chemical classes with the chemical composition significant for prevailing geogenic (F1), biogenic (F2) and anthropogenic (F3) record influence. The results of factor analyses (F1, F2 and F3) were mapped and correlated with other data in a GIS-based comparison (II.4.3.1 Figure 1c).

Analysing the results of the geochemical mapping in comparison with the geophysical data, various correlations could be observed. The most obvious was a strong anomaly in the results of the magnetic method in the south-eastern part of the prospection area (II.4.3.1 Figure. 1a). Application of FA in this area indicated strong positive loading of elements, which can be interpreted as consequence of weathering processes and therefore reflects the residue composed of resistant accessory heavy minerals (origin of geochemical factor F1 is interpreted as geogenic) (II.4.3.1 Figure 1c). A trial trench was excavated in the central part of the anomalous area and it yielded mostly stone material, which was found to be amphibolite with a high proportion of the iron oxide mineral magnetite (Fe_3O_4) (II.4.3.1 Figure 1d).

Geochemical mapping of the Poštela hillfort has proven its potential as a complementary method to the more frequently used geophysical methods and other applied prospection methods (i.e. ALS). It provided greater interpretational power when combined with results of previous and recent excavations, where potential sources of chemical elements and element associations were recognized and interpreted on the basis of properly selected multivariate statistics analyses.

II.4.4 Archaeological geophysics

II.4.4.1 Introduction

Branko Mušič, Barbara Horn

Geophysical methods are the only ones among the archaeological prospecting tools, which can give relatively detailed information on buried archaeological structures without excavations. While small archaeological features, such as postholes, graves and pits or clusters of those archaeological remains become visible in aerial archaeology only under perfect conditions, they are often detectable in high-resolution geophysical datasets, for instance. Due to the fact that almost all of the methods discussed here are even able to document the extent of buried archaeological objects in 3D and that recently developed motorized systems allow the surveying of large and relatively flat areas in the lowlands without dense vegetation cover or other surface obstacles at affordable costs. As a result of these advantages geophysical prospection techniques have become invaluable tools for landscape archaeology. The majority of prehistoric settlements are located on hilltops with dense vegetation cover, sites where they could be better preserved. By contrast it is far more difficult to discover prehistoric settlements in lowlands where the degree of sedimentation is usually higher coupled with the fact that most lowland areas have been used for intensive agricultural purposes during the last decades. In archaeological geophysics five basic geophysical methods (and their variants) have proved to be successful in delineating archaeological structures in various environmental conditions on the land and therefore provide an opportunity for instrumental exploration of archaeological phenomena:

- Magnetic method (magnetometry and magnetic susceptibility measurements),
- Electromagnetic method (low frequency electromagnetic method and ground penetrating radar–GPR),
- Resistivity method (resistivity mapping, electrical resistivity tomography–ERT, self-potential – SP and Induced polarization - IP),
- Seismic refraction method
- Microgravimetry

Magnetometry is by far most popular method in archaeological prospecting. GPR, resistivity and low frequency EM method are gaining more and more importance, while seismic, microgravimetry, SP and IP methods are rarely used at prehistoric sites and will therefore not be discussed further. It is possible to divide these methods into two groups based on the operating principles of the equipment used, these are: measurements using passive devices, where the role of the instrument is to sense and collect difference in physical properties (magnetic susceptibility, gravity and potential difference) through appropriate sensors, and active methods, where the role of the instruments is not only data collection but also introducing EM and elastic waves or electrical signals into the ground.

The suitability of individual geophysical methods or combinations of several methods for solving a given problem depends on the contrast of the physical properties of the targeted object with its surrounding media. Since each method measures specific physical properties, and has its advantages and limitations, there is no all-in-one method suitable for every purpose. Rather, the most suitable techniques have to be carefully chosen as a function of the given archaeological, geological, geomorphological and geographical context. Among the archaeological factors, the type of expected remains (stone-made structures, remains associated with craftwork activities, burned layers, pits, ditches etc.), size of the site or area under investigation and depth of buried structures have to be considered. Geological factors include type of rocks or sediments and their physical properties (i.e. porosity, moisture content, hardness–looseness, structure, texture, chemical and magnetic properties etc.) in which archaeological remains are situated. Geographical factors include latitude, longitude, altitude and consequently climate and weather conditions in the region. Geomorphology is a product of geological and geographical factors, while surface morphology reflects all factors mentioned above. All factors together form the characteristic setting of any landscape unit.

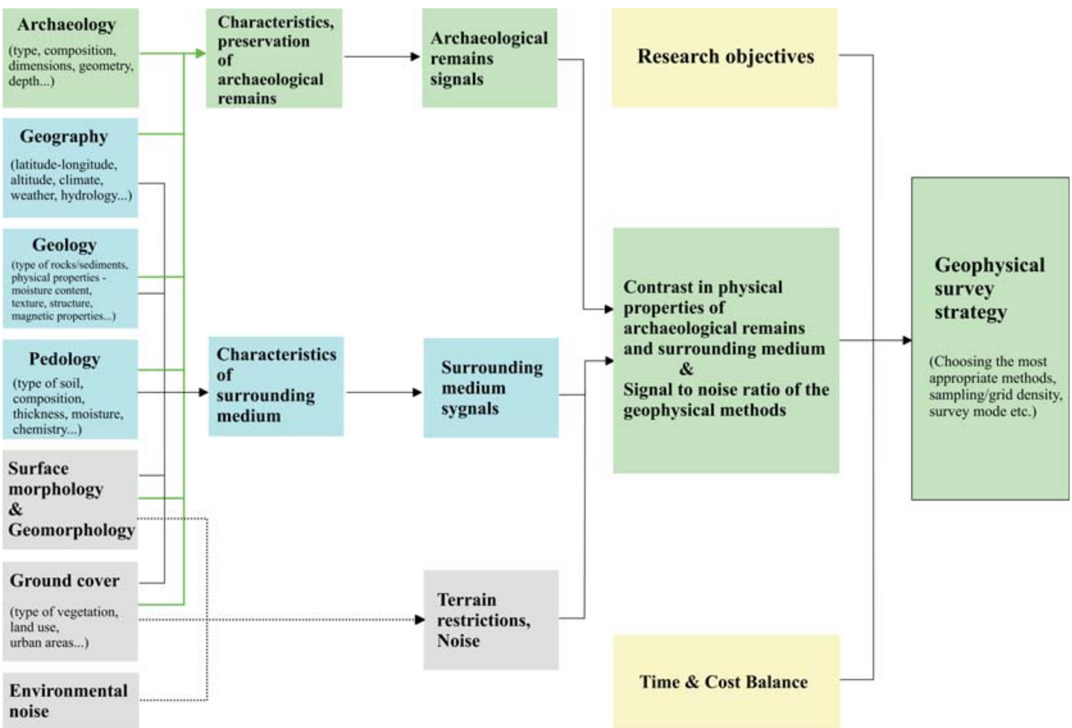
The territory discussed within the Iron Age Danube Project (IAD) framework can be divided into three general landscape units with different environmental settings relevant for geophysical survey strategy:

1. Lowlands: Pannonian plain (western Hungary, the eastern parts of Slovenia and Croatia)
2. Hills: the western transition from the Pannonian plain to the prealpine zone in Slovenia (Slovenske gorice) and horst structures in the Pannonian plain in Croatia (Papuk).
3. Alpine foothills: the central eastern Austrian prealps in Austria (Strettweg region) the eastern Slovene prealps in Slovenia (Pohorje)

Explaining the key decision – recognition/determination of relevant factors in archaeo-geophysical survey strategy is a rather complex task, since they are interrelated, influenced and dependent one upon the other. A simplified schematic illustration is shown below (Figure 1).

Furthermore, workflow in archaeological geophysics includes several steps, starting with preparations, i.e. evaluating all the available information of the site (archaeological, topographical, geomorphological, lithological etc.), followed by choosing the survey strategy, executing sequenced measurements applying different geophysical methods in the most productive, case sensitive multi-method approach survey design, geodetic data surveys, data processing and final interpretation of the results.

Various geophysical techniques were applied in compliance with the field conditions of each prehistoric settlement in specific environmental settings. These built upon preceding results from other surveys and used feedback offered by evidence from topographic surveys and small-scale excavations. The basic characteristics of geophysical methods



II.4.4.1 Figure 1: Simplified schematic illustration of key decision – making factors in archaeo-geophysical survey strategy

applicable in archaeological prospection are given in the table below, where a comparison is also provided for the frequency of use of each method on archaeological sites in general, on prehistoric sites and within the IAD project (Figures 2-3).

The basic workflow in archaeological geophysics

- Evaluation of existing archaeological sources for defining targeted features for geophysical research
- Evaluation of all available remote sensing data (aerophotography, lidar, satellite images) for additional spatial information on archaeological and environmental settings
- Evaluation of expected archaeological features
- Defining the details of field procedures on the basis of the expected physical characteristics of expected archaeological features
- Estimation of environmental conditions (vegetation, surface morphology, geology, pedology)
- Selection of geophysical method(s) for archaeological potential estimation
- Selection of complementary geophysical methods in accordance with the research objectives
- Geophysical multi-method survey design with execution sequences
- Geodetic data survey
- Filtering and processing of data in compliance with the expected physical properties of targeted archaeological features and the physical characteristics of the natural environment, incorporating topographic information, modelling (if applicable) etc.
- Interpretation of results

Method	Measured/modelled physical property	Operating principle	Interpretation	Time efficiency in capturing larger areas	Delineating depths of archaeological structures	Frequency of use on archaeological sites (in general)	Frequency of use on prehistoric hillforts	Frequency of use within the IAD project
Magnetometry	magn. susc.	passive	qualitative	yes	no	1	1	1
Magnetic modelling	magn. susc.	-	quantitative	no	yes	4	4	2
Magnetic susceptibility measurements	magn. susc.	passive	qualitative	no	no	4	3	3
Low frq. EM	magn. susc., conductivity	active	qualitative and/or semi-quantitative	yes	partial*	3	3	2
GPR	dielectric permittivity	active	semi-quantitative	yes	yes	1-2	4	4
GPR modelling	dielectric permittivity	-	quantitative	no	yes	5	5	6
ERT	resistivity	active	quantitative	no	yes	3	3	2
Twin Probe resistance mapping	resistance	active	qualitative	yes	partial*	3	4	4
Refraction seismic	elastic module	active	quantitative	no	yes	5	5	6
Microgravimetry	density	passive	qualitative	no	no	4	5	6
SP	potential difference	passive	quantitative	no	yes	5	5	6
IP	resistivity	active	quantitative	no	yes	5	5	6

partial* - within the bulk depth range interval

Legend:

1 - almost always	2 - very often	3 - often	4 - rarely	5 - very rarely	6 - never

II.4.4.1 Figure 2: Basic characteristics of geophysical methods applied in archaeological prospection

Applied geophysical method in IAD project	Recognizing Burrial mounds		Internal composition of Burrial mounds		Flat cremation graves		Hillfort ramparts, defence walls and ditches		Lowland burried ramparts, defence walls and ditches		Hillfort settlement structures		Iron blacksmith workshops and furnaces		Poterry workshops	
	Investig. Freq.	Succes in definition	Investig. Freq.	Succes in definition	Investig. Freq.	Succes in definition	Investig. Freq.	Succes in definition	Investig. Freq.	Succes in definition	Investig. Freq.	Succes in definition	Investig. Freq.	Succes in definition	Investig. Freq.	Succes in definition
Magnetometry	2	A	3-4	B-C	1	A	5	C-D	5	A	1	A	1	A	1	A
Magnetic modelling	6	-	2	A	4	A	5	C-D	5	A	5	A	5	A	5	A
Magnetic susc. measurements*	6	-	3*	-	4*	-	5	C-D	6	-	4	B	1	A-B	3	A-B
Low frq. EM	3	B	4	B-C	2	B	5	C-D	5	A-B	1	A-B	1	A-B	1	A-B
GPR	6	-	3	A	3	B	4	B	5	A-B	4	A	6	-	4	C
ERT	6	-	1	A	6	-	1	A	5	A	1	A	1	A-B**	6	-
Twin Probe resistance mapping	4	B-C	4	B-C	4	C	5	C	5	B	5	A-B	6	-	5	C

* Magnetic susceptibilty measurements are used as a complementary method to magnetic modelling

** ERT is applied as a complementary method to estimate depths and dimensions of furnaces

Legend:

1 - almost always	4 - rarely
2 - very often	5 - very rarely
3 - often	6 - never

A - very successful	C - less successful
B - successful	D - unsuccessful

II.4.4.1 Figure 3: Applied geophysical methods and their efficiency in the recognition of selected archaeological features at prehistoric sites surveyed within the IAD project

These methods are explained in the next chapters with some examples and with descriptions of specific limitations for every single method.

Apart from all the other factors, the time scale of most projects also poses severe constraints on field geophysicists. For most professional archaeologists, the time schedule for field activities is immovable to other time periods or seasons. This rigid limitation requires that the geophysical fieldwork, interpretation and report must be promptly completed so that follow-up investigators have enough time to produce their own report. Compressed time scale makes it essential for both the commissioning archaeologist and the geophysicist to be aware of the potential limitations and pitfalls of archaeological geophysics. From this perspective, archaeo-geophysical research should be carried out in close team work between archaeologists and geophysicists where both parts must be well aware about the specific archaeological problem and also about capacities and limitations of available geophysical techniques in given environmental settings.

Key facts about Archaeological Geophysics in Heritage Studies

- Coverage:
  - depends on method and equipment capacity
- Environmental dependency:
  - difficulties in woodland and steep slopes
  - very useful in farmland
  - GPR and EM applicable also in urban areas
- Research levels:
  - Level 1 Magnetometer prospection
  - Level 2 Elaboration magnetometer data
  - Level 3 GPR/electric/ERT/EM prospection
  - Level 4 GPR/electric/ERT/EM elaboration
- Social potential:
  - landscape animations
  - (paleo)Landscape reconstructions
  - useful for education and promotion

II.4.4.2 The basics of magnetometer measurements

Igor Medarić, Sándor Puszta, Zoltán Czajlik, Branko Mušič

Magnetometry is one of the most widely used methods in archaeology. High spatial resolution and rapid data acquisition in favourable environmental settings, allows the detection of almost any type of archaeological remains. With magnetometers we can detect local changes in the magnetic flux density in the Earth's magnetic field, due to differences in the magnetic susceptibility of materials under the surface. In this way it is possible to recognize magnetic anomalies created by archaeological remains with different types of magnetization - most commonly remanent and induced magnetization. Remanent, i.e. those that have their own magnetization are the ferrous (natural magnetization) and / or materials that have been subjected to great heat (thermo-remanent magnetization). The other component of magnetization is induced, which is the effect of the external magnetic field. An essential condition for the detection of archaeological structures is the presence of the Earth's magnetic field, which acts roughly as a slowly changing large dipole; it currently has an 11 degree tilt variation from Earth's rotation axis. At the poles, the magnetic force lines run perpendicularly to the surface of the Earth, in the magnetic equatorial region they run parallel, but in our area, they bend by 65 degrees (inclination). Their horizontal direction (declination), which is the direction of the magnetic north on the compass currently differs 4.2 degrees from geographical north in Hungary. The intensity of Earth's magnetic field varies between 67000 and 22800 nT (Nano Tesla). The properties of the Earth's magnetic field vary not only spatially, but also in time, and show a significant (20-50 nT) fluctuation daily (sometimes in an even shorter period), which is considerable during archaeological magnetometer surveys. It is thus important to correct the measured magnetic data from the influence of the Earth's magnetic field, which is usually performed by utilization of a reference (base) sensor. A practical implementation of this is when the "base" instrument moves together with the measuring sensor, placed e.g. 1 m above. Then the difference between the data from the two sensors is divided by the distance of the sensors (vertical gradient) is noted at the measured points.

The magnetic background can be significantly altered by magnetic rocks, mainly iron ore. The magnetizability, i.e. susceptibility of different materials is not the same. The magnitude of the magnetic effect depends only on the following two factors: the size of the magneto-acting object (i.e. the susceptibility contrast of the material and its environment), and the distance from the measuring sensors/devices, which becomes weaker by the third power. This is the reason why the sensors have to be mounted very close to the Earth's surface.

The physical basis of the differences observed in the magnetometer geophysical research of archaeological sites can be classified into two large groups. The first group includes anomalies that can be caused by objects with remanent magnetic properties (iron objects or concentrated and large ceramic pieces, e.g. bricks, pottery and/or burnt clay daub) and also by certain archaeological phenomena, e.g. burnt surfaces (furnaces, floors). The second group includes archaeological structures that had long been open during their original use, which allows the recognition of the induced magnetization of settlement structures for example, ditches and postholes. The differing magnetic properties of the burnt surfaces and materials as well as the iron objects appear to be self-explanatory, but the case of the slowly filling objects requires a more complex explanation. Although relatively few detailed studies have been conducted to better understand this phenomenon, Le Borgne had already stated that the upper horizon of the soil usually has a higher magnetic susceptibility than the layers below it. In most cases it is likely that the anomaly is caused by the rearrangement of the materials, which changes the Le Borgne-effect in a large part of the archaeological features on the one hand; and the differing magnetization of the fillings with accumulated bacteria, that have magnetic properties on the other. In some cases, the induced magnetization is supplemented by viscous magnetization on such structures, and TRM magnetization is also present (fireplaces, burnt clay layers, pottery dump, etc.).

Before starting with data acquisition, it is necessary to check the application possibility of geomagnetics for the identification of specific archaeological structures in a particular environment. In order to successfully recognize the sought-after archaeological structures using magnetic method, physical information about the archaeological structures, the optimal distance and the height above ground of the sensors all need to be chosen. Any iron object (e.g. fences, fence posts, cars, excavation tents, iron pipes etc.) but also electric power lines or pipelines have high magnetic effects and usually obscure any other measurement within a 10 meter wide buffer zone. Consequently, these objects need to be removed if possible; otherwise, the measurements within the buffer zone will be ineffective. Smaller magnetic influencers, i.e. dropped iron objects, usually appear as dipoles in the magnetogram. Their effect can be reduced during processing and, if possible, filtered out from the magnetic image. Other external factors that can significantly hinder the course of magnetic measurements and directly or indirectly influence the effectiveness of the research are: vegetation, the surface, and also the geological and pedological composition of the investigated terrain. Dense growth prevents the sensors from having and even or equal distance from the surface, which can also greatly obstruct the movements in the direction of the profiles. The measurement error is the sum of all these tiny inconsistencies. We can assign as much as 80-90% of the final result of the instrument resolution analysis and the consistency of control over the optimal measurement process.

The quality of the magnetometer surveys is influenced by many factors, the first being the sensitivity of the instrument used and the geometric arrangement of the measurement. The sensitivity of the magnetometer devices is given and promoted with decreasing values by equipment manufacturers, however, based on practical experience, values of less than 0.1 nT accuracy should not be considered.

Workflow

1. Choosing optimal density of data acquisition for specific archaeological structures.
2. Implementation of grid and reference points
3. Data acquisition
4. The main processing steps (preliminary data analysis, definition and filtering of signal/noise components, correcting data, enhancing data, displaying data)
5. Georeferencing, DEM
6. Advanced processing and interpretation

During the research it is advisable to measure by means of a network uniformly covering the area, the density of which is defined by the depth of the investigated features and the interfering sources, so the physical characteristics of the grid points can be extended to the examined area, fulfilling the sampling theorem (Shannon, 1948).

Measurements are usually acquired inside quadrants of a desired size in the bi-directional mode along parallel transects spaced at least 0.5m apart. For a detailed area survey we should carry out the measurements in an even denser grid of 0.25m. On the other hand, in areas under regular agricultural cultivation a grid denser than 0.75 m is usually not needed, because of the distance between the instrument and the non-rotated, i.e. archeologically intact layers. As the method is so successful and instrumentation seems to be affordable, an increasing number of archaeologists try to use these methods without a decent knowledge of the geophysical basis. However, as mentioned above, experience is needed for choosing the right instrumentation, setting, and environmental conditions. Also, correct processing of the acquired data cannot be fully automated. Good and valid results can only be achieved by customized parameters, tailored to the specific location.

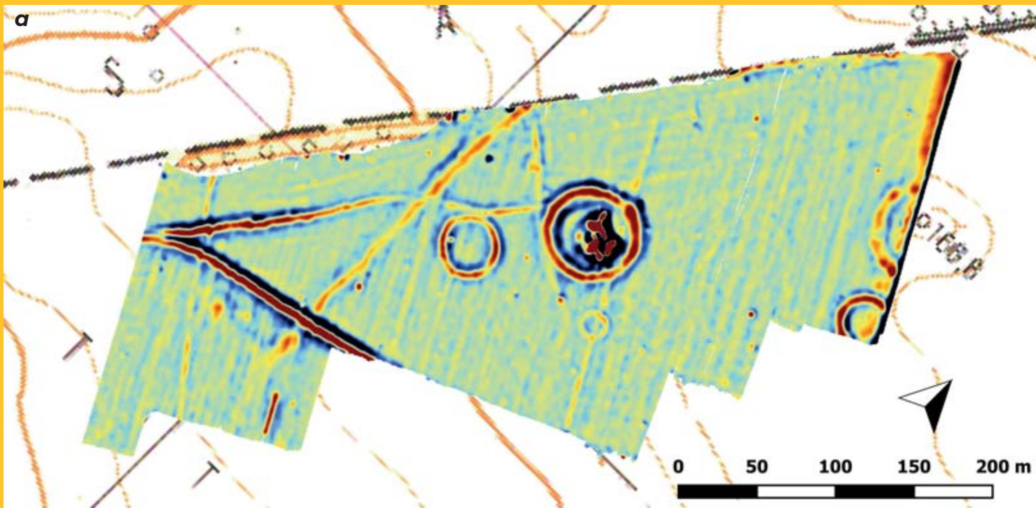
The appropriate processing steps and their parameters can be determined on the basis of a thorough analysis of the measured data. Analysing data and the noise on them lay the foundation of the expedient steps to highlight signs and the parameters of the procedures. The first stage of processing usually involves improving the quality of images by removing or correcting some of the errors. These are usually extremely high values and visible stripes on magnetograms, which are a result of conducting measurements in parallel profiles in zigzag manner. In the second phase of the processing, various filters are used and also magnetic field transformations that adapt to the special features of the targeted archaeological objects and the environmental conditions in which they are located. In most cases when this is done the attempt is made to convey certain anomalies and/or obtain certain information about the exact location of the sources of magnetic anomalies and the degree and type of their magnetization. Different transformations of the magnetic field can be used for this purpose: reduction to the magnetic pole, analytic signal, vertical and horizontal derivatives, gauss filter etc. It should be noted that the data are not processed in order to hide errors, but to enable a more precise and thus more reliable interpretation. More advanced quantitative analysis of magnetic data also includes implementation of 2D and 3D archaeo-physical magnetic models and depth estimations of archaeological structures by use of various methods as Euler deconvolution, SPI etc.

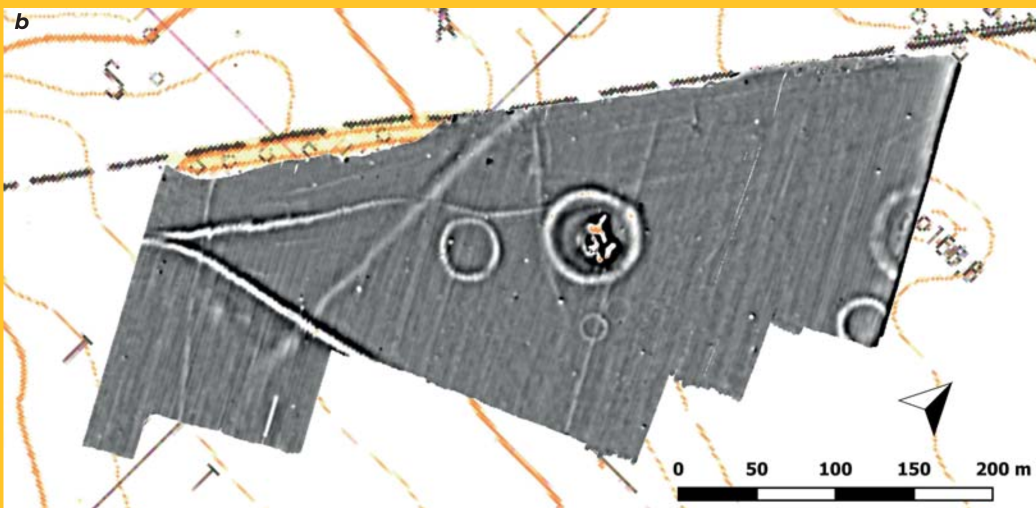
The application and limitations of magnetometer measurements

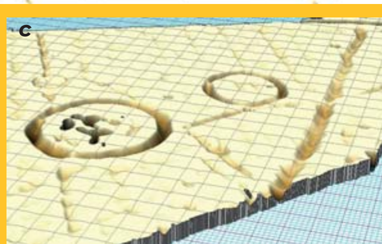
Magnetometers have proved to be extremely successful in identifying a wide variety of remains at prehistoric sites or on sites where, in addition to relatively rare stone constructions, settlements in the form of negative structures, such as ditches, postholes etc. are present. In addition, we can also easily recognise a wide variety of buildings, simple communications and more compact floor surfaces, metallurgical workshops with simple and poorly preserved furnaces, fireplaces and slag dumps, even contents of mounds and small structures as inhumation graves and urns. Not all structures are always visible on the magnetic maps. In some cases the susceptibility contrast of the material and its environment is too low for archaeological structures to be recognizable, while in other cases the magnetic effect of other natural materials or archaeological remains in the immediate vicinity can completely overshadow potential anomalies.

During the interpretation, a certain level of caution about the measured magnetic anomalies is required, as some of them may originate from the topographic effect of the surface. This should be taken into account especially while carrying out measurements over burial mounds – a common structure on prehistoric sites. Without understanding the effect of the topography, the origin of magnetic anomalies can be misinterpreted as

Case study Süttő (Hungary). The 2017 survey of the south-eastern zone of the Early Iron Age tumulus field in Süttő

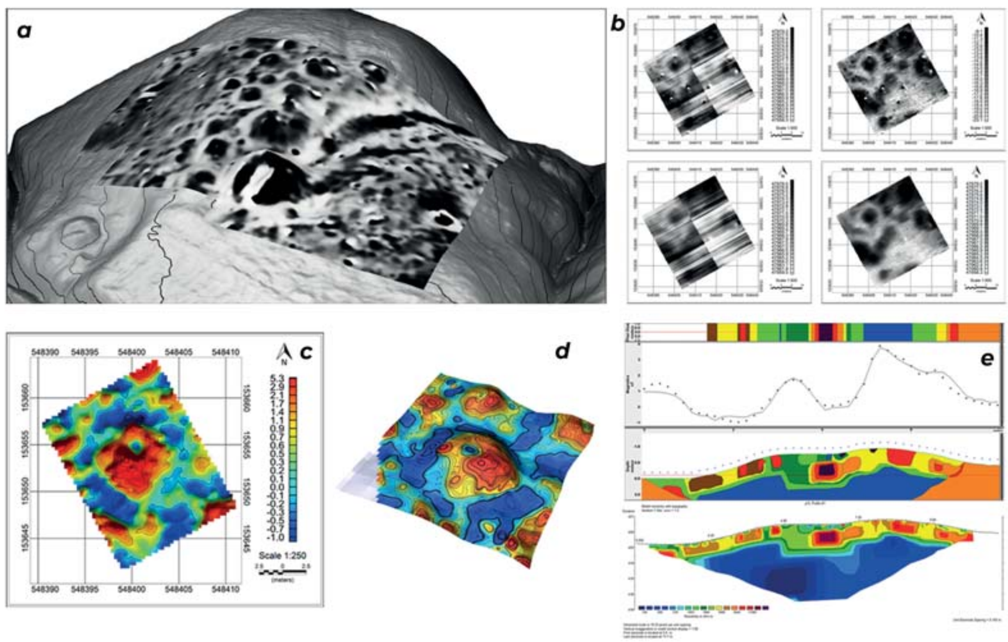






II.4.4.2 Figure 1: Materials with different magnetic properties (susceptibility) induce magnetic fields differing from their environment, which can be detected above them on the ground. The magnetic map shows blue and red lines, and circles in the areas where the material underneath the surface has different magnetic properties (II.4.4.2 Figure 1a). These were once probably trenches and roads. The ring-shaped features and the anomalies that can be observed in them can be assigned to the Early Iron Age and they indicate tumuli enclosed by circular ditches. There are only two tumuli visible on the surface today, while the roads are not visible on the ground; their age is unknown. Not all map elements are archaeological. When processing the measured data, we aim to keep only the effects of archaeological objects on our maps (II.4.4.2 Figure 1b). Using an axonometric method, the magnetic field can also be represented as a relief (II.4.4.2 Figure 1c).

Case study Habakuk below Poštela (Slovenia)



II.4.4.2 Figure 2: Magnetometry results on DEM (A). Corrections of the changes in the Earth's magnetic field at the selected area with the use of base magnetometer (B). Detailed segment of magnetic results for researched tumuli (C). The same segment on DEM (D). After obtaining the physical and magnetic data in the field (magnetic susceptibility and exact DEM of measured mound), it is possible to compare measured and calculated anomalies for better recognition of archaeological structures inside the tumuli by implementation of 2D or 3D magnetic models and to compare them with the results of other geophysical methods e.g. ERT inverse models (E) (Medarić 2018).

Key facts about magnetometer measurements

- Coverage:
  - depends on method and equipment capacity*
- Environmental dependency:
  - difficulties in woodland
  - very useful in farmland
  - GPR applicable also in urban areas
- Research levels:
  - Level 1 Magnetometer prospection
  - Level 2 Elaboration magnetometer data
  - Level 3 GPR/electric/ERT prospection
  - Level 4 GPR/electric/ERT elaboration
- Social potential:
  - landscape animations
  - (paleo)Landscape reconstructions
  - useful for education and promotion

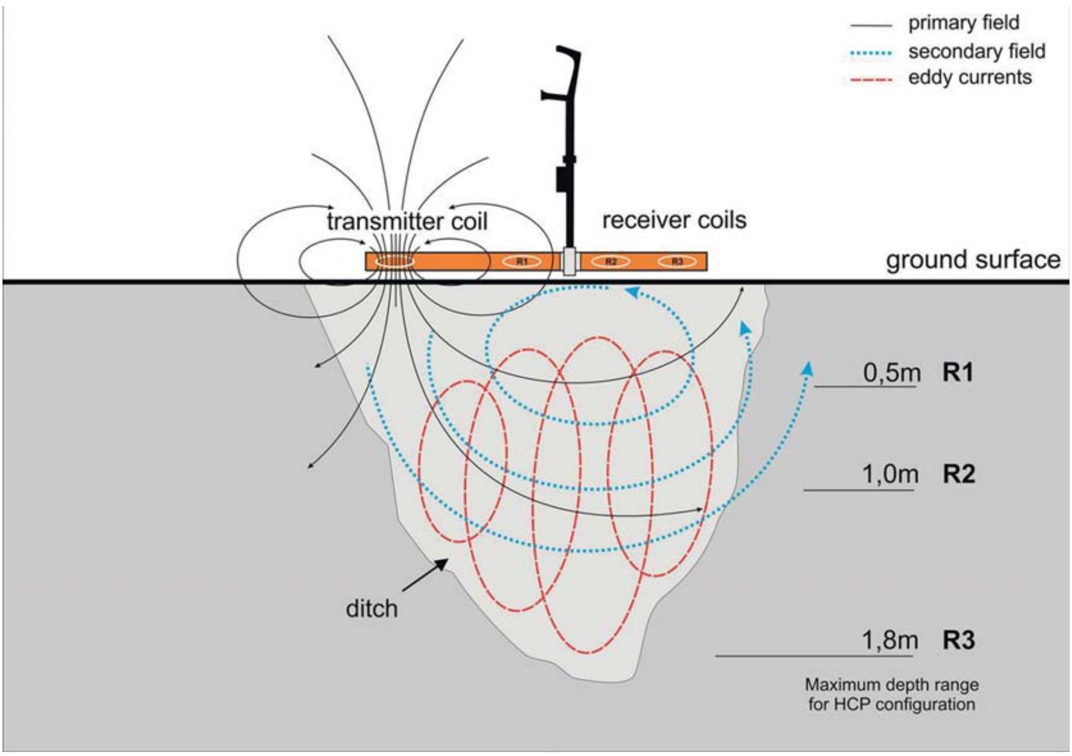
a possible magnetic effect of the archaeological structure within the mound. To check the effect of the mound and to both recognize and interpret the potential archaeological remains (chambers, urns etc.) 2D or 3D magnetic modelling can be successfully applied. After obtaining physical and magnetic data in the field (magnetic susceptibility and exact DEM of measured mound), we can compare the measured and calculated anomalies and recognize archaeological structures by this means.

II.4.4.3 The basics of low-frequency EM geophysical measurements

Petra Basar, Barbara Horn, Branko Mušič

Low-frequency electromagnetic (EM) systems can simultaneously measure and co-locate two different geophysical properties, magnetic susceptibility and electrical conductivity respectively. Unlike magnetics, these are active geophysical methods, which means they use the principle of electromagnetic induction to measure the response from the ground.

The *quadrature* component represents conductivity, which is the measure of a material's ability to allow the transport of an electric charge. Ground conductivity mapping allows us to detect larger negative archaeological features (e.g. larger pits or clusters of pits and ditches), earth made structures (e.g. embankments, ramparts, anthropogenic terraces...), stone foundations, walls and masonry. It is an adequate study method for archaeological features of heterogeneous composition, such as barrows (highly conductive ditch fills, less conductive mantles and stone/wooden burial chambers).



II.4.4.3 Figure 1: A graphical explanation of how the CMD Mini-Explorer operates.

The *in-phase* component is considered to be equivalent to soil magnetic susceptibility changes, so the high values can indicate areas with ferromagnetic anomalies and induced magnetization, such as kilns, furnaces, iron objects, layers of fired clay or deposits of ceramic material. Moreover, it is possible to define traces of metallurgic activities in addition to the accompanying production waste dumping areas with (Figure 1).

Workflow

CMD is a new electromagnetic probe that primarily aimed at the environmental prospecting requirements. It can measure three different depth levels simultaneously. Although the approximation of depth intervals for individual receiver coils are known in theory, the geophysical signal during field surveys is also under the influence of the interrelationship between the specific natural environment and properties of archaeological features.

The low-frequency EM methods generally do not require ground contact, which is a significant advantage over resistivity mapping, especially in dry areas during drought periods. However, when facing difficult survey environments, the instrument can be held on the ground for each measurement (Figure 2).

	Rx_1	Rx_2	Rx_3
Spacing from the transmitter coil (m)	0.32	0.71	1.18
Maximum depth range (m)			
VCP	0.25	0.5	0.9
HCP	0.5	1	1.8

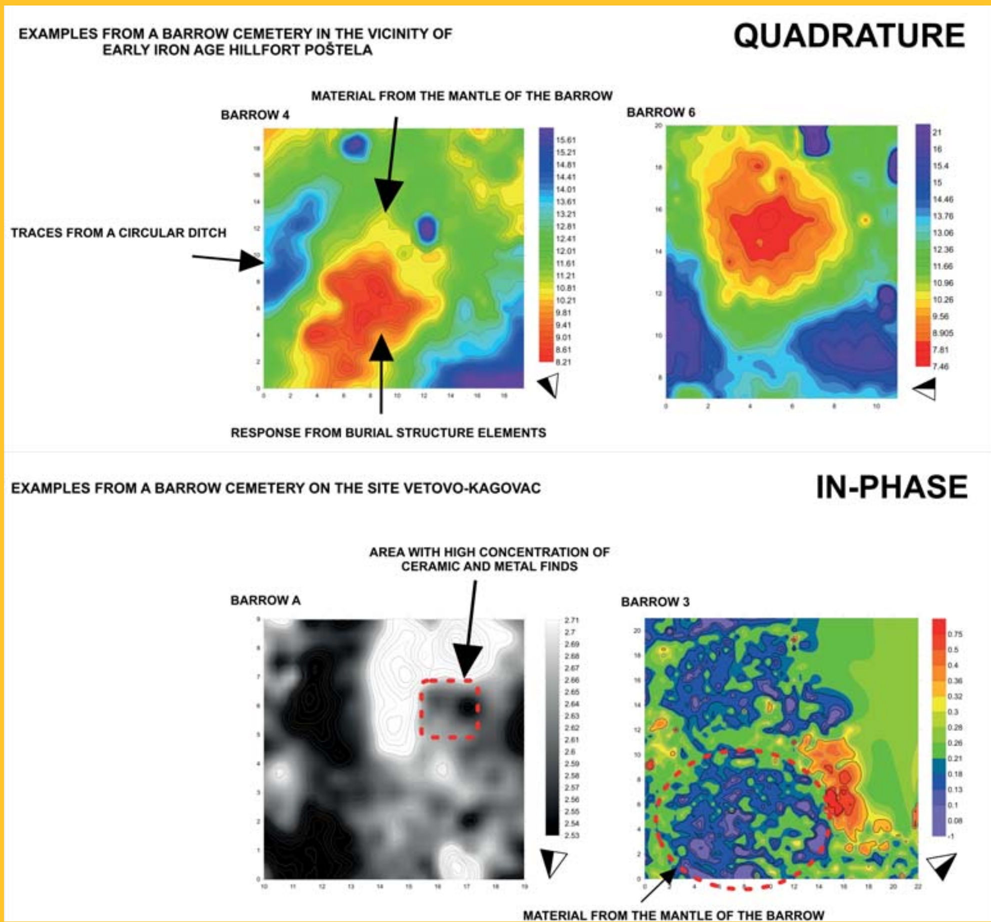
II.4.4.3 Figure 2: Theoretical depth ranges for three CMD receiver coils in VCP (Lo-depth) and HCP (Hi-depth) operational mode

Application and limitations of CMD Mini-Explorer measurements

The instrument can detect various archaeological features such as anthropogenic terraces, earth made structures (ramparts, embankments, turf buildings, house floors etc.), stone foundations, walls, hengiform monuments, burials (inhumations), waste pits, areas with traces of metallurgical activities (smelting furnaces and/or forges, deposits of waste material), as well as anomalies with thermos-remanent magnetization (e.g. various types of burned clay) or other types of magnetic traces (e.g. high concentration of ceramic sherds).The method is also suitable for the prospection of Early Iron Age barrow cemeteries and even has the potential to recognize flat cremation graves with ceramic or metal grave goods.

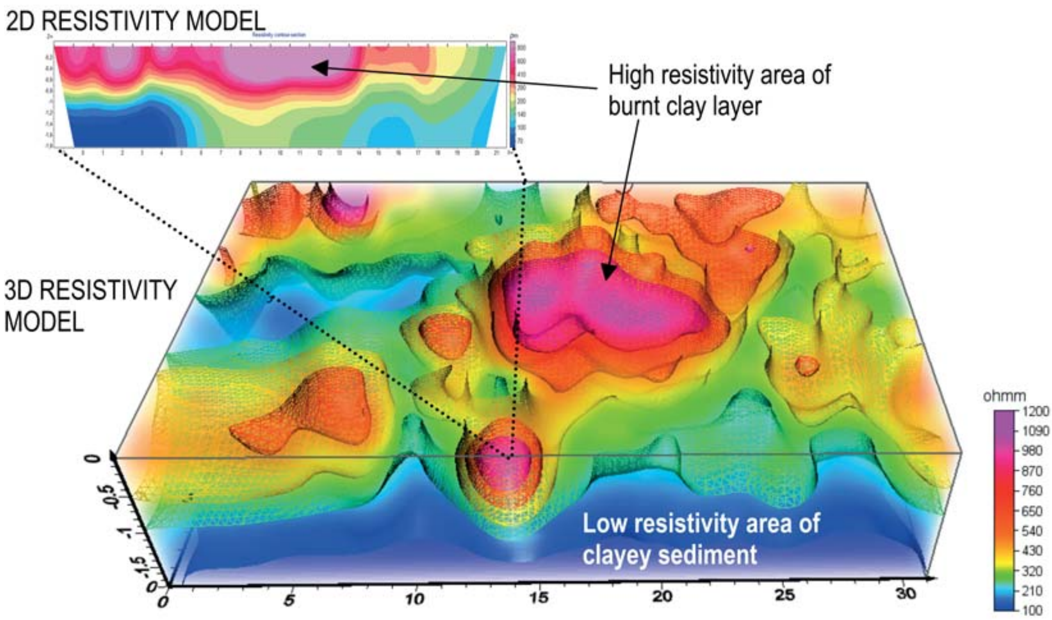
Low-frequency EM systems can measure two geophysical properties simultaneously which is a significant addition for geophysical prospection of archaeological sites. The results from in-phase geophysical parameter have proven to be comparable with magnetometry data and measurements of topsoil magnetic susceptibility (< 5-10cm). The apparent electrical conductivity data is complementary to the resistivity measurements (ERT or resistance mapping).

Case study Habakuk near Poštela (Slovenia) and Vetovo-Kagovac in Požeška kotlina (Croatia)



II.4.4.3 Figure 3: Early Iron Age barrows from the sites Habakuk near Poštela (Slovenia) and Vetovo-Kagovac in Požeška kotlina (Croatia) commonly have burial chambers made of stone and/or wood. The chambers were covered with the surrounding soil, leaving a circular ditch around the barrow which filled up through time with highly conductive material. Changes of the electrical conductivity, within the area where the barrows are situated, show traces of highly conductive ditch fills and also less conductive round-shaped mantles. The shape and size of the anomalies with low conductivity values in the central part of barrow 4, match the walls of the burial chamber which were documented during archaeological excavations during the 1980s. Results from barrow 6 show the same contrast between conductivity values. A rectangular shaped anomaly with low conductivity values, which is situated in the central part of barrow 6, suggests the presence of a burial chamber.

The in-phase results also showed that in some cases, the mantle of the barrow has slightly different magnetic properties, so it stands out from the background values. Results from three receiver coils of the CMD Mini-Explorer from barrow 3 on Vetovo-Kagovac site were integrated together by using the Minimum values method, which emphasizes discrete changes within the magnetic susceptibility data. Red lines mark a round-shaped area of slightly lower magnetic susceptibility, which are distributed in the same place where the barrow is situated. It is also possible to detect the presence of features with high magnetic susceptibility, such as metal or ceramic objects (possible grave goods) as well as possible traces of cremation graves or other burnt remains. Results from barrow A on Vetovo-Kagovac show two high contrast anomalies, where archaeological excavations have discovered a relatively well preserved cremation grave with various ceramic and metal grave goods (marked with a red line).



II.4.4.3 Figure 4: Example shows 2D and 3D resistivity inversion models of quadrature data component obtained at the bottom of a karstic doline near Cvinger hillfort, where a high resistivity burnt clay layer is observed in a relatively homogenous low resistivity clayey sediment. 2D and 3D inversion models obtained from quadrature data component.

Key facts about low-frequency EM method

- Simultaneously measures and co-locates
  - quadrature ~ electrical conductivity
  - in-phase ~ magnetic susceptibility changes
- Environmental dependency:
  - manual mode suitable for surveys in woodland
  - continuous mode acceptable for flat areas
  - sensitive to strong electrical sources
- Research levels:
  - suitable for determining areas with archaeological potential
- Research possibilities:
  - (paleo)landscape reconstructions

Furthermore, conductivity data inversion is possible in a way similar to that with data obtained by ERT, which allows further quantifying of resistivity (reciprocally of conductivity) distribution, although with only three depth data layers, which is sufficient for obtaining a rough overview of shallow depths resistivity distribution in homogenous geological background (II.4.4.3 Figure 4).

II.4.4.4 The basics of Electrical Resistivity Tomography (ERT)

Barbara Horn, Branko Mušič

There have been major improvements in instrumentation, field survey design and data inversion techniques for the geoelectrical method over the past 30 years. Multi-electrode and multi-channel systems have made it possible to conduct large 2D, 3D and even 4D surveys (time-lapse survey, i.e. repeating the survey of the same area at different times) efficiently to resolve complex subsurface structures that it was not possible to deal with at all using traditional 1D surveys. Continued developments in computer technology, fast data inversion techniques and software have now made it possible to make the interpretation on commonly available microcomputers. Multi-dimensional geoelectrical surveys are thus now widely used in many research fields, including archaeology.

Recently a more detailed 2D and 3D resistivity imaging has become increasingly popular amongst archaeologists, as the method permits a more advanced and detailed 2D and 3D visualization and also allowing quantitative interpretation of buried archaeological structures (i.e. giving accurate depths, extensions and to some level also composition of archaeological structures), thus offering invaluable information prior to excavation.

There are two designations each with abbreviations currently commonly in use for the same research method, which is electrical resistivity tomography (ERT) and electrical resistivity imaging (ERI), although various shorter terms (e.g. resistivity imaging, resistivity tomography, electrotomography etc.) are also widely used in the scientific literature.

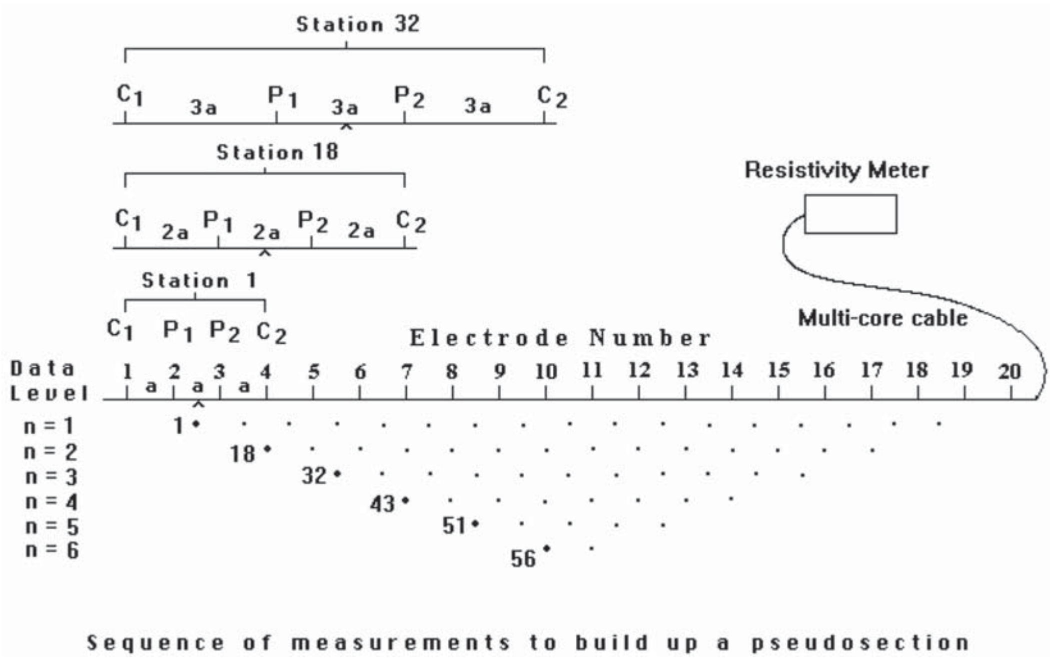
The basic principles, data acquisition and data processing

Resistivity measurements rely on the relative incapacity of materials to conduct electrical current and are based on the fact that electrical conductivity and/or resistivity of archaeological objects differs from the resistivity of geological medium in which they are buried. As resistivity depends mainly on factors that control moisture content with dissolved ionic compounds in the ground, depending on porosity, texture, structure and consistency of different materials, as well as the amount of precipitation, features such as wall foundations will give a relatively high resistivity response, while ditches and pits, which are prone to retain moisture, will give a lower one.

The distribution of the apparent resistivity values of the subsoil are obtained at the surface by injecting electrical current (by the current electrodes) into the ground and measuring the potential difference at two determined points on the surface. The apparent resistivity values measured at the surface (i.e. pseudosections) are then converted to the true subsurface resistivity distribution with inversion procedure. The results of the inversion procedure represent the final 2D or 3D subsurface models with true subsurface resistivity distribution, which further allows a quantitative interpretation of buried archaeological structures.

In an ERT (electrical resistivity tomography) survey multiple electrodes are placed along the line and switching between them is run automatically by a microprocessor, while the depth of investigation among the conventional electrode arrays is roughly 1/5 of the length of survey line (for example app. 5 m for a 30 m long 2D profile) (Figure 1).

Measured data (pseudosection) can be obtained with several conventional (dipole-dipole, pole-pole, Wenner, Wenner-Schlumberger) and unconventional (gradient, square etc.) electrode arrays (configurations), which differ in their horizontal-vertical resolutions, data coverage and depth of investigation. The choice of the most suitable array for the given investigated structures plays an important role in the method of obtaining the highest quality data, since archaeological contexts are very complex. Furthermore, electrode spacing for a finite number of available electrodes must be carefully chosen to provide an optimal (horizontal and vertical) resolution with sufficient depth of investigation. In 2D



II.4.4.4 Figure 1: Sequence of measurements to build up a pseudosection.
C1, C2 – current electrodes, P1, P2 – potential electrodes

measurements the orientation of the profiles is also important – the best way to conduct measurements is perpendicular to the expected elongated structure.

Archaeological application of the ERT method

The main advantage of the ERT method is providing accurate 2D and 3D resistivity models of the subsurface, where data obtained through inversion procedure are of quantitative nature, thus providing depths, dimensions, positions (orientation), as well as preservation and up to some level also composition of archaeological structures and their corresponding

Key facts about ERT method

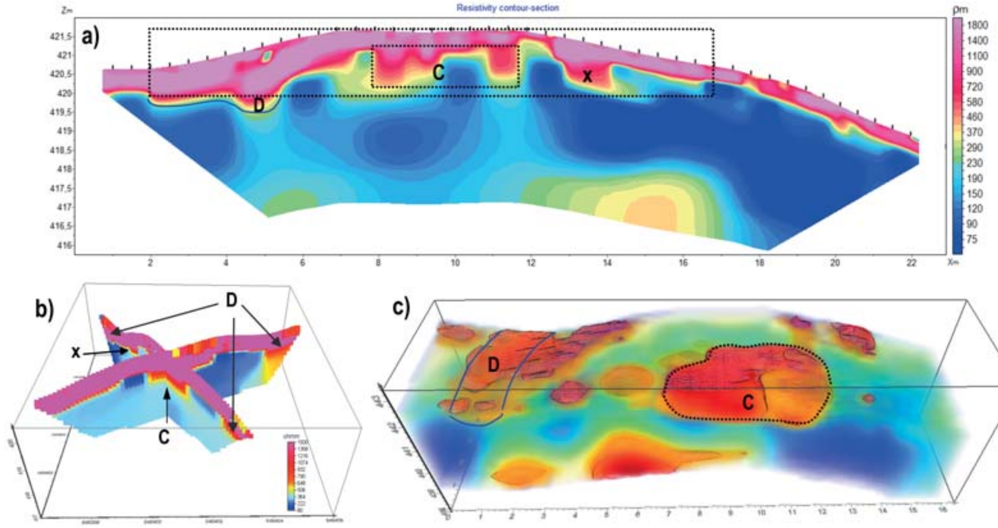
- Allows quantitative interpretation of 2D and 3D inverse ERT models:
  - provides depth, extension, orientation of structures
  - explains stratigraphic relations and geoarchaeology
- Environmental dependency:
  - very suitable in lowland as well as woodland
  - suitable for very steep areas
  - ground contact needed (not applicable in urban concrete and asphalt area)
- Research levels:
  - suitable for detailed researches, prior to excavation, in conservation studies, as a complementary
  - measure for all others methods
- Research potential:
  - (paleo)landscape reconstructions

geoarchaeological characteristics. On a basis of distinct resistivity values we can assume the composition of archaeological remains, for example stone-made structures (e.g. stone foundations, walls, or burial mounds chambers etc.) and areas with past metallurgic activities will usually show very high resistivity values. Burnt layers (e.g. burnt wooden constructions, burnt clay, a pottery area, a dumping area with ceramics etc.) usually give a medium to relatively high resistivity response, while low resistivity areas correspond to features which readily retain moisture like ditches, waste pits (kitchen waste), fillings of burial mounds mantle etc. Furthermore, among the most widely used geophysical methods in archaeological geophysics, ERT is the only method providing information on the stratigraphy of archaeological and geological horizons. It gives invaluable information prior to excavation and also in other cases in which detailed research is required.

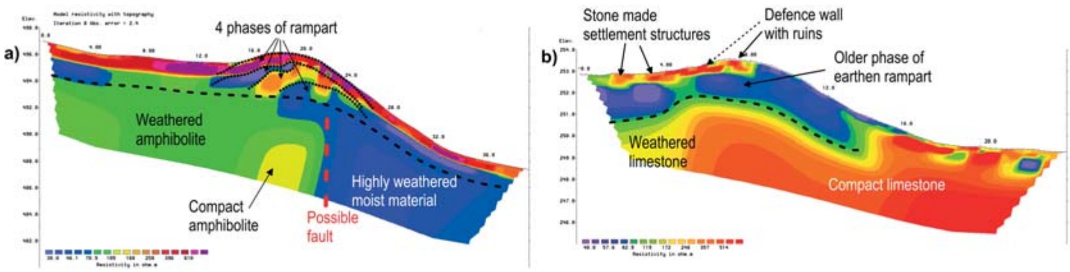
Since the measurements are based on a ground electrode contact, this method cannot be applied in urban areas with prevailing concrete and asphalt surfaces. The nature of this method and the process by which it obtains information in the course of vertical cross-sections of the subsurface, would also make it excessively time-consuming for use as a means of providing an initial overview, suggesting its use as a complementary measure to other faster methods (i.e. magnetometry, georadar and low frequency EM method).

The successful archaeological application of the ERT method across the scientific literature includes non-destructive characterization of various types of archaeological features, such as buried walls, voids, caves, passage-ways, multi-layered human settlements, prehistoric ramparts/defence walls and other hillfort structures, ancient city walls and preeminent monuments, burial mounds and tumuli, the detection of tombs and the definition of their geometry, the investigation of previously excavated and then backfilled features etc. Furthermore, ERT also contributes to the understanding of the geological setting and the geo-archaeological features of archaeological sites, while it also improves the comprehension of historic workflows and manufacturing processes. Seafloor archaeological applications of marine resistivity imaging have also been reported.

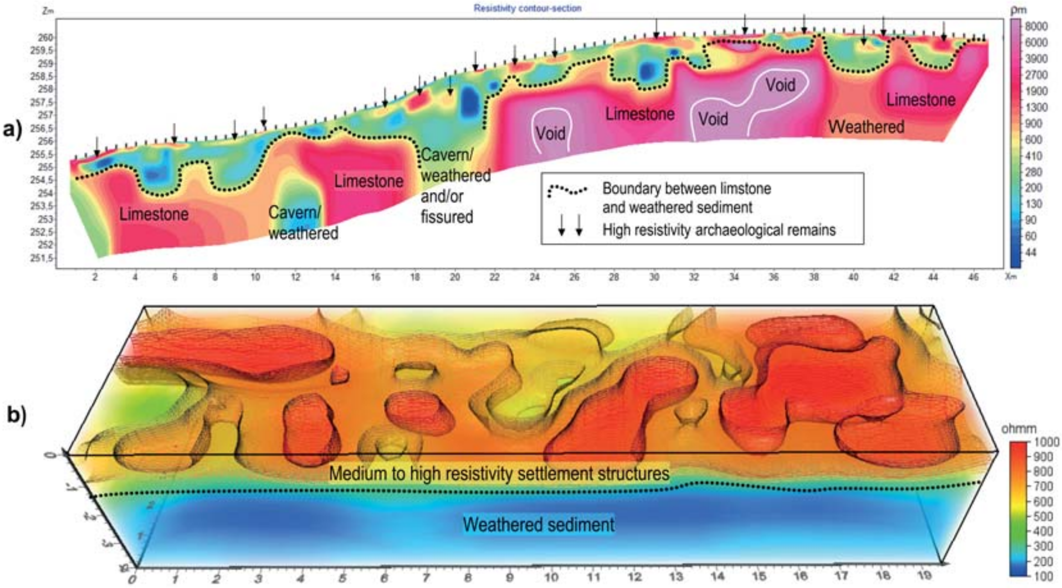
Lately – also within the framework of the Iron Age Danube project – the application of the ERT method has been thoroughly examined in the context of different prehistoric archaeological structures (e.g. burial mounds, ramparts, settlement structures...). Some examples with brief descriptions illustrating some of its applicability methods, are shown below (Figures 2-4).



II.4.4.4 Figure 2: ERT inverse models of Iron Age burial mounds with high resistivity stone-made chambers (C), surrounding ditches filled with high resistivity material (D) and other discernible high resistivity structures (X). a) necropolis Habakuk below Poštela (Slovenia), 2D inverse model; b) necropolis Habakuk below Poštela (Slovenia), two perpendicular 2D inverse models shown in 3D environment; c) necropolis Kagovac (Croatia), 3D inverse model



II.4.4.4 Figure 3: 2D ERT inverse models of defence structures, with black interrupted line showing the border between horizons with archaeological potential and geological layers and dotted lines showing borders between archaeological layers. a) multi-phase earthen rampart at Poštela near Maribor (Slovenia); b) earthen rampart from the late Bronze Age below the Early Iron Age limestone defence wall at Cvinger near Dolenjske Toplice (Slovenia)



II.4.4.4 Figure 4: ERT survey of hillfort settlement structures: a) Cvinger near Dolenjske Toplice (Slovenia), 2D inverse ERT model, karst environment; b) Čreta near Slivnica (Slovenia), 3D inverse ERT model, metamorphic geological environment

II.4.4.5 The basics of resistivity mapping (twin probe array)

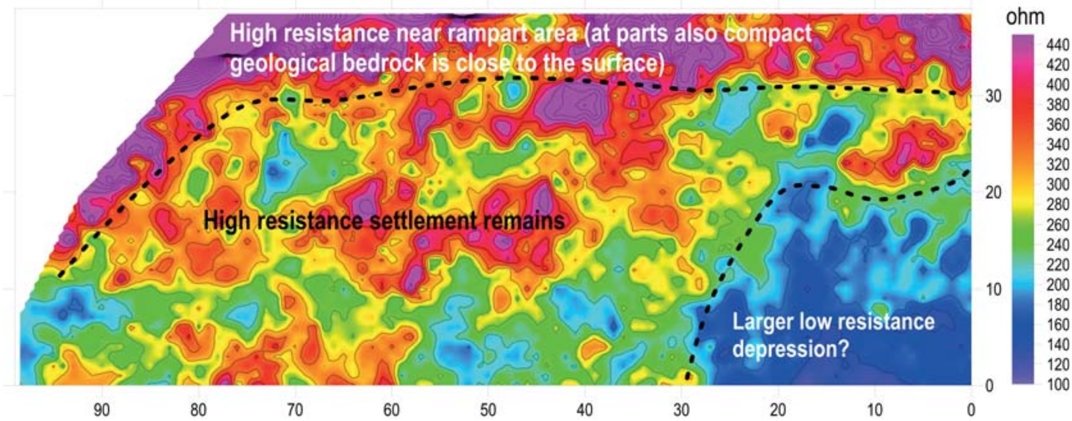
Barbara Horn, Branko Mušič

Until recently the lateral mapping of resistivity, more typically called earth resistance (i.e. the response of a fixed-geometry four-electrode array inserted into the soil, or the so-called twin probe resistance mapping method) has long been dominant amongst resistivity methods for characterizing large archaeological sites and discriminating buried man-made structures.

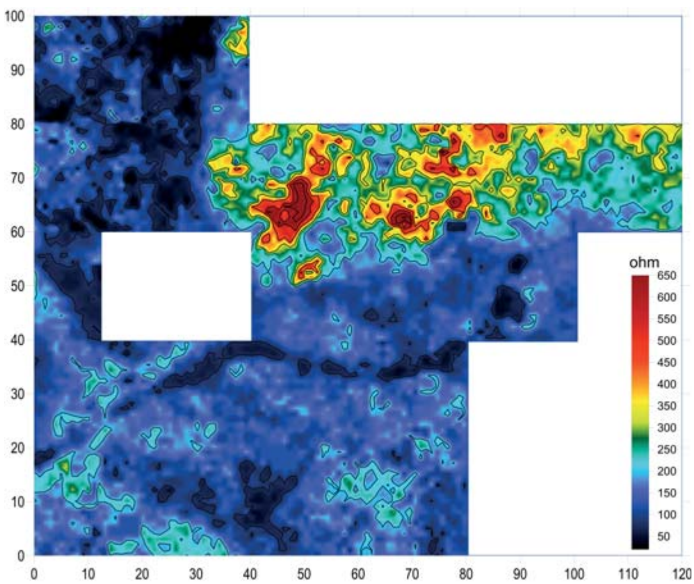
The basic resistivity theory for resistivity mapping is similar to that of the ERT method, except that in the case of the twin-probe method survey we need only four electrodes – two stationary remote current electrodes which are placed in the ground, while two constantly separated potential electrodes (usually 0.5m) are moved along the lines. The separation of 0.5 m will rarely give information on features below 0.75 m, greater separation will increase the depth penetration, although at the expense of resolution quality.

The measured data of earth resistance are interpreted directly in a qualitative manner, namely for the whole depth interval (0.75 m) lateral changes in resistance can be observed.

The twin probe method is usually more efficient in recognizing bulk lateral variation of archaeological structures in loose sediments and usually less efficient in investigating hillfort structures, which are normally located on hilltops with compact geological rocks close to the surface.



II.4.4.5 Figure 1: A twin Probe resistance map within depth interval app. 0.75m at the hillfort Čreta near Slivnica (Slovenia). Three general settlement areas can be determined: very high resistance anomalies coincide with the vicinity of the rampart with a higher density of ruins plus the solid bedrock being closer to the surface (upper part), high resistance anomalies scattered over the central part correspond to the settlement structures with a general course in the NE-SW direction, the low resistance area most likely represents a larger depression (lower right part).



II.4.4.5 Figure 2: Poštela near Maribor (Slovenia) burial mounds necropolis, Twin Probe resistance map within depth interval app. 0.75 m. The area with several burial mounds shows high to medium resistance, while the surrounding weathered sediment shows lower resistances. High resistance readings in the area of the burial mounds are the consequence of stone chambers in the central portions of the tumuli, stone debris in the mantle of the burial mounds and also solid bedrock between the tumuli.

Key facts about the twin-probe resistance mapping method

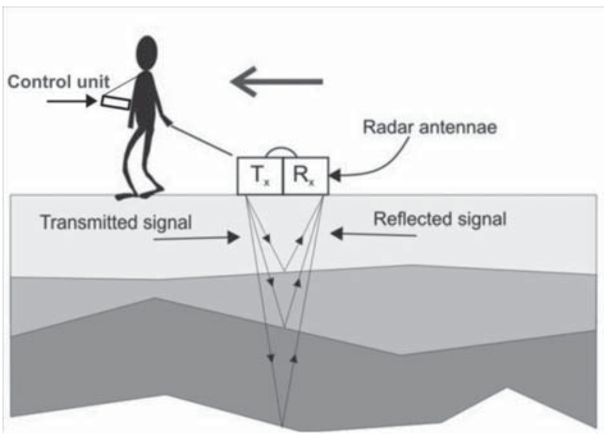
- Provides lateral extension of archaeological features:
  - within the specific depth interval (e.g. 0.75m)
  - recognizes high resistance structures and low resistance areas
- Environmental dependency:
  - very suitable for lowland use
  - lLess suitable above solid bedrock
  - ground contact needed (not applicable in urban concrete and asphalt area)
- Research levels:
  - suitable to estimate archaeological potentials
- Research potential:
  - (paleo)landscape reconstructions

II.4.4.6 The basics of ground penetrating radar measurements

Branko Mušič

Ground penetrating radar (GPR) sounding is commonly used on prehistoric sites as an important geophysical method to provide complementary results to those from magnetic methods (see the section The basics of magnetometer measurements), low frequency electromagnetic (see the section The basics of low-frequency EM geophysical measurements) and resistivity methods (see the section The basics of electrical resistivity tomography and The basics of resistivity mapping).

The primary goal of most GPR investigations is to differentiate and spatially map (geo) archaeologically relevant subsurface interfaces. The success of GPR surveys on prehistoric sites depends on local characteristics of a specific landscape unit: soil and sediment structure and texture, clay content, ground moisture, type, shape, volume, composition and depth of the archaeological remains, surface topography and ground cover with vegetation. It is not a geophysical method that can be applied in a routine manner to all environmental and archaeological settings, although with thoughtful modifications



II.4.4.6 Figure 1: Schematic display of GPR method operation. The GPR system consists of a control unit and signal transmitting and receiving antennas. In the most frequently used monostatic antenna configuration, both antennas are fixed at the short distance in the same box

in survey procedures and data processing methodology, GPR can be adapted to a great variety of conditions (Figure 1).

The GPR method is based on the physical principles of electromagnetic wave propagation in the ground. Whenever radar energy crosses a contact between two materials with different physical properties, the velocity of the waves passing between them will change and some energy will be reflected back towards the surface. Sedimentary layers and buried archaeological materials have particular properties that affect the velocity and quantity of electromagnetic energy transmission and determine the magnitude of reflected waves registered on the surface.

The velocity of radar wave propagation in the subsurface material is the most crucial parameter to be determined in an archaeological ground-penetrating radar (GPR) survey, because accurate velocity estimates comprise the basis for archaeological sources depth estimation. For velocity analysis in almost all situations, where at least some reflections occur as distinct hyperbolas, the simple and popular method of hyperbola fitting can be used. However, the propagation velocity of the radar waves can be altered dramatically throughout the site due to the extremely variable subsurface composition and moisture content.

The main properties of materials that affect radar wave propagation and generate reflected waves are relative dielectric permittivity (RDP) and electrical conductivity (related to the amount of retained water), to a lesser extent also magnetic permeability. If these are known (which is rarely the case for most sites, as detailed laboratory analyses must be conducted on soil and sediment samples), the amplitude of reflected waves at buried interfaces can be predicted in advance for presumed archaeological features and contexts.

If the targeted archaeological features are composed of almost the same material as their surroundings, sharing also about the same physical properties, there will be no variations in RDP between them. In these situations little or no reflection will occur at the interfaces between archaeological features and surrounding material. This makes such archaeological features faintly visible as discrete GPR echoes or completely invisible on radar signal displays.

There is always a maximum depth of radar energy penetration, which is different for every site, no matter what antenna frequency is used or post acquisition processing techniques are employed. The maximum effective depth of penetration of GPR waves is a function of the frequency of the waves and the physical characteristics of the material through which they pass. In a highly conductive medium in extremely wet conditions, the electrical component of the propagating electromagnetic wave is rapidly conducted away, and

Antenna frequency MHz	Wavelenght in dry soil λ, cm	Detectable targets 0.25λ, cm
400	25	6.25
500	20	5
1000	10	2.5

II.4.4.6 Figure 2: The theoretical relationship between transmitting antenna frequency, corresponding wavelength and dimensions of detectable targets

when this happens, the wave as the whole dissipates and reflection from potential archaeological remains is no longer possible (Figure 2).

The resolution of a GPR survey is strictly dependent upon the wavelength of the transmitting antenna. The wavelength of electromagnetic waves from a high-resolution 400 MHz antenna, which is commonly used at prehistoric sites, is in relatively dry soil approx. 0.25 m. Under favourable RDP contrast and shallow depth of targeted archaeological features it theoretically assures recognition of objects with a diameter of 6.25 cm or greater. Field practice has shown a relatively significant deviation from this theoretical calculation, since the theory does not take into account the extremely heterogeneous composition of

Antena frequency	Depth range (m)	Time range (ns)
100	10	200
200	5	100
500	2.5	50
1000	1.25	25

II.4.4.6 Figure 3: Depth range dependency on selected antenna central frequencies

archaeological remains at prehistoric sites having a wide span of materials with different RDP values, complex stratigraphic relations and a variable surface morphology with different soil types and dense vegetation cover (Figure 3).

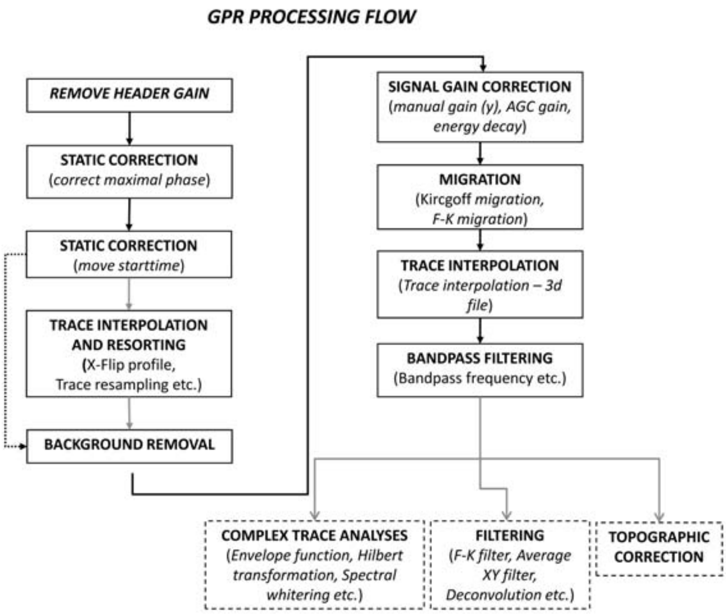
In practice, vertical resolution is the smallest distance at which two GPR reflections can still be treated as two separate GPR limits. The upper and lower limits of the consolidated layer: (sub)horizontal, irregular or inclined reflector (e.g. a badly preserved drywalls, burned house floor, clusters of post holes, shallow pits etc.) will be clearly recognized on the radargram if its width significantly exceeds one quarter of the wavelength.

Aside from the amplitudes of reflected waves, the measured parameter in GPR surveys is also double the time a wave travels from the transmitting antenna to the underground reflector (e.g. drywall structures/surrounding medium, etc.). It is expressed in nanoseconds (10-9s). By knowing the approximate RDP, and thus the propagation velocity of the radar waves in the investigated media, the times of the reflections may be calculated into units of length, or rather depth sections.

The best-known approach for presenting GPR results is the so-called time slices method; these are essentially time slices of a series of parallel and usually equally distant GPR profiles. Time slices together compose a diagram of equal amplitudes of GPR echoes in the same time range of returning waves. In the archaeological context, this generates a series of “plan views” at arbitrarily selected depth intervals. The georadar method enables also 3D portrayal of reflected GPR signal amplitudes on the basis of several parallel profiles, which is useful for visualization and analyses of GPR results at prehistoric sites. This is usually applied to visualize selected archaeologically relevant details extracted from GPR time slice analyses. Archaeologically relevant distinct GPR echoes in a 3D mode provide cross sections of the investigated soil volume in arbitrary directions, together with a detailed insight into the spatial relationships of the dry-wall and other compact structures in different necropolis or settlement contexts with their depths, widths and levels of preservation

Workflow

The most challenging aspect of GPR data processing is in the case sensitive steps required for reducing different types of noise generated by internal and external sources introduced during on-field data acquisition, with the nature of electromagnetic wave propagation generated by site specific composition of soil substratum, manifested in moisture content variability and by lateral and vertical differentiation in sediment structure and texture. It is of crucial importance that advanced processing flow is applied for a more profound study of the varied composition of prehistoric remains. The noise is usually significantly reduced after a case sensitive processing flow and slight irregularities in the composition appear as faintly visible background variability (Figure 4).



II.4.4.6 Figure 4: Schematic display of basic processing steps for GPR data spatial positioning, resorting, filtering and visualization

Workflow / General steps for GPR survey design:

1. Choosing an optimal antenna frequency and distance between parallel GPR profiles for proper density of data for specific archaeological structures recognition.
2. Grid positioning and the removal plants so that vegetation and surface morphology distortions are minimized.
3. Carefully selected processing steps, which create site specific processing flow.
4. Integrating results on spatially positioned GPR results with topography (DEM).

Integral interpretation on the basis of GPR method results in relation to other geophysical and archaeological data

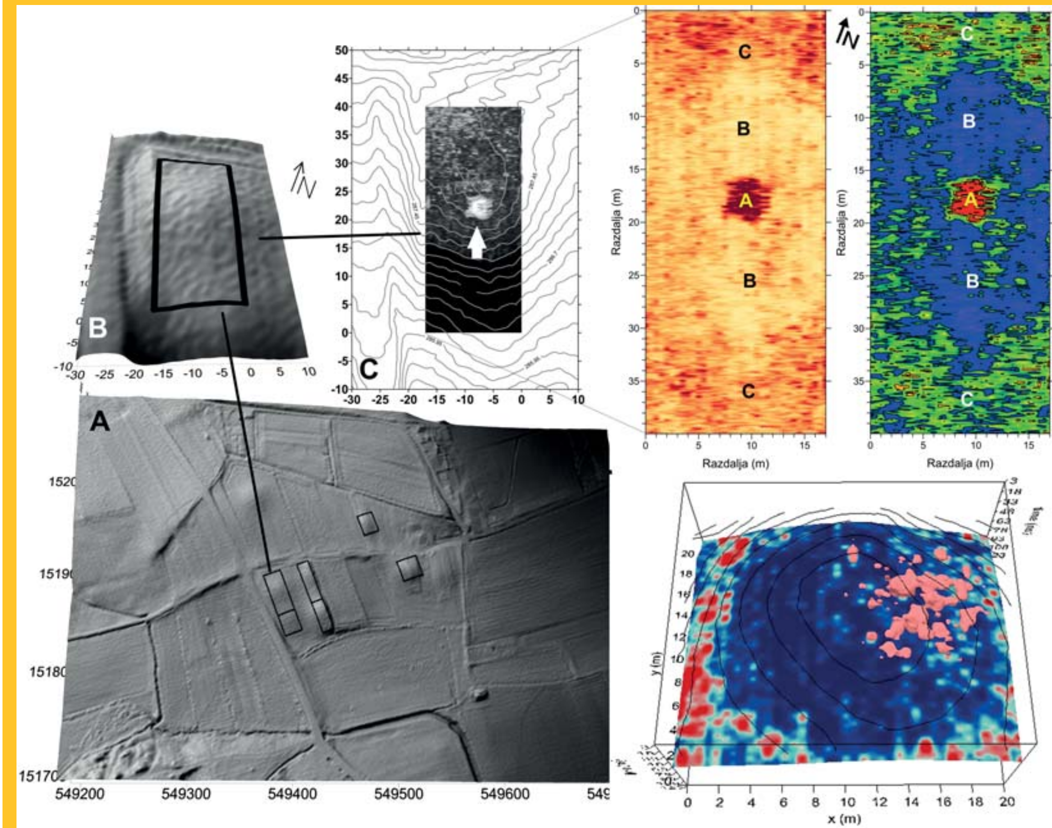
Application and limitations of GPR measurements

This technique is applied in general, at early Iron Age sites, using antenna frequencies between 100 and 800 MHz to resolve research questions concerning the recognition of drywall settlement structures, terrace walls, burned house floors, internal composition of ramparts and/or defence walls, stone made chambers in burial mounds, flat cremation graves with urns in stone slab grave constructions and to estimate the shape and depth of such compact archaeological structures. Apart from the recognition of archaeological features, the GPR method is also frequently used for revealing geoarchaeological characteristics of underlying bedrock morphology at shallow depths.

The GPR results confirmed the suitability of high-resolution antenna (for instance: 400 MHz) for recognition of stone masonry chambers in the central sections of small burial mounds. This antenna frequency is generally better suited for surveying shallow archaeological targets, especially for badly preserved stone chambers in central sections of small burial mounds, which is quite often the case at necropolises on intensively ploughed agricultural land. In such conditions, the GPR method provides important complementary data for the magnetic method. It is very suitable for revealing the internal composition of burial mounds, a faculty that is frequently lacking in the otherwise meaningful and expressive magnetograms, in which circular ditches are always clearly discernible. The GPR results confirmed the suitability of the 400 MHz antenna for barrows with heights up to 2m above modern surface.

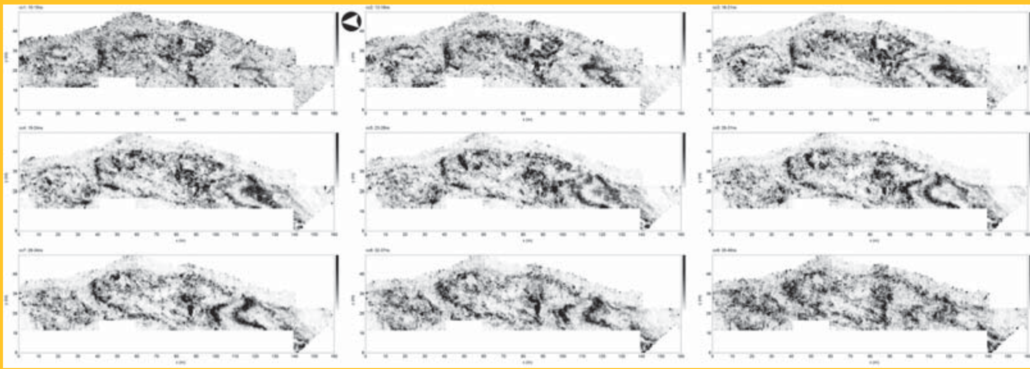
There are also some limitations to the successful application of the GPR method on prehistoric sites. Apart from the general influence of modern installations in a close vicinity to these sites, such as radio or radar transmitters, there are other different environmental noise sources of, which may also partly blur archaeologically relevant GPR signals. At the hillforts with igneous or metamorphic bedrock it is usually a thin topsoil cover with quantity of stone debris as a consequence of erosion processes and gravitational transition of material to the lower altitudes. In such environmental conditions, chaotic echoes appear on radargrams and make archaeological interpretation more difficult. In addition to a heterogeneous soil composition, bedrock of variable morphology close to the surface also generates strong radar reflections of different forms in horizontal cross sections. Achieving a specific RDP contrast between the archaeological remains and the surrounding medium is essential for recognition of archaeological features apart from their geometrical properties. The situation on most prehistoric sites is extremely complex and an accurate prediction of all the properties in the expected archaeological features is impossible. Topographic correction using lidar digital elevation models should be applied for the elimination of the distortions, which appear in the variable surface morphology. There is no unique strategy for GPR surveys in such situations and an empirical approach is required with GPR surveys applying high-resolution antennas at several areas, which are selected on the basis of previous archaeologically positive results, obtained by magnetic and low frequency electromagnetic methods. By this means the results of GPR surveys can contribute complementary information on a subsurface situation and help to achieve a more reliable integral interpretation.

GPR measurements case study Pivola below Poštela (Slovenia)

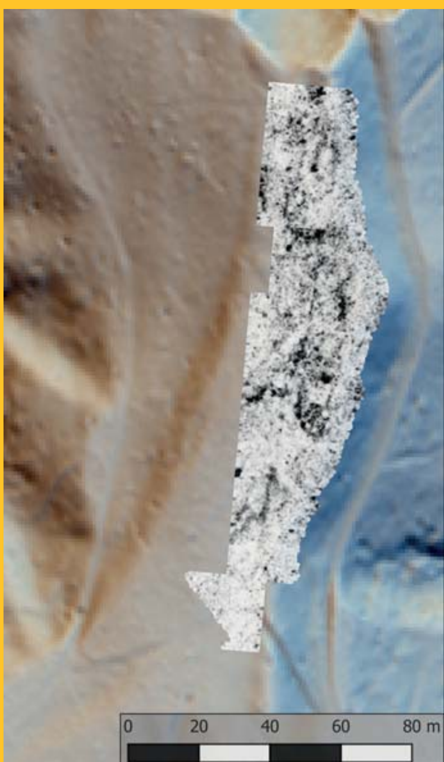


II.4.4.6 Figure 5: Original stone material from the central chamber is traceable in the burial mound mantle also in cases where it has been completely destroyed by intensive ploughing. While the width of the dry-stone burial chamber walls is deduced by applying migrations and the envelope function, the depth and preserved height can be determined by radar velocity determination using the hyperbola adaptation method. Lidar imagery with the position of a small burial mound at Pivola below Poštela (Slovenia) which has a well-preserved central stone chamber as revealed by GPR survey (top part) and an example of a completely destroyed chamber, which is traceable on the basis of GPR echoes from dispersed stone fragments in the badly preserved burial mound mantle (bottom right). Distinct echoes from the dry-stone burial chamber (top right: A), attenuation of the GPR signal in the water saturated mound made of sandy clay (top right: B) and chaotic echoes in the direct surroundings (top right: C) of the modern cultivated field. On the basis of these results it can be concluded that GPR surveys should be introduced in the initial stage of geophysical surveys at those prehistoric necropolises, which have been almost completely destroyed by intensive ploughing activities in modern times. Low burial mounds are the prevalent features on necropolises of this kind and the GPR method with the 300-500 MHz frequency antennas is the most suitable method for revealing the precise position, dimensions and plan view of dry-stone burial chambers or their preserved parts

GPR measurements case study Novine hillfort above Šentilj (Slovenia)



II.4.4.6 Figure 6: GPR time slice images for selected depth intervals at the hillfort settlement frequently show distinct echoes from compact subsurface features of relatively stronger GPR signals. These most probably represent GPR echoes from drywall structures such as terrace walls or similar linear features. Some other distinct GPR anomalies of almost rectangular horizontal cross-section and some of irregular shape, which are also generated by settlement drywall structures are often present. This gives an entirely reliable impression of the potential the GPR method has for the recognition of archaeological features in the internal parts of prehistoric hillforts in quite delicate environmental settings. GPR time slices for the two-way radar wave traveling time interval 10–40 ns correspond to the depth range of approx. 40–160cm. Distinct anomalies are represented by GPR reflections from compact archaeological settlement structures at different depths on the eastern part of the Novine hillfort above Šentilj (Slovenia). Time slices enable detailed impressions to be gathered through the relevant depths on the type, preservation level and variability of archaeological settlement structures



II.4.4.6 Figure 7: Selected time slice at the shallower section with several faintly visible GPR echoes generated by compact prehistoric settlement structures at the eastern part of Novine hillfort in a lidar image

II.4.5 Remote sensing data collection methods

II.4.5.1 Aerial archaeological photography

Zoltán Czajlik, Michael Doneus

Introduction

Aerial archaeology is one of the oldest and most cost-effective prospection techniques. It has become an invaluable tool for archaeology, as it is – next to field survey – the only method for the systematic (i.e. not coincidental) discovery of archaeological sites over large areas. This is of prime importance, as the major part of our cultural heritage is buried in the sub-surface. Most of these archaeological features, sites, and landscapes are still unknown, and therefore difficult to protect. In order to be able to introduce adequate protection measures, the archaeologist must know their exact position and dimension of the archaeological features. Therefore, archaeologists need fast, low cost and non-invasive methods that are able to show the extent and provide a detailed mapping of archaeological traces in a region – a requirement that is accomplished through the use of aerial archaeology.

Strictly speaking, aerial archaeology comprises any airborne technique, such as for example aerial photography, airborne laser scanning or multi- and hyperspectral scanning (known as airborne imaging spectroscopy). The focus of this chapter will be on aerial photography or rather air photo archaeology (which is a translation of the German term "*Luftbildarchäologie*").

The roots of aerial archaeology go back more than a century, when pilots with archaeological interests started to photograph sites in the course of their military reconnaissance missions during World War 1. Already in the 1920ies the work of O.G.S. Crawford exemplified the basic methodology and he is thus regarded as the founder of aerial archaeology. Today, this technique is actively applied in many countries of Europe and beyond. Also in areas with flying restrictions, open source image archives (such as for example Google Earth or Microsoft Bing) facilitate their archaeological interpretation.

The basics of aerial archaeology

Any prospection technique is based on the fact that human activity leaves traces on or in the Earth's surface. Air photo archaeology is at its best in identifying those traces that changed the subsoil: when a pit or ditch was dug, a wall was erected or a path was used, humans changed the sub-soil. The refilled pits and buried wall foundations are physically (grain size distribution) and chemically (quantity of nutrients) different from the undisturbed boundary subsoil. These generated contrasts are enduring and their effects (among others variation in moisture content, temperature, relief) locally influences the appearance of the Earth's surface. By this means archaeological features can be recognized by differences in the rate of thawing and freezing (frost marks), soil luminance and colour (soil and moisture marks), and most importantly by the height and colour of plants (vegetation marks), to mention just a few of these so-called visibility marks.

Negative and positive contrasts can be distinguished using all of these marks, which are evidence for the consistency of the buried feature. As an illustration, negative vegetation marks occur when the growth of plants is reduced due to moisture or nutrient deficit. As an effect of this, plants (especially crops) are stressed resulting in a lighter green and an early yellowish colour. They either wither or ripen quickly and remain relatively small, and in most cases are an indication of buried walls. Positive vegetation marks show an enhanced and prolonged plant growth, where crops grow larger, have a darker green and ripen later. These are usually a sign of refilled pits and ditches. In a similar way, soil and moisture marks can become evident by a lighter colour in the ploughed or harrowed field, indicating walls “showing through”, former pathways or complanated barrows. Darker coloured soil often appears on top of refilled pits and ditches.

While the identification of archaeological traces based on visibility marks seems to be straightforward, it can nevertheless prove difficult. In practice, whether or not a contrast becomes strong enough to become visible depends on a combination of many factors. Among the most important of these factors are the type of archaeological feature, the season, weather condition, amount of rainfall during growth period, time of day, viewing direction in relation to the visibility marks and also extending to the solar radiation, the wind strength, or the geological setting. Air photo archaeology must thus be applied systematically. This implies that obtaining a significant idea about the archaeology of a target area, will require that it is repeatedly covered by reconnaissance flights. A single photo flight without prior preparation may not provide any evidence of archaeological traces.

Workflow

The fascination of air photo archaeology is the fact that it works using the naked eye through direct observation of visibility marks on the earth’s surface from a bird’s eye view. On the most cost-effective level, it can be practiced by interpreting aerial photographs in specialized archives or from online sources. The downside of this approach is the fact that one relies on already existing air photographs, which may have been taken under unfavourable conditions. The key to obtaining control over the data acquisition process is thus either by conducting reconnaissance flights or ordering vertical photography taken under specific conditions to achieve better results.

Air photographs can be classified as either vertical or oblique images. The distinction is less on the viewing angle than the terminology appears to indicate. It is rather the theoretical and methodological background, which characterizes both types of photographs.

Oblique photographs are taken by an archaeologically experienced person through the side window of a low flying aircraft. During the reconnaissance flight, the photographer observes the ground and when archaeological traces are identified, they are documented from the most suitable angles preferably from multiple directions within a full circle. Colour differences are best seen in photos with the sun behind the camera, while height differences should be recorded against the sun, when the effect of shadows is most distinct. Photographs taken during an oblique photo flight have therefore to be regarded as pre-selected.

When obtaining vertical photographs, a predefined area is documented in its entirety systematically with overlapping photographs taken vertically along parallel flight-lines. This means that if a vertical coverage can be arranged under ideal conditions, the whole target area with all its visible sites will be depicted. Anyone who subsequently interprets the photographs will see the whole landscape in the same suitable condition, regardless of whether it is examined on the day when the film was developed or thirty years later. The landscape can be interpreted time and again and, as experience and knowledge increases, more and more sites will probably be found. Vertical photographs should therefore be a part of every reconnaissance strategy, especially in those cases where the time available for oblique flights is limited or where obstacles (borders etc.) hinder or prohibit free movement in the air.

Although aerial archaeology is very cost-effective, flights can nevertheless be expensive. This means it is vital to collect relevant data before the flight (among others information on the location and shape of already known sites, geology, agricultural practices, no-fly zones). In Central Europe, the (early) summer season is the most suitable for research of vegetation marks, but crop marks can also be found in March and in autumn. Photographing dry pastures can be successful from August to October, and soil signs can be traced from October to March. The basic requirements are an airborne platform (usually a high-winged aircraft, but balloons, helicopters, kites and drones can be used as well) with an experienced (!) pilot and a decent camera to document the archaeological traces that are spotted. In practice, digital SLR cameras with high quality (zoom) lenses have proven to be most useful. The most important attribute of the camera itself is the capability to work under extreme conditions.

A flight usually takes a few hours and yields several hundreds of photographs. It is important to document the process of flying and the location of each photograph together with its metadata. Digital cameras automatically document all photography-relevant metadata in the EXIF-header of each image. Combined with GPS devices they also record the position from where each photograph was taken. This will help to store the location of each photograph in what should preferably be a GIS-based database. GPS devices are also useful to record the flight track, including areas where no archaeological traces were recorded although reconnaissance had taken place.

The aerial archaeological workflow often stops after storing the air photographs and their archaeological sites in a database. To retrieve the full potential of aerial archaeology, the air photographs need to be rectified and their archaeological content needs to be mapped. This provides detailed information on the layout and individual features of archaeological and palaeoenvironmental sites and structures. This information, however, can only be used, when the photographs are georeferenced, (ortho) rectified, interpreted and mapped.

A wide variety of approaches is available for the rectification of aerial photographs. Besides specialized software for aerial archaeology, image-based modelling software based on structure from motion (SfM) algorithms is commonly used today. Depending on the quality of the photographic source material, they usually allow a high quality ortho-rectification.

The process of interpretative mapping is best done within a GIS environment. Here the interpretation map gets an attached attribute table, where for each drawn feature information about its description, function, and context, the number of the interpreted photograph, and the interpreter is stored.

Application and limitations of aerial archaeology

In recent decades, aerial archaeology has proven its value in many countries throughout Europe and beyond. Mapping a 600 square kilometre large landscape south of Vienna should be mentioned here as an example.

Between 2003 and 2005 several reconnaissance flights (altogether 35 hours of data acquisition) were carried out along the Leitha valley south of Vienna and together with more than 2,000 vertical photographs taken by the Austrian air force in Langenlebarn, these formed the basis for a detailed interpretation. All of the relevant aerial photographs (over 400) were rectified and consequently interpreted in GIS. As a result, more than 640 archaeological sites were identified, many of them multi-period settlements or graveyards.

Key factors about aerial archaeology in Heritage Studies

- Coverage
  - suitable for large areas
  - countrywide collections available
- Environmental dependency
  - very useful in agricultural landscapes
  - pastures may yield useful results
  - difficult in woodland
- Research levels
  - Level 1 Prospection
  - Level 2 Identification and delineation
  - Level 3 Interpretation
- Social potential
  - very comprehensible and persuasive
  - very useful for education and promotion
  - (paleo)landscape reconstruction

This means that with only 35 flying hours the total inventory of archaeological sites had been doubled. All of the newly discovered “potential” sites (more than 350) were also field-walked during autumn and winter 2004/2005.

Additionally, more than 30.000 individual archaeological features (pits, houses, graves etc.) and landscape features (mostly old river channels, ditches, and drains) were mapped. The resulting data was used as a basis to show the spatial distribution of the individual archaeological phases and to analyse in detail the late iron-age and Roman settlement patterns.

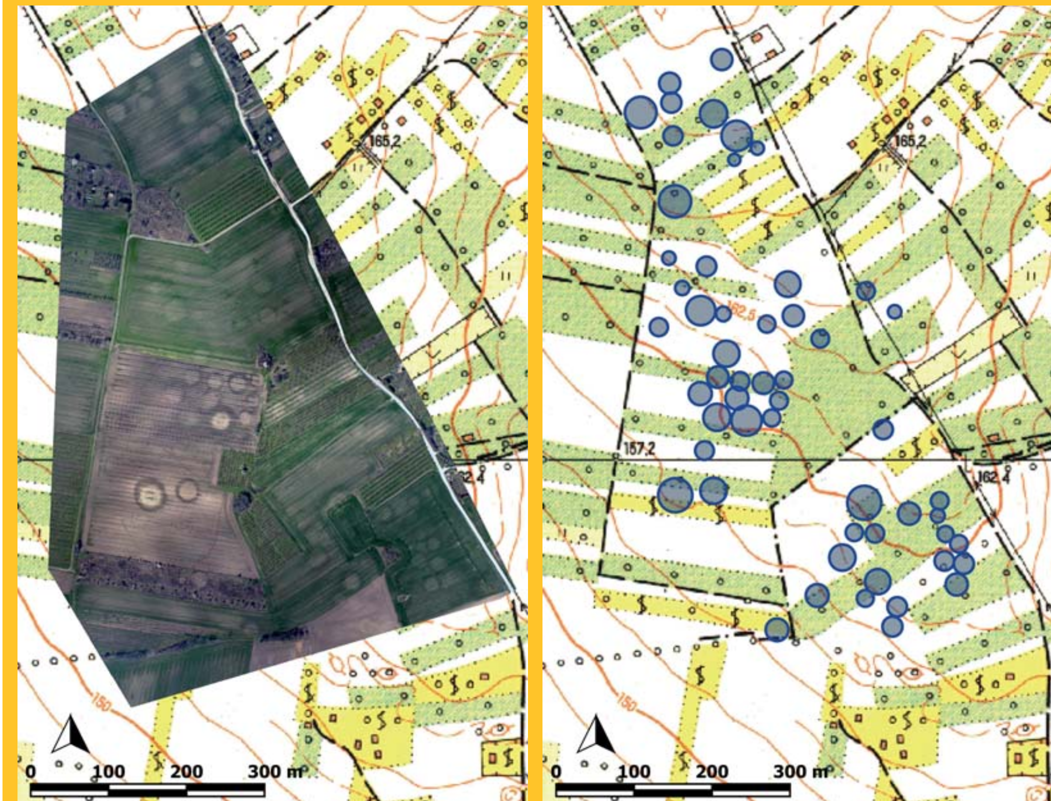
This example demonstrates the potential of aerial archaeology. It should not, however, detract from the fact that there are limitations to this method. Aerial photography is a passive remote sensing technique. During reconnaissance flights, only a few parameters such as the date and time of the flight, flying height, direction of view, and type of sensor can be influenced to improve the detectability of sites. Once an aerial photograph has been taken, there is only a limited variety of possibilities to enhance it for easier interpretation.

The visibility of buried archaeological traces depends on many factors. The degree of visibility of the different elements in an archaeological site will thus vary through time depending on climate, vegetation, agricultural regime, etc. Only repetitive observations conducted over a period of several years will reveal a sufficiently complete representation of the buried archaeology of a region. But still there are areas, where aerial archaeology will rarely or even never be successful, as for example built up areas, areas with high alluvium, or forests. Also, quite often, only major structures of an archaeological site

Aerial archaeology case study Süttő tumulus field (Hungary)

II.4.5.1 Figure 1: Our compilation shows the aerial photographs of the NE group of the Süttő tumulus field taken during the period between June 19, 2013, and February 28, 2018, from a SE direction for the sake of perspicuity. The photos were made by Zoltán Czajlik with Nikon D300 and D750 cameras from a Cessna small plane and Robinson-type helicopter. Of the two tumuli, the one in the north is well visible on the surface under the ploughing (II.4.5.1 Figure 1a, March 13, 2014), and the shadows of both still extant tumuli can be clearly made out on the snowy surface (II.4.5.1 Figure 1b, February 28, 2018). Maize covers the tumuli in the middle two images. In 2015, the top of the mounds was indicated by the absence of plants (II.4.5.1 Figure 1c, June 30, 2015); however, in the summer of 2014, the tumuli could not be detected (II.4.5.1 Figure 1d, June 18, 2014). In 2013 and 2016, wheat was planted in the area, which reacted differently to the mounds, according to the weather conditions of the given year. Large, bright patches indicated their location in 2016 (II.4.5.1 Figure 1e, June 21, 2016), but in 2013, mostly the dark ring of the circular ditch around the SE tumulus was visible (II.4.5.1 Figure 1f, June 19, 2013). The six images show not only the different surface coverage (soil, snow, maize, wheat) and the unique observation possibilities typical of the given year, but also the “mosaic” nature of the information that can be gathered, i.e. the procedure of how the details from long-term aerial archaeological research in the same area is put together.

Aerial archaeology in Iron Age research



II.4.5.1 Figure 2: The circumstances proved to be favourable for an aerial archaeological survey at the Százhalombatta site during March 2014. The traces of the burial mounds indicated by soil marks and crop marks can be seen in several fields. The circular ditches around the barrows are clearly visible, while the lighter material of the mounds and perhaps the structure of the chambers are only visible in some cases. The series of oblique aerial images can be processed using 3D photogrammetry in order to obtain an ortophoto mosaic. We georeferenced the images using ground control points (GCP) which have known geographical information. The accuracy of the data is largely determined by the origin of these points, the accessibility of the exif information and the quality of the oblique images. The next step of the workflow was the interpretation in a GIS environment. We only marked the features that could be securely interpreted as burial mounds. Nevertheless, it must be noted that the interpretation process is always greatly influenced by what is already known about the site. Some marks can be better explained and they can be identified as barrows in knowledge of the data provided by the geophysical surveys.

become visible. Even if subtle details, such as for example palisades or postholes, can show occasionally in an aerial photograph, this is not the common situation. In some cases, it is possible to provide dating evidence just from the structure and pattern of the visible traces, but very often, this is not the case.

As with any other prospection technique it must thus be stressed that we only get a coherent picture of the archaeology of a landscape when we integrate various prospection methods.

Workflow of aerial archaeology

- Data collecting
- Preparation of the flight using meteorological forecasts and actual land coverage data
- Flight and photography, with GPS-navigation, saving-log
- Downloading photographs, data documentation, identifying the photographed sites
- GIS-based archaeological interpretation

II.4.5.2 Airborne laser scanning

Michael Doneus, Martin Fera

Introduction

Human activity leaves traces on the Earth's surface. Whether building a house, digging a pit, raising a barrow, ploughing a field or simply by repeatedly walking the same route the surface relief becomes locally altered. Consequently, human activity is 'engraved' into topography. The survival of these kinds of traces depends on a wide range of factors, including the dimension of the original structure, geological and pedological conditions, geomorphological processes (erosion and accumulation), animal activities, vegetation, and re-modelling of the relief by repeated re-occupation through time. One of the most important factors for the conservation of micro-topography is the presence of vegetation, which protects archaeological remains to a certain degree from erosion. Therefore, in wooded areas, archaeological structures often survive in relief and can be detected and mapped on the ground.

It seems almost a discrepancy that this favourable preservation of archaeological traces in woodland is not reflected in our archaeological knowledge. Quite the contrary, wooded areas usually leave blank spaces on archaeological distribution maps. Until recently, this was a result of the failure of large scaled archaeological prospection in densely vegetated areas. While pronounced traces (such as well-preserved banks, ditches, hollow-ways, barrows or terraces) are easily detected in-situ or from the air (at least in the leaf-off season), faint micro-topographical structures are often invisible on the ground even to the trained eye.

A very detailed digital terrain model (DTM) with at least one point per square meter is needed to make these structures visible. Furthermore, this needs to be digitally enhanced using virtual light sources, exaggeration of relief, colour coding and similar visualization techniques. Using airborne laser scanning (ALS) it is now possible to accurately measure surfaces and to create DTMs from the collected data.

The basics of ALS

ALS is based on the technology of light detection and ranging (LiDAR): an ALS-sensor (laser-scanner), mounted below an airborne device (airplane, helicopter, drone), actively sends out short infrared flashes (so-called 'pulses') towards the earth's surface in a fan-shape across the flight path. When a pulse (*light …*) hits an object (e.g. tree, car, ground surface), part of it will be reflected back towards the sensor. The returning echo is detected by the sensor (… *detection* …) and the distance to the reflecting object is derived from the travel-time of the pulse (… *and ranging*). As the aircraft moves forward, a differential global navigation satellite system (GNSS, e.g. like GPS) and an inertial measurement unit (IMU) determine the position and altitude of the scanner in a global co-ordinate system. With this information, the 3D-co-ordinates of each single echo can be calculated. Since the pulse repetition rate (i.e. the number of emitted pulses per second) can be extremely high (currently more than 200.000 pulses per second), an airborne laser scan will result in a high density of measured points that can be used to generate a highly precise and accurate model of the Earth's surface (Figure 1).

For eye safety reasons, airborne laser scanners usually generate near- or short-wavelength infrared pulses (typically 1064 nm or 1550 nm, respectively). As infrared light is largely absorbed by water bodies, green lasers (532 nm) are used to document (micro-)topography under shallow water.

Workflow

A typical ALS workflow from the project planning to the final archaeological result usually comprises the following steps:

It is essential for the user to understand that a DTM is not a given, "objective" description of an existing relief. It is rather one possible representation that more or less fits for the desired purpose. The quality and archaeological suitability of any resulting DTM and its visualizations are therefore not certain but depend on many decisions that were made throughout this process chain. Choice of scanner type (discrete echo or full-waveform), scanner model, scanning parameters, point density (resulting from pulse rate, field of view, flying height, speed of aircraft, overlap between two neighbouring scan stripes), and the time of year when the data collection was made are typical considerations for the acquisition and have been discussed in various publications.

Geo-referencing of the data is a standard procedure that is usually done by the data providers. Inaccuracies will, however, lead to problems within the overlapping area of two strips in cases where the co-ordinates of a single object point that was scanned (approximately) twice will deviate from each other horizontally and vertically. This will affect the final DTMs, where doubled objects, noise and formation of non-existing structures (sinusoidal curves, but also edges) will be apparent. This can be irritating for the subsequent archaeological interpretation. A simultaneous 3D strip adjustment of overlapping strips usually improves the resulting DTMs.

Workflow ALS

- Data acquisition
- Geo-referencing (echo detection and generation of a 3D point cloud from the scanner, GNSS and IMU data; strip adjustment and quality control).
- Filtering, i.e. classification of surface and off-surface points.
- DTM interpolation.
- Calculating visualizations based on the DTM (typically hillshade, slope, local relief model, openness).
- GIS-based archaeological interpretation.

During the process of filtering, the geo-referenced point cloud has to be classified into terrain and off-terrain points. The last-echoes of the laser pulses are the only ones that potentially represent terrain points. However, often last echoes also return from tree stems, cars, or other objects. Specialized filtering software is used to identify those echoes as off-terrain points. A choice can be made from a large number of software packages in different price ranges today. Depending on the filtering methods and user-based settings applied, all points from the point-cloud can be classified into e.g. low, medium and high vegetation, buildings, water, wire, noise, or surface. Depending on the purpose of the resulting DTM, filtering can lead to terrain models with or without buildings and including or excluding small-scaled features and micro-topography.

Finally, the resulting interpolated DTM needs to be visualized in order to be interpreted. Until now, the standard has been to use 2D visualisations. The simple shaded relief (derived from a virtual light source in the upper left corner of the DTM) can be regarded as the standard technique, as it creates an image that is easy to read. However, it has reduced information content, as linear features running parallel to the rays of the light source do not throw shadows and therefore become invisible. As a consequence of this, a second shading from perpendicular light-rays must be used at the very least. Additionally, there is a wide range of further, and to some extent more sophisticated visualization techniques, including dense contour mapping, a simple combination of slope and hillshade, geostatistical filtering, local relief model (LRM), principal component analysis (PCA) based on several shaded reliefs with varying illumination angles, sky-view factor (SVF), or negative and positive openness. The list of techniques and the literature on this topic is constantly growing, however, it needs to be stressed that there is no single technique that is universally applicable. For a sophisticated archaeological interpretation, it will always be necessary to utilize a combination of different visualizations. DTM visualization and consecutive archaeological interpretative mapping will typically take place in a GIS-based environment. Relief objects interpreted as 'potential' archaeological sites and features will be identified and drawn as lines or polygons.

Application and limitations of ALS

The potential of ALS was introduced to archaeology in the year 2000. Within a few years of development and application, ALS revolutionized archaeological recording of forested areas. As ALS has a huge potential for discovery and for the detailed documentation and monitoring of archaeological sites and structures under vegetation, the number of applications that use this technique is constantly increasing.

In addition to the use of geometrical information ALS offers also the possibility to explore the spectral response of laser pulses. In the infrared spectrum the reflexions can reveal archaeological traces by exploring changes in the reflexion, which are characteristics for separating out a healthy and a stressed crop. This expands the possibilities for the use of this method also on farmland during the crop season and therefore adds new possibilities to aerial archaeology approaches.

Today, general-purpose data (with usually a resolution of 1 point per square meter) has become available for large areas in several parts of Europe. This provides archaeologists with the opportunity to avoid the costly production of special purpose DTMs for their archaeological application. While this development is very positive, it has to be understood that general-purpose DTMs can have a reduced amount of archaeological information. To evaluate its archaeological potential, it is of vital importance that the archaeological user understands the technology and also the issues and limitations involved in data collection, filtering, surface creation, and interpretation of ALS information. This knowledge is a prerequisite for the assessment of the archaeological potential of a given general purpose

Key facts ALS in heritage studies

- Coverage:
  - countrywide datasets*
  - special coverage can be ordered
- Landcover dependency:
  - very useful in woodland
  - good results in farmland
  - applicable in urban areas
- Research levels:
  - Level 1 Prospection
  - Level 2 Delineation
  - Level 3 Characterisation
- Dissemination:
  - landscape animations
  - (paleo)landscape reconstructions
  - very useful for education and promotion

dataset, and therefore will assure a reasonable and successful application of ALS for archaeology.

Additionally, one has to be aware that ALS-based interpretation results will contain a high degree of bias. The most obvious, but essential, constraint is that ALS can document only sites and features that still survive in (micro-) relief. This means that the range of archaeological information to be found in an ALS-based project is usually biased in terms of chronology and site-type. Other restrictions are the type of tree cover and the relatively short time-frame available for the capture of the ground surface in wooded areas (during the period when the trees have lost their leaves but with no snow on the ground). Topography under conifers, evergreen vegetation, heather and similar extremely dense and low vegetation can hardly be measured in detail, although drone-based scanners with small footprints seem to be advantageous in these cases. It is thus also necessary to have a good understanding of the ground conditions present during data capture.

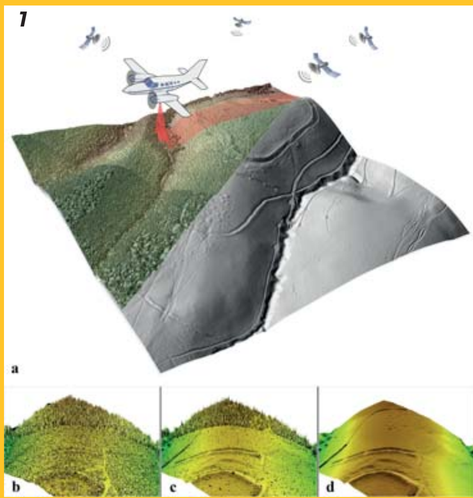
In conclusion, the archaeological interpretation of ALS-derived DTMs is a subjective process and the resulting confidence will vary from site to site. There are many natural and recent features that could affect the interpretation of ALS data, and to distinguish a pile of wood from a barrow can be a very difficult task when working solely with ALS data. Hence, non-sites may be identified as potential archaeological sites or vice versa. In order to evaluate the accuracy of this identification process, these 'potential' sites will need to be visited to ascertain whether they are archaeological sites or not and, if not, what has caused the response. These visits are essential to the production of an image interpretation key, which should help in turn to improve future interpretation.

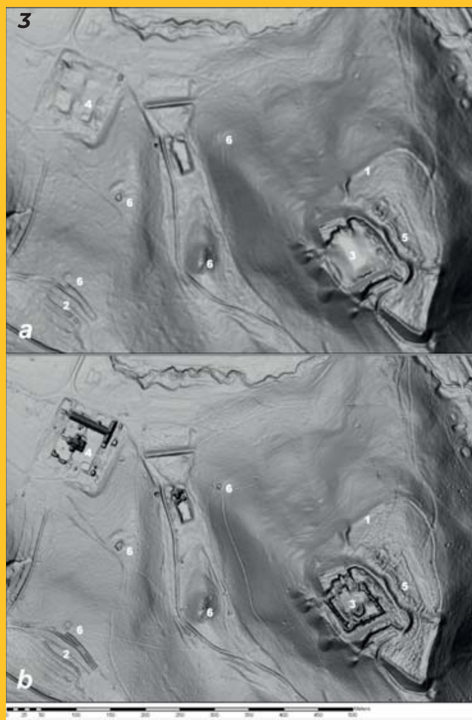
ALS case study Schandorf, Burgenland (Austria)

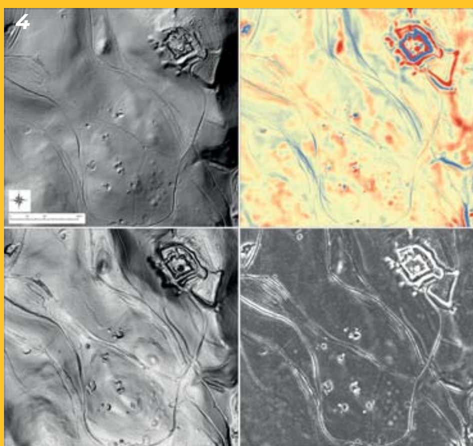
II.4.5.2 Figure 1: ALS reveals traces from a broad variety of processes on different spatial and temporal scales. While natural processes were and are forming and transforming the topography on larger scales, traces of human activity can be preserved and identified from various prehistoric and historic periods. One of the distinct classes for Iron Age research is that of burial mounds, which were able to survive under the canopy of forests from the Hallstatt-period for over 2500 years (mounds at the Austro/Hungarian border; Schandorf, Burgenland, Austria). The lack of agricultural transformation of the surface allowed large groups of mounds to be detected in the relief by the use of ALS. In the study areas not only the number of known cemeteries could be at least doubled, but special filtering and visualisations also allowed a much better quantitative assessment of this types of monuments and spatial analysis of their size, distribution and position in the landscape.

In the Danube area another distinct monument form is often situated in forested areas: hilltop settlements, some of them fortified and some positioned solely at naturally protected places in the topography. The high resolution of ALS-derived DTMs is perfectly suited to be used as a basis for intensive analytical studies, which can contribute to a better understanding of the sequential development of fortification systems or the extent and character of settlement terraces. The latter, in the form of parallel terraces surrounding a hilltop or shaping a slope from the highest spot downwards, seem to be a typical layout for early Iron Age settlements throughout the entire Danube Region. Systematic investigation of the project in all regions revealed some additional monuments of this site type, previously unknown to Iron Age research.

ALS in Heritage Studies







II.4.5.2 Figure 2.1: (a) Scheme of airborne laser scanning. (b) DSM of the first pulse data showing the canopy of the scanned area. In the foreground, the vegetation consists of dense bushes. In the background there is a dense forest with understorey. (c) DSM resulting from the unfiltered last echo point-cloud. There are many points, which represent, tree-trunks, very dense vegetation or narrow vegetation, which do not represent the actual ground. (d) filtered DTM showing even faint archaeological traces, as e.g. round barrows with shallow depressions from looting. (a: Martin Fera, b: Michael Doneus)

II.4.5.2 Figure 2.2: Schwarzenbach, Austria. Iron-age hillfort. (a) Roundish depressions are introduced to the DTM shading due to a missing strip-adjustment (errors in the geo-referencing). (b) the same area after a simultaneous 3D strip adjustment. The quality of the DTM could be improved significantly. (Michael Doneus)

II.4.5.2 Figure 2.3: St. Anna in der Wüste, Austria. Comparison of a general purpose DTM (a) and a DTM derived from ALS data scanned and filtered for archaeological purposes (b). While the general purpose data of (a) shows important archaeological information, such as the rampart of a prehistoric hillfort (1) or hollow ways (2), the building structures of the ruined castle of Scharfeneck (3) and a monastery (4) have been completely removed due to the filtering parameters. Finer archaeological detail, such as pit-structures surrounding the castle (5) and three out of four hermit's cells (6) are hardly to be recognized. The same area can reveal more information when the original ALS point cloud is filtered in an archaeologically adapted way or special purpose ALS data is used (b). (Michael Doneus)

II.4.5.2 Figure 2.4: St. Anna in der Wüste, Austria. Comparison of various visualization techniques: Upper left: hillshade; upper right: local relief model; lower left: slope; lower right: negative openness.

II.4.6 Archaeological excavations

Martin Fera

Introduction

The main aim of archaeology is to learn about past societies based on their material residues. Consequently, archaeological interest is often focused on artefacts resulting in a predominance of data collection methods that allow to detect 'finds', namely surface collection and even excavation.

When considering the myriad ways of archaeologically investigating the remains of human activity the primary method is traditionally excavation. Its dominance over any other archaeological method is best signified by the popular image of the 'digging archaeologist', who has become a symbol for the whole discipline: Archaeology has become the 'science of the spade'.

During the 19th century investigations on archaeological sites placed a sole emphasis on the retrieval of artefacts/antiquities. Further methodological developments started around the time of Schliemann's excavation at the tell of Hisarlik - the site of ancient Troy - during the 1870's and the establishment of academic archaeological institutions at universities and museums in Europe in late 19th century. This changed the focus from a pure antiquarian perspective towards an archaeological view considering all elements of the material inventory in its archaeological context and highlighting the importance of the stratification of archaeological deposits.

The dependency of archaeology on the destructive application of excavations has led to the development of different theoretical and practical frameworks to understanding the bias involved with different methodological approaches. The broadly accepted understanding of the formation of the archaeological record and its stratification includes both cultural (anthropogenic) and natural (environmental) formation processes (Schiffer 1987). In simplified terms, excavation tries to identify as many of these processes as possible through the controlled and systematic removal and subsequent documentation of distinguishable stratigraphical units (Harris 1991), recording and analysis of artefact and ecofact distributions and the collection of a broad variety of samples. The analysis of which allows knowledge to be gained on the sequence of events at the site under investigation that may be linked to activities of past societies connected to e.g. housing, production, or funeral practices.

The basics of archaeological excavations

All archaeological work is based on the presupposition that past human activities have left recognisable traces, which can be investigated and used as sources to gain knowledge about (pre-)historic societies. Popular understanding of these sources is often based on the "Pompeii Premise" which (erroneously) assumes, that archaeological excavations reveal a "frozen" status of the past that needs only to be uncovered to show a representative image of ancient life. Modern archaeology tries to consider the fact that the archaeological record, the material residues related to human activity, is actually biased. On the one hand, because of the necessary transformation of objects from a living culture (the systemic context) into a representation, the archaeological context, which cannot comprise all aspects equally; on the other hand because of processes of degradation, where certain material groups simply cannot survive in the ground. A third factor is active during excavations, in which it is not possible to recognise the entirety of the material cultural remains, which are either preserved or recorded; a plain fact of this process was epitomized by Stuart Pigott as “making the best of a bad job”.

Modern archaeology has developed a variety of methods and techniques for this, including the involvement of specialists from bioarchaeology (palaeoanthropology, paleozoology and paleobotany), geoarchaeology and other supportive disciplines. The choice of strategies depends on the research objectives and must comply with relevant legislation and applicable standards. While there may be differences in the project design, whether it was generated by academic research or development-led interests, any project including archaeological excavations should factor in resources to analyse and interpret the results and disseminate them. Additionally an appropriate archiving strategy has to be present to guarantee the appropriate treatment and accessibility of retained artefacts, ecofacts and the documentation for future research and analysis.

Within landscape oriented research programmes, excavations are an essential part of an applicable method-mix; they are still the only method to get a detailed understanding of site formation processes and a – limited – insight into life in the past. The study of excavated structures and artefacts allows typological, chronological and cultural historical comparisons of cultural groups over larger areas.

However, restricted resources limit excavations to small areas. Only in exceptional instances can sites be excavated in their entirety. Consequently, despite the abundance of data collected during an excavation, the fact that only small parts of sites can be uncovered results in very ‘narrow’ insights. Due to the often missing larger context enclosing the excavated area frequently being missing, excavated objects are often difficult to interpret. With the advent of large-scaled and detailed archaeological prospection, the dominance of excavation has thus shifted towards a multimethod approach of landscape archaeology, where excavation is next to a variety of prospection and sampling techniques just one of many integrated approaches to get a broader view of (pre-)historic societies.

Workflow

The workflow of archaeological excavations begins well before the turning of the first sod in the field. Beside the obligatory desktop assessment using archival records, historical maps and archived aerial/satellite imagery, non-destructive archaeological prospection, as remote-sensing, geophysics and more traditional field survey methods provide a broader context of archaeological sites, structures and features in areas of interest. This enables identifying areas of human activity and developing research questions which can then be targeted by key-hole investigations, as excavations.

The detailed type and amount of pre-excavation bureaucracy may change from country to country due to the different legislative frameworks, which often entail the use of country specific recording systems and excavation methods. Nevertheless, there seems to be a general consent that stratigraphic excavations are the most suitable method to gain archaeological information through excavation.

During the excavation process, the stratigraphic sequence of deposits is removed in reverse order of their deposition in individual stratigraphic units (single surface recording), which are considered as the basic entities relating to events of deposition and removal or construction at the site. As this process of sequential removal is destructive and non-repeatable, a strict documentation policy is of prime importance. This involves the detailed three-dimensional documentation as well as a standardised characterisation of the composition, structure, and artefact and ecofact content as well as distribution of recognisable stratigraphic units. Nowadays the recording of their extent is achieved by advanced digital surveying and recording techniques, which apply terrestrial laser scanners or more often image-based modelling techniques. Their application results in the geometric documentation of the extent and topography of single surfaces and thus the full volumetric recording of a stratigraphical excavation event. The stratigraphic relations of single units are recorded in form of a sequential diagram, the Harris-matrix (Harris 1989), representing the temporal relations of stratigraphic units. The find and sample registration is often implemented with three dimensional measurements using a digital total station.

Workflow archaeological excavation

- Non-destructive/minimal invasive preliminary studies
- Definition of research objectives and excavation area
- Definition of other accompanying analyses and their strategies (e.g. sampling for paleobotany, micromorphology, sedimentology etc.)
- Characterisation of stratigraphic units, three dimensional documentation and stratigraphic position (Harris-matrix)
- GIS-based collection of complementary data
- Specialist analysis and interpretation of finds and samples
- Feedback to prospection and integration of various data
- Post-excavation archaeological synthesis

Modern archaeological documentation systems utilise digital tools as geographic information systems (GIS). These allow collecting, organising, analysing and visualising the data already during the excavation. Furthermore, they allow the integration of results from complimentary methods, as historic maps, geophysical measurements or geochemical analyses. Results from pre-excavation prospection can be a helpful guidance during an excavation. Additional *in situ* measurements of surfaces through magnetic susceptibility, geochemical surveys or the use of digital cameras sensible to infrared or ultraviolet wavelengths provide further information and can be applied to identify the extent of deposits. They can help to determine boundaries between deposits that cannot be discerned by normal human vision.

All excavations result in additional conservatory measures for the finds and laboratory work of collected samples for further analyses. Systematic sampling for geoarchaeological and bioarchaeological research should be a standard procedure on all excavations and be supervised by specialists to ensure the quality of the samples. The analysis of micromorphological soil samples can contribute to the understanding of the function and use of different parts of structures or the taphonomical processes involved after their use, whereas the archaeozoological and archaeobotanical record can contribute to the understanding of subsistence and also for the reconstruction of the environment at certain phases.

Application and limitations of archaeological excavations

Within the toolkit of archaeological research methods, excavations can provide finer detail of the archaeological record. They allow a keyhole insight into human activity contributing to a functional, chronological and cultural characterisation of sites and single features. The stratigraphic analysis of artefacts, ecofacts and samples and scientific dating methods enables the identification of phases, events and long term processes, which contribute to the understanding of the development of sites and their environment. In a reflexive and iterative process they can also significantly improve the archaeological interpretation of complementary methods with a broader coverage, like remote sensing or archaeological geophysical prospection.

Key facts archaeological excavations in heritage studies

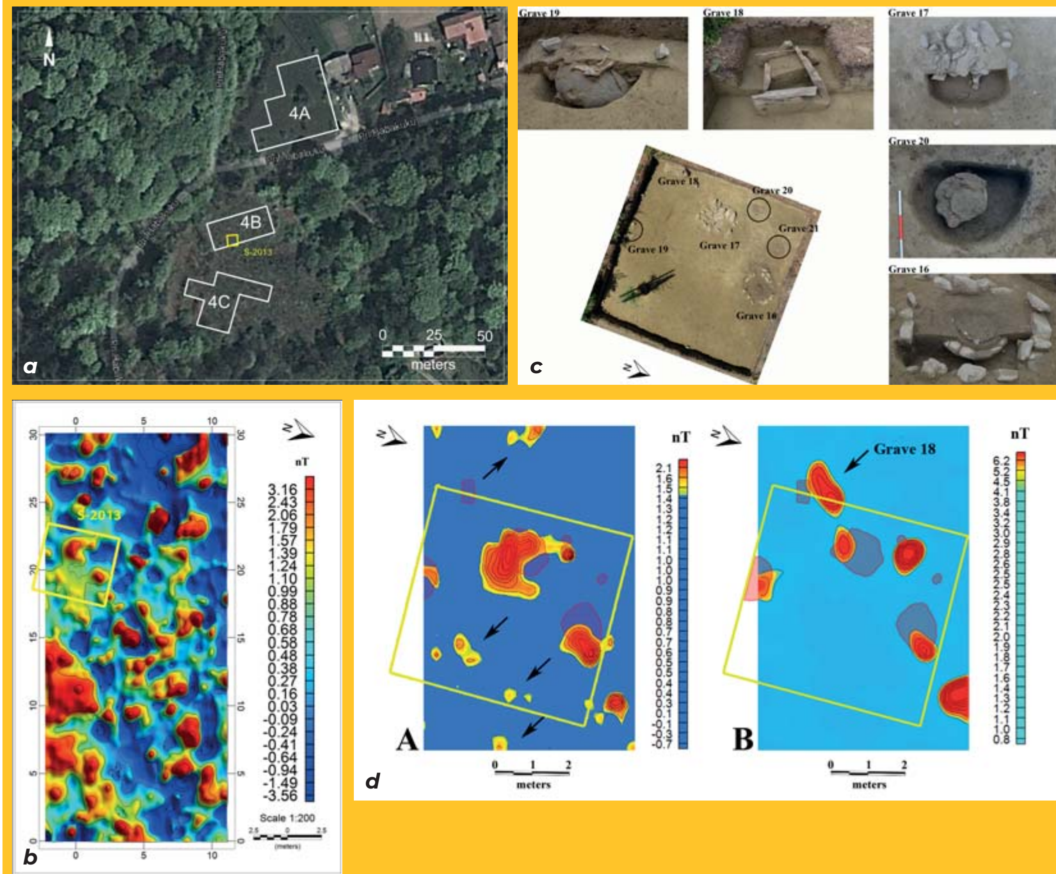
- Coverage:
  - limited area, project dependent
- Landcover dependency:
  - no specific limits
- Research levels:
  - Level 1 Verification of and feedback for prospection
  - Level 2 Delineation
  - Level 3 Characterisation of archaeological sites and features
- Dissemination:
  - virtual reconstructions
  - architectural reconstructions and on site preservation in open air museums
  - artefacts in museum exhibitions
  - public events during excavations

Excavations additionally allow data to be obtained on the physical properties of archaeological remains that influence the archaeological geophysical prospection results. In situ magnetic susceptibility measurements of excavated features can be used to model magnetic anomalies and manipulate existing datasets to allow a better understanding and visual representation of the subsoil structures and thus a better quality of their interpretation.

However, the destructive character and the relatively high cost of modern excavations, which include specialist conservatory, analytical and storage expertise as well as facilities for post-excavation, should be taken into account before any excavation. Nonetheless excavations provide ideal complimentary information for helping to answer the questions raised by non-invasive methods. Thus these are most effective towards landscape investigations if integrated into a thorough non-invasive archaeological research framework.

Excavations as only one step of the multidisciplinary process

Matija Črešnar, Branko Mušič, Igor Medarić, Manca Vinazza



Flat cremation cemetery on the Habakuk plateau below the hillfort Poštela near Maribor (Slovenia).
II.4.6 Figure 1a: areas of the flat cremation cemetery investigated with the magnetic method

II.4.6 Figure 1b: results of the magnetic measurements of the areas 4B after using destriping and symmetric convolution filters with a 7 × 7m window

II.4.6 Figure 1c: graves 16–21, excavated in the 2013 trial trench

II.4.6 Figure 1d: positive magnetic gradients (A) and the analytic signal (B) in the area of the trial trench. Figure B shows the magnetic anomalies above the graves, while anomalies of the basic geology (on Figure A – pointed by arrows) were eliminated (a, b, d – preparation: I. Medarić, c – preparation M. Vinazza).

The systematic multidisciplinary work at Poštela near Maribor was targeting various parts of the landscape around the Poštela hillfort. One of the tasks was also to research the extend and the structure the flat cremation cemetery on the Habakuk plateau below it. Following the basic desk-based analysis we have used various geophysical methods to survey the most prosperous areas (magnetometry, resistivity and GPR). After the first analysis of geophysical data (b, d: A), an areas with varying anomalies was located for excavation, i.e. ground-truthing.

In the trench we have unearthed 6 graves of various structures and compositions. As clearly visible not all of them were recognized after the first results of the magnetic method (b, d: A). However other anomalies were detected, which by the excavations clearly associated with geological bedrock formations. These data was of crucial importance for the re-evaluation of the geophysical data (d: B), which was followed by a much more reliable interpretation of the whole cemetery.

II.4.7 Modern methods and approaches in archaeobotany

Andrej Paušič, Ignac Janžekovič, Janja Kotnik, Andrej Šušek

Introduction

Biogeographical changes and plant occurrence/dynamics through the studied time epochs in a specific area or habitat are key topics in many scientific research projects, dealing with the topics of archeobotany, which is one of methods of understanding the environment in the past. Today, the plant remnants (seed, pollen material and other plant tissues) are crucial for understanding the development of the landscape structure and for studying agricultural practices in the Iron Age era.

The remnants of plant tissues; diaspores and plant pollen give us an insight into the plant taxa inventory the farmers in the Iron Age time used and the native taxa that existed in a particular place.

However, we should also be able to recognize the limitations these remnants (and methods in botany) bring, regarding the overall understanding of plant communities, potential natural or even real vegetation in the time the plant remnants date.

2 Modern methods in (paleo)botany

For the investigation of recent and past vegetation and its changes, the taxa occurrence and the crop dynamics in different regions of Central Europe, botanical studies use either (1) pollen analysis (palynology) or (2) macroscopic analysis of fossilised or charred plant remnants (seed, plant tissue - wood).

Compared to the available publications, which present palynological data and a large number of papers with anthracological records (charred seed remnants and other plant tissues), only few studies use both methods (Nelle et al. 2010, Nayar 2017). The first modern macrofossil analysis that fully integrated macrofossil techniques with pollen studies was presented by Watts (Birks 2006).

Pollen and macrofossil analysis are presented in detail in the following chapters.

2.1 Pollen analysis

Pollen analysis enables us to identify occurrences and relative changes with a high taxonomical resolution, encompassing both tree and herb species, higher plants and cryptogams, and an increasing ability of identifying and interpreting non-pollen palynomorphs (Stika & Heiss 2013, Andrič et al. 2016).

In association with archive quality, pollen analysis enables us to work diachronically, and depending on archive size, it gives the possibility of reconstructing local and/or regional plant taxa occurrence as well as temporal dynamics (shift) of the existing, wild (and cultivated) taxa.

Because of the overall usefulness and low costs connected with the botanical analysis of macrofossils, pollen analysis became less popular and consequently, the number of skilled pollen specialists gradually declined. However, some of them continued their work and used pollen and seed remnants in order to reconstruct floristic and vegetational history (Watts 1959).

Since 1960s, this trend has become even more evident and the use of macrofossils, which can be considered as a complementary technique, has become a standard approach in botany (Birks 2006).

2.1.1 The procedure for the extraction of pollen material and its determination

The procedure of pollen extraction represents in many aspects a specific method of archaeobotanical research. The procedure itself is often species specific and therefore requires different approach for a given taxa (Birks 2006, Andrič et al. 2016).

The first step in pollen analysis is the determination of suitable sampling strategy (depended on the goal of the study). For a further explanation see the workflow macrofossil preparation and the sampling process for macrofossil plant material. Step that follow is the sampling process and preparation of pollen material- pollen samples (process of chemical digestion).

Chemical digestion follows a number of steps. Initially, the only chemical treatment used by researchers was treatment with potassium hydroxide to remove humic substances; deflocculation was accomplished through surface treatment or ultra-sonic treatment, although sonification may cause the pollen exine to rupture (Birks 2006).

Palynological studies using peats presented a particular challenge because of the presence of well-preserved organic material, including fine rootlets, moss leaflets and organic litter. This was the last major challenge associated with the chemical preparation of materials for palynological study. Acetolysis was developed by Gunnar Erdtman and his brother to remove these fine cellulose materials by dissolving them. In acetolysis, the specimen is treated with acetic anhydride and sulfuric acid, dissolving cellulistic materials and thus providing better visibility for palynomorphs (Birks 2006).

Some steps of the chemical treatments require special care for safety reasons, in particular the use of hydrofluoric acid, which diffuses very quickly through the skin, causes severe chemical burns and can be fatal. Another treatment includes kerosene flotation for chitinous materials.

Once samples have been prepared chemically, they are mounted on microscope slides using silicon oil, glycerol or glycerol-jelly and examined using light microscopy, or mounted on a stub for scanning electron microscopy.

The last steps that normally follow are identification or botanical determination of pollen material and presentation of results. Those two steps are similar with the procedures in the method of botanical analysis of macrofossils and are therefore explained in the next chapter.

Workflow pollen analysis

1. Determination of suitable sampling strategy
2. Sampling process and preparation of pollen material- pollen samples (process of chemical digestion)
3. Mounting the samples on microscope slides
4. Identification/ botanical determination of pollen material and counting
5. Presentation of results

Researchers often study either modern samples from a number of unique sites within a given area, or samples from a single site with a record through time, such as samples obtained from peat or lake sediments, glacial sediments or as a charred material, found in archaeological sites.

More recent studies have used the modern analogue technique in which paleo-samples are compared to modern samples for which the parent vegetation is known. When the slides are observed under a microscope, the researcher counts the number of grains of each pollen taxon. This record is next used to produce a pollen diagram. An additional important step is dating of crucial analysed horizons and interpretation of the pollen diagram.

2.2 Botanical analysis of macrofossils

The use of plant macrofossils for investigating recent vegetation and vegetation history dates back to the 19th century. Before the recent development of modern pollen analysis, it (the botanical analysis of macrofossils) was the only technique available for studying the floristic and vegetational genesis (Birks 2006).

Plant remnants or plant macrofossils can be considered as fossils that is large enough to be seen by the naked eye and that can be manipulated by hand, usually with the aid of a brush or fine forceps under a stereomicroscope (Birks 2006). We consider plant macrofossils as diaspores (seeds, fruits, spores), charred tissues and all the vegetative parts, such as leaves (cuticles, leaf spines, etc.), buds, all the remnant elements form flowers, bulbils, roots, tissue fragments, bark, and wood, etc.

Many scientists treat large plant-remains as megafossils. These can be found in mires and bog deposits and exposed on river banks, in lakes of the boreal forest (Eronen et al. 1996) and of course also on the archaeological sites. Lower plants can be found as macrofossils, most notably mosses and occasionally liverworts (which do not survive in such a good state of preservation as mosses), lichens (Sernander 1918), and marine algae (Pedersen – Bennike 1992). The tissues and other remnants, which form macroalgae are frequently represented by their oospores.

This method provides site-related information on species occurrence and woodland composition, depending on the archive context. The method can provide information on a broad woodland biome composition on a broader, regional scale. The analysis of charred wood is of special interest in regions or on sites where sediments containing pollen are lacking, and where it thus provides the only source of information about the specific occurrence of plant taxa.

2.2.1 The detailed procedure for the extraction of (archaeo)botanical material (plant macrofossils) and its determination

The procedure for the extraction of botanical macrofossils is a straightforward one in comparison to the extraction procedure for pollen material. Usually, the procedure includes the following steps: (1) determination of a suitable sampling strategy, (2) sampling process, (3) sample preparation, (4) macrofossil picking, (5) taxa identification (and counting) and (6) interpretation and presentation of results.

(1) The determination of suitable sampling strategy and (2) the sampling process are first steps that are dependent on each other to an enormous extent. We shall therefore describe both of these steps together.

The right choice of a sampling strategy and sampling process depends on the goal of the study itself. If ecological/biogeographical studies are undertaken (e.g. the study of past flora in a particular region or area), the sampling strategy will normally be influenced by the sampling methods used in botany (with samples taken on grid system etc.).

If studying plant ecology, the sampling strategy will depend on the occurrence of a studied taxa. In this case, the samples are taken directly under or in the vicinity of a studied plant.

If studying the evolutional process of selected taxa, the information about the age of soil horizons (the depth of sampling) is crucial. Cooperation with geologists is crucial this purpose. Cooperation with an archaeologist is probably advantageous when studying past land use (changes) or even for the determination of plants on archaeological sites.

(3) The preparation of samples is the next step in the procedure. A botanist first receives raw samples. A known volume of sediment (measured by displacement of water in a measuring cylinder) is taken, usually depending upon the type of sediment and the problem in hand. If necessary, it is soaked in sodium pyrophosphate (water softener) solution (approx. 10 %) to disaggregate it.

Highly humic sediments can be soaked in 10 % sodium hydroxide, and calcareous sediment can be treated with 10 % hydrogen chloride. However, sodium pyrophosphate seems to be the most universally effective and a benign sediment disperser (Birks 2006).

The sediment is placed in a sieve with an appropriate mesh or eventually a sieve with larger mesh size can be combined in series above it (depending on the sediment type). Firstly, one should separate coarse and fine fractions, so that coarse material does not obscure tiny objects during sorting (Figure 1).

A minimum diameter (depends on the minimum seed diameter one expect to find in the observed sample) of it is recommended, because many minute seeds (e.g. *Juncus, Saxifraga, Ericaceae, Pyrolaceae, Polypodiaceae sporangia*) can pass through a mesh and be lost (Birks 2006, Andrič et al. 2016).

The sediment is rinsed through the sieve(s) with a gentle spray of tap water delivered through a shower head. The spray must be strong enough to wash the finest material through the sieve, but not so strong as to damage delicate fossils. The residue(s) is(are) transferred to a lidded storage container and kept cool while awaiting examination.

(4) The seed picking is the next step in the botanical analysis. The sample residue is evenly dispersed in 2-3 mm depth of water in a petri dish or small plate, so that small objects are separated and easily visualised and are consequently exposed and ready for the determination itself.

The suspension is systematically examined under a stereo-microscope or a simple stereo magnifying glass (Figure 2) at an appropriate magnification until all the material has been pushed aside. Remains of interest are picked out using a fine 'soft' or entomological forceps or a fine brush to minimize damage to plant tissues.

(5) Step taxa identification and counting. Seed identification is the crucial step for a botanist. The selected fossils are sorted and identified. A reference collection is indispensable for

II.4.7 Figure 1: Wet sewing. The sediment is rinsed through the sieve(s) with a gentle spray of tap water delivered through a shower head. The spray must be strong enough to wash the finest material through the sieve, but not so strong as to damage delicate fossils (photo: University of Ljubljana, archive).

II.4.7 Figure 2: The macroscopic plant material is systematically examined under a stereomicroscope or a simple stereo magnifying glass. Seed atlases and illustrations in publications can be used as aids to identification of specific taxa, genera or plant family (photo: A. Paušič).

II.4.7 Figure 3: Common remnants of native tree and shrub taxa, found during the botanical studies in NE Slovenia (A. Paušič)

precise and dependable identifications. The recommended arrangement of a seed/fruit reference collection is alphabetical by family, alphabetical by genus within a family, and alphabetical by species within a genus. This enables material to be found easily and to be replaced accurately.

The identified material is best stored in plastic bags. A well made reference collection can be built up from field collections, ensuring accurate identification of the specimen and/or collection of a voucher. The collection is given a number and its details recorded (Birks 2006).

Because of the difficulties involved in compiling a comprehensive reference collection, seed atlases and illustrations in publications can be used as aids to identification of a specific taxa, genera or plant family (see appendix 1, Figure 2). There is no comprehensive seed determination key that will cover a broader Central European area up to date. However, there are several useful seed atlases, some of which include keys, and numerous articles on individual groups or genera.

(6) Interpretation and presentation of results. The last step in the archaeobotanical analysis is normally the interpretation and ultimately the presentation of results. The interpretation itself depends on the goal of the study (the goal can be plant biogeography, phytocenological studies, a classic botanical study, archaeobotany etc.)

The results can be presented as lists, tables or stratigraphic diagrams. For stratigraphic presentation, the numbers of fossils in a sample should be converted to numbers in a constant volume for all the samples in the sequence. The data can be entered into a spreadsheet and used to draw a concentration. We include photos of recent plant material from the phytosociological investigations in NE Slovenia (Styria) as a sample. The photos show an array of species-specific shapes of seed taxa, which are also native to Styria (Figure 3).

Workflow macrofossil determination

1. Determination of suitable sampling strategy
2. Sampling process
3. Sample preparation
4. Macrofossil picking
5. Taxa identification (and counting)
6. Interpretation and presentation of results

Limitations and advantages of modern methods

We know today that there are some specific limitations to understanding the vegetation ecology of the past when studying and comparing solely plant remnants (plant tissues, pollen and seed material of past era). Since different plant species, native to one region are ecologically adapted to very specific ecological conditions, it is impossible to link the plant communities that prospered in the region during the Iron Age with the archaeobotanical findings (plant remnants, macrofossils). Plant communities are also determined by a rate (a percentage) of occurrence of a specific taxa in it. Here, we speak about the Braun-Blanquet cover-abundance scale (Braun-Blanquet 1964, Čarni et al. 2011). Plant taxa in different succession type and ecological conditions (association) produce different quantities of plant material (e.g., seed) (Paušič - Čarni 2013). We are thus not able to link the presence of a seed (amount) of specific taxa to an exact plant community type.

Another ailment is the relationship between palynological remnants found in a certain area with a specific vegetation type (plant communities) in past times (e.g. Iron Age). We know that pollen in particular is prone to being a very delicate plant remnant that is conserved for a long time period in a very specific environment (peat bogs, mires etc.) (Pedersen - Bennike 1992). These habitats represent per se special environments where specialist taxa grow and their ecological conditions in the time of Iron Age COULD NOT be generalized to a broader, macro geographical region.

An actual example:

Are we able to link the ancient remnants of a pollen of some Erica species, found in a central European mire with the occurrence of mountain or spruce belt vegetation (Erico - Pinetum)? Probably not. Micro-ecological conditions, occurring in a particular growing site effect the potential natural vegetation, which of course, represents a mosaic of adapted array of plant taxa and their specific traits.

Second example: one finds seeds of Carex elongata (elongated sedge) during some ecological study of past flora. We are not able automatically to link the seeds to a vegetation type or association Carici elongatae-Alnetum glutinosae Tüxen 1931 (nor to any other association, where this taxon has a high abundance rate!). In order to do this one would need much more information about the occurrence and the ABUNDANCE of other plant taxa (Čarni et al. 2011).

Because of specific geomorphologic and edaphic conditions, many ecotones prevail (transition areas between two biomes) prevail in Central European area. It is where two communities meet and integrate). Therefore, it is almost impossible to describe the Iron Age vegetation of a particular broader region, solely based on the macro botanical remnants.

However, different macro botanical remnants (charred seed remnants and tissues) of domesticated taxa (or even a wild fruit bearing species, found in settlements or potential areas of settlement) give us a superb insight into the **taxa assortment farmers have sown**, used for their diet or other purposes in their daily life. If we compare the (archaeo) botanical findings from different areas (dated from the same time period), we can gain an idea about a specific drift or shift in the occurrence of planted species and the differences between central European regions in the broader time of Iron Age (Poschlod 2015).

An important influence or consequence the macro botanical remnants have on our perceptions about the stage and development reached by agriculture, or even a of a landscape change are derived from macro botanical remnants (tissues, seeds), which it is frequently not possible to determine botanically and taxonomically determined nor to describe adequately. In this we are thinking about the charred seed material, found in different archaeological sites that is either damaged (crushed material, with missing crucial morphological traits; parts that are important for determination), or otherwise difficult to determine. Specifically, here we should take great care not to determine species merely on the basis of one single remnant (one seed). The problem with similar taxa is that in all probability they can only be well differentiated from one another if a large number of seeds is found. In this case of an adequate find, an exact morphometrical analysis can be performed that would eventually attribute a correct taxonomical status to a particular taxa.

It is known for example, that determining the exact taxonomic ranking of some genera is problematic. This is the case for the taxa such as those from the cabbage family (Brassicaceae), the ecological adaptations of which are very different (and may grow in different ecological conditions) and furthermore produce small seeds that are sometimes difficult to recognise. These species are great indicators of bioecological conditions of particular time.

Summary

This short review of plant macrofossils and basic description/application of the methods used in archaeobotany illustrates the diversity and flexibility of (archaeo)botany mother methods in general. Plant macrofossils, aided by their identification to low taxonomic levels, provide records of past terrestrial (and aquatic) vegetation, from which the ecological and environmental conditions and (to some extent) the climatic condition of the past can be deduced.

The use of plant macrofossils complements pollen material for this purpose emphasising and defining the local vegetation rather than the regional biome and correcting false conclusions that may be drawn from pollen spectra containing large proportions of long-distance transported pollen.

Plant macrofossils are of increasing importance in (palaeo)environment and climate reconstructions. The analyses are relatively cheap once the cores have been obtained, although the procedures of seed picking, identification and quantification are time consuming and demand considerable patience and experience.

The most important success factors for this method are the skills and the botanical knowledge of the analyst. A second crucial factor is the availability of a reference collection to aid identification.

Appendix 1 Macrofossil identification and reference works

Identification Manuals

ANDERBERG, A. L., 1994
Atlas of Seeds. Part 4. Resedaceae-Umbelliferae. Swedish Museum of Natural History, Stockholm, 281 pp.

BEIJERINCK, W., 1976
Zadenatlas der Nederlandsche Flora. Backhuys & Meesters, Amsterdam, 316 pp. In Dutch.

BERGGREN, G., 1964
Atlas of Seeds. Part 2. Cyperaceae. Swedish Natural Science Research Council, Stockholm, 68 pp.

BERGGREN, G., 1981
Atlas of Seeds. Part 3. Salicaceae-Cruciferae. Swedish Museum of Natural History, Stockholm, 259 pp.

ELIAS, S., POLLAK O., 1987
Photographic atlas and key to windblown seeds of alpine plants from Niwot Ridge, Front Range, Colorado, USA. INSTAAR Occasional Paper 45: 28 pp.

JENSEN, H. A., 1998
Bibliography on Seed Morphology. A. A. Balkema, Rotterdam, 310 pp.

KATZ, N. J., KATZ, S. V., KIPIANI M. G., 1965
Atlas and keys of fruits and seeds occurring in the Quaternary deposits of the USSR. Nauka, Moscow, 365 pp. In Russian.

MONTGOMERY, F. H., 1977
Seeds and fruits of plants in eastern Canada and northeastern United States. University of Toronto Press.

SCHOCH, W. H., PAWLIK, B., SCHWEINGRUBER F. H., 1988
Botanische Makroreste. P. Haupt, Bern & Stuttgart. German, English, French.

For Mosses- Floras for identifying modern mosses are used for identifying fossil mosses.

JANSSENS, J. A., 1990
Methods in Quaternary Ecology 11. Bryophytes. Geosci. Canada 17: 13–24.

Wood- Atlases for systematicaly identifying wood tissues.

BAREFOOT, A. C., HANKINS, F. W. 1982
Identification of modern and Tertiary woods. Calendon Press, Oxford, 189 pp.

GROSSER, D., 1977
Die Hölzer Mitteleuropas. Springer, Berlin. 208 pp.

SCHWEINGRUBER, F. H., 1990
Anatomie europäischer Hölzer; Anatomy of european woods. Verlag Paul Haupt, Bern & Stuttgart, 800 pp. In German and English.

Cuticles-bud scales

PALMER, P. G., 1976
Grass cuticles: a new palaeoecological tool for East African lake sediments. Can. J. Bot. 54: 1725–1734.

TOMLINSON, P., 1985
An aid to the identification of fossil buds, bud-scales and catkin-bractsn of British trees and shrubs. Circaea 3: 45–130.

WESTERKAMP, C., DEMMELMEYER H., 1997
Blattoberflächen mitteleuropäischer Laubgehölze: Leaf surfaces of central European woody.

Part III

III.1 Summary, conclusion and outlook

Marko Mele, Michael Doneus, Martin Fera, Matija Črešnar

The Iron Age Danube Project aims to build bridges between new scientific approaches in archaeology and the interested public. We regard this publication as an important contribution to the development of this aim.

Our prime focus is on all the various ways that archaeological landscapes can be approached scientifically. These are the key to opening up completely new insights into (pre)historic societies and their co-habitation with the natural environment. There is no doubt, however, that this is a highly complex task, involving a wide range of new theoretical and methodological approaches that need a greater understanding of the underlying technologies. This is already a significant challenge for professional archaeologists, but it is even more demanding for heritage managers and policy makers and also for the upcoming generations of young archaeologists in Europe.

In the course of researching, protecting and promoting archaeological landscapes across boundaries, we are attempting to share with the interested readership this understanding of landscape archaeology, including all of the many disciplines it involves. Our goal is to reach beyond the archaeological community, with the focus on heritage managers and policy makers.

The various topics have been approached differently in each of the chapters and this also reflects the heterogeneity of the methods involved. Despite this breadth of outlook, we have tried to follow a red line throughout the book, reaching from existing policies and legal frameworks to research methods with practical examples, in work which was mainly carried out within the framework of the Iron Age Danube Project.

The book starts with a definition by Dimitrij Mlekuž of what we today understand as "archaeological landscapes". The next step was taken in the direction of policy making, which concerns archaeological/cultural landscapes as integral components of our cultural heritage. Strategy 21, which is the European Cultural Heritage Strategy for the 21st Century, adopted by the European Council, is presented in this volume by one of its co-authors, Jelka Pirkovič, who adds an important shaping to the form of the publication. Learning from the strategy proposed here, we proceed by suggesting innovative new approaches for practical application of the strategies (see I.3 and I.4). In doing this we are attempting to create a direct link between an adopted paper, in this case Strategy 21, with the practical work that is being done by all the researchers and heritage managers. The possibilities that arise for the practical use of strategies in the planning and evaluation of archaeological projects were tested by Marko Mele and Martin Fera.

The second part of the publication has the character of a manual, it including practical guidelines and many examples. This can provide help for researchers in future as they begin to plan their research and it can also present experienced professionals with some specifics of the research area/chronological period, i.e. the Danube region/the Early Iron Age. A start is made here with the basic evaluation of costs, timing and accessibility in the chapter by Zoltan Czajlik. These first considerations are followed by a practical guide on how to obtain permits for different types of archaeological research in the four project countries, Austria, Croatia, Hungary and Slovenia (see II.3). A team of experts on legislation drawn from each of these countries worked together to create a comprehensive overview in this chapter. This section is also backed with practical information about the different accessible data sources that can be very useful for the work on and off field.

The descriptions of individual methods (see II.4) are all structured in the same way and start by providing basic information about the method used, followed by a workflow stating what is needed for implementation and applicability and also including an account of the limitations that must be faced for each method. The selection and focus are fixed on methods that are suitable for application in the framework of landscape archaeology, including remote sensing, geophysics and surface surveys. Nevertheless, we by no means neglected the role of archaeological excavations and paleo-environmental research (e.g. archaeobotany), which are important for the understanding of the dynamics of archaeological/cultural landscapes. However, since a number of recent publications already deal in detail with these topics, we focused mainly on archaeological methods more relevant for landscape research. We attempted to bring together researchers from different countries for each method considered, with the aim of combining different traditions and experiences and as a result to create state-of-the-art descriptions.

As a means of better understanding the methods and the “language” used by archaeologists, we also added Part IV of our publication. This includes a thesaurus in five languages, which is also the first attempt to unify the terminology of these various and sometimes complex topics.

Finally, we would like to emphasize, that a holistic and multidisciplinary approach should be considered a standard when researching archaeological landscapes. The planning of any research activity always comes down to the bottom line of the available personnel and also the technical and financial possibilities, since each of these will certainly shape the research that is done. We must keep in mind, however, that only the right combination of methods can result in high-quality data. Moreover, high-quality data is essential for us since we need and must use the best possible results from research, for the continuing protection and promotion of archaeological landscapes and our cultural heritage in its broadest sense.

This book should be a help for making the right choices.

Part IV

IV.1 Glossary and dictionary (eng-deu-hrv-hun-slv)

aerial survey

airborne survey (eng)
Luftbilderkundung; Luftbildfernerkundung (deu)
istraživanja iz zraka (hrv)
légi felderítés (hun)
aeroprospekcija (slv)

Archaeological survey conducted from an airborne platform. Most commonly used are airborne laser scanning and aerial photography.

airborne laser scanning

ALS; LiDAR; lidar; LIDAR; Light Detection And Ranging (eng)
Airborne Laserscanning (deu)
lasersko skeniranje iz zraka (hrv)
légi lézeres szkennelés (hun)
zračno lasersko skeniranje (slv)

Direct measurement of terrain from an airborne platform using a sensor that continuously sends out short infrared pulses vertically downwards toward the terrain along the ground track of the aircraft. When emitted pulse hits an object its part is reflected back to the sensor. The distance to the reflecting object is derived from the travel time of the pulse. The final product used in archaeology is typically a georeferenced digital terrain model. The method is especially useful to uncover the topography of areas covered by forest canopy.

archaeobotanical analysis of macrofossils

Archäobotanische Analyse von Makroresten (deu)
arheobotanička analiza makrofosila (hrv)
makromaradványok archeobotanikai elemzése (hun)
arheobotanična analiza makrofosilov (slv)

Analysis of fossils of diaspores (seeds, fruits, spores), charred tissues and all the vegetative parts, such as leaves (cuticles, leaf spines, etc.), buds, all the remnant elements form flowers, bulbils, roots, tissue fragments, bark, and wood to determine past ecological and environmental conditions and (to some extend) the past climate. The use of plant macrofossils complements pollen material for this purpose emphasising and defining the local vegetation rather than the regional biome and correcting false conclusions that may be drawn from pollen spectra that contain a large proportion of long-distance-transported pollen.

archaeological aerial photography

archaeological aerial photography (eng)
Luftbildfotografie; Luftfotografie (deu)
zračna fotografija (hrv)
légi fényképezés (hun)
arheološka aerofotografija (slv)

The taking of photographs from above using equipment mounted on, or used from an aircraft or other airborne vehicle. The photographs may be taken in a systematic way covering a larger part of the landscape or observer directed, when only points of interest are photographed (hand-held oblique photography). On aerial photographs archaeological features that are preserved on the surface or are projected on the surface due to specific sub-surface characteristics can be observed.

archaeological evaluation of resources

Archäologische Auswertung von Quellen (deu)
arheološka evaluacija resursa (hrv)
természeti erőforrások régészeti kiértékelése (hun)
arheološko vrednotenje virov (slv)

See desktop assessment.

archaeological excavation

excavation; archaeological dig (eng)
Ausgrabung (deu)
arheološko iskopavanje (hrv)
régészeti feltárás (hun)
arheološko izkopavanje (slv)

Archaeological excavation is a destructive method that uncovers remains and traces of past human activities. Stratigraphic sequence of deposits is removed in reverse order of their deposition. All finds as well as the individual stratigraphic units have to be appropriately documented.

archaeological prospection

archäologische Prospektion (deu)
arheološka prospekcija (hrv)
régészeti kutatás (hun)
arheološka prospekcija (slv)

Detection and mapping of archaeological features on a scale of a landscape using non-invasive or minimally invasive methods such as remote sensing techniques, geophysical survey and field-walking.

archaeological record
archäologischer Befund; archäologische Überreste (deu)
arheološki zapis (hrv)
régészeti adat (hun)
arheološki zapis (slv)

Archaeological record is physical evidence about past human activity.

archaeological supervision
archäologische Baubegleitung (deu)
arheološki nadzor (hrv)
régészeti felügyelet (hun)
arheološki nadzor (slv)

Development-led archaeological works carried out during construction works.

archaeological surface survey
field walking; pedestrian survey; surface collection (eng)
archäologischer Oberflächensurvey (deu)
arheološki površinski pregled (hrv)
régészeti terepkutatás (hun)
arheološki površinski pregled (slv)

A non-destructive method employing several techniques in order to conduct research on past human activities and their interactions with natural environment on a landscape level. This approach is also used to predict and discover so far unknown archaeological heritage.

archival aerial archaeology
historical aerial photographs analysis (eng)
analyse historischer Luftbilder (deu)
analiza arhivskih zračnih izvora (hrv)
archív légi fotók vizsgálata (hun)
analiza arhivskih aerofotografij (slv)

Using historic aerial photographs and cartographic material for archaeological research. These images were usually taken as a part of repeated military reconnaissance flights and therefore cover larger areas. Also other authorities such as water conservancy, forestry, and geodetic companies may possess such historic aerial images. These historic images can provide information about the archaeological sites in their former landscapes and track environmental changes and transformations of sites and heritage objects during the last century.

building analysis
Bauanalyse (deu)
analiza gradnje (hrv)
épületkutatás (hun)
stavbna analiza (slv)

The documentation and study of standing built structures. The analysis includes investigation of construction type, building phases, usage, and dating etc.

core drilling

drills; coring (eng)
Kernbohrung (deu)
Bušenje (hrv)
fúrásos talajmintavétel (hun)
vrtanje (slv)

The collection of samples by drilling a small diameter probe into Earth's surface at regular intervals across an area of interest. The probe may be used for various types of soil analysis.

desktop assessment

desktop heritage assessment (eng)
Kabinettforschung (deu)
uredska istraživanja (hrv)
adatgyűjtés (hun)
kabinetne raziskave (slv)

Assessment of existing resources about a specific area or a site such as published and grey written sources, historical (written, cartographic, imaging) sources, information provided by the locals and other existing documentation.

electric resistivity method

Widerstandsmessung (deu)
metoda mjerenja otpora (hrv)
talajellenállás vizsgálat (hun)
metoda električne upornosti (slv)

Electrical resistivity methods are based on the fact that electrical conductivity and/or resistivity of archaeological objects differs from the medium in which they are located, which is influenced mainly by factors that control the moisture distribution in the ground (with electrolytes, ionic compounds), which depends mainly on the amount of precipitation, texture, structure and consistency of the subsurface

electrical resistivity tomography

ERT; resistivity imaging; resistivity tomography; electrotomography; electrical resistivity imaging survey (eng)
Geoelektrik; geoelektrische Untersuchung; geoelektrische Vermessung (deu)
mjrerenje pomoću geoelekrične tomografije (hrv)
geoelektromos felmérés (hun)
električna upornostna tomografija (slv)

Continuous measurements of voltage difference simultaneously in lateral and vertical direction of the subsurface, which results in 2D, 3D, or even 4D (time-lapse) cross-section of the subsurface with the true resistivity distribution.

electromagnetic induction survey
Messung der elektromagnetischen Induktion; Faradaysche Induktion (deu)
mjerenje pomoću elekromagnetske indukcije (hrv)
elektromágneses felmérés (hun)
meritve z elektromagnetno indukcijo (slv)

Electromagnetic induction can be used to determine the conductivity and susceptibility of the substrate. The latter indicates how strongly a body can influence the earth's magnetic field, i.e. how large the anomaly of the magnetic field it causes is.
The method is suitable for detecting layers and structures at shallow depths that conduct electric current well (conductivity measurement) or have different magnetic properties (susceptibility measurement). It can be applied in urban areas. It can be applied at different frequencies to get information on the structures at different depths.

See also low-frequency electromagnetic method.

electromagnetic method
elektromagnetische Methode (deu)
mjerenje elekromagnetičnosti (hrv)
elektromágneses módszer (hun)
elektromagnetna metoda (slv)

A number of electromagnetic instruments used in archaeological geophysics transmit and detect electromagnetic energy and are classified by their transmitted frequency and type of transmission. Magnetic susceptibility, ground penetrating radar, low frequency electromagnetic instruments and metal detectors are types of electromagnetic instruments.

field walking
field walking survey; field walking techniques (eng)
Feldbegehung; Begehung; Geländebegehung; Geländeerkundung (deu)
terenski pregled (hrv)
terepbejárás (hun)
površinski terenski pregled (slv)

The main technique used for archaeological surface survey. During field walking archaeological artefacts are systematically collected following different systems such as line-walking or grid-surveying.

See also archeological surface survey.

geochemical mapping
geochemical survey; geochemical analysis (eng)
geochemische Analyse (deu)
geokemijsko kartiranje (hrv)
geokémiai térképezés (hun)
geokemično kartiranje (slv)

See soil analysis.

geophysical survey

geophysical method; archaeological geophysics (eng)
Geophysikalische Untersuchung; Geophysik (deu)
geofizikalno istraživanje (hrv)
geofizikai felmérés (hun)
geofizikalne raziskave; arheološka geofizika (slv)

Using geophysical methods for prospection of sub-surface with the intention to detect buried archaeological features. There are five main methods that have been proved useful for archaeology: magnetic method (such as magnetometry and magnetic susceptibility measurements), electromagnetic method (such as ground penetrating radar), resistivity method (such as electrical resistivity tomography), microgravimetry and seismic refraction method. Usually a combination of methods is required as each method measures specific physical properties and therefore has its advantages and limitations.

ground penetrating radar survey

ground penetrating radar; GPR; georadar survey (eng)
GPR-Survey; Bodenradar-Survey (deu)
georadarska mjerjenja (hrv)
talajradaros felmérés (hun)
georadarske meritve (slv)

Ground penetrating radar is not a geophysical method that can be applied in a routine manner to all environmental and archaeological settings, although with thoughtful modifications in survey procedures and data processing methodology, GPR can be adapted to a great variety of conditions.

hand-held oblique aerial photography

observer-directed aerial photography (eng)
Freihand-Schrägluftbilder (deu)
snimanje kosih zračnih fotografija iz ruke (hrv)
ferde tengelyű légi fényképezés (hun)
poševna aerofotografija (slv)

See archaeological aerial photography.

historic maps assessment

Analyse historischer Karten (deu)
procjena povijesnih karata (hrv)
történeti térképek régészeti vizsgálata (hun)
vrednotenje historičnih kart (slv)

Prospection of historic maps dating from mid 18th century (with some exceptions from late 17th century) onwards to recognize, locate, and contextualize archaeological sites within their past landscape, before the major regulation of rivers, urbanization and building of modern infrastructure took place.

induced polarisation
IP (eng)
Induzierte Polarisation (deu)
metoda inducirane polarizacije (hrv)
indukált polarizáció (hun)
metoda inducirane polarizacije (slv)

Induced polarization (IP) is regarded as an electrochemical phenomenon. Polarizable archaeological materials can be distinguished by their complex conductivity or resistivity spectra. Wood, for instance, is a polarizable material. As a consequence, the spectral IP technique can be used for the detection of wooden remains. This fact might open a wide field of application for this still very rarely used technique in archaeological prospection.

intensive field walking survey
intensive field-walking survey; systematic field walking survey; systematic field-walking survey (eng)
systematische Feldbegehung (deu)
intenzivni terenski pregled (hrv)
intenzív terepbejárás (hun)
intenzivni površinski terenski pregled (slv)

See systematic surface survey.

invasive technique
invasive Technik (deu)
invazivna tehnika (hrv)
invazív technika (hun)
invazivna tehnika (slv)

An approach that physically interferes with the researched area or object often in an unrepeatable and often destructive manner, for example an archaeological excavation.

low-frequency electromagnetic method
niedrigfrequente elektromagnetische Methode(deu)
elektromagnetska metoda niskih frekvencija (hrv)
alacsony frekvenciás elektromágneses módszer (hun)
nizkofrekvenčna elektromagnetna metoda (slv)

Low-frequency electromagnetic systems, also known as Slingram or FDEM (*frequency-domain electromagnetic induction*), enable acquiring data from two different geophysical properties at the same time. The *in-phase* component is calculated into a reliable approximation of apparent magnetic susceptibility and the *quadrature* component of the collected data represents values of the apparent electrical conductivity

magnetic method
Geomagnetik (deu)
magnetska metoda (hrv)
mágneses módszerek (hun)
magnetna metoda (slv)

A geophysical prospecting method that maps variations in the magnetic field of the Earth that are consequence of magnetic susceptibility differences between archaeological remains and surrounding medium. Magnetic surveys are used to detect and map variety of archaeological artefacts and features.

magnetic susceptibility method

magnetic susceptibility measurements; magnetic susceptibility mapping (eng)
Messung der Magnetischen Suszeptibilität (deu)
mjerenje magnetske susceptibilnosti, kartiranje magnetskog susceptibiliteta (hrv)
mágneses szuszceptibilitás mérés (hun)
meritve magnetne susceptibilnosti, kartiranje megnetne susceptibilnosti (slv)

Magnetic susceptibility mapping is an electromagnetic technique, which assesses the ability of the topsoil and archaeological material within it to be magnetized. Burnt debris and also the incorporation of settlement and craft workshop waste in soils can enhance their magnetic susceptibility value.

magnetometer measurements

magnetometry survey; magnetometry; magnetic survey (eng)
Magnetometermessung (deu)
magnetomerija, magnetsko mjerenje (hrv)
magnetométeres felmérés (hun)
magnetometrija, magnetne meritve (slv)

Magnetometry is one of the most often used geophysical methods in archaeology, as it allows for detection of almost any type of archaeological remains in favourable environmental conditions. First group are object with remanent magnetic properties such as iron object, a large concentration of ceramics or burnt areas (e.g. furnaces). The second group includes archaeological structures that have long been open during their original use, which allows the recognition of the induced magnetization, for example ditches and postholes.

metal detector survey

Untersuchung mit Metalldetektor; Metalldetektor; Begehung mit Metalldetektor (deu)
pregled detektorom metala (hrv)
fémkeresős kutatás (hun)
pregled z detektorjem kovin (slv)

The use of instruments based on electromagnetic induction for the detection of metal.

microgravimetry survey

Messung der Mikrogravitation (deu)
mikrogravimetrična istraživanja (hrv)
mikrogravimetriás mérés (hun)
mikrogravimetrične raziskave (slv)

The microgravimetric surveying technique is applicable to the detection of shallow subsurface structures if a lateral density contrast of subsurface constellation is presented. In general, the detection of subsurface cavities, such as crypts, cellars and tunnels belongs to successful applications of the employment of surface gravity measurement techniques.

non-intensive field walking survey
extensive Feldbegehung (deu)
intenzivni terenski pregled (hrv)
nem-intenzív terepbejárás (hun)
ekstenzivni terenski pregled (slv)

Compare unsystematic (intuitive) surface survey.

non-invasive technique
nicht-invasive Technik (deu)
neinvazivna metoda/tehnika (hrv)
nem romboló módszer; roncsolásmentes módszer (hun)
neinvazivna tehnika (slv)

An indestructible and repeatable approach used to discover and interpret archaeological features without a direct contact. The approach includes different types of archaeological survey such as remote sensing and geophysical prospection.

off-site survey
distributional survey; non-site survey; siteless survey (eng)
Umgebungserkundschaftung außerhalb bekannter Fundplätze (deu)
istraživanje izvan nalazišta (hrv)
lelőhelyen kívüli kutatás (hun)
raziskave območij izven najdišč (slv)

Using artefacts to discern different uses of the land in different periods without focussing on particular sites.

ortophotography
Orthofotografie (deu)
ortofotografija (hrv)
ortofotózás (hun)
ortofotografija (slv)

Taking or geometrically correcting aerial photographs in such a way that the scale of the image is uniform and can be used in the same way as a map.

paleobotany
Paläobotanik (deu)
paleobotanika (hrv)
paleobotanika (hun)
paleobotanika (slv)

A discipline investigating paleo-vegetation. Most commonly used methods are pollen analysis and macroscopic analysis of fossilised or charred plant remnants such as seeds and plant tissues.

photogrammetry
Photogrammetrie (deu)
fotogrametrija (hrv)
fotogrammetria (hun)
fotogrametrija (slv)

Photogrammetry is concerned with extraction of metric information about the location, size and form of an object from a photograph. In archaeology photogrammetric algorithms implemented in different software packages are often used for image rectification and together with computer vision algorithms for 3D image-based modelling.

pollen analysis
Pollenanalyse (deu)
analiza peluda (hrv)
pollenanalízis (hun)
pelodna analiza (slv)

Studies of the plant life of a certain period using the remains of pollen grains found in the soils of the same period. The proportions of pollen grains representing different species will give an indication of the type and mix of flora.
(T. Darvill 2009 The Concise Oxford Dictionary of Archaeology (2 ed.), Oxford University Press.)

probability sampling survey
Stichprobenuntersuchung (deu)
istraživanje prema uzorku vjerojatnosti (hrv)
valószínűség szerinti mintavétel (hun)
pregled v obliki naključega vzorčenja (slv)

A type of archaeological surface survey sampling only a certain percent of a region or a site to draw conclusions about the entire region or site using statistical models. The approach has been subjected to many critiques and is thus not widely used anymore.

remote sensing
Fernerkundung (deu)
daljinsko istraživanje (hrv)
távérzékelés (hun)
daljinsko zaznavanje (slv)

Collecting and interpreting information about the environment and the surface of the earth from a distance without direct physical contact, primarily by sensing radiation that is naturally emitted or reflected by the Earth's surface or from the atmosphere, or by sensing signals transmitted from a device and reflected back to it. Examples of remote-sensing methods include aerial photography, radar, and satellite imaging.

rescue excavation
Rettungsgrabung (deu)
zaštitno iskopavanje (hrv)
mentőásatás (hun)

zaščitno izkopavnje (slv)

Archaeological excavation carried out because of planned construction works on an archaeological site.

research excavation

Forschungsgrabung (deu)
istraživačko iskopavanje (hrv)
tervásatás (hun)
raziskovalno izkopavanje (slv)

Archaeological excavation carried out after careful study with the intention to solve a specific archaeological research question.

resistivity mapping

earth resistance; twin probe array resistance mapping (eng)
Widerstandskartierung (deu)
kartiranje električnog otpora (hrv)
elektronomos talajellenállás-mérés (hun)
kartiranje električne upornosti (slv)

Similar to ERT geophysical method the resistivity mapping is usually more efficient in recognizing lateral variation of archaeological structures in loose sediments ands less efficient in investigating hillfort structures that are usually impacted by compact geological rocks close to the surface.

resistivity profiles

Profil des elektrischen Widerstand (deu)
profili otpora (hrv)
talajellenállás-szelvények (hun)
profili električne upornosti (slv)

The chosen probe array is moved from position to position over a previously defined line. Line orientation should be perpendicular to the expected archaeological remains orientation. This technique should be used carefully, because the chosen geometry of the array used might introduce a portion of noise in field measurements and therefore introducing false anomalies.

review excavation

Nachgrabung (deu)
revizijsko iskopavanje (hrv)
hitelesítő ásatás (hun)
revizijsko izkopavanje (slv)

Review excavation is not an independent research method. However, it has some common goals – to re-evaluate previously researched areas, to regain lost knowledge or to gain new insight into these areas/locations. It is often combined with other modern methods, e.g. geophysics.

satellite imaging

Satellitenbilder (deu)
satelitske snimke (hrv)
műholdfelvételek (hun)
satelitski posnetki (slv)

Using imagery taken from a spaceborne platform to locate archaeological sites. Since the spatial resolution of satellite imagery has improved to ca. 0.41 m for the latest products from the GeoEye-1 satellite, this type of imagery has gained importance in archaeological remote sensing.

seismic refraction method

Refraktionsseismik (deu)
mjerenje seizmičke refrakcije (hrv)
refrakciós szeizmikus módszer (hun)
seizmične refrakcijske raziskave (slv)

The seismic refraction method depends on the fact that seismic waves have differing velocities in different materials: in addition, the waves are refracted when they cross the boundary between different types of archaeological and/or geological materials. This is an effective tool for characterization of geometrical characteristics of structures. Despite of its low data acquisition in recent years seismic refraction methodologies have been employed to locate buried archaeological structures in a variety of archaeological conditions.

self-potential polarization

SP (eng)
Eigenspannungspolarisation (deu)
mjerenje polarizacije metodom vlastitog potencijala (hrv)
gerjesztett polarizáció (hun)
metoda lastnega potenciala (slv)

The purpose of the self-potential (SP) method is to measure variations in natural potentials from less than a milivolt to over one volt. The SP anomalies are caused by temperature, porosity, resistivity variation and moisture content of soil. SP method might be useful in prehistoric sites that include burnt materials, soils with physical and chemical changes and different moisture content.

shovel test

Schaufeltest (deu)
test lopatom (hrv)
lapátteszt (hun)
podpovršinski terenski pregled (slv)

An extensive survey technique to sample the content of topsoil within a defined area by taking a fixed volume of soil (usually a shovelful) out of the ground and sieving/screening it to separate out and quantify the artefact population. Widely used in the field evaluation of large areas in order to identify buried sites and define their approximate extent.

(T. Darvill, 2009, The Concise Oxford Dictionary of Archaeology (2 ed.), Oxford University Press, 10.1093/acref/9780199534043.001.0001)

site survey

Fundstellenbasierte Oberflächenbegehung (deu)
pregled nalazišta (hrv)
lelőhelykutatás (hun)
terenski pregled najdišča (slv)

An archaeological surface survey using sites as basic units of observation to investigate large areas or entire regions. It is a traditional approach that often fails to detect smaller, ephemeral sites and off-site activity.

soil analysis

archaeological soil chemistry; soil mapping (eng)
Bodenuntersuchung (deu)
analiza tla (hrv)
üledékvizsgálat (hun)
pedološke analize (slv)

Analysis of chemical and physical signatures in soil caused by human activities such as farming, cooking, building, fertilizing, walking, cleaning etc.

sonar survey

Vermessung mit Sonar (deu)
mjrenje sonarom (hrv)
szonáros mérés (hun)
meritve s sonarjem (slv)

Sonar is a technique that uses sound propagation under water to detect submerged archaeological objects and composition and morphology of the seafloor or riverbed. To measure the distance to an object, the time from emission of a pulse to reception is recorded. Side-scan sonar system identifies the different type of seafloor (such as sand, rocks, mud, etc.) and objects eventually dispersed on the seafloor (such as wreck). Sub bottom profiler allows to identifying the litho-stratigraphic sequence of the seafloor and it is based on the different sound speed through the sediments.

stratigraphy

Stratigraphie (deu)
stratigrafija (hrv)
stratigráfia (hun)
stratigrafija (slv)

Stratigraphy is the description of the layered deposits derived from cultural and natural formation processes at sites. It is mainly revealed during the excavation process by the observation of changes in the material that can be recognized by the bare eye or the help of in situ measurements. The excavation tries to identify discrete stratigraphic units and excavate them in the reverse order of their creation. A common form of recording is the schematic form of the Harris matrix, that depicts the temporal succession of stratigraphic units. These consist of deposits, structures and cut surfaces and form the stratigraphic sequence, that relates to a temporal succession of events and activities at an excavation area.

structural survey

Strukturanalyse (deu)
strukturalna analiza (hrv)
épületfelmérés (hun)
strukturna analiza (slv)

Structural survey is one of the prospecting field techniques on the surface used to detect or verify the presence of manmade structures. It represents a link between the buried stratigraphy, recorded and studied during excavation, and standing stratigraphy analysed through architectural survey. The aim is to identify surface structures in various forms, architectural remains from walls or ruins to earthworks or subtle vestiges of subsurface structures. Structural survey can be an autonomous procedure where the result is a detailed map of recorded structures during fieldwork. In case the base map derives from data gathered with remote sensed techniques such as air photo interpretation or airborne laser scanning, the technique serves as their verification on the ground.

sub-surface survey

unterirdische Untersuchung(deu)
ispodpovršinski pregled (hrv)
felszín alatti kutatás (hun)
podpovršinski pregled (slv)

A type of archaeological survey, which is commonly combined with the surface survey and is applied in similar ways. It is however applied in areas with dense surface coverage, where the surface is therefore not accessible for research.

See also surface survey, etc.

systematic surface survey

systematischer Oberflächensurvey (deu)
sustavni površinski pregled (hrv)
szisztematikus terepkutatás (hun)
sistematični površinski pregled (slv)

Sampling of the whole survey areas using full coverage approach to detect new sites and off- and intra-site distributions in the landscape.

test excavation

trial excavation (eng)
Testgrabung (deu)
probno iskopavanje (hrv)
próbaásatás (hun)
testna izkopavanja (slv)

Test excavation is not a uniform research method and is mostly adapted to given circumstances. It is mostly applied as one part of a multi-method approach, after conducting other methods, e.g. ALS or geophysics. However, it can be also used as part of a sampling programme to evaluate the presence/absence, nature, preservation, age and extent of any buried archaeological features.

See also trial trenching.

test pit

shovel pit testing (eng)
Testgrube (deu)
testna jama (hrv)
kutatógödör (hun)
testna jama (slv)

See shovel test.

topographical survey

topographische Aufnahme; topographischer Survey; Geländekunde; Geländeaufnahme (deu)
topografski pregled (hrv)
topográfiai felmérés (hun)
topografske raziskave (slv)

The study of the arrangement of natural and artificial features of an area.

See also archaeological surface survey.
(S. Mayhew 2015, A Dictionary of Geography (5 ed)., Oxford University Press.)

trial trenching

sondage; test trench (eng)
Suchschnitt; Testschnitt (deu)
testni rov (hrv)
szondázás (hun)
testni jarek (slv)

Archaeologically excavated trench, either hand of machine dug, as part of a sampling programme to evaluate the presence/absence, nature, preservation, age and extent of any buried archaeological features.
(HISTORIC ENGLAND THESAURUS:
http://purl.org/heritagedata/schemes/agl_et/concepts/145175)

underwater excavation

Unterwassergrabung (deu)
podvodno iskopavanje (hrv)
vízalatti feltárás (hun)
podvodna izkopavanja (slv)

Archaeological excavations carried under water, for example excavation of a ship-wreck, harbour structures that are today under water and similar. The techniques used in this case have to be adjusted to the specific underwater conditions.

unmanned aerial vehicle (UAV) survey

UAV photography survey; unmanned aerial system (UAS) survey; remote operated vehicle survey, drone survey (eng)
Luftbildfotografie mit Drohne (deu)
zračno fotografiranje pomoću bespilotnih letjelica (hrv)
drónnal végzett légi felderítés (hun)
aerofotografija z brezpilotnim letalnikom (slv)

Conventional three-band photography from above with a camera fixed on a remotely operated vehicle.

unsystematic (intuitive) surface survey

Unsystematische Begehung (deu)
nesustavni površinski pregled (hrv)
nem szisztematikus terepkutatás (hun)
nesistematični površinski pregled (slv)

A type of archaeological surface survey that is used to detect new sites by randomly collecting finds and acquiring limiting information in a wider area, mostly on pre-targeted locations. As such it is to be avoided.

vertical electrical sounding (VES)

vertikale geoelektrische Sondierung (deu)
metoda vertikalnog geoelektričkog sondiranja (hrv)
vertikális elektromos szondázás (hun)
metoda vertikalnega električnega sondiranja (slv)

The vertical electrical sounding (VES) method is based on the estimation of resistivity of the medium in vertical direction. The use of VES is not very common because resistivity methods in archaeology look for lateral changes and not for layering associated with vertical changes. If layering is the aim only small depths of investigation are looked for. Anyhow, electrical resistivity tomography (ERT) is much better solution in the case that someone is interested in distinguishing deposits sequence in the vertical directions.

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