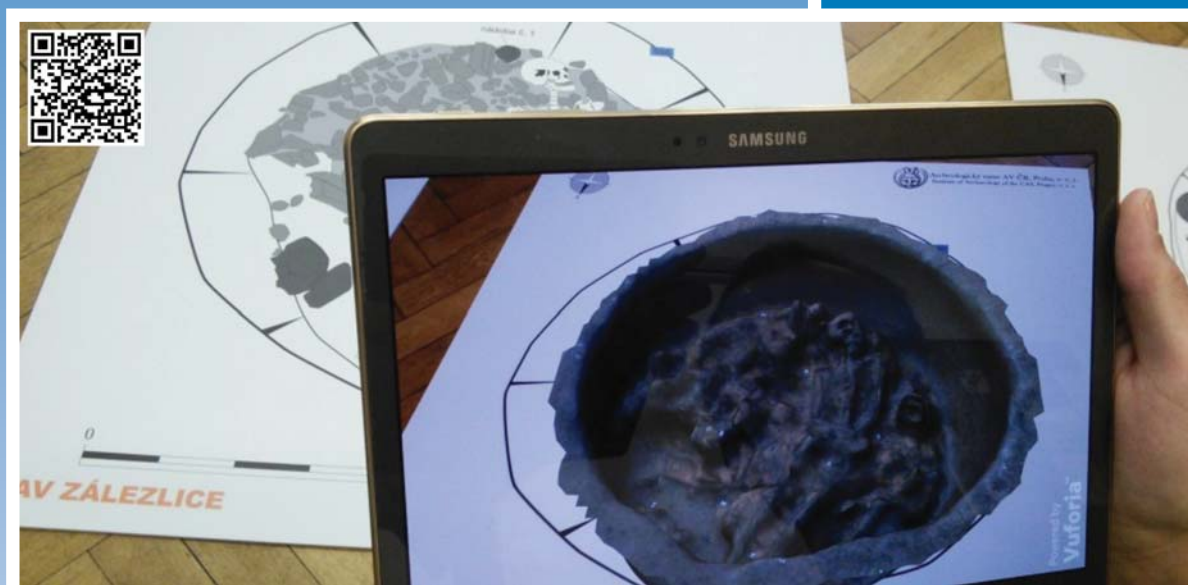


EAC Occasional Paper No. 12

Digital Archaeological Heritage



Edited by Keith May



Working together with
Historic England

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Heritage Information Strategy Advisor, Historic England Research Group

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Digital archaeological heritage: an introduction

A call to action for Europe's archaeology was set out in the Amersfoort Agenda (Schut et al. 2015). It identifies digital technologies and the expanding phenomenon of online and social media as fundamental aspects of the future of archaeological endeavour through its three key agenda items:

- Use emerging digital technologies to share, connect and provide access to archaeological information; this will require improved collaboration and the development of (and participation in) European networks
- Encourage cooperation with other disciplines and share data in order to create a shared benefit
- Aim for the greatest possible access to digital archaeological resources for various user groups and exploit digital databases to their full potential, including uses for the greater public.

The 17th EAC Symposium (Europae Archaeologiae Consilium) in Brighton was convened under a concept note that recognised that 'Digital technologies are developing at an unprecedented speed. As they do, they are opening up many new possibilities for the conduct and presentation of archaeological research and investigation. The digital realm is one which knows few borders and so the sharing of understanding about these new methods, techniques and possibilities across Europe is extremely valuable'.

The Brighton Symposium was held over one and a half days (17-18 March 2016) and consisted of three presentation sessions, followed by discussions that included questions and comments from the floor. The presentations were aimed at one of the three broad themes of the symposium although, in actuality, a number of the presenters raised topics that spanned more than one theme. The three general themes were:

- *Session 1. Measuring and sensing*

The aim of this session was to explore developments in how we perceive, identify and characterise archaeological landscapes, sites and artefacts. It is clear that our capacity to use ever-growing processing power to visualise archaeology has developed dramatically over the last 20 years. Tools such as geophysics and GIS have led directly to wonderful new discoveries even on very well-studied sites, and will likely continue to do so. The papers presented in this session explored the latest developments in high-resolution remote sensing for mapping and analysis of buried archaeological and wider topographic landscape, to state-of-the-art laser scanning survey of sites and buildings deemed of national and international importance.

- *Session 2. Data to knowledge*

Information technology continues to unlock new ways that we can create information from raw data. In the computer sciences, and in related heritage work, researchers are exploring the best ways that some of that information

might be processed by machines to generate new, or improved, knowledge. The papers presented in this session covered a number of initiatives using GIS and related technologies, such as geophysics, for data management and research, which ranged in coverage across Europe, from Poland to Albania, or Hungary and the Czech Republic to Scotland. Other papers presented research challenges being faced in Sweden and the Netherlands from integration and digital archiving of data at national scales, along with the ARIADNE project that is tackling the sizeable task of developing infrastructure for networking archaeological research across the whole of Europe.

- *Session 3. Visualising the past*

The challenging task for this session was to review the myriad ways in which we can digitally present archaeological research and results to the heritage sector and everyone else. The opportunities for this are developing at a breathtaking speed with greater adoption of digital technologies, and especially a wide participation across society in online media. The papers in this session considered perhaps the most difficult and diverse questions to answer at the symposium, around how to use new or established digital technologies in ways that most engage different audiences with the outputs and results of archaeological enquiry. The presentations considered how different 3D recording techniques can be used to enable suitable outputs for online dissemination, or more direct interpretative experiences on-site, including using the 4D immersive world of augmented reality. In the actual reality of the Brighton conference hall, we were also treated to a truly interactive hands-on experience of replica archaeological objects, produced by the latest techniques for 3D printing.

Towards a research agenda for digital archaeology

The articles in this issue are seen to add to a significant and growing corpus of work by others in the field of digital archaeological heritage. This background, along with the Amersfoort agenda's reference to 'the future of archaeological endeavour', provides a suitable landscape for some horizon scanning, and to give a brief examination, or 'Observatory', of possible trajectories or implications of some key emerging digital technologies, particularly where further research is likely to be of strategic benefit to the heritage sector. In any such attempt at 'reading the archaeological runes', and especially one involving possible innovations in Information Technology, the timescale cannot be quite the same as might be more familiar to archaeologists, for whom a century is considered such a brief passage of time. Undoubtedly, this horizon scan and its observations will need to be supplemented by further updates or references to other forward-looking agendas over the course of the coming years. It will be interesting to what degree, and how quickly, the current pace of change in IT can overtake it. Such a scan can currently identify seven major challenges.

The magnificent seven: grand challenges for digital archaeological heritage

1. Re-engineering heritage processes to include digital technologies where most appropriate (but not just re-inventing the wheels)

A challenge resulting from the Amersfoort agenda is to re-design, or re-engineer, fieldwork, analysis, synthesis and publication along with related processes (Larsson *et al.*) as necessary to best enable appropriate access to digital historic environment information. Where possible, this would be an opportunity to research and design direct digital data capture in the field using appropriate recording methods (e.g. laser scanning, Structure from Motion, 3D modelling, remote sensing, UAVs and AUVs unmanned aerial and underwater vehicles) (Meylemans; Musteață). There is an associated risk that re-engineering could be taken forward inappropriately for the discipline, but equally a risk that if others outside the sector (e.g. predictive modelling, big data analysts) take on this challenge, then more ‘mainstream’ heritage research could at best be seen as outdated and irrelevant to the wider world, or more worryingly, the direction of heritage research could become misdirected by others. Strategies and actions to help direct the most appropriate uses of digital technologies would include:

- Enabling the best re-use of data to provide the foundations and knowledge base for new research by integrating and supporting best practice in the use of digital technologies in the research cycle
- Investigating and promoting digital techniques for investigation that deliver suitable digital end products
- Exploring new digital technologies for recording, analysis and dissemination
- Identifying best practice and training requirements for ever emerging and new digital techniques and methods
- Identifying more seamless approaches to creating, managing and re-using digital historic environment information
- Adopting and improving cooperative research tools and mechanisms to best enable sharing and re-use of heritage data
- Archiving should be designed for re-usability in order to be sustainable. Archive material that is *never* re-used is literally ‘use-less’.

2. Defining the best digital end products for correctly identified audiences (The Heritage Research Cycle – bridging or ‘minding the gap’)

- There is an opportunity and need to better define the *digital* end products of the process of investigating the historic environment. This means that information should be generated and held in ways that best enable use for all the expected means of academic publication or more general dissemination, together with the development and support of an infrastructure to enable access to the information (e.g. Aloia *et al.*). This also requires a clear understanding of different audiences that will be researching, re-assessing, or simply enjoying the information (Shaw; Unger and Kvetina). Without this better definition there is the risk that historic environment information will remain fragmented, disparate, and fail to be current and relevant, both within the sector and, possibly equally significantly, for related sectors.

- Digital records also provide a greater opportunity for front-loading the archives, so that new investigations consider the implications and requirements of creating artefacts of the future or ‘technofossils’ (Zalasiewicz et al. 2014) of the future when depositing new digital archive materials. Key strategic activities which would help promote the best digital end products would be:
- Identifying the appropriate target audiences for different historic environment online information and other digital heritage information resources
- Investigating and responding to how archaeologists and other heritage researchers use and re-use the digital end products of investigations
- Re-defining so-called archaeological ‘grey literature’ as fit-for-purpose digital publications, identified and citable using Digital Object Identifiers (DOIs)
- Developing ways of making digital data most readily available to researchers and promoting ‘Best Practice’ in digital archiving that includes re-usability criteria
- Promoting sharing and re-use of archaeological data to improve the ability to synthesise the results of archaeological research, especially data and reports from developer-funded investigations
- Exploring new methods and providing exemplars of online digital publication and greater integration of data within digital publications through the wide adoption of appropriate data citation by the sector.

3. Endorsing best practice and standards in digital methods

Considerable work has been done on providing online access to digital collections. Much of this information is at index level to signpost where resources exist. There is a lot of existing material from the pre-digital era and issues arise about what could or should be digitised. Given the scale of the resource, though, it is difficult to assess which archives researchers might eventually want in digital formats, and how to future-proof such formats (Hollander; Aloia et al.). It is seen as a priority to define the particular audience requirements for different specialist researchers seeking digital archive information (e.g. archaeological, architectural, academic or professional, etc.). While considerable progress has been made in the digital archiving of single types of resource (e.g. image libraries), it has proved less straightforward to develop an integrated digital archiving strategy for more composite archives of projects involving various media and formats, such as archaeological excavations. A key strategy for digital archiving of more complex project datasets, and particularly where these require digital dissemination, is to deposit with a recognised digital archive. To help promote best practice and development of appropriate standards for digital methods some key approaches are recommended:

- Promoting best practice that delivers suitable digital end products
- Producing guidance documents for new techniques and approaches
- Supporting the historic environment take-up and wider use of social media and other evolving internet communication and data-sharing technologies through events such as online fora or appropriate communities of practice
- Establishing best practice to record, track and disseminate online archaeological research questions, and the associated research outputs from research frameworks, strategies and agendas, using semantic technologies

- Valuable guidance has been produced about digital dissemination and digital archiving (e.g. the ADS *Guides to Good Practice*. Also see Hollander and Aloia et al.). This will need to be kept up to date and other guidance should be produced as and when new technologies are developed and widely adopted (i.e. they reach the plateau of productivity on the Gartner hype cycle) or are identified as necessary for digital aspects of heritage project management.
- Developing new infrastructure and guidance on best practice use of Open Source software (Bibby)
- Development of Open Data publications and data citation.

4. Capacity building and infrastructure for heritage use of digital technologies

A mechanism will be needed to update strategy where the adoption of new technologies produces a previously unknown skills shortage in the wider heritage sector. The discussions in Brighton suggested that ‘crowd-sourcing’ skills might be one approach to supporting skills in the heritage sector, which does not generally find it easy to maintain the ‘cutting edge’ of new technologies.

One of the intended aims of the Brighton symposium was to hold a short parallel student event to gauge adoption of new technologies by up and coming researchers. The difficulty in getting students to such an event ultimately highlighted a gap between the heritage management sector and the academic research sector. To bridge this it might be useful to:

- Coordinate the publication route for early career researchers in digital technologies – e.g. through the local chapters of the CAA conference and support an article in *Internet Archaeology* (e.g. for the best paper from each national chapter of CAA through EAC member countries?)
- Scholarship appointments to key university departments (e.g. MSc 2-year scholarships) to build capacity in key digital skills for heritage resources (e.g. supporting a Europe-wide community of practice for FISH-HEIRNET and related European standards initiatives – see below).

A recent Historic England horizon-scanning report noted the need for greater development of GIS-related skills and data analysis (see McKeague et al.; Novák et al.; Oniszczyk and Makowska; Stibrányi) which ‘require high degrees of expertise in two areas: knowledge and understanding of datasets and their properties, and expertise in statistics and in using GIS and related ‘spatial’ technologies (such as 3D modelling and rendering)’ (Thomas 2015). Some other key priorities might be:

- Establishing and promoting projects that establish or support the necessary procedures and infrastructure to sustain identified best practice and standards
- Promoting training and Continuing Professional Development to address new information technology implementations for the heritage sector
- Development of useful Internet-based infrastructure for the historic environment

- Develop Heritage/Historic Building Information Modelling (HBIM), which will have critical importance for future re-use of Buildings Information Modelling and data exchange among architectural historians and archaeologists
- Working on heritage projects with volunteers from other sectors who might 'share' the skills they already hold (e.g. IT skills, interface design or computer programming, etc.) in return for involvement in heritage activities, i.e. crowd-funding approaches to skills sharing
- Developing and supporting communities of practice for the promotion of best practice use of digital data standards and digital technologies, e.g. extending the role of the Forum for Information Standards in Heritage (FISH) and the Historic Environment Information Network to be a European-wide forum and network, along with existing European bodies such as ARCHEs.

5. Heritage data analytics (the real potential of Big Data for heritage)

With ever-growing use of new digital investigation methods there are associated issues of how to process, manage, communicate and publish the often increasingly large digital resources that much research is now based on. Approaches that are used in the university research environment to develop high-performance parallel computing resources and increase such uses over the Internet do enable researchers to carry out work away from the more mundane limitations of the WWW. The development of such networks and infrastructure is something that the ARIADNE project in particular has begun to address (Hollander; Aloia et al.). The negotiated use of such 'High Performance Computing' for relevant heritage computing needs (e.g. new scientific dating and data-processing techniques; direct research on Heritage Data Analytics and data mining; or through specific research projects, may need further investigation, particularly with regard to some of the issues relating to the management and dissemination of results from so-called Big Data technologies. Some key priorities could be:

- To understand and explore the potential for different types of historic environment research datasets to be used in, or related to, the disciplines of data science and network science
- Improving the understanding of the nature of digital heritage data and related information so it can best be analysed and processed, to enable an increase in the overall knowledge dividends for understanding and managing the historic environment
- Developing sustainable strategies for increasingly complex and increasing amounts of digital data, especially in digital archives, to cover new and as yet undeveloped research techniques to create the best and fit-for-purpose *digital artefacts of the future*.
- Explore any potential for historic environment uses of so-called Big Data technologies used in more commercial and business contexts.

Much of the focus of Big Data analysis is on modelling current social and economic data to find trends and to make predictive models, rather than looking at the potential use of longer term historic data. Although much archaeological data can be, and will continue to be, more interpretative than much commercial Big Data, there may still be considerable potential – and indeed a negative risk management requirement – to

establish what archaeological data *is not suitable* for data mining metrics, along with identifying where certain types of historic environment datasets would be useful for informing other multidisciplinary analysis. Some other key priorities might be:

- Managing the sustainability and ongoing curation, dissemination and re-use of continually evolving and emerging extremely large digital data formats
- Managing the interoperability of data and information, including policy, security standards and open data rights issues relating to interoperability.

6. Interoperability and semantics of heritage datasets

Much research is currently taking place in exploring ways to develop greater semantic interoperability between existing, or newly developed, datasets. This is based on the idea of a further stage in the Internet's development known as the Semantic Web, which has been most publicly propagated by the inventor of the web browser, Tim Berners-Lee (Berners-Lee 2001). While at present the degree to which the vision of a semantic web is realisable remains debateable (the position seems similar to that in the early 1990s before the WWW became global), there are already major businesses in the IT domain (Oracle, IBM, BBC) who are benefiting from utilising the sorts of technologies that are being developed to create the semantic web. In the academic and research domains – where free information exchange and interoperability are more readily adopted principles – the emergence of semantically enabled data and tools such as Natural Language Processing (NLP) are growing fast (Aloia et al.). With this in mind it will be important for heritage organisations to make sure that existing data are kept up to date with such developments, and that new data are recorded and stored in ways that best enable this form of interoperability, so that the information remains useable by, and relevant to, others into posterity. Research as a result of this, while including new aspects of information management, may go further and include opening data up (see Challenge 7) for new areas of cross-domain research by the ability to search and data-mine semantically-related information resources that have not been previously interoperable (e.g. much greater potential to cite the information held in, or related by, online archaeological reports produced by many disparate projects and organisations). Opportunities for promoting research can be seen in the following areas:

- Development of semantic technologies and related interoperability requirements and infrastructure
- Ensuring that heritage information is most (re)useable for other users through access to digital data and archives online
- Exploring new dissemination mechanisms and interoperable technologies such as Linked Open Data (LOD), particularly championing the use of the W3C SKOS standard for online shared heritage vocabularies (e.g. <http://www.heritagedata.org>)
- Through R&D establishing how to best address, track, and disseminate archaeological research questions, and the associated research outputs from research frameworks, strategies and agendas, using semantic technologies.

7. Open access to data and publications supporting data sharing and re-use

A key agenda item from Amersfoort was aimed at providing and encouraging 'the greatest possible access to digital archaeological resources for various user groups. Archaeology should embrace the trend towards open access' (Schut et al. 2015, 22). But how best to put these words into practice? Some useful ideas are given in Amersfoort:

These new digital opportunities might require a reconsideration of our working ethics, including *the question of what we do and do not wish to share*. The development of shared digital databases offers benefits not only to the professional world; it also provides potential benefits for society. We will need to exploit digital databases to their full potential and explore the possible uses for the greater public. The discipline could also put more effort into researching existing data and facilitating syntheses. (Schut et al. 2015, 22)

This emphasises the need for some serious reconsideration or 're-engineering' of archaeological processes that were established in a different era, when many of the tools we now have for data recording, analysis, research synthesis and publication, were simply not available (and in some cases barely conceivable) to previous generations of archaeological excavators, scientists or researchers. Archaeologists have never been reluctant to adopt and adapt new and innovative software and IT. The broader directives towards Open Data, and Open Access publishing (EU Commission 2016) and Open Science, along with the emergence of widely used Open Source software (Bibby and Ducke), are providing a new impetus to data sharing and more open research opportunities. The Amersfoort publication also noted in particular that:

it is important to realise that data is not the same as knowledge. Easy access to more standardised, interlinked data does not necessarily lead to new and different stories about the past. It is therefore important not to lose sight of the focus on interpretation and knowledge gains. (Schut et al. 2015, 21)

Key areas of research for encouraging and supporting better sharing and re-use of data include:

- Adopting and improving cooperative research tools and mechanisms to best enable the most open sharing and re-use of heritage data
- Encouraging either (or both) models of Open Access publication: Green (self-archiving) and/or Gold (open access publishing)
- Consider the potential cost-benefits for wider use of Open Source software and support development of communities of practice for best practice use of Open Source IT
- Developing and supporting communities of practice for the promotion of best practice use of open digital data standards and open digital technologies, e.g. helping the sector with the sometimes complex (or legal) issues around Open Data licensing (e.g. review and where possible adopt appropriate Open Data license options across Europe and globally).

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[Links to videos on EAC website/YouTube](#)

<http://www.europae-archaeologiae-consilium.org/media-page>

Heritage Information Access Strategy

<https://www.historicengland.org.uk/research/support-and-collaboration/heritage-information-access-strategy/>

<https://www.youtube.com/watch?v=sExIGgDEFOE&feature=youtu.be>

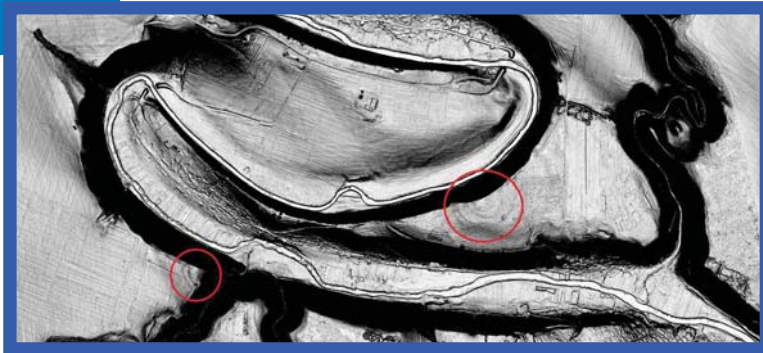
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The text of this paper with a full bibliography is available online at dx.doi.org/10.11141/ia.43.1

Measuring and sensing

The aim of this session was to explore developments in how we perceive, identify and characterise archaeological landscapes, sites and artefacts. The papers presented in this session explored the latest developments in high-resolution remote sensing for mapping and analysis of buried, and submerged, archaeological and wider topographic landscape, to state-of-the-art laser scanning survey of sites and buildings deemed of national and international importance.



Stolniceni – interpretation of the geophysics and aerial photo
(after Țernă et al. 2016a) (Photo: Musteață et al.)

The Rae Project: digital documentation of a nation's heritage

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Introduction

Initiated in 2011, *The Rae Project* is named in memory of the Orcadian surveyor/explorer John Rae who is credited with discovering and mapping part of the Northwest Passage in the 19th century. It is Historic Environment Scotland's (HES) ambitious initiative to 3D digitally document over 300 properties and more than 300 collections objects, cared for under a Scheme of Delegation for Scottish Ministers over a ten-year period.

Whilst HES maintain and manage paper and digital records for all the properties in care, a frank assessment of the documents (maps, site plans, elevations, sections, etc.) recognised that the records were, in some cases, partially complete or inadequate. The Scheme of Delegation requires HES to conserve and manage the properties in care and collections, and also ensure their accessibility. The Rae Project is core to the delivery of these objectives.

Initiation of the Rae Project

The use of 3D digital documentation technologies, including laser scanning and digital photogrammetry, is steadily increasing within the heritage sector and HES was an early adopter and advocate. Working in partnership with The Glasgow School of Art since 2007, the combined team delivered the pioneering *Scottish Ten Project* (Wilson et al. 2013), which 3D digitally documented Scotland's as then five World Heritage Sites and international heritage sites including the Sydney Opera House, Australia and the Nagasaki Giant Cantilever Crane, Japan, for conservation, site management and educational purposes. At HES, we are using the unique experience gained through digitally surveying large and complex global heritage sites as the catalyst for the Rae Project. The project is expected to form the backbone of major conservation initiatives and provide baseline 3D data for a management and information system for

the entire organisation. The aspiration of the project is to produce a consistent digital benchmark of each property and many objects in care. This metrically accurate data feeds into practical applications that are used on a day-to-day basis by HES architects, architectural technicians and conservation scientists, primarily to assist with and enhance the conservation of the estate.

Prioritising properties and collections

To drive the Rae Project forward, the professional assessment of the estate by internal HES stakeholders was a necessity. This allowed the 300+ properties and objects to be systematically evaluated and prioritised. Key site assessments were undertaken on the basis of:

- Conservation need
- Climate change risks
- Fire risks
- Major architectural interventions/projects
- Accessibility needs
- Archaeology priorities
- Interpretation and education priorities
- Commercial opportunities
- Practicalities and achievability.

This assessment was an opportunity to take on board priorities of business areas across the organisation. These priorities were weighted to ensure that conservation remained the primary driver and the assessment is revisited annually to ensure its currency.

Rae Project Compliance

The Rae Project generates multiple digital outputs, sites and monuments are deemed to be 'Rae Project Compliant' if they have:

- Complete written site description and documentation
- Complete topographic survey to the specifications of the Historic England Metric Survey Specification (Andrews, D. et al. 2015) as agreed by HES
- Complete Measured Building Survey to the specifications of the Historic England metric survey specification (ibid.) as agreed by HES
- A registered point cloud with as close to 100% data captured as possible of the area that is in HES care, with accompanying metadata that supports an exported and archival ASCII format of the data and Web viewable 'TruViews' or equivalent that allow end users to view and mark up the data as appropriate to their requirements.

Objects are compliant if they are digitally documented, meshed and archived in *.OBJ format. Many objects are now taken to the 3D printing stage. The final data, not the print, is considered the final reproducible product.

Using the data

While the Rae Project generates essential baseline survey data, it also provides essential raw material for many of HES's key conservation initiatives, including:

- The management of the estate and making this process as efficient as possible – data captured digitally is the core of new and revised architectural drawings for site interventions and condition surveys
- Maintaining and updating Geographic Information System records of the estate, which helps site management at the macro level
- Providing 3D data as a basis for Building Information Modelling (BIM) projects that can help with the management of sites and fulfil specific government legislation requirements, e.g. Edinburgh Castle Palace BIM project

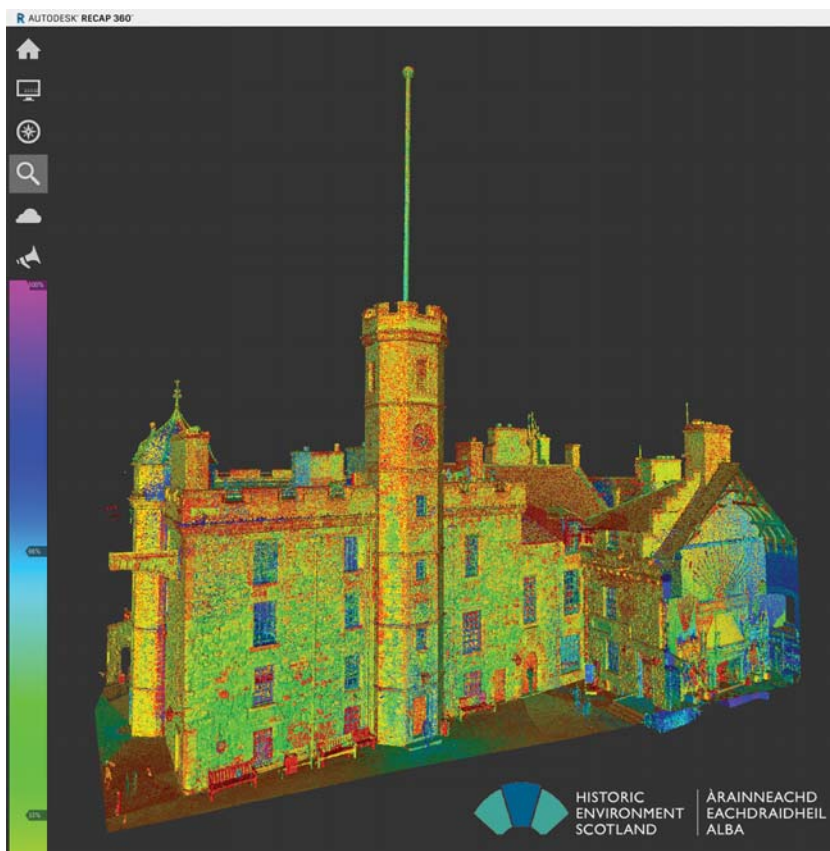


Figure 1. Autodesk ReCap screenshot of Edinburgh Castle Palace Scan to BIM project.

- Supporting research that promotes and enables a better understanding of how to document and manage technically complex conservation issues that are site specific (Valero, E. et al. 2016), e.g. combined analysis of Skelmorlie Aisle using 3D scan data, infrared thermography and 3D moisture mapping
- 4D conservation monitoring of HES sites that help us protect against and understand natural environmental impacts on heritage, e.g. biannual coastal erosion monitoring at Skara Brae.

Further proposed developments within HES include a complete 'Properties in Care Asset Management System' (PICAMS). Rae Project data will feed into this, alongside every other strand of organising and managing the properties. In addition, critical to making PICAMS work is making the data accessible and useable. When HES Architects visit and condition assess a monument, they need to see a full visual record of the site that they can interact with and ensure that they are working with the same accurate and current data as we supply to stonemasons, contractors and researchers. It is intended

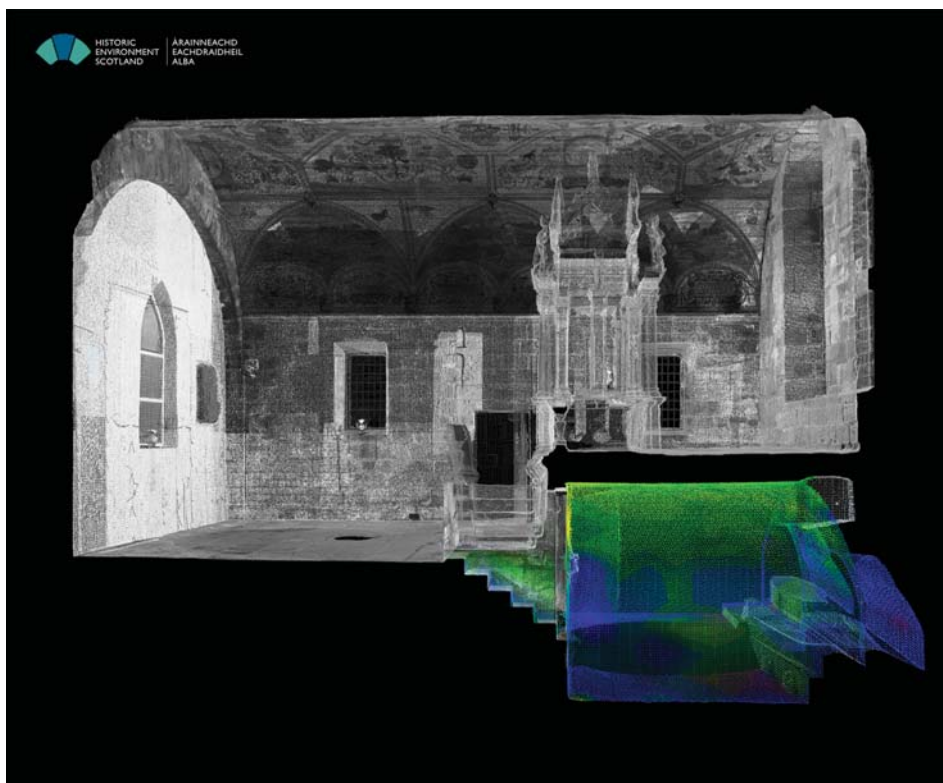


Figure 2. Point cloud image of Skelmorlie Aisle with 3D moisture data mapped onto surface to help visualise conservation issues.

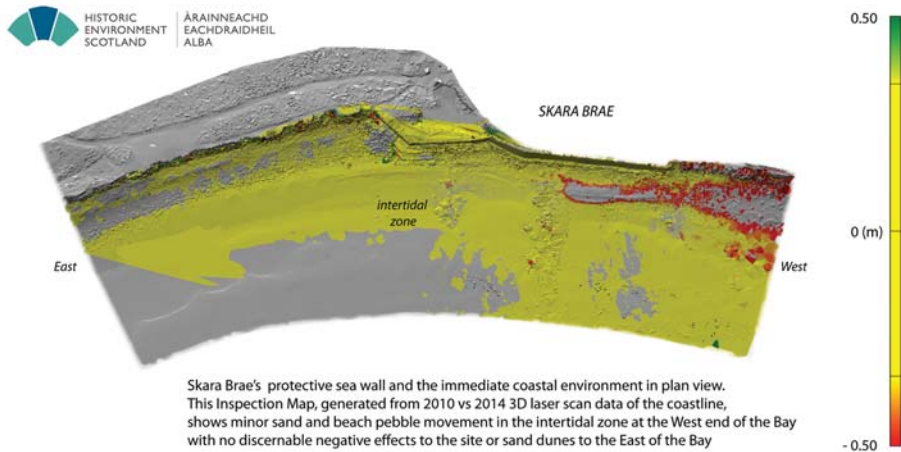


Figure 3. Skara Brae coastal erosion monitoring inspection mapping.

that this will be achieved using a bespoke tablet based asset management system based on the British Geological Survey's successfully implemented SIGMA (System for Integrated Geoscience and Mapping). HES data trials with this system started in 2015.

In summary, the Rae Project is proving to be an essential input to a broad range of HES initiatives, most significantly aiding in the conservation and management of our nation's heritage.

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It's all in the Pixels: high resolution remote sensing data and the mapping and analysis of the archaeological and historical landscape

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Keywords: Lidar, archaeological prospection, landscape archaeology, heritage management

In Flanders (Belgium) a large amount of remote-sensing data has been acquired and processed over the past few years, including high-resolution Lidar and multi/hyperspectral aerial photography. These new data are contributing to the detection

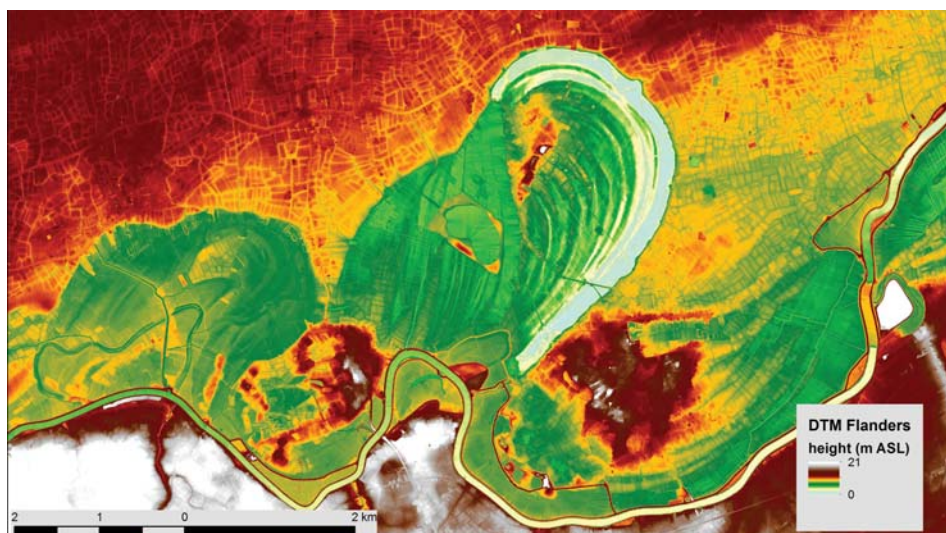


Figure 1. Colourscale Lidar raster map of part of the Scheldt valley, showing fossil channels and point bar topography.

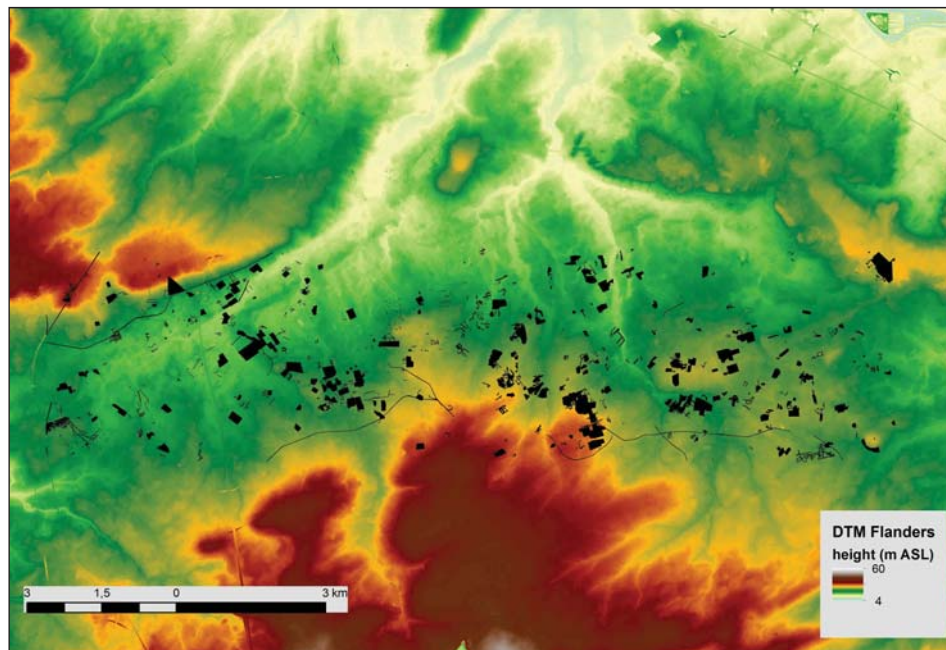


Figure 2. Archaeological traces based on a combination of remote-sensing sources (historical land archaeological aerial photographs, Lidar) for a test region in the vicinity of Torhout (e.g. Stichelbaut et al. 2015).

of archaeological sites and the characterisation of the cultural/historical landscape. Of particular use in historically stable areas under forest and pasture, Lidar demonstrates the presence of a large number of previously unknown features and sites such as the so called 'Celtic Fields', burial mounds, medieval field systems, in some cases constituting extended fossilised cultural landscapes (Meylemans et al. 2015).

As well as the value to archaeological prospection, the analysis and modelling of these data, combined with other landscape data such as soil maps, augering data, geological and historical maps, and aerial photographs, provide possible new instruments for the characterisation and evaluation of prehistoric and historic landscapes, for example erosion risk modelling of archaeological sites and landscapes (Meylemans et al. 2014). In combination with the archaeological data gathered in the 'Central Archaeological Inventory' of Flanders (Van Daele et al. 2004), this in turn allows the development of new ways of looking at and analysing archaeological data (for example Finke et al. 2008), for both scientific purposes as well as heritage management.

This vast amount of new remote sensing data, plus the information it delivers, however, presents not only obvious opportunities but also a number of challenges. One of these is data storage and dissemination. For this a centralised online system was developed

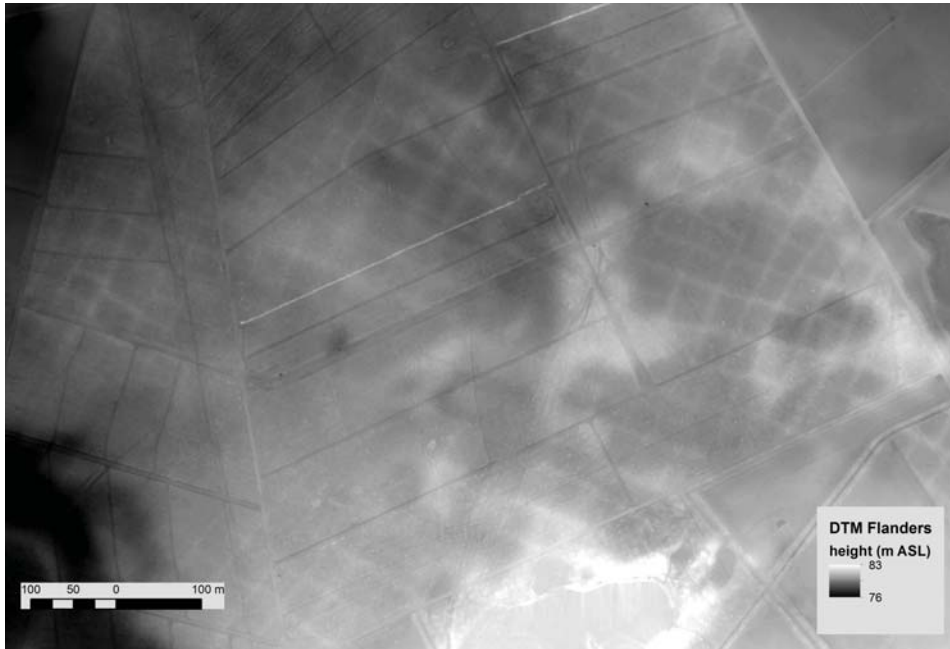


Figure 3. Combination of greyscale and hillshade of Lidar raster map with several barrow structures under forest.

by the 'GIS-Flanders agency', storing both processed and raw data from multispectral recordings, airborne Lidar, mobile mapping images etc., and presenting several download and visualization possibilities and tools. Besides this, a new system is being set up to handle specific archaeological and cultural historical data (historical images and aerial photographs, archaeological field data).

A second challenge concerns heritage management. This mainly applies to the historically stable forested areas, which in a large number of cases are shown to harbour almost continuous and well-preserved archaeological landscapes. These areas are mainly managed with ecological purposes and goals in mind. For some of these sites and landscapes, dialogue is needed so that the preservation and management needs for the archaeological heritage are also included.

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Non-invasive archaeology in the Republic of Moldova – An example of multidisciplinary approach and international partnership

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Keywords: non-invasive archaeology, geophysical techniques, Republic of Moldova

Over the last decades a wide array of new non-invasive techniques has been available for archaeological research, particularly since the use of non-destructive archaeological research methods fits perfectly in the context of the international conventions and recommendations.

One of the first non-invasive surveys in our region was done in 1974 by V. P. Dudkin using an 'M 27' magnetometer in a prehistoric site. After that, most non-invasive archaeological research was limited to field surveys. Not until 2005, with the participation of colleagues from the Free University of Berlin, was another magnetometer survey done, on the Bronze Age site from Miciurin–*Odaia*.

The situation changed during the last decade, as a result of a number of international partnerships and projects.

The Moldo-German project 'Geophysics surveys in Moldova'

A very active party during the last decade in organising and conducting such non-invasive researches has been the 'Ion Creangă' Pedagogical State University from Chișinău. Thus, with the support of the German Institute of Archaeology in Frankfurt am Main, the first geophysical surveys were carried out in 2009–2011.

During October 2009, surveys with a five-channel magnetometer of the 'Dr Förster' type, were undertaken in five archaeological sites from the Republic of Moldova, namely in the villages of Horodca and Costești (Ialoveni district), Petreni (Drochia district), Sobari (Soroca district) and Trebujeni (Orhei district). It was possible to take geomagnetic readings for an area of over 20,000m², leading to the discovery of the

remains of habitation structures and fortification works. Particularly interesting results were obtained, for instance, in the Cucuteni-Trypillia site located between the villages of Petreni and Sofia (Drochia district), and in the late Roman settlement from Sobari (Soroca district). In other cases, it was possible to identify several magnetometric anomalies that, on account of their shape and size, can be assigned to remains of dwellings. The results provided sufficient conditions for a complete geomagnetic investigation, which was carried out during the 2010 and 2011 campaigns.

In 2010, the German Institute of Archaeology provided the team with an even more advanced magnetometer, comprising 16 channels of the 'Dr Förster' type. The speed of propulsion varied between 0.6 and 15km/h. This equipment was used for geomagnetic surveys in a number of pre- and proto-historical sites, as well as in the medieval town near Trebujeni, Orhei district. Extensive geomagnetic surveys were carried out in the site of Sângerei (Sângerei district). More than 20 ha were investigated and the existence of Cucuteni-Trypillia and Sântana de Mureş-Chernyakhov sites could be confirmed.

Particular attention was given to the investigations in the settlement of Petreni. On account of the scientific potential proven by the 2009 investigations, more than 14 ha of the site were surveyed. The area surveyed in 2010 represents approximately half of the settlement. The size of the settlement was previously estimated on the basis of air photographs and by charting the surface remains. As a result of the 2010 and 2011 surveys, the general map of the site was established, which facilitated the analysis of the structure and organisation of the prehistoric Cucuteni-Trypillia site from Petreni, recently published in a collective work.

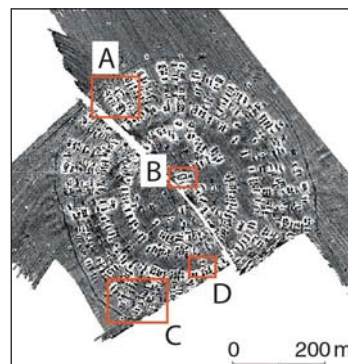
The Moldo-German project 'Cultural relations of the Sântana de Mureş Culture between the rivers Prut and Dniester'

Between 2010 and 2015, the Moldo-German-Romanian team developed the project on landscape archaeology from the area of the Cubolta valley in northern Moldova. The most important discovery to date has been the settlement area of the late Roman culture between the villages of Putineşti and Cubolta in the southern part of the valley. During the summer of 2015, investigations were undertaken in a settlement of the Sântana-de-Mureş Culture (c.AD 230–430/450) at Putineşti, Floreşti district. The site rests on a slope slightly inclined to the west, is of an elongated shape and is delimited on the northern and southern sides by gullies. Despite the unfavourable conditions created by the erosion of soil on the slope, as well as by the fill of a gas pipeline that crosses the site in its northern part in an east–west direction, it was possible to survey an area of c.82,000m². A series of magnetic anomalies were identified, which correspond to archaeological complexes of various shapes and configurations, the functions of which will be clarified by future research.

The Moldo-Romanian non-invasive surveys in the medieval fortress of Soroca

The medieval fortress of Soroca is one of the most known and visited cultural sites from the Republic of Moldova. Between 2012 and 2015, researchers from Moldova and Romania carried out archaeological surveys inside and outside the fortress. The first

Figure 1. Petreni – the magnetometric map of the prehistoric site, results of 2010 and 2011 surveys. The red rectangles mark the remains of former excavations (after Rassmann et al. 2016).



stage consisted of a topographic survey of the area around the fortress and of the fortress development plan, using a total station and high-precision GPS. Taking into account the traces of late medieval buildings around the old fortress shown on old maps (ditches, fortress vallum, church, cemetery, etc.) and the current configuration of the park, a number of non-invasive techniques were applied in order to verify these and identify their location. Measurements were made with a soil electrical resistivity system, ground-penetrating radar and magnetometer. The data obtained from the fluxgate gradiometer were processed in a GIS environment. The anomalies were charted and the areas of archaeological potential were highlighted. Non-invasive geophysical surveying close to the Soroca Fortress proved to be difficult because the area around the fortress underwent various interventions and reconfigurations, especially during the building of the present-day park. Some sectors were levelled by depositing soil up to a thickness of 2m, while in other sectors the soil was completely removed. Notwithstanding these hurdles, the geophysical surveys revealed anomalies in several sectors during the archaeological investigations, which proved to be structures of various historical periods.

Other non-invasive surveys in the Republic of Moldova

A. *Moldo-Romanian project.*

In 2010, the Arheoinvest research team from the 'Al. I. Cuza' University of Iași, Romania, carried out geo-electrical surveys on the Saharna-Țiglău ancient site (Rezna district), aiming to identify the remains of the necropolis in a strip of crop land. Extensive investigations were also carried out in the same year in Saharna Mare, including GPR, magnetometric, 3D scanning, fluxgate, and georeferenced topographic surveys. After 2010, small-scale works only (topographic survey, GPS corrections) were carried out in Saharna Mare. Many anomalies were discovered in the area of the ancient hillfort, such as the remains of the defensive ditch and wall or other constructions, later confirmed by excavations.

B. *Moldo-German project.*

Another Moldo-German team (High School of Anthropology, the National

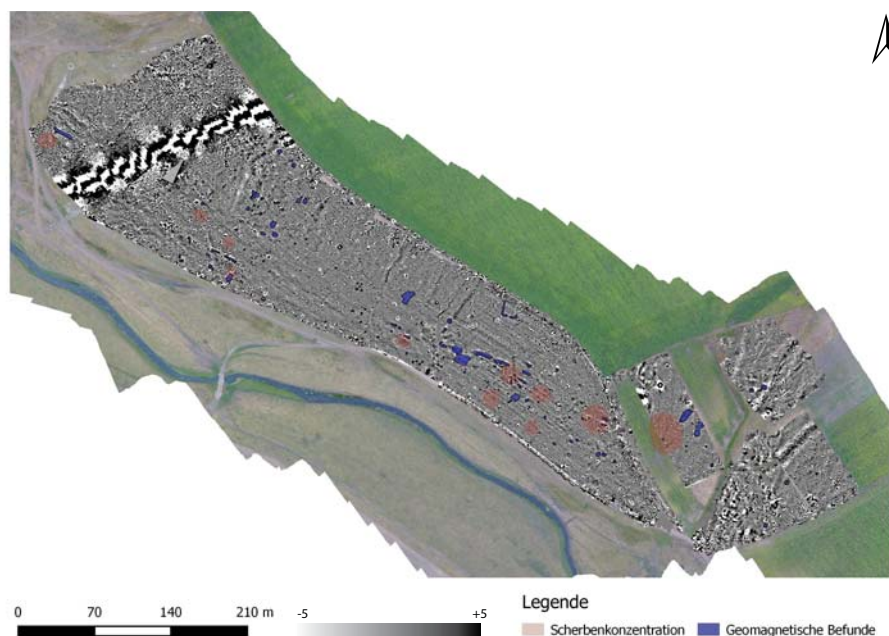


Figure 2. Putinești – the magnetometric map of the Late Antiquity site (after Voß et al. 2015a).

Museum of Moldova and RGK/DAI) carried out a geophysical survey in Stolniceni (Edineț district), a prehistoric site known since 1970. The investigations took place during the summer of 2015, in the form of magnetometric surveying of a 23 ha area, from a total of c.33 ha. The survey led to the discovery of the remains of c.140 dwellings, c.280 pits, and a defensive system composed of three ditches enclosing the settlement. These are very promising results, and the authors intend to extend the investigations to the rest of the settlement.

C. *Moldo-American project.*

In 2014 the American College of Cultural Site Research and Management (CSRM) from Baltimore, USA, employed the LIDAR technique on the site of Orheiul Vechi, nominated for the World Heritage List. LIDAR and multispectral data analysis of Orheiul Vechi revealed numerous archaeological structures and landscape features, many of which were not previously known, such as traces of a new ancient hillfort on the Butuceni promontory. At the same time, the structure of other partially known Mășcăuți ancient hillfort was established.

Conclusions

The results of the non-invasive investigations undertaken during the last decade in the Republic of Moldova confirmed the presence of a number of already known archaeological locations and facilitated new discoveries, which warrants their future



Figure 3. Soroca – medieval fortress, picture of the GPR survey (after Asandulesei et al. 2015).

investigation. The extension of the partnerships with colleagues from other countries would ensure the transfer of experience and knowledge of modern methods of archaeological research, since a multidisciplinary approach and the involvement of international teams are the surest route to quality research. The use of non-destructive research methods in archaeological projects in the Republic of Moldova is in line with international conventions sanctioning the use of non-destructive techniques and *in situ* conservation of archaeological traces.

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Acoustic research on historic submarine hulls

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Keywords: submarine, ultrasonic, underwater survey, Autonomous Underwater Vehicle, maritime archaeology

The gasoline-powered *U-15*, a Type U 13 U-boat, was the first submarine casualty of the war: it was rammed and sunk by the British light cruiser HMS *Birmingham* on 9th August 1914 in the North Sea with the loss of all hands. The engines of *U-15* had apparently failed as she was laying stopped on the surface in heavy fog when *Birmingham* spotted it and could clearly hear hammering from inside the boat (presumably from attempted repairs). The cruiser fired on it but missed, and as *U-15* began to dive, *Birmingham* rammed the submarine cutting it in two. A further 204 U-boats were either rammed, mined, torpedoed or sunk by gunfire during the war (source: uboat.net).

Recent research commissioned by Historic England records the fact that 44 U-boats were lost in England's inshore region (that is, areas of the ocean generally within 12 nautical miles of the coast) during the war and that just over one fifth of ALL U-boat losses lie within 12 nm of England's coastline. Only two of these U-boats are protected as military maritime graves – *UB-65* and *UB-81*: access to these submarines is restricted by the Ministry of Defence.

Perhaps unsurprisingly, British submarine losses largely lie further afield having been lost in operations overseas. Only three are known to have sunk during the war close to our coast – *C29* (accidentally mined in the Humber estuary, August 1915), *D5* (mined off Great Yarmouth, November 1914) and *E6* (mined off Harwich, December 1915).

As a contribution to commemorations associated with the First World War, Historic England has devised a project to assess and understand the location and condition of specific British and German submarines known to have sunk within UK territorial waters adjacent to England. Although these sites are not new discoveries, we are particularly interested in researching, surveying and diving 11 of these on account of their special interest, rarity and archaeological group value in order to understand the extent of their survival and the current chemical and physical threats to them.

We are working closely with the Ministry of Defence to identify overlaps in legislative protection and we have been asking researchers and divers to contribute data, such

as dive logs, photo stills and video). This increased understanding will help to inform management and protection options which might be considered in the future.

In order provide quantitative data to support the protection of sunken archaeological remains and to test the application of new acoustic equipment for (marine) archaeological research, Historic England recently commissioned an innovative Autonomous Underwater Vehicle (AUV) survey of the remains of the German submarine U-8. This early U-boat was lost in 1915 some 10 nautical miles off Dover in the English Channel in the dangerous marine traffic separation zone.*

Autonomous Underwater Vehicles (AUVs) have been used offshore for some time and the development of smaller systems has opened up a range of inshore opportunities for archaeological investigation. With recent advances in technology, these small AUV systems boast a suite of remote sensors that can include impressive underwater survey tools: side-scan sonar, multibeam echosounder, sub-bottom profiler, magnetometer and an underwater camera.

We deployed an Ocean Server Iver3 AUV for the investigation which carried Edgetech 2205 sonar transducers and towed a Marine Magnetics Explorer magnetometer. The AUV was about 2 m in length and weighed approximately 40 kg; light enough to be deployed by two people. The stated endurance of 8 hours was enough to ensure sufficient coverage of the U-8 target area. However, it was not known how the system would cope with a moderate sea state and tidal streams of up to 2.6 kn, so it was therefore decided to deploy the system to coincide with slack water during neap tides to give the best operational window possible.

Before the AUV could be used to acquire data over the U-8, its buoyancy needed to be adjusted for the salinity and density of the seawater, and underwater survey lines were planned on a laptop with software calculating where the AUV needs to dive down and where it was to come back up. Survey positioning was provided by a GPS receiver within the AUV when at the surface and below the surface positioning was provided by a RDI Doppler velocity log, depth sensor and corrected compass. The AUV can only be communicated with, via Wi-Fi, when it is at the surface.

Deployment of the AUV at the wreck site was relatively straightforward, even in the slight to moderate sea state encountered, and it was programmed to fly around 10 m off the seabed. Unlike a conventional towed system though, the geophysicist was unable to see live images of data as the sensor passes over the seabed: there is no way of knowing that the data is of sufficient quality or that the survey lines have been positioned correctly to ensonify the target site, until the AUV is recovered to the vessel. This can make for a nervous time whilst the geophysicist is waiting to see the data!

The sea state did have an effect on the performance of the AUV whilst in the water in two ways. Firstly, the waves tended to swamp the 'conning tower' containing the

* Historical information on the loss of the U-8 is available online: <https://thewreckoftheweek.wordpress.com/2015/03/20/no-78-u-8-straits-of-dover/> (accessed 29/04/16)



Figure 1. An Ocean Server Iver3 Autonomous Underwater Vehicle, used for underwater remote sensing (Wessex Archaeology for Historic England).

GPS tracking system, which meant that the AUV sometimes had difficulty acquiring a GPS signal, causing it to refuse to start surveying. Secondly, when slack water was lost, the AUV struggled to get into its start of line position as it laboured against the tide, unable to dive. However, its endurance seemed good despite this, with the AUV deployed for about 6 hours with no requirement for a battery change.

Following recovery of the AUV and data download, we could see that the side-scan sonar imagery showed a clearly defined submarine with detail of the conning tower visible. Sharp detail was observed in the acoustic shadow that shows the presence of three distinct upstanding narrow features, two on the conning tower (possibly periscopes) and one just behind (interpreted as the radio mast). The magnetometer data was also of good quality with a large magnetic anomaly observed over the location of the wreck as would be expected.

In addition to using underwater acoustics for site mapping, we are also undertaking a programme of ultrasonic investigation and analysis. This was prompted by the necessity of understanding the stability of steel hulls of wreck sites without causing damaging and increased degradation (see Dunkley 2015).



Figure 2. Sidescan sonar image of U-8 collected by an Autonomous Underwater Vehicle (Wessex Archaeology for Historic England).

Here, ultrasonic thickness gauges are especially useful for non-destructive measurement, particularly where access is restricted to the outer side of a hull only. These gauges are employed in many industrial applications around the world. As they listen for echoes and can measure virtually any material such as plastics, metals and internally corroded materials, they are ideal archaeological tools. For our research, we used a Cygnus DIVE underwater ultrasonic thickness gauge because of its ease of use and portability. Rated to 300 m depth, the Cygnus gauge can be worn on a diver's forearm enabling a valuable free hand when working underwater.

Using an ultrasonic thickness gauge for the first time as an archaeological management tool in British waters, we have been able to develop a diver-based methodology to monitor metal hulls of historic wreck sites. This will allow us to implement measures where sites are at risk so as to manage the recent past for the future.

The third element to our programme of investigation comprises a need to understand changes in ocean chemistry. Dissolving excess atmospheric CO₂ in surface waters has already noticeably increased their acidity and this may in turn affect the ocean's ability to take up further CO₂. There is a high confidence in calculations which indicate that the pH of ocean surface water has decreased by 0.1 since the beginning of the industrial era.



Figure 3. Cygnus DIVE underwater ultrasonic thickness gauge, used for non-destructive thickness testing (Wessex Archaeology for Historic England).

A more acidic ocean will clearly have a detrimental effect on metal structures and shipwreck sites, and the wider consequences for all underwater cultural heritage, including the corrosion potential of metal-hulled shipwreck sites (such as submarines), needs to be explored. The rates of potential decay are not well understood and so

work is needed to further our understanding of the potential effects and impact of changes in ocean chemistry.

Recording pH levels on historic wreck sites in English waters is not a new concept but such work has hitherto been limited to individual (wooden) wreck sites, rather than part of a wider systematic programme of research associated with alloys of iron, aluminium or copper. Historic England has since commenced such a programme to compile current bed-level pH values (coupled with temperature & depth measurements) levels, during planned diving fieldwork around England from 2014. Using a Hanna Instruments Piccolo® Plus pH meter, archaeological divers are, for the first time in British waters, able to collect pH data to an accuracy of ± 0.01 . The instrument was used for the first time in the immediate vicinity of the German submarine UB 31, which lies off England's South-East Coast, where a pH value of 8.31 was recorded. Such data will assist with change management in the marine environment though a much wider programme of investigation is required for there is anecdotal evidence that pH values can, at depth, vary over a tidal cycle.

However, we recognize that such work will be a long-term project conducted over an extended period and it will be some time before we can make accurate judgements about the rate of acidification relative to natural annual and inter-annual cycles of pH. Greater links to current research (which is not driven by the need to understand impacts on underwater cultural heritage, such as the European free ocean carbon dioxide enrichment experiment) will be essential in order to determine wider variability.

Acoustic survey and investigation, coupled with oceanic chemical research, is allowing us accumulate quantitative data for England's oldest submarine wrecks. Such data can be used to identify the extent of their survival and the current chemical and physical threats to them. In addition, the programme will assist in understanding and managing change in order to help inform Historic England's archaeological management and protection options, which might be considered in order to help this and future generations understand the conflict through its tangible remains.

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Free and Open Source Software development in archaeology. Two interrelated case studies: gvSIG-CE and Survey2GIS

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Keywords: Free and open source software, GIS, surveying, software, programming, open data

This abstract illustrates the use of open source GIS tools in European archaeology, drawing on the experience gained using the programs gvSIG, gvSIG-CE and Survey2GIS by Oxford Archaeology, UK and the Landesamt für Denkmalpflege Baden-Württemberg, Germany. It demonstrates the advantages of open source software for archaeological research and fieldwork, while not ignoring the pitfalls and hazards to be avoided in the FOSS world.

Today archaeology relies on computer hardware and software but the potential of 'Free and Open Source Software' (FOSS) has not yet been fully realised by archaeology and related disciplines. However, open source applications for GIS are readily available and these can be well employed in archaeological fieldwork and research. This abstract looks at two FOSS programs and analyses their potential in this respect. The programs gvSIG-CE and Survey2GIS are both published under the GNU General Public License (GPL; <https://gnu.org/licenses/gpl.html>), for FOSS is neither 'freeware' nor 'shareware', even though the license terms are liberal. Both these programs have helped the Landesamt für Denkmalpflege Baden-Württemberg (State Cultural Heritage Department, Baden-Württemberg) to rethink its habitual acceptance of the 'pay-per-license' model and aided it in offsetting the prohibitively high costs of replacing outdated commercial software, hardware and operating systems and changes in proprietary licensing models that were due at the end of the first decade of the 21st century. In fact, the Landesamt's hand was forced and it started its own open source development in the form of Survey2GIS (<http://www.survey-tools.org>). Survey2GIS has become a successful piece of surveying software, at the time of writing, well past the BETA stage, it is in action in the field across the state of Baden-Württemberg and beyond. An unexpected but gratifying aspect of the development of Survey2GIS is not just the speedy and simple transfer of survey data into GIS but also the new 'data-centricity' of the fieldwork and research which it has made possible. With Survey2GIS

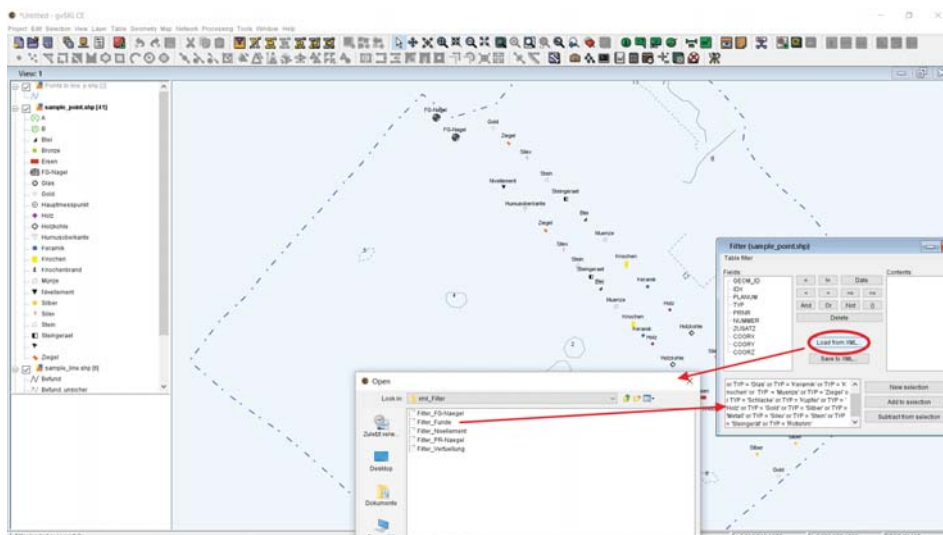


Figure 1. Screenshot of gvSIG-CE showing the use of pre-existing xml-scripts to filter features, finds and topographic points.

it is possible to adapt the method to the project, rather than approaching projects to suit the software.

Survey2GIS, although a completely autonomous program, comes from the same 'stable' as gvSIG-CE (<http://csgis.de/gvsigce>), itself a fork of gvSIG, Open Source software originally developed on behalf of Generalitat València Sistema de Información Geográfica, Spain (<http://www.gvsig.com>). Soon after its inception, gvSIG was quickly and enthusiastically adopted by Oxford Archaeology as the core element of its FOSS GIS migration. While travelling further and further down the gvSIG road, Oxford Archaeology began to realise the inadequacies for archaeology of the native version of gvSIG. With no possibility of turning back, Oxford Archaeology had little choice but to continue independent development of gvSIG for its own requirements (made possible by the fundamental FOSS ethos of open program code). The result was the gvSIG OADE 2010 (Oxford Archaeology Edition), still popular with archaeologists today. GvSIG OADE 2010 ultimately led to the development of gvSIG Community Edition. At the time of writing the 64-bit version is vital, well developed and (alongside Quantum GIS) established as an important tool in both the Landesamt für Denkmalpflege Baden-Württemberg and the Bayerisches Landesamt für Denkmalpflege (State Cultural Heritage Department, Bavaria).

Survey2GIS is a light-weight FOSS tool for use in field documentation and surveying which functions both as a plugin from within gvSIG-CE and also as a standalone program processing surveying data for any preferred desktop GIS. It has been under development since 2011/2012 and available in version 1.3.3 at the time of writing.

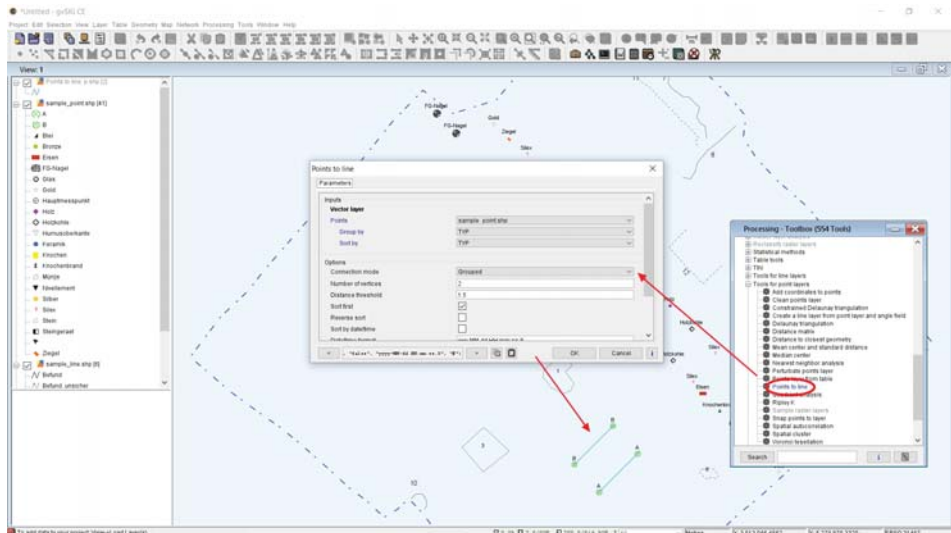


Figure 2. Screenshot of gvSIG-CE showing the use of onboard tools to create section lines between section nails recorded with Survey2GIS.

A central element in the Landesamt für Denkmalpflege's strategy in developing Survey2GIS was the transition of topographic survey activities from proprietary CAD to (FOSS) GIS (gvSIG CE and Q-GIS). To make this possible, a new software had to be devised to act as the link between the surveying hardware and the GIS software. The result was the development of Survey2GIS. Survey2GIS is a fully developed, compact and flexible solution for handling topographic survey data. It processes 2D or 3D point measurements into geometrical objects, including multipart features and polygons with holes. Input data consist of one or more survey data files with coded coordinates. The output generated by Survey2GIS is ideal for direct use in GIS. The process can be fully steered by the user, allowing flexible adaptation to individual survey workflows and data structures. Input and output formats can be adapted to fit the requirements and constraints of virtually any project. During its development, high priority has been given to the generation of topologically correct output, suitable for quantitative analysis in GIS. Survey2gis is highly customisable and includes a number of features designed to boost productivity in the field. This is a significant return on investment, often overlooked when comparing the license-free savings against the cost of open-source software development and staff training.

This abstract does not intend to condemn either proprietary software or traditional business models. FOSS and proprietary software coexist and will continue to do so for the foreseeable future. However, excessive or fluctuating license fees, cloud solutions, the risk of vendor lock-in and a lack of shared investment options should open the minds of those in research and education to consider alternatives. The case studies

show that at least one large and important authority in German archaeology, echoing a solution initiated by Oxford Archaeology some years earlier, has in the case of Survey2GIS recently put this into practice.

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Historic Building Information Modelling

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Keywords: Building Information Modelling, BIM, HBIM

The UK Government Construction Strategy was published in 2011 within which was announced its intention for 'collaborative 3D BIM on its projects by 2016'. Although a stimulus for change and investment across some related sectors, most focus still remains on new-build construction, meaning that adoption of Building Information Modelling – BIM for existing buildings, heritage and archaeology is still unclear.

The presentation given at EAC Brighton 2016 discussed existing work to assess the relevance and potential adoption of BIM across the English Heritage historic estate and the impact of BIM on the external advice now provided by Historic England. It also covered the geospatial technologies, such as laser scanning, Structure-from-Motion photogrammetry and drone-acquired imaging, which typically supply the base BIM-ready survey datasets and, once constructed, the digital outputs and potential areas of application that BIM may have across archaeology. Although project application of BIM across the UK heritage sector still remains low, such background work has allowed Historic England to increase its knowledge on BIM and formulate targeted research relating to Historic Building Information Modelling (HBIM) that will widen appreciation of its respective benefits and target some current areas of concern across an archaeological context.



Figure 1. The 15th-century Great Barn at Harmondsworth, near Heathrow airport.

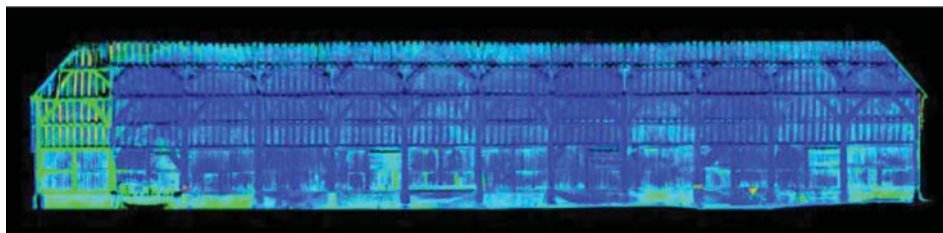


Figure 2. Harmondsworth Barn: existing archive of measured survey data supplemented by laser scanning in 2012.

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Data to knowledge

Information technology is unlocking the way we create information from raw data. We can now mine vast datasets to find associations, perceive patterns or serve up rich Geographic Information Systems for national heritage protection or sophisticated research, and we are learning how to manage and curate these priceless archives and stores of knowledge. This session explored new approaches being adopted by member states.



The Internet application of the *Archaeological Atlas of Bohemia* on a smart phone. From the left: (i) loading of the QR code from the book; (ii) introductory page of the České Lhotice site; (iii) a plan of the same site, and (iv) downloaded source of additional information, in this particular case an article from the *Památky archeologické* journal (Photo: Novák et al.)

Archaeological data in the GIS portal of the National Heritage Board of Poland

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Keywords: archaeology, GIS, INSPIRE, National Heritage Board of Poland, listed sites, Poland

The INSPIRE directive was the starting point for the creation of a monuments database and the map portal of the National Heritage Board of Poland. The *Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE)* came into force in May 2007. According to its provisions, the spatial data infrastructure is to enable environmental spatial information to be shared among public sector organisations and facilitate public access to this information across Europe. The extensive data are to help in informed policy-making across boundaries. The directive is all about efficiency and compatibility of the data. The information should be collected on many levels of detail, and its scope as well as conditions of the data re-use, should be explicitly formulated and easy to find (INSPIRE, *About INSPIRE*). On a national level, in Poland the directive was followed by the *Act of 4 March 2010 on spatial data infrastructure*. According to its provisions, the Minister of Culture and National Heritage is responsible for protected sites in the part referring to immovable monuments (Rada Ministrów 2010b, Art 3, par. 7, pt c). In 2010 the implementation task was assigned to the National Heritage Board of Poland.

The entire cultural heritage sector in Poland, at least as far as various public bodies are concerned, generally lags behind with digital technologies. It is enough to say that binding regulation on the register of monuments, issued in 2011, specifies which colour of ink has to be used to separate entries in the book of the register (black) and to cross them out (red). The use of green and blue is also provided but, needless to say, a digital version of the register is not. In 2010 our organisation was no different and a large-scale digitisation was regarded as an earthquake. The implementation of the INSPIRE directive was not only about digitising thousands of documents but also about the change in our approach to archives, including the archaeological ones. Until then, access to the documents in our possession was mainly limited to archaeologists (including archaeology students), professionals involved in spatial planning and public developments, and landowners, which was justified with the need to protect

archaeological heritage against detectorists. Their number is estimated at about 50,000 people across the country, and the overwhelming majority operates illegally (Makowska et al. 2016). On the other hand, however, there never was any straightforward legal backup to enforce such limitations.

The digitisation project began with the identification of the datasets we should deliver within INSPIRE. From among the four forms of the legal protection of monuments we chose monuments entered in the national register of monuments and recognised by the President of Poland as Monuments of History as we kept the record of these two categories. We also decided to deliver data on world heritage sites in Poland. The register includes over 70,000 immovable monuments (buildings, historic urban and rural layouts, parks and gardens) and the current number of registered archaeological sites is 7743. However, the archives of the National Heritage Board of Poland also include the documentation of over 455,000 archaeological sites recorded within the fieldwalking projects of Polish Archaeological Record. The Record, being the main source of information for archaeological heritage management in Poland, is not mentioned as one of the legal forms of monument protection, which is why at first we decided not to digitise the archive within INSPIRE.

The register of monuments is particularly relevant to archaeological heritage. First entries of archaeological sites into the register were made in 1929, soon after the introduction of the first legal regulations. Thus, the register of archaeological monuments has been created by several generations of monuments protection officers, working under changing laws and changing administrative division of the country. In the absence of national guidelines and policies, different, sometimes personal, criteria for the assessment of the value of monuments have been used. The register was also influenced by political reality. In the 1960s and 1970s the work of Voivodeship Monuments Protection Officers was centrally controlled and the number of administrative decisions on the entry of monuments into the register was one of the main quantitative indicators. As a result, over these two decades, just over 30% of the sites were inscribed in the register each December, which raises doubts as to the actual value of those sites.

Having defined the resources to be digitised, we, the NHBP archaeologists, approached the project with two basic premises. INSPIRE 'forced' us to digitise according to very precise demands but we wanted to create a database adjusted to our needs. We were to present only the register of archaeological monuments, but we would prepare tools for the eventual presentation of the entire Polish Archaeological Record. To summarise, archaeological heritage management must have come first.

The rest of the paper describes the process of building the database and the creation of the data model and thesauri, always from an archaeological perspective. We show the challenges that we have had to overcome on the way, resulting from the state of the archive and the necessity to adjust Polish archaeological archives to the INSPIRE data model. We present the visualisation of our spatial data in the GIS portal of the National Heritage Board of Poland (www.mapy.zabytek.gov.pl), created in cooperation with Warsaw University of Technology. We then discuss the scope of the visible data,

reasons behind the visual classification, the pros and cons, and conclude with the prospective developments of the database and the GIS portal.

The text of this paper with a full bibliography is available at dx.doi.org/10.11141/ia.43.5

Digitising the archaeological process at the Swedish National Heritage Board: producing, managing and sharing archaeological information

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Keywords: digital archaeology, digital documentation, field archaeology, heritage management, open access

In 2014 The Swedish National Heritage Board initiated the Digital Archaeological Process (DAP) programme in order to create a more seamless digital process for information generated through archaeological surveys, excavations and site management. The main aims of the programme are to increase availability of digital data as well as the quality of the information. The overarching goal is to facilitate more effective heritage management for officials and archaeologists, as well as companies and government agencies working with development in general, and in the process make the information more available to researchers and the general public.

In Sweden development plans must be approved by the County Administrative Board. The administrators may order archaeological surveys and preliminary excavations before any sites are excavated and documented, and the developer must cover the cost of these. The results are presented in reports, a copy of which is to be sent to the National Heritage Board, and the original field documentation is to be delivered to a national archive. However, only analogue documentation can be archived in the current system while over the past 20 years field recording has become more and more digital and georeferenced. Information is therefore lost when it is transformed into publications and illustrations. Not only does this mean a loss of valuable information, but it also results in extra time and work for administrators and archaeologists when new projects are planned.

The National Heritage Board has previously digitised the entire national Sites and Monuments Register and published it online. However, it was clear that there needed to be a more comprehensive approach to the entire heritage management process wherein archaeological information is produced, used and archived, as it is involving the archaeological contractors, various government agencies and museums. There

are five main areas of archaeological information that are connected in theory, but dispersed in practice:

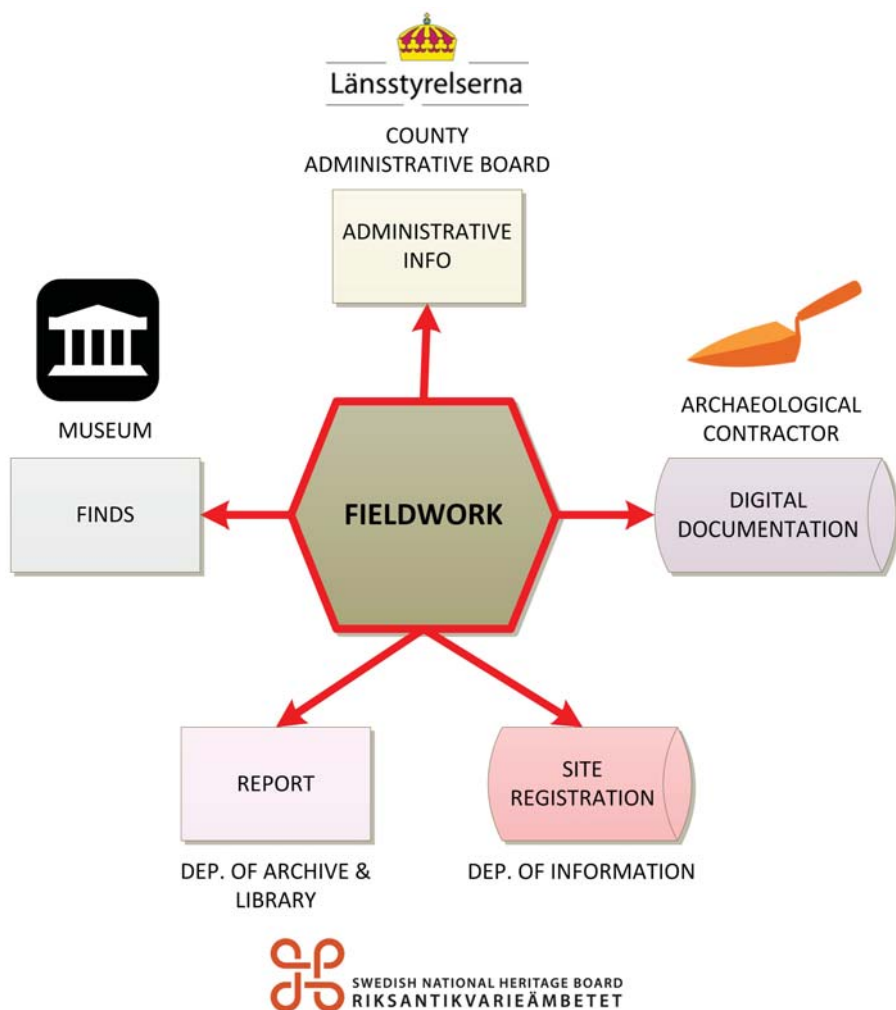


Figure 1. Types of information produced by archaeological fieldwork, and where they end up in the current system. While Swedish National Heritage Board maintains the Archaeological Sites and Monuments Register and an Open Archive of archaeological reports, these two are not interconnected presently. Digital field documentation has not been consistently collected from the contractors up until now.

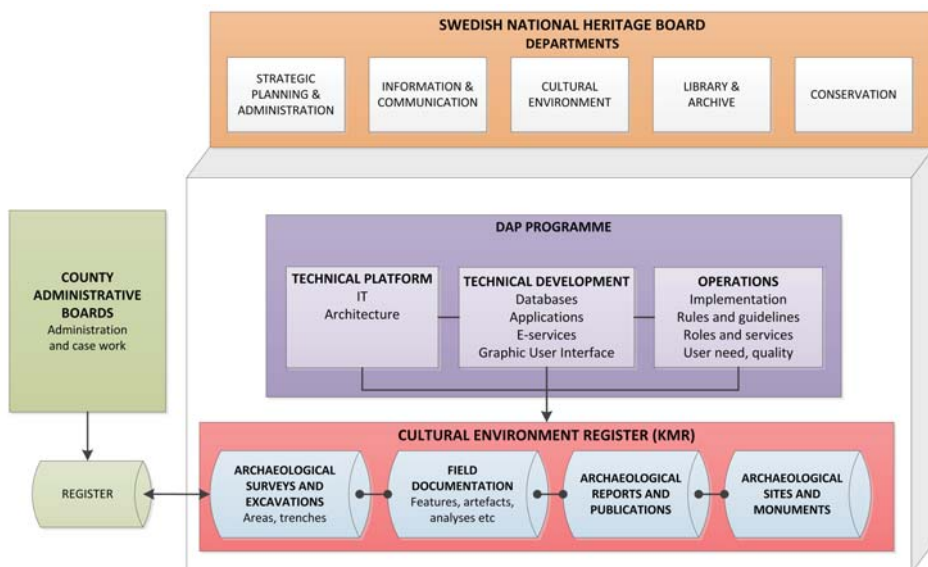


Figure 2. The Cultural Environment Register, *Kulturmiljöregistret* (KMR), is being developed by the DAP programme. While information may be stored in different databases 'beneath the surface' the posts will be interconnected through links. A system is also being developed to receive some information machine-to-machine from the County Administrative Boards.

- **Site info:** Historic and prehistoric sites in the landscape, their characteristics and preservation status. The register is managed by the National Heritage Board's department of information.
- **Project info:** Surveys and excavations done where, when and by whom. Areas covered in the landscape. Files and documents archived by 21 County Administrative Boards.
- **Results:** Reports and publications of the projects. Printed copies are held by the Archive of the National Heritage Board. Since 2013 PDFs are also available online.
- **Digital documentation:** The databases and georeferenced features. Kept by the Contractors – presumably. Contractors in Sweden include a number of museums, foundations and private companies.
- **Artefacts:** Kept by a local, regional or national museum, which add them to their collection register, only some of which are available online.

In order to create a more comprehensive platform for retrieving all this information, DAP is developing the Cultural Environment Register (*Kulturmiljöregistret* – KMR). It will be an umbrella system containing both databases and links to information stored elsewhere. DAP will both improve on existing registers and develop new ones.

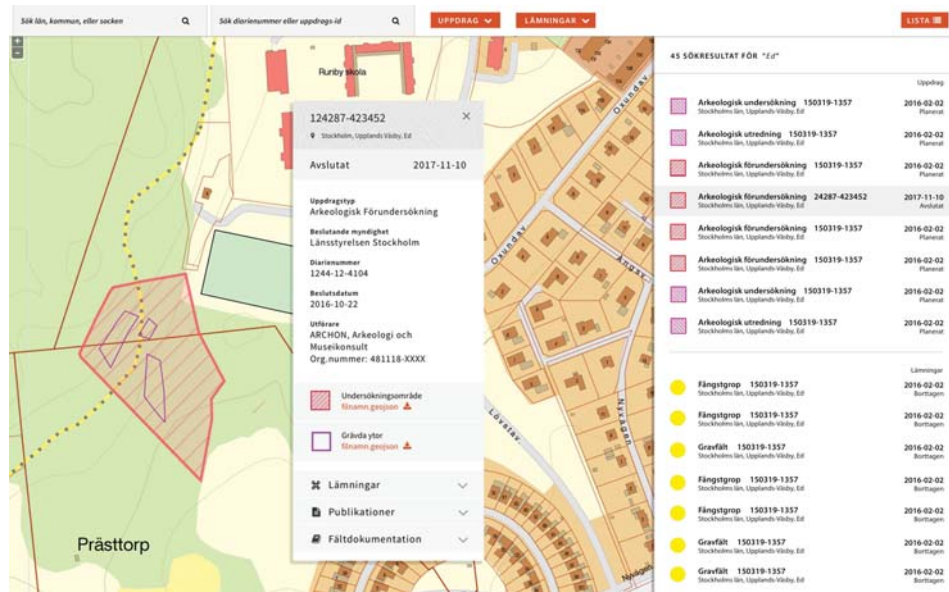


Figure 3. The Fieldwork Register part of KMR is now under development. This is one of the models made by the graphic designers. These are used first to test if the product will be user-friendly and meet our requirements, and only then for the programmers to build from.

Site Register

The Sites and Monuments Register is maintained by the National Heritage Board. Newly discovered sites, and additional information about known sites, are registered after being reported by archaeological contractors and the County Administrative Boards. The process is time consuming, resulting in a Register that is not up to date. DAP is developing a new tool for archaeologists to register information directly into the Register, and for administrators at the County Boards to inspect and approve the registration before it is made public. The tool will also help to make sure that the reports by the archaeologists are correct and of comparative quality.

Project Register

A new Project Register is being developed, where all archaeological surveys and excavations will be visible on a map. The register will contain basic administrative information for each project and links to where publications, documentation and artefacts can be found, as well as to the sites that were affected by the project.

Publications and Field Documentation Register

Information on new fieldwork projects will be documented in KMR as a part of the digitised process that DAP aims to establish. However, another aspect of the programme involves the preservation and dissemination of *existing* digital fieldwork documentation. While analogue fieldwork records are deposited with national or regional archives, this has not historically been the case for digital records due to the lack of a digital preservation infrastructure within the sector. As part of DAP, digital fieldwork documentation and reports are now being collected from museums and archaeological contractors across the country. The reports and data will then be archived and published through a new long-term digital repository at the National Heritage Board and linked against their corresponding fieldwork records in the KMR. All of the data collected will be licensed under the Creative Commons: CCo for the fieldwork documentation, and CC-BY for the written reports.

The data being collected spans some twenty years of archaeological fieldwork practice, and unsurprisingly this means that a variety of file formats are represented. Format migration is a necessary part of digital preservation and dissemination, and so in order to ensure that the data we publish is as broadly accessible as possible, DAP is working with the Archaeology Data Service in York towards a common, platform-independent format for our digital fieldwork data.

Process also means people

The DAP programme involves more than just developing new technical solutions and e-services. The new system will also lead to new guidelines and regulations and new ways for people to perform their jobs, whether at the National Heritage Board, museums, County Administrative Boards and other government agencies, or for the archaeological contractors. In order to make the new system functional in reality as well as in theory, the programme is continuously in communication with representatives from these groups, involving them in the decision making and in the testing of the products. To make sure the correct standards are used and quality goals met, educational tools and courses are also being developed. We do not underestimate the fact that a more streamlined archaeological process, with better quality and efficient sharing of information, is ultimately dependent on the people actually contributing to and using it.

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Why the historic environment needs a Spatial Data infrastructure

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Keywords: Historic environment, INSPIRE, Spatial Data Infrastructures, data standards

Heritage professionals create or use spatial data on a daily basis across a range of processes from desk-based assessments, remote sensing techniques and field survey to excavation. Objects in museum collections and the results of scientific analysis also have an inherent spatial relationship derived from location.

Brought together, results from diverse data sources and projects combine to form the evidence base to support decision-making processes across a range of sectors and actors. Data informs heritage management activities, including formally protecting archaeological sites, buildings and landscapes, applying conditions as part of the planning process, asset management, for both academic and personal research and increasingly for public engagement.

However, co-ordination of spatial data for the historic environment is lacking. Approaches are fragmented across national and regional boundaries, between national and local agencies, the public, private sector and academia. Accordingly, there tends to be no consistent approach to capturing, storing, sharing and presenting spatial data about the historic environment. The value of data captured at some expense is simply not being realised. It may be retained by the creator, lost or, if deposited in an archive, it may not be stored in an easily accessible or in a reusable form, accessible only as an illustration in a publication orphaned from other datasets. Intellectual Property Rights, copyright and restrictive data retention also inhibit reuse.

Existing methodologies may be convenient for individual projects and organisations but the fragmented and inconsistent approaches to sharing spatial data about the historic environment can appear unprofessional. Attitudes are shaped by the need to deliver projects and established institutional practices are slow to adapt to the impact of new technologies.

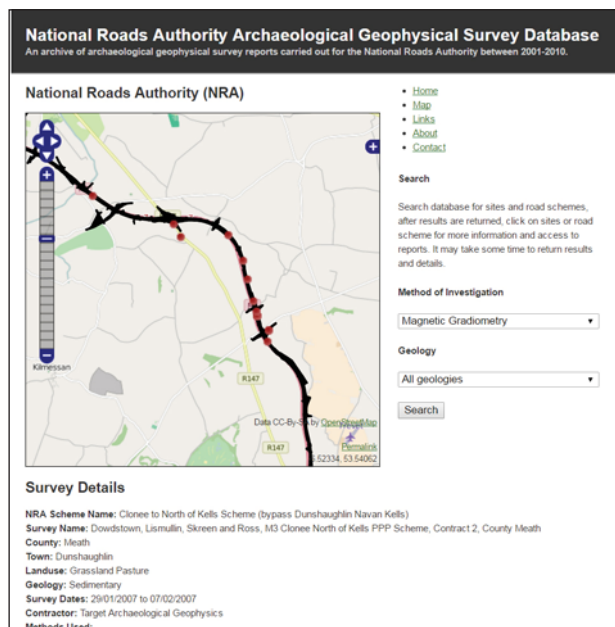


Figure 1. Delivering spatial content from remote sensing datasets. This screenshot from The National Roads Authority Ireland archaeological geophysical survey database shows the locations of magnetic gradiometry survey along the route of the N3 motorway to the east of the Hill of Tara, Co Meath.

APIs delivering remote access to data and particularly publication of spatial datasets as view (Web Map Services – WMS) and download (Web Feature Services – WFS) enables spatial data held by one organisation to be accessed remotely, combined and used with other datasets outside the host body. Yet the lack of consistent data standards and data harmonisation prevents historic environment data realising its potential.

Across Europe, there is already a requirement to share some historic environment data. Through the European Commission INSPIRE Directive (<http://inspire.ec.europa.eu/>), transposed into member states national legislation since 2009, all European Union countries are required to share environmentally related datasets so that they can be easily accessed by other public organisations within their own and neighbouring countries for the purposes of community environmental policies and policies or activities which may have an impact on the environment. There is an increasing expectation that publicly held data should be available without undue restriction, to inform decision making about the environment. Key to delivering INSPIRE is the establishment of Spatial Data Infrastructures (SDIs). An SDI provides the framework for coordinating the policies, infrastructure and standards needed to acquire, process, distribute, use, maintain and preserve spatial data to deliver GI enabled business applications and services for social, economic and environmental benefits.

Within INSPIRE, the Protected Sites theme covers a range of historic environment data including the World Heritage Convention; the national laws of each European country, EU and international sector policies and National Monument Records. Protected Sites may also be managed through other effective means including planning guidance.



Figure 2. Consistent symbology is essential to mapping the archaeological landscape. Part of the archaeological landscape at Badentarbat, Achiltibuie, Highland, Scotland, mapped by the Afforestation Land Survey, RCAHMS 1997. Contains Ordnance Survey data © Crown copyright and database right 2016.

Individual data holders across Europe already publish a range of datasets through Web-GIS portals often supported by INSPIRE compliant metadata, WMS and WFS. Some of these portals and services have been published through national SDIs and harvested to the INSPIRE Geoportal (<http://inspire-geoportal.ec.europa.eu/>) where users may discover datasets and services logged on the register. Whilst very powerful, the Geoportal is not designed for ease of use and definitely not for someone interested in the cultural heritage and historic environment of Europe. There is a strong case for

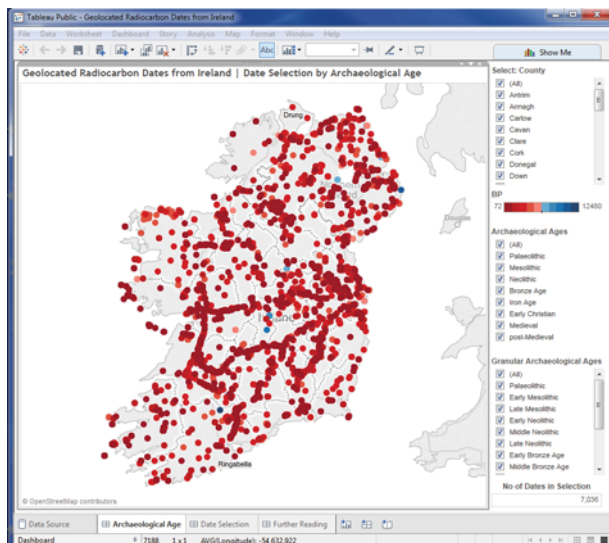


Figure 3. Adding value of scientific data: georeferenced radiocarbon dates for Ireland compiled by Robert M. Chapple (2015) presented on a Tableau dashboard.

developing a dedicated website to enable the easy discovery, access and monitoring of national and regional portals, metadata and the various WMS and WFS to promote heritage datasets. What is required should build upon existing European Infrastructure projects such as CARARE (<http://www.carare.eu/>) and EUROPEANA (<http://www.europeana.eu/portal/>), or the recently launched ARIADNE Portal (<http://portal.ariadne-infrastructure.eu/>).

Spatial data is more than simply the mapped extent of each asset; it also includes associated attribution. For Protected Sites data, INSPIRE defines a simple or core application schema, containing a very limited set of fundamental attributes, including geometry, identifier, name and legal foundation date and document reference. Within the extended schema INSPIRE recognises and publishes through the INSPIRE Registry Designation, UNESCO World Heritage Designations (<http://inspire.ec.europa.eu/codelist/UNESCOWorldHeritageDesignationValue>) and National Monuments Records (<http://inspire.ec.europa.eu/codelist/NationalMonumentsRecordDesignationValue>). Research through the ARIADNE Project can help develop data harmonization for some of the attribution.

View and download services not only provide live data to dedicated heritage portals, they can also stream data to third party portals for display alongside related environmental datasets. These services can be consumed directly into remote computers for use alongside proprietary datasets to inform project work and decision making. Data must therefore be current. With the open approach to data, more consideration of the attribution is required so that the non-specialist can understand the value of the data. For some approaches, detailed classifications may need to be supplemented by ranking the value of individual assets into broad brush, High-

Medium-Low values. This will become particularly important as automated process will inform decision modelling process for eco-system services scenarios.

INSPIRE only applies to a limited range of datasets used to inform decision-making processes. It does not address the full range of spatial data created in recording our cultural heritage, particularly that collected through fieldwork. The Directive only applies to publicly held data whereas much of the primary archaeological data is created by the private sector or through research. Publicly funded projects may stipulate data preservation in an appropriate archive and data from developer or privately funded work may eventually be deposited with a public archive at which point it is held and managed at public expense.

Realising the value and potential of these datasets requires the development of a thematic SDI for the historic environment. The metadata and attribution for each dataset should include the following categories of metadata:

- *Discovery* – describing the nature and content of the resource.
- *Exploration* – the technical information to ensure data is appropriate for purpose
- *Exploitation* – the information required to access, transfer, and apply the data in an application.

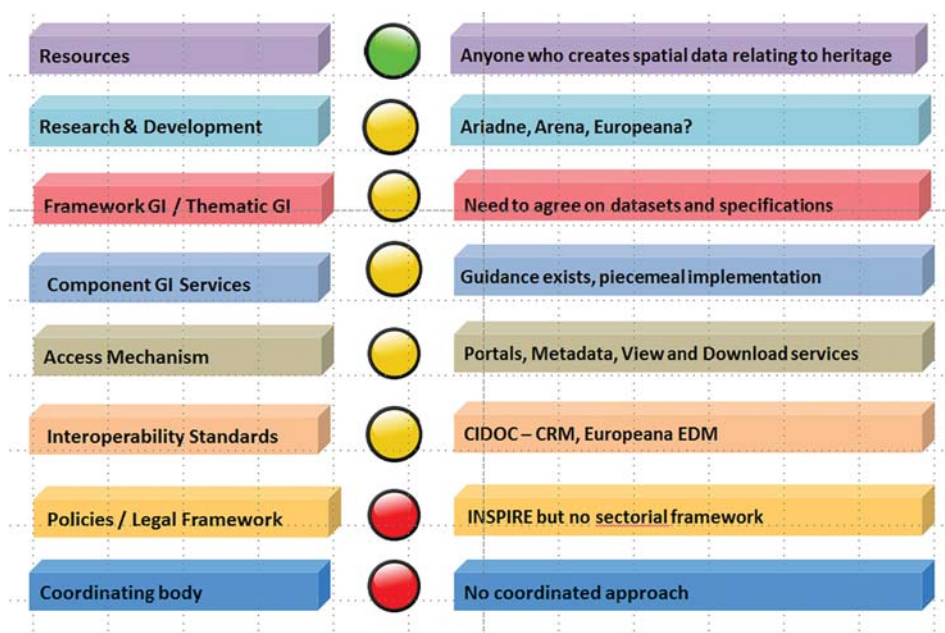


Figure 4. The building blocks of an SDI and how historic environment data conforms.

Whilst a wealth of spatial information is created through fieldwork and interpretation, the potential value of that data is not realised beyond the individual project. A thematic SDI for heritage will help realise that potential, improve accountability and delivery efficiencies. The building blocks are already in place. As an inherently spatial discipline, there are plenty of resources although datasets and standards need to be defined. Existing research initiatives could be expanded to address spatial data while both the CIDOC-CRM and The Europeana EDM point to interoperable datasets. What is lacking is a coordinated approach underpinned by a sectorial framework to harness the potential of spatial data for the historic environment. If the OpenStreetMap community can develop a collaborative approach to produce an editable map of the world, why can't the historic environment profession collate their data?

**The full text of this paper with bibliography is available at
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Switching to digital tools: heritage evaluation for preventive archaeology in Hungary

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Keywords: Archeological heritage management, assessments, geophysical survey, site identification, magnetometry, Hungary

During the last decade in Hungary, preliminary operations for large-scale archaeological excavations have become more and more important: the stakeholders have realised that it is cost-effective to spend more on the assessment phase rather than incurring higher expenditure because of problems related to an ill-planned project. Thorough knowledge of the size and characteristics of archaeological sites can largely contribute to the protection of cultural heritage, as well as to saving time and money.

From 2011, the so called 'Preliminary Archaeological Evaluations' have been made a mandatory part of the permission process of large-scale constructions (that is to say, a total minimum of c.1,600,000 EUR). These evaluations consist of desktop studies as well as field investigations with a budget of up to 0,35% of the total construction cost. The goal is to make precise archaeological project plans, and to assess the optimal mitigation process. These documentations consist of the establishment of the actual area to be excavated, as well as the cost and duration of the archaeological mitigation process. The funding of further archaeological activities is based on these evaluations, which renders them one of the cornerstones of preventive archaeological activities in Hungary.

The Forster Centre – and its predecessor – has been responsible for the coordination and execution of preventive archaeological evaluations since 2013. The Forster Centre is a government office acting as an independent third party between the investors and the institutions responsible for further archaeological mitigation processes following the evaluations. In recent years, we introduced and tested a GIS-based method that we found effective in large-scale investments and which – due to financial constraints – relies greatly on non-invasive methods as tools to help our investigation strategies.

Our current strategy relies on three interdependent tasks: GIS-based field surveys, large-scale magnetometer surveys and targeted trial excavations. The first step is always a desktop study and a full-scale systematic field survey over the whole area of interest in order to collect archaeological materials and identify sites and features. The

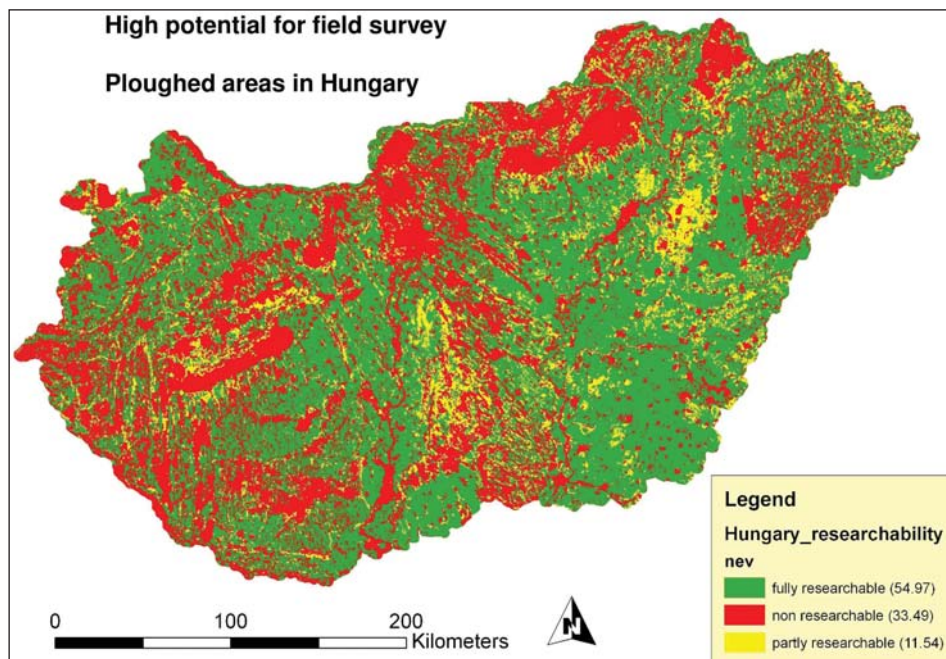


Figure 1. Distribution of areas available for field survey (plough-walking) in Hungary based on the CORINE land cover map.

Figure 2. Conducting geophysical survey in the Great Hungarian Plain.



next step sees magnetometer surveys performed within these areas – including areas with no surface finds but with a high potential for archaeological features – in order to identify actual archaeological areas. As the third step, the previously collected data are validated through trial excavations. Funding is usually very limited, thus the trenches are laid out based on the results of the field survey and magnetic prospection either to validate archaeological features or confirm the lack of them. The current legislation also limits the extent of trial excavations at archaeological sites in development areas. Obviously, this approach is based on surface finds, and therefore has a restricted potential regarding archaeological features invisible during field surveys. Nevertheless, considering limited financial resources, we must focus on areas where the presence of archaeological features can be confirmed. In general, at least 30-40% of the entire project area is covered by magnetometry survey. If needed, we also can carry out supplementary surveys such as coring, aerial archaeology or GPR survey.

The scale of our tasks is challenging and demanding at the same time: the investigation of large areas with various methods gives us substantial and reliable data on the archaeological landscape. The greatest strength of this approach is the integrated use of magnetometry for preventive archaeological tasks. In the recent past geophysical surveys were mostly used as a scientific attribution in Hungary, scarcely used in the

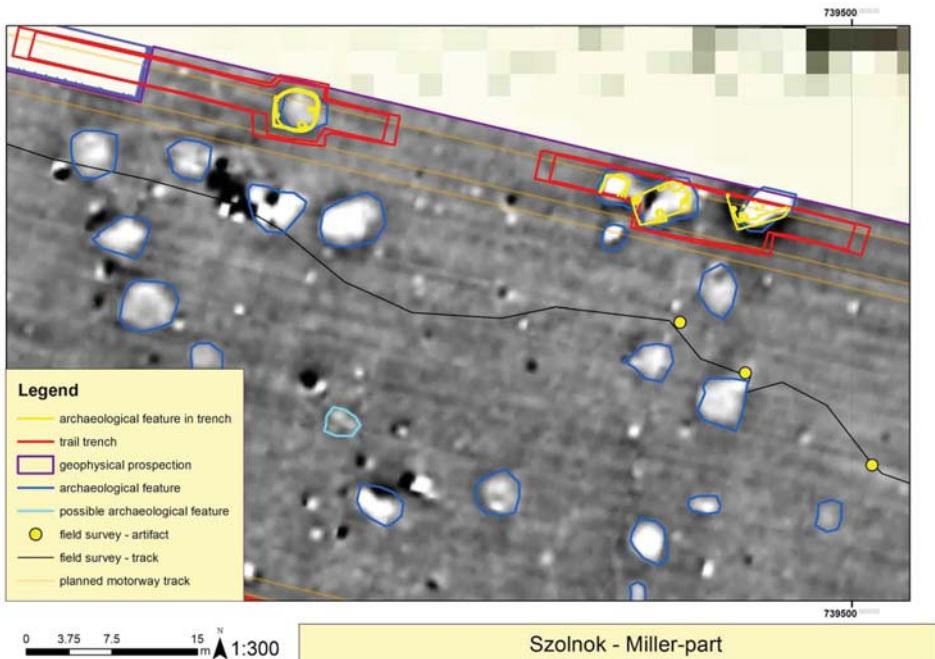


Figure 3. Geophysical survey and validation with trial trenching in the planned M4 motorway (Jász-Nagykún-Szolnok county, Hungary).

decision-making process. However, geophysical investigations should be integrated into regular site identification strategies of preventive archaeology whenever possible in order to be used to its fullest potential and to make useful predictions. The archaeologists responsible for excavations should be provided with support in order to understand and use these data during the planning phase.

Accumulating and comparing GIS-based information on a nationwide scale gives us an opportunity to examine the methods most effective in identifying and saving archaeological heritage. One of the most promising opportunities is to create a comparative database, where the outcomes of geophysical surveys and excavations from hundreds of hectares are available across the country. The option to survey across very different areas and validate it with trial trenching is a very powerful tool to understand the impact on and advantage of magnetic survey in archaeological heritage management. Beginning in 2013, magnetometric surveys have been carried out for more than one hundred projects, and included 360 archaeological sites, measuring an approximate total of 500 hectares. Using the results, we can set up a comprehensive archaeological geophysics database that would facilitate making our magnetic prospections more accurate and our methods more targeted. By comparing the results of magnetometer surveys and excavations, we estimate an overall predictability of 80 per cent of features (for true positive and true negative values) during our prospections. If we could further evaluate the data derived from this constantly growing dataset, it could serve as a strong argument to persuade stakeholders to utilise these analytical methods more systematically, giving the archaeologists more chances to obtain information about the affected archaeological sites and making the mitigation process more effective.

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Saving treasures of the World Heritage at the Digital Archive DANS

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Keywords: digital, archive, archaeology, sustainable, access, certification

Hidden treasures in the sea of data

Why is it necessary to store archaeological data in a digital archive that follows policies, protocols and strict procedures? Why not simply put your files in Dropbox? This article will explain in detail the benefits of the existence and use of certified digital repositories, the impact of national regulations for conducting archaeology, the trend of clustering European infrastructures with a focus on cultural heritage and finally, give some future recommendations for shared European archaeological policies to ensure good quality of metadata, data and repositories.

Certification for digital data archives

DANS (Data Archiving and Networked Services, The Hague, The Netherlands, <http://dans.knaw.nl/>), the Dutch national digital research archive, is an institute of the Royal Netherlands Academy of Arts and Sciences (KNAW) and the Netherlands Organisation for Scientific Research (NWO). Collaboration between the Dutch Cultural Heritage Agency (RCE) and DANS makes it possible to ensure sustainable archiving and unlocking of digital documentation of cultural heritage in a central national repository.

There is a great need to store archaeological data in a sustainable manner. What happens if an organisation loses their data, for example because the lifespan of the discs on which the excavation archives are stored is shorter than expected, or software ageing causes a system failure? An excavation cannot be done twice; the work to scan possible remaining analogue material such as photographs is enormous and probably the associated documentation (metadata) would be missing. Without information describing the image, the scientific value of it would be lost. Reorganisations within the archaeological sector are common and sometimes the data are forgotten as the result of changes in personnel. Data is not well described and cannot be understood anymore. A solid backup strategy is needed to protect this unique type of data presenting the world heritage.

In the Netherlands, DANS acts as a trusted repository to curate the archaeological data. The data remain accessible and usable in the long term at the national e-depot for Dutch Archaeology located at DANS. A wealth of archaeological excavation and exploration data such as maps, field drawings, photographs, tables and publications are digitally accessible via EASY, the online archiving service (<https://easy.dans.knaw.nl>). The description and data relating to thousands of archaeological research collections can be downloaded. The data are stored according to protocols and standards that make them easy to recover and share.

What actually is a trusted repository? DANS has the remit to provide reliable long-term access and therefore operates according to the OAIS (*Open Archival Information System*) model for digital archives. DANS holds the Data Seal of Approval (DSA), the internationally recognised quality mark for trusted digital repositories. In 2016 DANS extended this basic DSA certification with the DIN 31644 certification, which is based on an externally reviewed self-audit. The highest standard is the ISO 16363 and DANS has recently completed the test application for this certification. As a Regular Member of the International Council for Science – World Data System (ICSU-WDS), DANS is certified according to international standards and seen as a trustworthy party in terms of authenticity, integrity, confidentiality and availability of data and services. The preservation policy of DANS outlines the principles of sustainable archiving. Constant monitoring and biannual revision of this preservation policy improves the quality of the archive as the impact of threats and risks are understood. National and international agreed standards for digital preservation are followed and audits take place on a regular basis.

Revision of national regulations for conducting archaeology

In July 2016 the new Dutch Cultural Heritage Law replaced the old system of excavation permits with a new system based on certification. Archaeologists deposit their completed research results at DANS to boost their work's visibility and accessibility. A national protocol was introduced and used to describe, exchange and deposit data. Agreements to this end have been laid down in the quality standard for Dutch archaeology called 'KNA'. Over the last two years the Dutch archaeological community worked together to update this standard, and included digital methodologies and the statement that the archaeological data should be archived at a trusted repository which is certified (minimally DSA) according to the European Framework for Audit and Certification of Trusted Digital Repositories.

After submitting the data at DANS (deposit instructions for archaeological data | January 2013: https://dans.knaw.nl/en/deposit/information-about-depositing-data?set_language=en), a data manager will process the data according to an established protocol. The metadata (extended Dublin Core) and the readability of the files will be checked. If this has not yet been done, the data archivist will also convert the files into a durable digital file format. This preservation format is often a simple text file format that is also used for exchange purposes (csv, dxf, mif/mid). The files will be archived both in the original (native) format and in the preservation format. In the presentation of the research project, the files will only be displayed in the preservation format. This

will enable as many researchers as possible to reuse these data while using their own software.

For each data type, a brief overview is given of the preferred format chosen, the use of the data, and any conversion possibilities. It is a dynamic document, and a working group within DANS is responsible for monitoring file formats and updating the recommendations based on new developments. It is far from being the only list of recommendations regarding file formats in the world. There are numerous other sources and wikis about formats and risks. DANS has evaluated several existing documents based on their experiences with the file formats encountered (<http://guides.archaeologydataservice.ac.uk/g2gp>; <http://www.digitalpreservation.gov/formats/index.shtml>; <http://www.loc.gov/preservation/resources/rfs/index.html>; https://www.archivematrix.org/wiki/Significant_characteristics).

DANS encourages researchers to let their deposited data enter the public domain using the Creative Commons Zero (CCO) licence, a common international standard.

A majority of the data is in the public domain; 80% is open access. The remaining 20% is restricted to professional archaeologists or is available on request. After 10 years of archiving data digitally, Dutch archaeologists are used to sharing their data and show a growing trust in other people who want to use their data.

DANS is interested in the opinion of users who have downloaded datasets from EASY.

They are asked for feedback as this can be helpful for other users and a general impression of the quality of the datasets can be offered.

Clustering of European infrastructures

To integrate archaeological data at a European level the <http://www.ariadne-infrastructure.eu/> target="external">ARIADNE Infrastructure was set up in 2013. Now, in 2016, a portal exists that has search and browse functionality, thus allowing researchers or the broader public with an interest in archaeology to cross search through time and space. Thesauri are helping to link related terms in different languages. The data of partners from 16 countries have commonalities that allowed integration.

'Table 1 gives an overview of the current contents of the Catalogue. All descriptions provided by the ARIADNE partners could be mapped to the ACDM and therefore inserted into the Catalogue. The numbers are already significant, covering a large percentage of the data made available by the ARIADNE partners. Further additions are expected before the end of the project. Above all, it is expected that opening the Catalogue to the whole archaeological community will bring other descriptions, further enlarging the ARIADNE information space' (taken from Binding et al. forthcoming ARIADNE: a research infrastructure for archaeology, *Journal on Computing and Cultural Heritage*).

Table I. Contents of the ARIADNE Catalog (as of March 2016)

Data Resources		Data Resource Properties		Data Resource Types	
Datasets	1,534,375	Spatial	98%	Sites and monuments databases or inventories	1,529,498
Collections	43,182	Temporal	100%	Event/intervention resources	51,820
Textual Documents	50,807	Native Subject	97%	Artefact databases or image collections	40,726
Total	1,628,364	Derived Subject	48%	Scientific datasets	4,904
		Publisher	100%	Fieldwork archives	1,340
				Burial databases	76

Table 1. Contents of the ARIADNE Catalog (as of March 2016).

To increase data visibility to a broad public and to integrate data on a European level, DANS ensures that archaeological and dendrochronological data are included in portals like Europeana and ARIADNE. Tree-ring data, coming from dendrochronological research done at archaeological sites, shipwrecks, buildings, furniture, paintings, sculptures and musical instruments, are made available by the Digital Collaboratory for Cultural Dendrochronology (DCCD) <http://dendro.dans.knaw.nl/>.

International best practice and guidelines are developed like the Guide to Good Practice on Dendrochronology http://guides.archaeologydataservice.ac.uk/g2gp/Dendro_CS.

‘This document serves as a good-practice guide for the collection and archiving of dendrochronological data in the context of archaeological and historical research. The guide is aimed at both those creating dendrochronological datasets, and those that commission dendrochronological analyses. This guide does not cover the methods involved in dendrochronological analyses, but focuses on how to describe and archive the data and metadata involved in these analyses. This guide is concerned with best practice for the curation of digital information but does not cover the equally important aspects of the curation of physical samples. However, physical samples are the primary source of information in dendrochronological analyses and should always be managed alongside the digital data wherever possible. This ensures that samples can be re-evaluated where necessary and also re-examined as new analytical techniques are developed’ (Website ADS).

DANS has improved and expanded the online archiving system EASY. A map-based search functionality was added that allows researchers a visual way of finding data.

Work was done on the controlled vocabularies of EASY, which are based on the national thesaurus (ABR) and recently updated to a SKOS version by the Dutch Cultural Heritage Agency (RCE). Dutch researchers carrying out research abroad (e.g. Greece) found their way to DANS, and mappings to CIDOC-CRM (Archeo) are undertaken by researchers supported by DANS.

Participation of DANS at projects like ARIADNE and PARTHENOS makes it able to share expertise on topics on data preservation and dissemination within an international network of partners. Revising documentation and policies to continue format monitoring is done with the Archaeology Data Service (ADS) and the Deutsches Archäologisches Institut (IANUS-Forschungsdatenzentrum Archäologie &

Altertumswissenschaften). Sharing knowledge with partners in Sweden, Slovenia and Austria about implementing new ways of systematic archiving of data but also the organisational aspects of setting up a repository is mutually beneficial.

The PARTHENOS project empowers digital research in the fields of History, Language Studies, Cultural Heritage, Archaeology, and related fields across the (Digital) Humanities. It provides a thematic cluster of European Research Infrastructures, integrating initiatives, e-infrastructures and other world-class infrastructures, and builds bridges between different, tightly interrelated fields. The motto of PARTHENOS is: *Investing in culture is investing in the future!*

Developing common policies to ensure the quality of the metadata, data and the repositories where the data is stored is one of the main targets of PARTHENOS. DANS is leading this Work Package. Expected flagship results of the project are:

- Guidelines on data management: Produce a coherent, authoritative, well-accepted set of policies/guidelines/tools concerning the management of data lifecycle and related issues such as IPR, quality and so on.
- Standardisation and semantics: Produce a wide set of standards and semantics, originated from community needs and tailored to the methodology and intended use by researchers.
- Services and tools: Produce a coherent set of tools for carrying out research using and re-using data.

PARTHENOS is making it possible to position the archaeological community in an interdisciplinary field of sciences and to connect archaeological data for example with linguistic data or historical data. A pan-European infrastructure allows integration of the work previously done by other European infrastructures, projects or initiatives.

Recommendations for European archaeological policies

After 10 years of expertise in the field of long-term preservation of archaeological data, DANS makes the following recommendations:

- It is not important where data is stored if the repository complies with international standards and guidelines of trustworthiness
- Funding organisations should oblige researchers to deposit their research data in a Trusted Digital Repository
- Researchers should share/deposit their research data; Open Access should be the norm
- Persistent Identifiers should be used for referencing data sources in scientific publications, e.g. DOI
- Support (financial and political) on a national level is necessary for a sustainable and effective system.

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Archaeological map of the Czech Republic. Current state and future visions of virtual research tools in the Czech Republic

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Keywords: archaeology, archiving, fieldwork management, e-infrastructures, archaeological data, digital humanities, digital heritage

The task of creating a record system of archaeological fieldwork and finds has emerged from the long-term history of the Institute of Archaeology of the Czech Academy of Sciences (CAS), Prague, which was established in 1919. Historical circumstances have determined not only the need to create the system precisely in this institution but also some of its characteristics. It has been necessary (and this obligation still remains) to respect the organisational structure of the discipline, while certain parallel attempts to structure the information flow in Czech archaeology by other institutions (previous data models but mainly the legal framework of Czech archaeology) exist. The key problem of archaeological heritage recordkeeping in the Czech Republic (CR) results from the very fact that this task has never been required by law, nobody has been directly charged with it recently and, last but not least, nobody has been directly financed to create and maintain such a record system. The Institutes of Archaeology CAS record archaeological fieldwork as part of their research activities, albeit without effectively enforcing the supply of information.

While the Archaeological Map of the Czech Republic (AMCR) project has been influenced by the above-mentioned conditions, it has also partially anticipated new legal provisions that may, in this respect, improve the current situation. At the same time, the AMCR project benefits from the fact that it is created at a research institution and aims to perceive archaeological heritage recordkeeping as part of the complex research infrastructure.

The AMCR information system has been conceived as a backbone infrastructure of Czech archaeology. It combines a branch administrative application designed for archaeological fieldwork management with the comprehensive administration of the knowledge about their results, including retrospective archaeological data collected since the late 19th century. The AMCR system works with a dynamic model

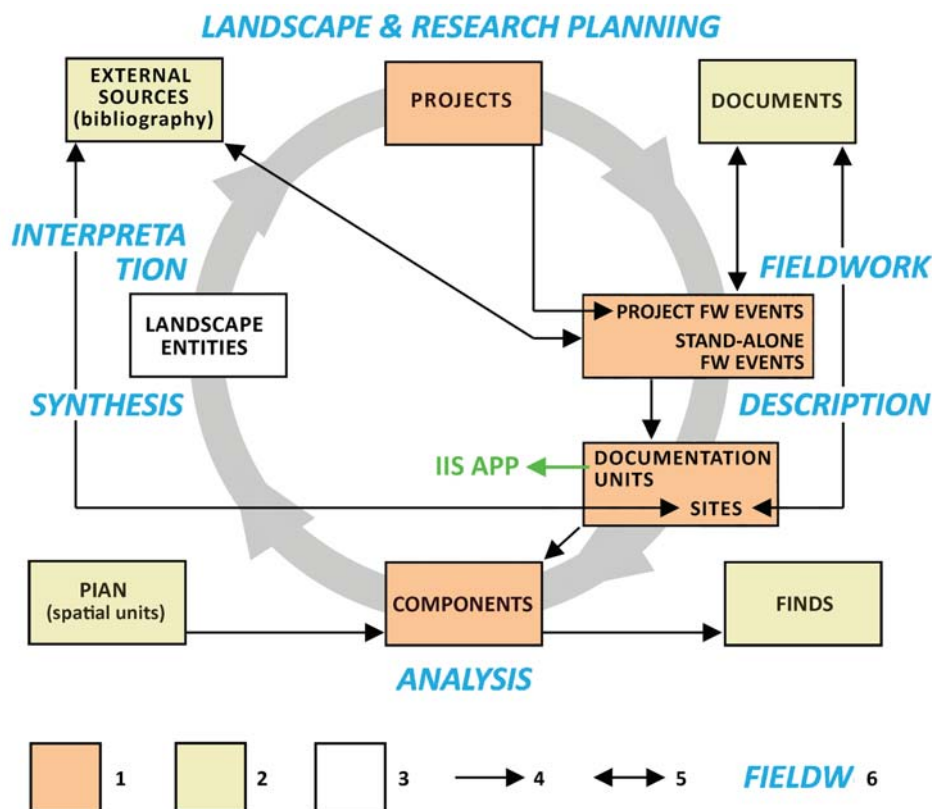
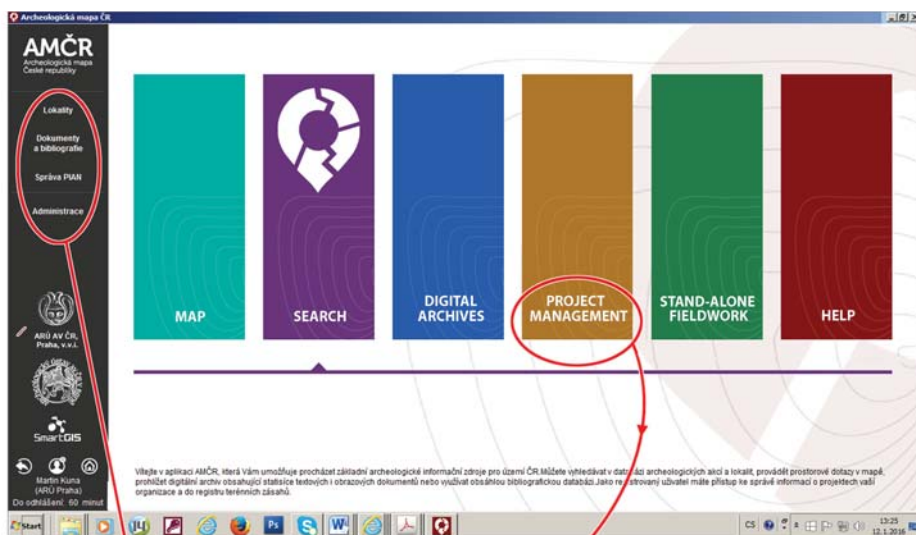


Figure 1. Model of an iterative cycle of archaeological knowledge formation based on fieldwork research. 1. Main categories – data classes; 2. Referential data classes; 3. Categories of a potential development of the AMCR in the future; 4. 1:N relations; 5. M:N relations; 6. Phases of archaeological fieldwork activities.

of archaeological knowledge formation and is designed to hold the evidence from various phases of fieldwork activities: from research project articulation through the description of archaeological fieldwork to the analysis of their results and their linking metadata to field documentation.

The AMCR contains a register of planned archaeological interventions and follows their progress through to results in the excavation report. It creates an authority file of 'fieldwork events' and assigns unique and persistent identifiers, on which additional information can be bound, e.g. field documentation, bibliographic entries or even finds in museum collections. Links between authority records of various contents produce a complex network of specialized information.



Sites - Documents & External sources - PIAN management
- Administration

A

Register project - Reserve project - Initiate fieldwork - Complete fieldwork - Report management -
Complete project - Select project - Our projects - Project archiving

Figure 2. A. Entering screen of the AMCR desktop client with the signpost towards the main AMCR modules; B. Project record form with several parts corresponding to individual phases of data collection (process states).

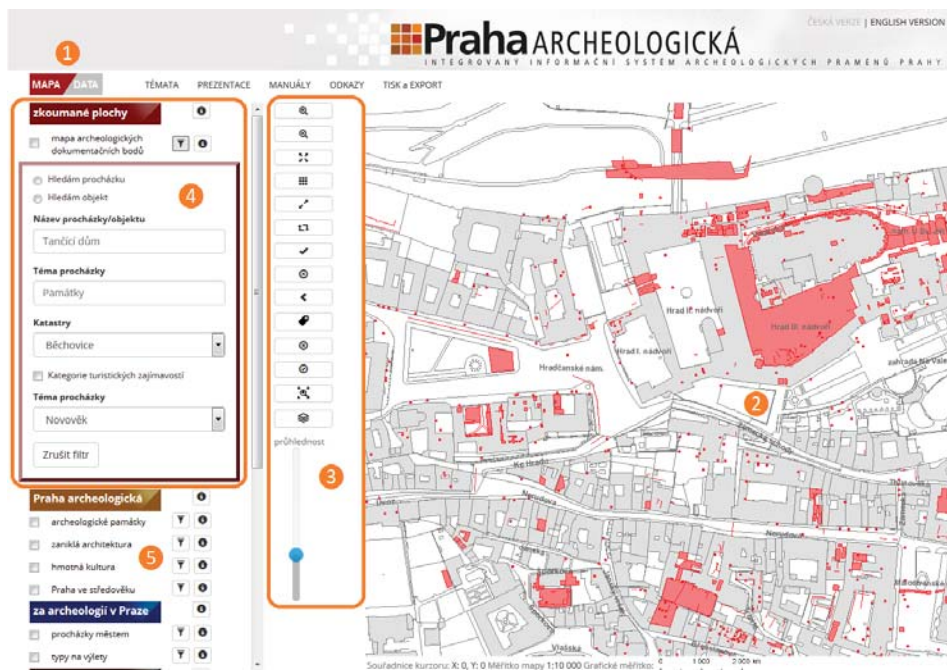


Figure 3. Screenshot of the alpha-version of the GIS interface (map) of IIS ASP. 1: Switch of the map and data views; 2: mapping interface; 3: drivers and tools of the map interface; 4: filter form of an active specialised layer; 5: other specialised layers. Data sources: © Institute for Planning and Development of the City of Prague.

Besides its administrative function, the AMCR also aspires to play the role of a 'national' archaeological database. With this intention in mind, the re-examination of the majority of existing data was carried out within the framework of the AMCR project, and these data were included in the authority list of fieldwork events and 'sites'. Records that have not been revised thus far and records of events that have not yet appeared in the database can be entered and edited by users in the future. Today, this form of crowdsourcing seems to be the only viable way to sort out the huge amount of data that have been collected (but not revised and gathered in one place) in the course of the 150 years of Czech archaeology. While the volume of data grows each year, data continues to be unnecessarily lost if not properly registered, structured and stored within an information system. Among other positive effects, co-operation in the creation and management of the common information system could reinforce integration in the Czech archaeological community.

Archaeological research infrastructures therefore must be developed with a vision of the future needs of the professional public. It is crucial to systemize access to archaeological knowledge at the central level and to involve users directly in the

process of data creation. The development of archaeological information sources in the CR should aim at the integration of departmental information systems both in terms of data connectivity and user interfaces in order to design and deliver this data with common heuristic and analytic tools. Emphasis has to be placed on the importance of a suitable legal framework and institutional cooperation, the advantages of Open Access, Open Source and data standardization. Currently, the Institutes of Archaeology CAS represent the only institutions that have the potential to deal with this task. Activities in this field are the part of the ongoing project (Archaeological Information System of the Czech Republic, AIS CR), whose goals are to anchor archaeological e-infrastructures in professional environment and to build branch virtual research environment for the public use.

The significance of this development largely surpasses the sphere of electronic sources in archaeology. For several years, archaeology has been increasingly searching for relevant and at the same time solvable topics of theoretical research. More and more frequently, archaeology has to work with large sets of data derived from numerous sites and fieldwork projects and thus it has to deal with problems of accessibility and data comprehensibility. Quite frequently, information about archaeological fieldwork is missing, submitted excavation reports fall short of the recommended standards, reports written by various specialists are not being delivered to archaeological archives, data are not standardised, etc. Among archaeologists, the processing of field documentation is traditionally regarded as a burden and an obstacle to theoretical work. However, in the long term, only archaeological communities who process extensive electronic infrastructures will be able to advance towards opening and solving new theoretical topics.

A qualitative shift can occur in Czech archaeology only if the approach to processing primary data is fundamentally changed. Furthermore, the quantity of commonly processed data should also increase along with their accessibility; the variety of analytical procedures and tools should expand and, last but not least, fundamental theoretical and methodological concepts should be codified. It is of the utmost importance to take an imaginary 'step back' (as many would, albeit falsely, feel it) and to conclude the creation of basic branch infrastructures as a more efficient service for theoretical research and for the public in the future.

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Archaeological Service Agency: an Open Source WebGIS application for Albania

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Keywords: WebGIS, Albania, geospatial, open source

The Archaeological Service Agency is the first and only public institution in Albania charged to exercise its authority over rescue and preventive archaeology. It was created in 2008 as a necessity for the preservation, protection and promotion of archaeological cultural heritage to major developments on the increase in Albania. Its functional activity is subject to further studies and consultation for institutions and specialists who are connected directly in the field of cultural heritage; development project investors; stakeholders.

Until today, the ASA has fulfilled almost all archaeological processes such as:

- Archaeological verification on the territory
- Archaeological Survey
- Archaeological trial pits
- Archaeological rescue excavation
- Documentation of the archaeological material
- Supervision of the archaeological processes
- Drafting the archaeological protected areas
- Exhibition of archaeological objects.

The result of this long and complex process is the preservation, protection and promotion of archaeological heritage to the developments in the territory, while obtaining accurate data from archaeological processes in order to update and enrich the unexplored archaeological areas. ASA's activity and the information obtained from archaeological activity are preserved in the archive of ASA in hardcopy files and in ASA's annual reports. In 2015, ASA implemented the WebGIS application based on the Open Source platform, which will be used to digitally record ASA's activity. It is open for public and also serves the data using public WMS to all the stakeholders. The WebGIS platform enables:

- Expectations regarding a development project to be clearer
- Information obtained from archaeological processes, from their supervision and during the implementation phase of construction projects, as well as data

from scientific archaeological projects, will be integrated into a database, which will be accessible to stakeholders, in order to be useful

- Sets a balance between the important developments in the territory and cultural heritage in general in Albania.
- That this platform will be the basis of the archaeological map of Albania.

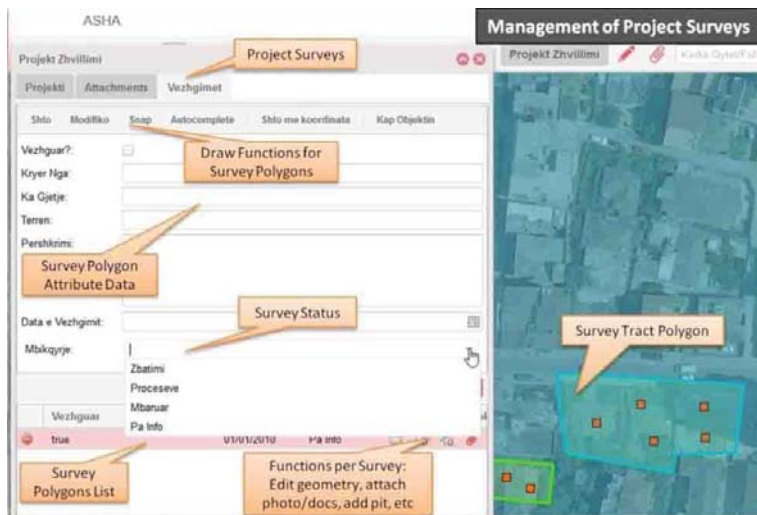


Figure 1. For each of the tracts it is possible to attach docs/photos, which are consultable through information function.

The main objective of ASA was to create a digital archive by digitizing all Geospatial information associated with the institution's activity. Also, the creation of a GIS system based on Web will enable registration, management and updating of Geospatial information in order to maintain the protection of heritage and informing stakeholders on the existing archaeological field data. The WebGIS platform enables management, from the archaeological point of view, of all processes and documents that are part of a project:

1. Enables the recording of general data for a project, registration of new projects, existing research projects and editing attributes.
2. Allows the attachment of technical and legal documentation associated with the project as well as attachment management, for example deleting and downloading documentations.
3. Enables management of all tracts of observations related to a selected project (more than one tract per a project can be registered). It provides the required functions for managing the existing tracts as well as the addition of new ones. It records personalized data for each observation tract (location, if there

are findings, etc.) and defines the surveillance status for any archaeological survey conducted for a project, enabling tracking of monitoring status for any development project or archaeological process.

4. Enables recording of positions for each archaeological process together with their attributes associated with a specific tract, where they are performed; offers the possibility of uploading attachments such as docs and photos to each of the archaeological processes.
5. The application enables consulting of all documents and photos attached to each of the project's features. Each WebGIS user can consult docs and photos without the need for credentials.

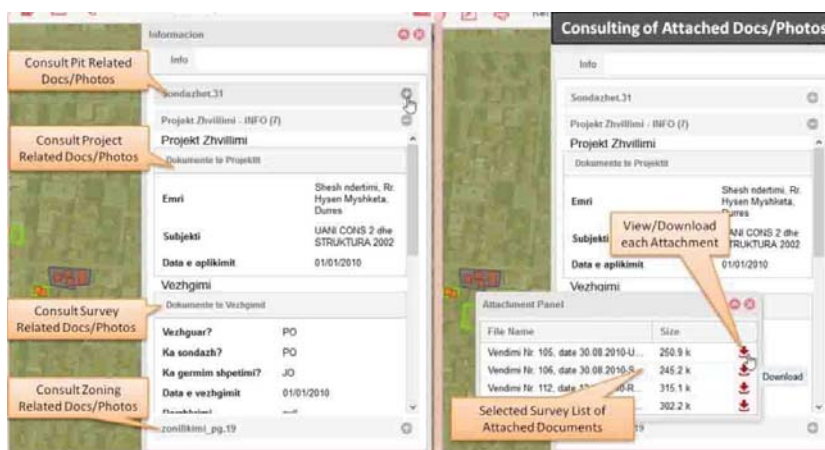


Figure 2. The platform enables consultation of all documents and photos for each project feature as well as its attributes.

Besides the data layers whose features are created and managed by the ASA the WebGIS application integrates other data layers updated automatically by the institutions that hold the service.

WebGIS allows all ASA's applicants to:

- Draw features using functions provided without the need for credentials
- Draw features in WebGIS, in the user's computer in SHP format
- Import objects stored in the user's computer in SHP format
- The application enables to download features drawn by users in SHP.

Web GIS application enables PDF map creation by the combination of layers with appropriate user information and with standards defined by ASA. This image shows the options that each user has to create the map in PDF.

The WebGIS application enables predefined query functions. The user has the option to search for tracts where there are archaeological findings or excavation or archaeological trial pits or a certain monitoring status. The WebGIS application offers the possibility to setup custom queries such as 'Find where attribute field 'City=Tirana or Year =2010', etc. Search results display a list of all objects fulfilling the requirements of the search with attributes and the spatial search.

In the second phase of the project, the Archaeological Service Agency will expand the existing WebGIS system with the function that will change the working methodology. It will enable:

- Stakeholders to record/digitize their scope of work and in this way ASA will perform the functions of data controlling
- Digitalization of features from stakeholders through WebGIS will ensure that the information displayed in the application will be always updated in real time
- Each user will be responsible for the information entered by himself until this information passes under the responsibility of ASA
- It will accelerate the communication of features documentation towards Agency
- Digitalisation of the feature will be followed by attachment of all required documentation. The Agency will be able to examine the feature and relevant documentation in real time, accelerating/facilitating all control procedures.

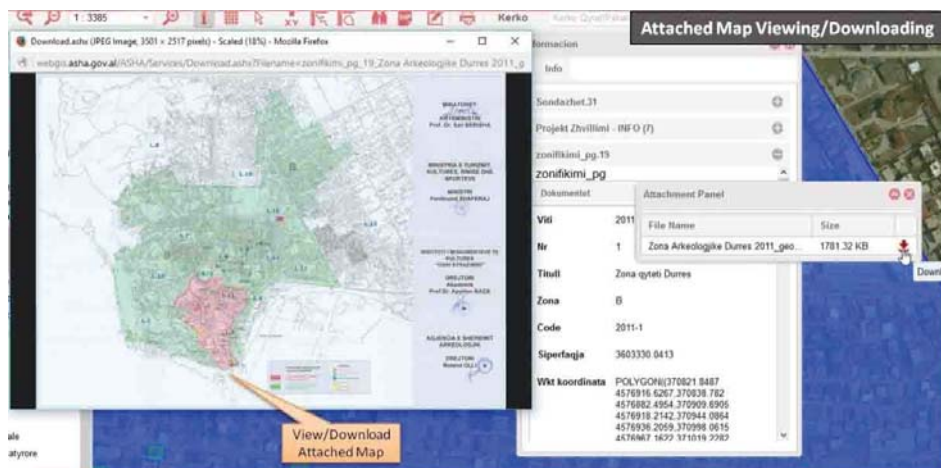


Figure 3. In this image an example of doc-map for zoning layer is shown.

Long-term data preservation and re-use: the work of the Archaeology Data Service

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Keywords: cultural heritage, e-infrastructure, computer graphics, data standards, digital preservation

Heritage management tends to focus on issues surrounding the physical protection and display of archaeological sites and monuments. However, the intellectual record of centuries of archaeological research is just as precious. These resources may have been destroyed, either by the act of research itself, or by subsequent events. The concept of ‘preservation by record’ is deeply embedded in the archaeological process, and most countries have developed systems of heritage protection, and where destruction is unavoidable, legislative structures generally require some record to be made. Even though few archaeologists would accept that a completely objective record is possible, the primary professional ethic is still the presentation of a full record of observations, through publication and archive.

For the last hundred years, the preservation of that record has largely been taken for granted. At the completion of a project the archive – including notebooks, plan and section drawings, files of recording pro-forma and photographs – would be boxed up and deposited with the appropriate museum or archive where it would be accessioned and consigned to a dusty shelf. Such archives were relatively stable, and although they might not be regularly used – if at all – it was a pretty safe bet that, short of war, fire or flood, they would still be there in 50 or 100 years. It also became standard practice that there should be a fairly exhaustive journal or monograph publication of the results of the research, although in most countries the scale of fieldwork combined with the range of data now recorded – and the cost of traditional publication – has led to a backlog, if not a crisis, in publication. Once more, however, so long as a hard copy report was published on paper, its longevity was more or less guaranteed. Copies would be distributed to academic libraries around the world, and although few were read from cover to cover, the intellectual content was safe for future generations of scholars.

Consider then, the contents of an archaeological research archive in the twenty-first century: word-processed files, CAD drawings, digital photos, spreadsheets, database tables, GIS layers, and virtual reality reconstructions. The intellectual content is

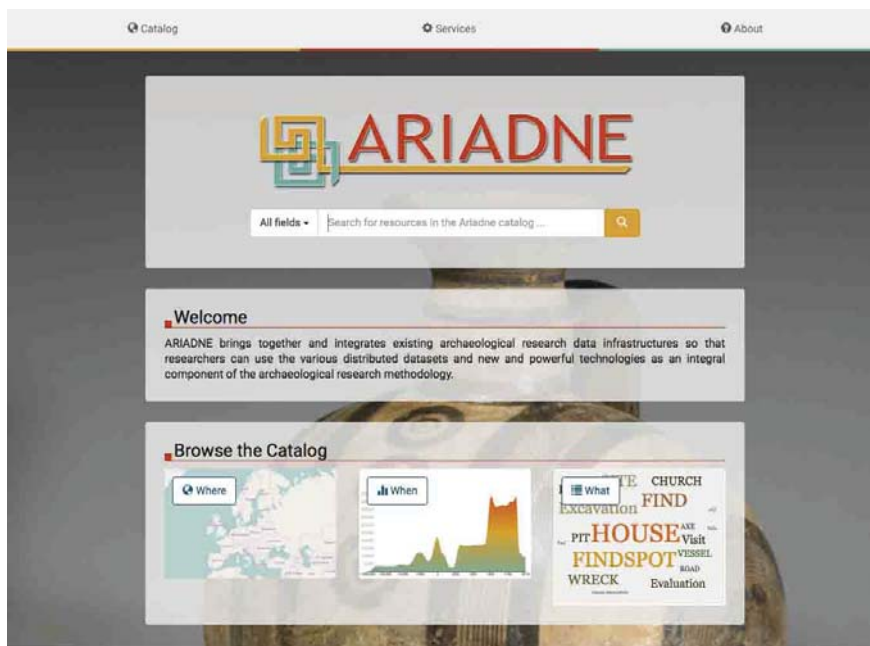


Figure 1. The initial page of the ARIADNE portal.

encoded in a complex sequence of binary information, recorded on magnetic or optical media. It is, of course, invisible to the naked eye, and requires sophisticated and rapidly changing technology to access it. Once decoded, it relies upon specialised and frequently proprietary applications software before we can make any sense of it. Furthermore, this precious archaeological resource is increasingly 'born digital', through data logging in computer-based survey systems, hand-held computers, or digital cameras. It never even touches paper between the ground and computer record. Even if it were possible to print it out, the sequence of numbers would mean little, and even a printed map falls far short of the functionality of a GIS application. Consider too, the form of the report, often available only as grey literature or distributed as a PDF file, and rarely accessible for scholarly research.

There is, at least, a growing awareness of the fragility of digital data and a realisation that digital data require active curation. A DVD may provide a durable means of preserving a particular sequence of binary digits, but contrary to popular belief, once the drive has been rendered redundant by the next upgrade in storage technology, it will be no more secure than a 5¼-inch or an 8-inch floppy disc or a punched card or even paper tape. In short, the archaeological record is now at greater risk than it ever was whilst it was buried in the ground. However, there is also a realisation that the continuing trend to digital recording and storage provides unparalleled opportunities for the online dissemination of the intellectual results of archaeological research, and

that electronic publication has the potential to provide unrestricted worldwide access to heritage information, at a variety of levels, and to broaden its appreciation. As well as facing a preservation crisis, heritage managers also have an opportunity, therefore, to make their discipline more accessible than ever before.

In the UK the Archaeology Data Service (ADS) has taken a lead role in the preservation and dissemination of digital data since 1996. It hosts over 1.3m metadata records for the archaeology of the UK, over 35,000 unpublished fieldwork reports, and over 900 data rich archives. In 2012 it was awarded the Digital Preservation Coalition's Decennial Award for the most outstanding contribution to digital preservation of the last decade. The role of the ADS is to preserve, catalogue, and describe digital data generated in the course of archaeological research and to facilitate its re-use. These activities are mutually supportive as unless digital data are actively curated they will not be available to future scholars, and unless researchers are going to re-use data there is little point in expending effort attempting to preserve them. Preservation is therefore inseparable from publication from the outset.

With the proliferation of national repositories, there is also a compelling need to bring together and integrate existing archaeological research data infrastructures to enable researchers to use new and powerful technologies. There is a need for work on standards, and to create mappings between national and regional ontologies and vocabularies. This situation is being addressed by ARIADNE, the Advanced Research Infrastructure for Archaeological Dataset Networking in Europe. This e-infrastructure comprises 23 European partners, including heritage agencies and organisations, universities and research institutions and specialist digital archives; it is funded under the European Union's 7th Framework Programme. ARIADNE enables archaeological data providers, large and small, to register and connect their resources to the developed e-infrastructure, and a data portal provides search, access and other services across the integrated resources. ARIADNE thus acts as a broker between data providers and users and also offers additional web services for products such as high-resolution images, Reflectance Transformation Imaging (RTI), 3D objects and landscapes. Employing such services in research projects or for content deposited in digital archives will greatly enhance researchers' capability to publish, access and study archaeological content online. ARIADNE therefore represents a substantial advance for Archaeology, providing a common platform where currently dispersed data resources can be uniformly described, discovered and accessed. It is also an essential step towards the even more ambitious goal of offering archaeologists integrated data, tools and computing resources for web-based research that creates new knowledge.

An extended paper about the ARIADNE e-infrastructure is available at [dx.doi.org/10.11141/ia.43.11](https://doi.org/10.11141/ia.43.11)

Visualising the past

This session considered the ways in which we can present archaeology to the wider public, ways which are developing at a breathtaking speed. 3D printing, immersive technologies, Augmented Reality, are just a few examples of the remarkable advances which seem set to change the way people access and enjoy archaeological knowledge.



White Island figures, with embedded narrative, as they appear on Sketchfab
(Image: Shaw et al.)

Using 3D technology to digitise and replicate the near Lewes Hoard

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Keywords: Structured light scanning, fringe projection, Reflectance Transformation Imaging (RTI), digital acquisition, digital cultural heritage, 3D print, replication, reproduction, Bronze Age, hoards, metalwork

The near Lewes Hoard

In March 2011, a metal detectorist working on land owned by the Glynde Estate in East Sussex, UK, discovered a hoard of Middle Bronze Age artefacts contained in a vessel. In total, the assemblage consisted of 79 whole and fragmentary objects made from gold, bronze, amber and ceramic. These included four gold appliqué discs; three complete palstaves; five Sussex Loop bracelets; four twisted torcs; eight coiled finger-rings; four conical 'tutuli' mounts; fragments of quoit-headed pins and coiled spiral ring necklaces. In addition, 26 complete and partial amber beads were also found, some still attached to the coiled spiral ring necklace fragments, as well as a single ceramic bead. The range of material contained within the hoard suggests a date of deposition between c.1400-1250 BC. Unusually for a Middle Bronze Age hoard, the assemblage was contained in a vessel. The vessel had been placed within a pit that had been cut into the natural chalk close to the terminal of a ditch of unknown date. The upper segment of the vessel was lost as a result of ploughing, leaving only the base of the container with its artefacts intact. The hoard is significant because it combines objects of local, regional, and continental significance.

The artefacts from the so-called 'near Lewes Hoard' were declared to be Treasure in 2011. The hoard was subsequently purchased by the Sussex Archaeological Society in 2014, with the aid funds from the V&A purchase fund and donations from its members. Three years after its discovery, the near Lewes Hoard formally entered the collections of the Society under the accession number LEWSA 2014.3. The Sussex Archaeological Society secured Treasure Plus funding from the Art Fund and The Headley Trust to create an exhibition to display and interpret the hoard. The exhibition, called 'Treasuring the Past', would include traditional displays, the use of 3D digital models which visitors could manipulate using a touch-screen and physical replicas.



Figure 1. Overview of the near Lewes Hoard.

Two different techniques were used to scan the artefacts in the hoard. The larger and more complex items such as the palstaves and Sussex Loop bracelets were scanned using a Breuckmann smartSCAN structured light scanner. Smaller, flatter artefacts such as the gold appliqué discs were digitised using a dome-based capture tool developed by the University of Lueven.

The most obvious application for the 3D digital scan data was a mechanism to provide visitors to the exhibition with a means to directly engage with the artefacts. To achieve this, a bespoke viewer was produced for use on a touchscreen. However, it was also decided to use the scan data to produce physical replicas for a public handling collection and to sit alongside the original artefacts in the exhibition. This would highlight the contrast between the archaeological artefacts and the objects as they may have looked when new.

Having digitised an artefact it may seem an odd choice to then make it physical again in the form of a replica. However, the use of data derived from scanned artefacts to produce museum replicas is long established. Such replicas can have a variety of roles ranging from display items, objects for handling collections, tools for experimental research or merchandise. One of the key benefits of 3D scanning compared with taking a cast of an artefact is that 3D scanners are able to acquire the 3D shape of an object in high resolution without physical contact with its surface.

One of the replicas explored in this paper was of a palstave from the hoard. Originally the palstave would have been cast from bronze in a bi-valve mould. The flash lines that run along the sides of the palstaves show where the two parts of the mould joined. Replicas can be of an artefact 'as found' or they can be of the object as it was when newly manufactured, and each has its own implications for production. After being buried for more than three millennia, many of the artefacts in the hoard were broken, corroded or heavily patinated. This can make it difficult for the public to visualise how they looked when manufactured. For example, when newly produced, the bronze artefacts would have been a bright metallic golden bronze colour rather than the dull green seen today.

If a replica is intended to represent an artefact in its newly manufactured state, then it is necessary to remove such modifications. 3D models provide researchers with a tool to remove such changes digitally without affecting the original. Two forms of digital correction were applied to the model: correction of post-manufacture and post-depositional damage, and compensation for shrinkage of the bronze in casting. A high-resolution 3D print of the object was subsequently made in resin. This resin copy was then used to produce a mould from a high-temperature silicone and it was from this mould that the replica palstave was cast in bronze.

It may seem somewhat anomalous to go to the trouble of creating a silicone mould from a 3D print in order to create a replica when it would be much simpler to directly 3D print the replica in bronze. Printing in bronze would reduce the cumulative errors caused by creating a copy of a copy; however, at the time of writing 3D printing in metal was very expensive (although undoubtedly these costs will reduce over time). More significantly, the process of creating a mould from an original was used as part of the learning outcomes for the handling collection. Museum curators and learning officers were able to use the resin 3D print and the silicone mould to help explain the process by which an original palstave or other object was cast far more effectively than with just a replica palstave alone. While the process is not completely analogous, it does allow the audience to



Figure 2. Rough cast of palstave.



Figure 3. Polished replica of palstave.

engage more directly with the process of casting and some of the difficulties that Bronze Age smiths would have encountered. The use of cutting edge 3D printing also allows the audience to reflect on the development of technology. In many ways, bronze casting was the 3D printing of its time.

**The full text of this paper with bibliography is available at
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The digital dimension of cultural heritage. New opportunities for digital access to cultural goods by the Hellenic Ministry of Culture and Sports

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Keywords: conservation, data management, Greek cultural heritage, archaeological cadastre

The right of all the members of society – not just the experts' community – to direct, free and continuous access to the cultural wealth of their native country is an essential, lasting, and thus always current and timely issue. It is also becoming a central axis of academic discussion and broader policy making. Consequently, it forms basic criterion for government and private funding on a European and global level. This is evident in all related international conventions, EU directives and recommendations.

The applications of digital technology and the Internet in the sectors of research, education and culture have created new opportunities for access to science, knowledge and cultural goods, in ways unattainable by traditional and conventional means. Overcoming distances and boundaries, socio-political and cultural divides of the real world, the world of Information Technologies and the Internet offers new ways of communication, information, expression, exchange of views, and dissemination of knowledge and experiences, in a strongly participatory and more direct and democratic manner. In its virtual spaces and perceptual communities, the average person can 'navigate', interact, contribute and share as a global citizen, with the help of a new kind of universal 'common language'.

This new environment thus actively contributes to the alleviation of inequalities and the creation of more open and cohesive societies. It strengthens the bonds between science, education and culture by enriching research and education processes, and by infusing the cognitive and aesthetic foundations of society with the knowledge, values and emotional wealth of cultural heritage. By facilitating and encouraging access to and contact with heritage, it also raises public interest and awareness, and in so doing, essentially contributes to the rational, sustainable and efficient management, promotion and protection of the cultural capital. Furthermore, it generates added value by providing abundant resources and creating a plethora of opportunities for social and economic growth.

The great potential residing in the affiliation of heritage with digital technologies and the ensuing need for the effective use of the latter in the protection, management, promotion and dissemination of the cultural capital, is at the center of the policies and the strategic planning of the Hellenic Ministry of Culture and Sports. Identifying and meeting the needs and expectations of the academic as well as of the general public, encouraging cooperation and joint actions on a national and international level, adopting an inter-sectorial and interdisciplinary approach on the basis of up-to-date research and established standards, and making the best possible use of available funding, are key points in our considerations.

Our strategy and planning in the domain of digital cultural curation revolve around three main axes:

- The creation and continuous enrichment of national and European repositories of digital cultural content
- The long-term and sustainable conservation and management of our digital cultural assets
- The uninterrupted availability and accessibility of digital cultural assets through the implementation of up-to-date and constantly renewed technologies.

The great diversity, geographical dispersion and tremendous multitude of Greek cultural assets of all periods (as far as moveable monuments alone are concerned, a very rough and modest earlier estimate based on storage volume raised their number to over 60 million) generate different needs and special requirements for addressing and handling each particular category and genre of the material, necessitate prioritization, and call for the implementation of a variety of specialized tools and methods of digitization and original digital recording and documentation. At the same time, the larger and richer the digital cultural reserve becomes, the greater and more pressing is the need and obligation for its long-term and sustainable conservation and management, for the establishment of efficient mechanisms to ensure compliance with new standards and technologies and to apply constant adjustment and modification of strategies and procedures in order to guarantee uninterrupted availability and accessibility to all audiences. This also raises the issue of cost, the necessity to maintain all this on sustainable levels and to provide adequate and steady financial resources under particularly hard and adverse economic circumstances.

The great diversity of the original cultural wealth results in the need for diversity and specialization in the methods and means of making the ensuing digital capital available and accessible to the audience. And since this audience is neither single nor uniform, the methods and means of address and approach also need to be variable, multifaceted and properly adapted to meet the requirements of different population groups according to age, ethnicity, profession, social origin, etc. They need to take into consideration particular interests, skills and needs, making use of new technologies in different ways for different target groups and for different purposes.

The variability of uses and users of the digital cultural capital, combined with the speed and ease of propagation and reproduction and amplified by the inherent difficulties

of monitoring and regulation of the vast world of the Internet and the Social Media, create additional challenges in preserving the integrity and identity of the digital cultural content. It can easily be cut off from its meaningful context, which is necessary for its interpretation and understanding. At the same time, complex legal issues and implications – including but not limited to copyright – emerge in the process.

All these factors are taken into consideration as current projects are carried out and future ones are being planned in the domain of digital cultural management. For twenty years now, the Hellenic Ministry of Culture and Sports, through its competent units, has been actively involved in many research and development-oriented programmes both autonomously and in close cooperation with academic institutions and other public and private entities from Greece and abroad. I will briefly mention Greek participation in: a) the *AQUARELLE* project (1996-1998), b) the *MINERVA* network, in the context of which the Greek side contributed to the coordination of cultural and scientific content digitization and documentation activities at a European level, c) the *AREA* and d) the *MICHAEL* projects that brought together the cultural sector with scientific research and technology, creating and expanding the necessary infrastructures through the *DC-NET* network, e) the *ATHENA* network, providing internet access to cultural objects and archival material from European museums and archives and f) the *CARARE* program, promoting immovable monuments of the European archaeological and architectural heritage.

All these actions, together with national projects such as a) the *Ongoing Catalogue of the Listed Archaeological Sites and Monuments of Greece*, compiled and published since 1999, b) the first *National Archive of Monuments Information System* ('*POLEMON*' 1995-1997 and 2006-2008), designed to meet the needs of the various units and services of the Hellenic Ministry of Culture providing an integrated set of tools for *Monuments and Collections Management*, c) the '*POLYDEUKIS*' platform (1999-2000) for producing a thesaurus of terms related to cultural heritage and d) an ongoing nationwide digitization campaign have greatly contributed to the enrichment of Greek and European repositories and aggregators of digital cultural content, providing access to cultural heritage through various providers such as the *Europeana Digital Library*.

The principal long-term objective of the Hellenic Ministry of Culture and Sports has been to create a '*National Archive of Monuments*', an all-inclusive registry and inventory of all the material evidence of Greek cultural heritage, composed of both the moveable and immovable monuments. Hosted and supported by modern, purpose-designed and produced, cloud-based, web accessible and secure IT platforms, when completed this extensive digital record will hold the data and provide the tools that will allow all competent units of the Hellenic Ministry of Culture and Sports to form an accurate, real-time picture about the state and condition of the Country's whole cultural capital, enabling firmly founded and efficient short and long term strategic decisions concerning its preservation, protection and management. It will also make this information available to the wider public through dedicated Internet portals and electronic services.

The first platform hosts the 'Archaeological Cadaster', the first coordinated, systematic and constantly updated digital recording and documentation of all the Public Real Estates in the territory managed by the Hellenic Ministry of Culture and Sports. This integrated information system will be populated with reliable and detailed geospatial, descriptive and legal information related to the historical identity and administrative status (including but not limited to acquisition procedures, ownership and management data) of land plots, buildings and other structures acquired or supervised by the Ministry, primarily consisting of ancient and recent immoveable monuments, archaeological sites and historic places. When this project – currently underway through EU funding – is completed, all the information (including orthophotomaps) will become available to the international public through a dedicated portal and multiple other channels over the Internet.

In parallel to the 'Archaeological Cadaster', the Ministry has undertaken – also with EU funding – the task of developing a second integrated IT platform that will allow all central and peripheral units to effectively record, document, administer, curate, and, most importantly, monitor and protect their collections of moveable monuments – exhibited in museums or held in storage – against wear, loss and theft. It will be equipped with modules for the employment of expandable multilingual thesauri of archaeological and technical terms, for the management of digital images and other audiovisual material with the ensuing copyrights, for the analytic description and documentation of diverse types of objects of all periods, for the documentation of conservation procedures, for the management of permanent and periodic museum exhibitions, for the supervision and handling of storage facilities, for the processing of matters related to the import and export of antiquities and the issue of internal and global alerts related to objects missing, stolen, involved in illicit trade or other criminal activities. The platform will interoperate with that of the 'Archaeological Cadaster' in order to provide accurate administrative as well as geospatial data concerning the locations where moveable monuments were produced, discovered and are being exhibited or stored. It will also facilitate the publication and promotion of Greek cultural heritage through an Internet portal and various kinds of digital applications, including but not limited to virtual exhibitions, story boards and personalized virtual collections.

In order to facilitate access to Greek cultural heritage for the international public, the interface of all portals will be available in English and so will the description of each displayed moveable and immoveable monument as well as the technical and archaeological terminology included in the documentation thesauri. Part of the information will also become available through national and international aggregators of digital cultural material such as the Europeana Digital Library.

In tandem with the two IT platforms the Ministry is also carrying out two large-scale, nationwide projects aimed at a) the digital topographic, geospatial and archival documentation of over 7,500 urban and suburban land plots, agricultural parcels, buildings and other structures acquired or supervised by the Ministry, 5,100 land and underwater archaeological sites and their protection provisions (buffer zones and other measures) as well as over 20,000 ancient and recent listed monuments (building

complexes and individual structures with their surroundings), b) the digitization of a small part of the vast collections of moveable monuments (pottery, sculpture, jewelry, coins, etc.) held in museums and storage facilities of Ephorates of Antiquities, a significant proportion of which has never before been indexed, photographed or studied. Currently, through EU funding, digitizing stations have been set up throughout Greece, and c.620,000 objects (160,000 previously uncatalogued, 340,000 catalogued, 120,000 digitally catalogued in various earlier formats and platforms) are systematically being identified, photographed, described, indexed, and then digitally recorded in order to populate the new integrated information system.

The above projects are being complemented by the digitization of the historical archive of the Greek Archaeological Service. This is one of the earliest and most important archives of the Greek State dating back to 1834, which consists of documents, prints, drawings and other material related to the history and actions of the Service through time, and holds valuable information related to the discovery, conservation and curation of archaeological sites and antiquities over the years. A dedicated platform serves the digital archiving and Internet publishing of the material for the benefit of the academic community and the general public.

Together with the large-scale horizontal projects described above, over 40 more actions, specifically targeted or of peripheral character, are being carried out nationwide, aimed at: a) the incorporation of digitization and digital cultural management techniques in everyday curatorial practice, b) the standardization of digitization procedures, c) the implementation of new and specialized techniques of digital scanning, measuring and modelling of monuments, d) the homogenization of pre-existing digital material, e) the clearing of copy and other rights of digital material and f) the development of IT tools and applications for public access to digital cultural assets, research and educational purposes, virtual touring of museums and major sites.

In general, our future plans are aimed at the deeper integration of the cultural sector with digital technologies and the 'information society' in the context of national and EU-funded projects and actions in the following fields:

- The continuation of the digitization process of the Greek cultural capital, the further enrichment of the National Archive of Monuments as well as the maintenance and long-term preservation of the digital material produced
- The expansion of the capabilities and scope of the IT platforms currently under development in new fields such as that of digital excavation management and documentation
- The improvement of accessibility and experience of the digital cultural capital by the scientific community, the educational system and the greater public by means of specialized web and other applications targeted at different types of users and audiences, based on their particular needs and requirements
- The wider deployment and consolidation of Information and Communications Technology in the daily operation of all units of the Ministry of Culture and Sports, in order to improve their efficiency in terms of cultural management and administration

- The encouragement and support of private or social initiatives to develop value-added applications and services based on available digital cultural content
- The encouragement and support of the use of new technologies in the production and promotion of contemporary culture as well as of all aspects of intangible heritage.

An on-site presentation of invisible prehistoric landscapes

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Keywords: virtual and augmented reality, cultural heritage, on-site presentation, public archaeology, mobile application development

The aim of this paper is to demonstrate the possibility of presentation of prehistoric sites in locations where there is neither preserved construction, nor any relics of the original landscape. Such sites usually meet with indifference both from the public and from institutions involved in preservation of historical monuments. The possibility of creating virtual and augmented reality proved to be a potential tool to grasp the invisible and to describe the disappeared. Based on the examples of the Neolithic sites in Bylany near Kutná Hora and Prague Vinohrady and Bronze Age site in Zálezlice in the Czech Republic, we show a potentially powerful tool for digital heritage management. Terms such as 'virtual' or 'augmented reality' no longer represent a million light-years away science-fiction concept, but rather a new tool for public archaeology and this paper discusses its use for *in situ* presentation of archaeological sites. The very rapid development of information technology, the accessibility of the Internet and the overwhelming scale of the adoption of computer technology in recent years have created room for a change in presentation of archaeological features and their reconstructions. However, on-site virtual presentations have very specific requirements and possible solutions still need to take into account technical limits.

The advantage of using augmented reality (hereinafter AR) is evident for 3D reconstructions displaying non-existing archaeological or historical structures. Already established AR applications use two basic technologies to overlay digital data with real environment. The first and the most used is the marker-based method, where virtual data are extended on two-dimensional images or in some cases three-dimensional objects. The second method works without these auxiliary markers and for locating of virtual data to real environment are used in portable device functions such as GPS, digital compass, and accelerometer sensors. This mode usually contains a database for locational information and when a device using GPS location and compass orientation establishes a match, it will display the desired virtual visualization. The downside to this method, however, is the inaccuracy of the GPS localization, which on mobile devices can be out by metres. This may not matter for applications that provide data overlays of supplementary information for physical objects that are perfectly

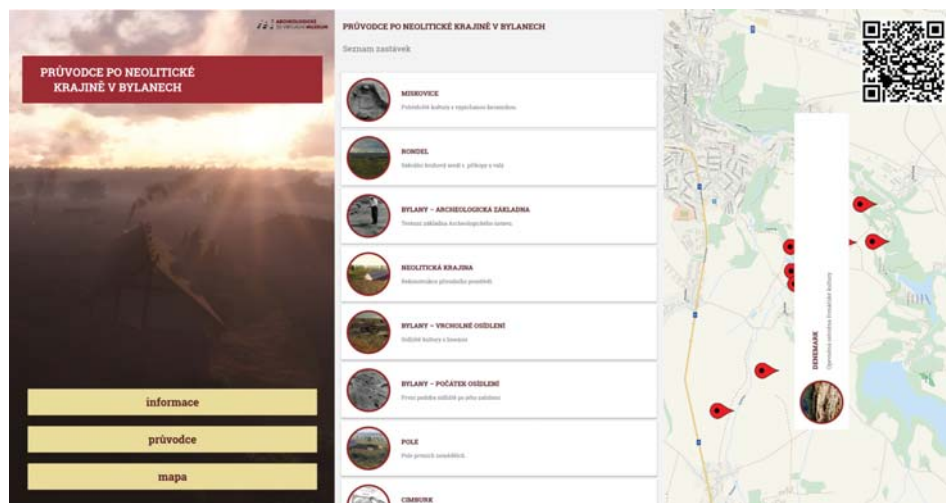


Figure 1. Printscreens from application guiding visitors through the Neolithic landscape in Bylany.

visible with the naked eye, but for placing archaeological/historical buildings in their surroundings, it has a significant impact. Another possibility is the application based on mixture / augmented reality, which works without an auxiliary marker on the basis of an algorithm that teaches the device to identify the real natural objects while, at the same time, also utilising the special method called Speeded Up Robust Features. The

Figure 2. 3D reconstruction of prehistoric landscape rendered to 360 degree panoramic image.





Figure 3. Information panels including two markers enabling AR visualisations.

implementation of this method is still difficult for mobile devices because of limited computation performance, memory, network connectivity, etc. and as far as we know, it has not been used to display 3D virtual reconstructions of archaeological or historical sites.

The above-mentioned technical limits and specifics of Central European prehistoric sites that are not visible in the modern landscape forced us to find another and more simple solution for presenting them in the field. The first application encompasses nine stops located in the extended surroundings of Bylany to capture the main features and settlement components of the Neolithic landscape. The application enables visitors using the map to navigate themselves between stops while the current position of the visitor is also highlighted, and to obtain basic text and visual information about each point of interest. All the 3D reconstructions that are displayed are based on archaeological evidence from almost half a century of archaeological research that has taken place in Bylany since the 1950s. Based on the data obtained by means of aerial laser scanning, the selected landscape section was subsequently modelled, with particular features being geo-referenced and exactly positioned where the original constructions stood. Visitors have the opportunity to see displayed on their own device the different phases of the Bylany Neolithic settlement's evolution, including the nearby Neolithic circle enclosure (i.e. a rondel) and the Miskovice burial site, all incorporated with the character of the cultural landscape at that time. In order to facilitate the visitor's opportunity to better understand and experience the 3D reconstruction at the prehistoric site, the above-mentioned principle of virtual reality, combined with the gyro mode function, was used for this part of the application. It is therefore possible after implementing this feature of the application at a predefined location to 'set foot' in the middle of this Neolithic village and, by moving the device sideways, to look all around it. This results in combining the virtual world, comprising 3D reconstructions of Neolithic dwellings, with the real world, since the current form of the contemporary landscape has been incorporated in the model. Information panels set up next to the Institute of Archaeology's field base included two markers enabling an AR visualisation of a full-size Neolithic burial, and a 3D model of a vessel that was found in Miskovice.

Another virtual open-air museum was put into use in Prague Vinor, where, in 2014, a rescue excavation uncovered parts of a Neolithic settlement, including the remains of two longhouses. The excavation results, including plans and geodetic localisation, were used to produce an ideal 3D reconstruction of the village and its vicinity. The application works analogously – the attached map highlights the points in the newly built-up area where users should initiate the specific virtual views in order to preserve the spatial context. Each of these 360-degree panoramic views captures a different part of the Neolithic settlement. By clicking on the points on the displayed 3D reconstruction that are marked, information boxes will pop up and provide explanations of the different features or show images of sample artefacts that can be found locally. One of these views takes the user to a photogrammetrically recorded excavation site, enabling an explanation both of the rescue excavation process and the manner of the detection of archaeological features.

3D photogrammetry was conducted at the rescue excavation of a Late Bronze Age settlement in Zalezlice near Melnik and enabled the creation of 3D models of all the inhumation burials in settlement pits. The augmented reality application that was devised for their presentation uses the marker principle previously discussed. At present, leisure shelters with inbuilt markers and information panels are being constructed along a popular cycling route adjacent to the site.

The full text of this paper with bibliography is available at dx.doi.org/10.11141/ia.43.13

Recent developments in the application of new digital technologies in archaeological heritage management in Hungary

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Keywords: digital technologies, heritage management, cultural landscape, teaching, publishing

Introduction

Our paper presented at the EAC Annual Meeting in Brighton summed up the joint efforts of the Archaeolingua Foundation and the Cultural Heritage Studies Program of the Central European University in spreading the application of digital technologies in cultural heritage preservation. In the past two years, mainly in education and, partly connected to it, through printed and online publications, we not only kept archeology students and colleagues but also a wider audience informed about the latest research results in digital heritage protection.

New Digital Technologies and Hungarian Innovations in Heritage Management – Archaeology, Historical Landscape and Built Heritage

The conference and exhibition organized under this title in February 2015, Budapest, covered a rich theme. Presentations by Hungarian participants (12 contributions) were organized around three keynote speeches. The lectures delivered by Wolfgang Neubauer (Director, Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology), Stefano Campana (University of Cambridge and Siena) and Sorin Hermon (The Cyprus Institute) were followed by presentations of thematically diverse case studies offering insight into latest Hungarian research.

The event-related exhibition and poster and book presentations aimed at raising awareness of Hungarian ongoing and already completed projects and of the results of Hungarian archaeologists' foreign expeditions. The referenced literature contains more detailed information on these topics. The real and virtual presentation entitled 'Exhibition on new technologies and Hungarian projects: Drones, laserscanners, 3D printing, remote sensing, holographic pyramids, augmented reality' attracted a large number of visitors.

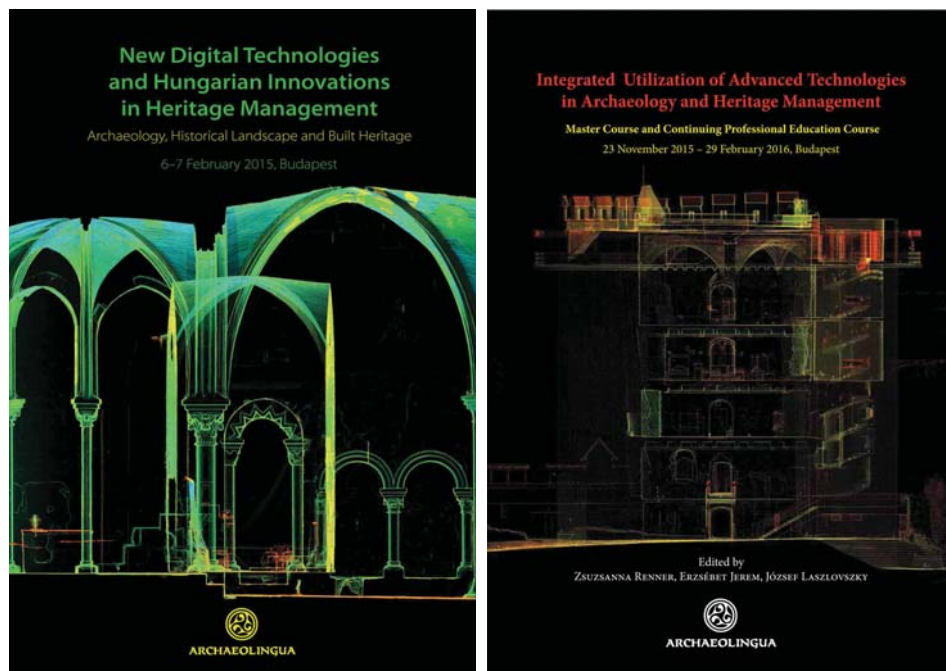


Figure 1. Covers of the publications *New Digital Technologies and Hungarian Innovations in Heritage Management* and *Integrated Utilisation of Advanced Technologies in Archaeology and Heritage Management*.

Integrated Utilisation of Advanced Technologies – Master course (lecture series) on the digital aspects of archaeological heritage

Archaeolingua Foundation, in conjunction with the Cultural Heritage Studies Program of the Central European University, offered a Master Course on archaeological heritage between November 2015 and February 2016. The series of six lectures looked back, as its antecedent, to the conference entitled *New Digital Technologies and Hungarian Innovations in Heritage Management – Archaeology, Historic Landscape and Built Heritage*, held between 7 and 12 February 2015, and supported by the National Cultural Fund.

It was the first ever Master Course on this topic organized in Hungary, despite that the approach and knowledge indicated in the title have become part of current archaeological practice at the international level. The program was intended to speak to a broad audience from university and doctoral students through researchers and practicing professionals to a wider public.

Internationally recognized European experts were invited to speak at the Master Course who introduced the archaeological and heritage preservation applications of digital technologies according to their specific fields of research interest. The guest speakers were introduced to the audience by Erzsébet Jerem, Managing Director of Archaeolingua Foundation, and József Laszlovsky, Director of the Cultural Heritage Studies Program at Central European University, at whose initiative the Master Course had been organized. After each presentation a Hungarian expert was invited to add some remarks on the Hungarian results or scientific experience in the specific topic under discussion.

Problems and issues discussed in the lecture series were:

- Digital heritage, digital humanities
- New technical devices (drones, 3D scanners)
- Archaeological data management
- 3D as a research tool and presenting archaeological sites
- Internet-based publications
- Archaeological surveys and the digital tools
- Digital tools in education

Cultural Heritage Studies Programme at the Central European University and the archaeological heritage management

Cultural Heritage Studies is an interdepartmental and interdisciplinary two-year MA program at Central European University, intended to educate individuals who wish to become heritage experts and practitioners. The Cultural Heritage Studies Program combines theoretical and practical education, offering a variety of theoretical and methodological approaches with a strong emphasis on practical knowledge and skills based on fieldwork, and internships with local, regional and global heritage organizations. Graduates of the program will be capable of working at various levels in cultural heritage and resource research, protection, and management. The program focuses on developing aptitudes for the critical assessment of tangible structures and objects such as buildings, monuments, archaeological sites, and works of art; on intangible heritage such as traditions, languages, and knowledge; and on environmental heritage connected to human-nature interactions.

The Cultural Heritage Studies Program degree should be broadly convertible, future professionals might include architects, art historians, archaeologists, cultural anthropologists, environmental professionals, museum curators, archivists, librarians, conservators of artifacts and monuments, policy and management experts, and so on. Heritage-related activities can be connected to various types of institutions or organizational structures, with special emphasis on governmental decision-making bodies (policy issues) and networks of NGOs in the field of cultural heritage management.

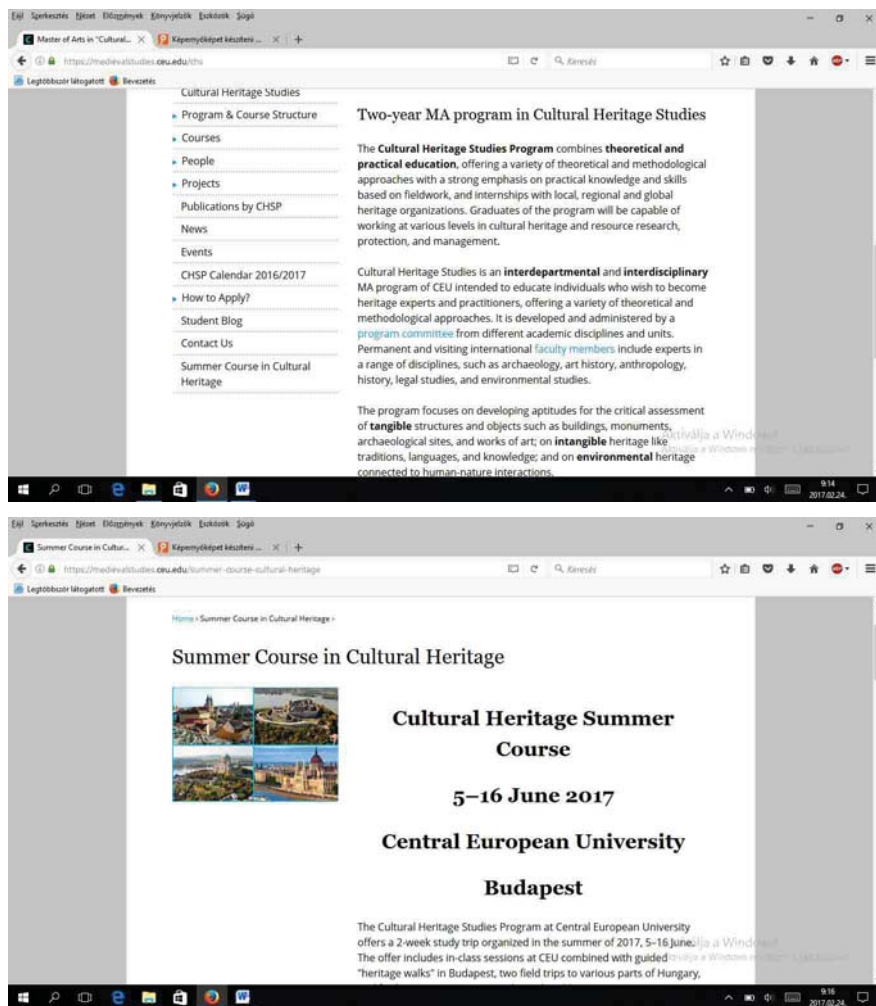


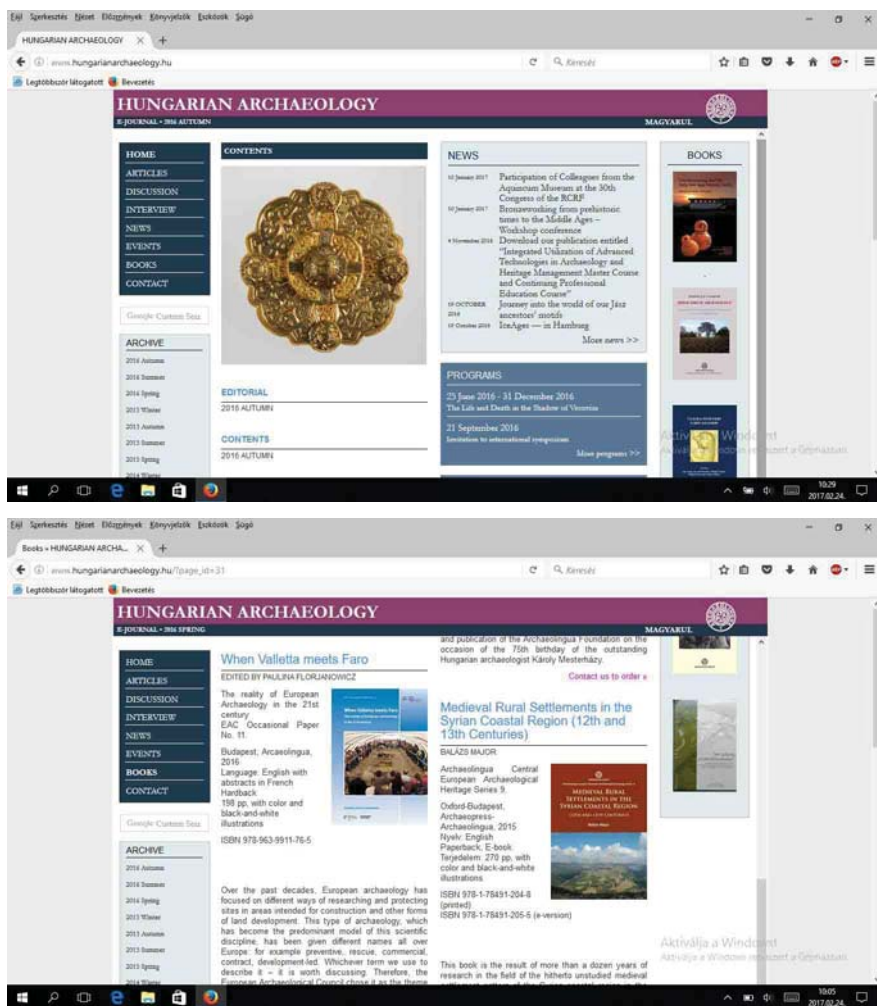
Figure 2. The Cultural Heritage Studies Program at Central European University, Budapest. Information on the MA program and on a summer course.

Research fields:

- Changing attitudes in past societies to different cultures and civilizations, global interactions of cultures and civilizations in the past, and the impact of this process in the present
- Relation between academic research fields and analytical approaches; the ability to conduct research using a variety of academic methods

- The impact of tourism and commercialization on object-based and intangible cultural heritage policy
- Connections between heritage elements and identity building (universal, European, national, minority, local, etc.) processes
- Policy and management aspects of cultural heritage and of the need for a holistic approach to heritage protection and sustainable development
- Archaeological heritage management and interpretation
- Institutional history of cultural heritage

Figure 3. Hungarian Archaeology online (cover page and book review).



- GIS applications in cultural heritage research
- Crowdsourcing and social media in cultural heritage studies and management
- The interaction of cultural heritage and environmental management
- Legal protection of cultural heritage and illegal trade
- Intangible cultural heritage and memory
- Ethical issues, intellectual property, and privacy
- Publication and presentation of cultural heritage
- Curriculum development and cultural heritage studies in higher education

Hungarian Archaeology – online archaeological journal of Archaeolingua Foundation and its impact on digital heritage

The online journal Hungarian Archaeology, founded in 2012, has the following main features:

- Four issues per year
- Papers, review articles, book presentations, reports on academic programmes
- All archaeological periods
- Digital and landscape archaeology in the focus
- 8000 visitors per month (Hungarian)
- 7000 visitors per month (English)
- increasing number of downloads

Further cooperation between the organizing institutions is reflected in the scholarly publications jointly issued by CEU and Archaeolingua as well as in the Central European Series jointly published with Archaeopress.

Finally, we would like to emphasize that, within the activities of Archaeolingua, EAC's publications play a key role and indicate Archaeolingua's commitment to the dissemination of the current topics of European heritage protection.

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<https://medievalstudies.ceu.edu/>

Hungarian Archaeology

English-Hungarian online journal. <http://www.hungarianarchaeology.hu/>

Archaeology and geohistory: building a multi-user platform in the Brussels Capital Region, Belgium

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Keywords: GIS, lidar, Brussels, 3D modelling

The Department of Archaeological Heritage of the Brussels Capital Region, together with the Cinquantenaire Museum, is actually working on the creation of an online geohistorical platform combining archaeological, geographical and historical sources.

This process of digitization did not start from scratch. Already in the early 1990's, the Department laid the foundation for the *Atlas of the archaeological potential of the Brussels Region*, a series consisting of 24 volumes in which the inventory of the known archaeological heritage of the different communes within the Brussels Capital Region was made. This inventory consists of archaeological research results and the listing of ancient chance finds on the one hand, and of historical and cartographical research on the other. However, this Atlas is not purely an informative reference work; it is also – and primarily – the legal base for the management of archaeological heritage and for the organization of preventive archaeology. Every volume contains a detailed map with every known or possible archaeological site and their expansion zones, a detailed description of the site, its history and the associated finds. In this way, any demand for infrastructural work can be monitored against the map and guide the archaeologists in their documentation of the site before destruction.

Today 858 archaeological sites are mapped, but this number is of course still growing thanks to ongoing research. The actual map can be consulted on BruGIS, the cartographic website of *Brussels Urban Development*, containing all urbanistic information concerning the territory (<http://www.mybrugis.irisnet.be>). For every feature visible on this GIS, some metadata can be consulted: name of the site, typology, state of conservation, period of existence, reference to the paper publication, etc.

This detailed mapping applies to the communes of the Brussels Capital Region. But, when consulting the cartographic website, one notices one large pink zone in the centre of the territory, the historical town of Brussels. This zone actually lacks the same level of detail as the surrounding communes. Having a very rich and complicated

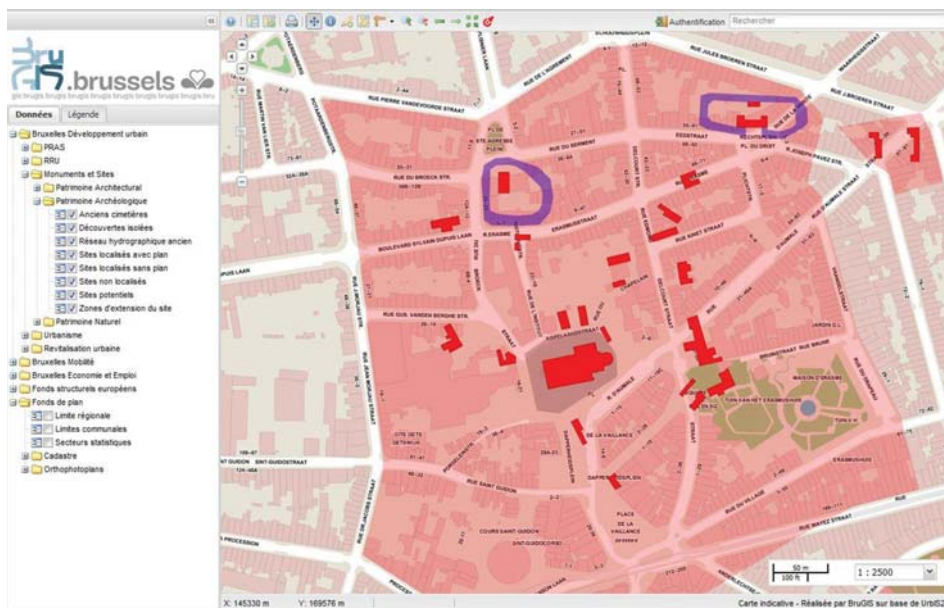


Figure 1. Excerpt of the archaeological potential for the commune of Anderlecht on BruGIS, the cartographic website of Brussels urban Development (© BruGIS).

history like any other mediaeval town, it is obvious that the entire city can be seen as one single archaeological site. But, given the complexity of the growth of a historical centre with buildings continually being transformed and changing functions and therefore the abundance of possible and overlapping sites, it is not possible – as it was for the communes – to locate every possible site in the same simple way. It was thus decided to walk another path.

In the first phase, a method was developed in order to map all kinds of sites as precisely as possible on the actual cadastre, using multilayers in a straightforward uniform technique. Since premodern maps and historic written sources are often not precise enough for our objectives, we first analysed the 19th-century pre-cadastral map of Bastendorff (1821) in detail, in order to find a link between the early modern sources and the actual cadastre. This map shows the town as it was during the Ancien Régime while some big infrastructural works that completely transformed the inner city, as e.g. the covering of the river Senne, the construction of the Haussmanian Boulevards and the construction of the north-south railway connection, were not yet executed. Each different map sheet has been georeferenced and vectorised, creating thus a digital 19th-century cadastral map to which a database is attached, carrying metadata information on the use and typology of the parcels (gardens, courtyards, houses, roads, bridges, wells, fountains, fortifications, etc.), extracted from the internal localisation system of the map (Blanchaert, H., 2013: 'Le plan de Bastendorff – un trait d'union entre passé et présent', *Bruxelles Patrimoines* 9, 124–129).

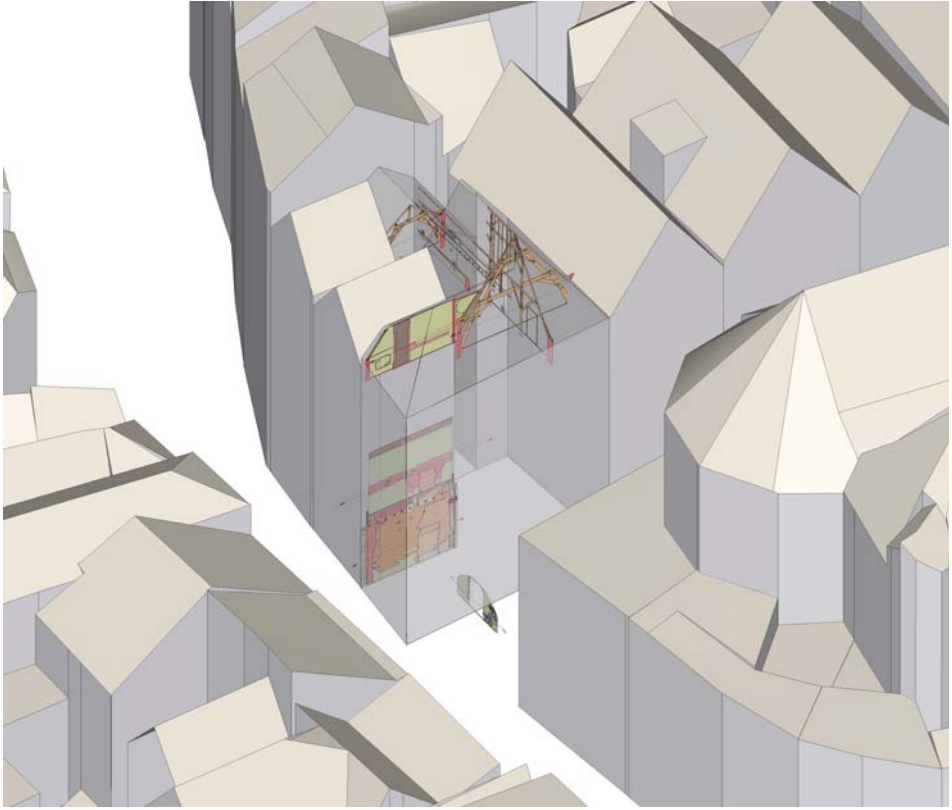


Figure 2. Implementation of archaeological research on ancient buildings in the Region's LIDAR model (Denis Willaumez © BRPS).

This map, having a lot of parallels with the actual cadastre but also with the older maps of the Ancien Régime, therefore becomes the perfect link between pre-cadastral maps and the written sources on the one hand, and the modern maps on the other. A first test case consists of breweries from the 17th-19th c.: almost 200 lost breweries have been inventoried, combining textual information with geographical localisation via the Bastendorff map and the actual cadastre, resulting in a richly detailed annotated map.

In a next phase, other themes such as the city convents, the various fortification systems, cemeteries, mills, etc. will be treated in the same way so as to construct a comprehensive historical GIS for the medieval city of Brussels, arranged around a choice of themes. In the future, this information will be functioning on an interactive online platform based on the BruGIS cadastre principle, allowing scholars in the future to integrate their research on ancient Brussels in the same environment and enriching thus the city's history.

In addition to this 2D information, experimental 3D modelling has been started, based on an integrated historical, archaeological and cartographical research. The test case here is the house where the famous Renaissance anatomist Andreas Vesalius lived.

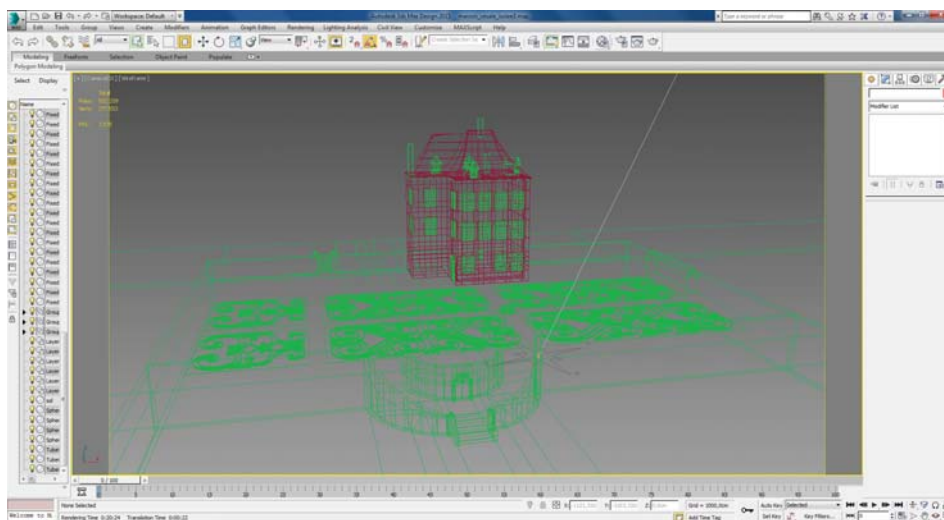


Figure 3a. Wireframe for the 3D-modelling of Andreas Vesalius' house in Brussels.

Figure 3b. Textured 3D-model of Andreas Vesalius' house (Daphné Van Grieken, RMAH © BRPS).



Disappeared from the urban landscape today, the above-mentioned georeferencing method has made it possible to localize it with precision. Through the combination of the georeferencing with the images originating from ancient drawings a 3D model was created, giving not only a vision of what the city looked like in this particular part of town, but also producing a better understanding of the architectural composition of buildings in general.

Since two years before, the Brussels Capital Region also disposes of a complete set of LiDAR images for the whole territory. The exploitation of these data has just started and is extremely promising as it gives extra archaeological information not only for the dense Sonian forest around the city but also for the city itself. Implementation of building and subsoil archaeology data in the LiDAR model and thus putting them in a general city perspective shows the research potential on medieval building methods and town planning in general.

3D-ICONS Ireland – Fulfilling the potential of a rich 3D resource

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Keywords: 3D models, 3D-ICONS, laser scanning, structured light scanning

As a partner in the EU co-funded 3D-ICONS project, which ran from 2012-2015, the Discovery Programme undertook the 3D documentation of some of the most iconic cultural heritage sites in Ireland. This pan-European project aimed to establish a complete pipeline for the production of 3D replicas of archaeological monuments, historic buildings and sculptures, and to promote access and reuse through Europeana. The Irish content ranges from wider cultural landscapes to smaller ornately carved stones and includes a wide range of chronological periods: from Brú na Bóinne Neolithic rock art from 2500 BC to Derry's 17th-century fortifications.

The primary digitisation methods include airborne laser scanning (ALS), phase-based terrestrial laser scanning (Faro Focus 3D) and close range structured light scanning (Artec EVA). These are now mainstream approaches for surveying historic landscapes, structures and objects, generating precise, high-resolution point cloud data. The challenge was to convert these complex high-volume data sets into textured 3D models, retaining the geometric integrity of the original data whilst reducing the overall file size of the model to enable delivery and use via the Internet. The paper highlights the development of a pipeline to produce a lightweight 3D WebGL model which enables the public to interact with a photorealistic model based upon accurate survey and texture data utilising the Sketchfab web service.

3D-ICONS ended in January 2015, but a website *3dicons.ie* was designed to offer continued access to the Irish 3D models and the associated content generated during the project. The website was launched by the Heather Humphries TD, Minister of Arts Heritage and Gaeltacht, with coverage on the national TV news and online media. In the months that followed the value of this 3D resource became apparent through a diverse range of activities either directly using the site, or inspired by the content. This paper will focus on these developments, explain how they arose and how we hope they will develop in the future.

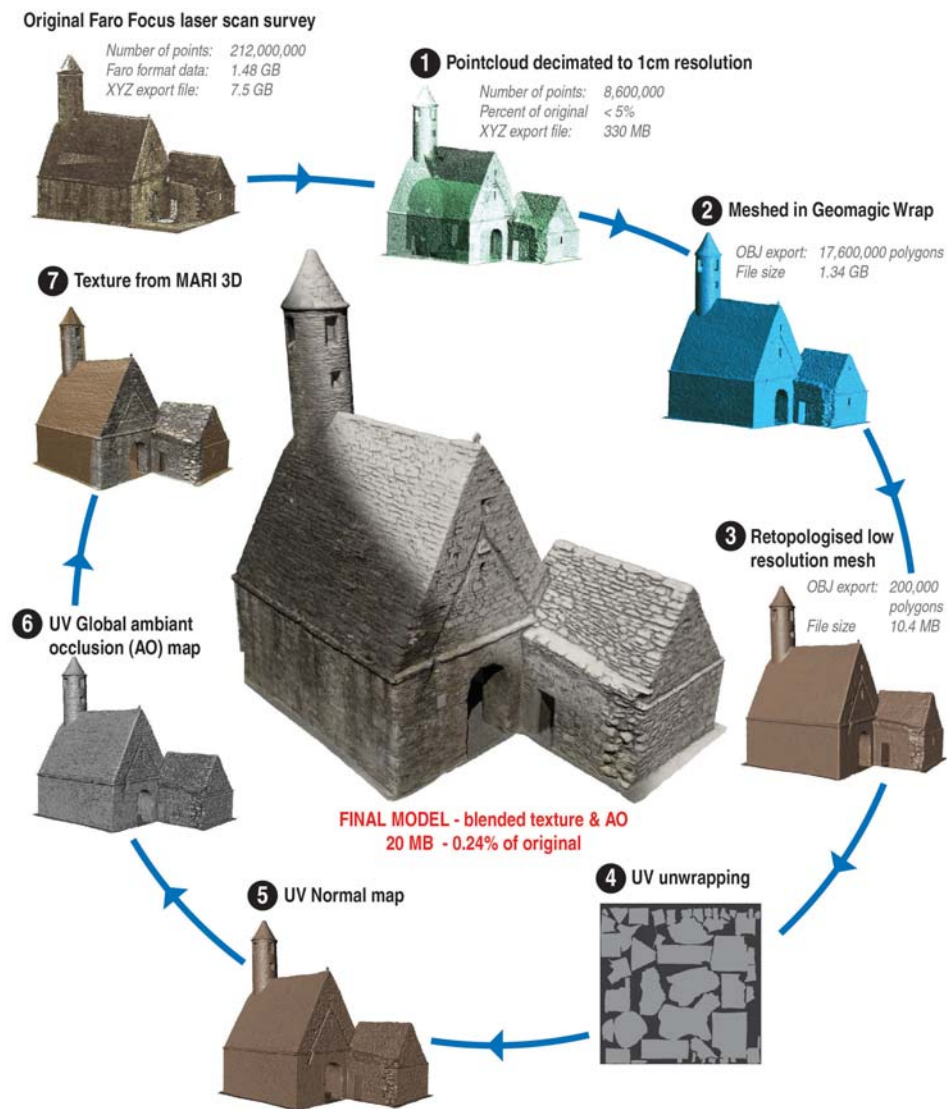


Figure 1. The processing stages to create a lightweight 3D model based on high quality survey data.

Public engagement – Website traffic has fluctuated with spikes reflecting promotion or publicity, but generally at the level of 50 engagements per day through the 3dicons. ie website and varying levels of use of the 3D models directly through Sketchfab, with the most viewed models having an audience of 5000 users.



Figure 2. 3D prints generated by the students in Southeast Missouri State University.

Education – Two separate school's initiatives were brought to our attention where teachers had found the resource and embedded it in their teaching. A Junior Certificate teacher was using the models, information and images to support History lessons, projecting the website onto a screen. Another teacher, the History of Art this time, asked pupils to use the 3D content on the website as inspiration to create their own physical art pieces. Following these *ad hoc* initiatives, our Outreach Officer opened dialogue with teachers' institutions gaining feedback on how 3dicons.ie could be improved or adapted to better fit the curriculum and become a formal teaching resource. During the initial promotion of the project, the models were given the accolade of 'Resource of the Week' by Scoilnet, the Department of Education and Skills (DES) official portal for Irish education.

Recently contact was made with the BBC Research and Education Space (RES) programme to promote access and reuse of the content through linked open data (LOD).

Tourism – The agency managing heritage sites in Ireland, the Office of Public Works (OPW) saw great potential in our 3D models to improve the visitor experience, particularly where public access is limited or restricted. With this in mind, a collaborative pilot project has been initiated with OPW to develop an immersive 3D experience of the great mound at Knowth in the Brú na Bóinne World Heritage Site. Both passages are closed to the public, being too narrow and potentially hazardous to allow access; visitors on tours can only get a tantalising glimpse through locked iron gates. The project aims to recreate the passages in a 3D virtual experience, based on 3D-ICONS data, giving visitors a sense of what it is like to walk and crawl through these remarkable passages to the cruciform chambers.

The content of the project is also being utilised by Fáilte Ireland for their new tourism initiative: Ireland's Ancient East (IAE), which aims to package and brand the cultural heritage of Ireland's east coast as a potential draw to tourists.



Figure 3. Left: Photograph of the Cross of St Patrick and St Columba, Kells. Centre: Top is a photograph of a plastercast mould of a piece of the centre of the cross, below is the reverse engineered 3D model of the mould. Right: 3D model of the original cross.

Commercialisation – The 3D models are also beginning to be seen as an asset with a commercial value from diverse sources. Approaches have been made from a number of companies who have offered to provide a 3D printing service for our models for which a licence fee would be paid per model printed. Further monetisation options have been explored in meetings with the Irish Film Board looking at the value of 3D content in pre-production planning and post-production visual effects.

Conservation science – All the sites and monuments documented by the 3D-ICONS project were surveyed to a high standard, with resolution and accuracy appropriate to the scale of the object. This original data has the potential to be an extremely valuable resource in the maintenance, care and conservation of sites and monuments. Cloud comparison software can not only detect but also quantify even subtle change if sites are re-surveyed in the future.

Academic research – Data gathered primarily for 3D-ICONS has already fed into academic research, being actively used by the Digital Replica Project, a collaborative project with UCD School of Archaeology. A module of this project is planning to use the original full

data gathered for 3D ICONS and compare this with modelled scan data of 19th-century moulds and casts to see what we can learn about the production process and what has happened to the originals and replicas in the intervening years. In addition, several Universities have requested data for postgraduate research projects.

The paper shows how exposing the 3D content can open a wide and varied range of applications, adding huge value to a rich data resource initially gathered as part of a focused European research project. This model of capture once and reuse many times makes the investment in high quality 3D data a more economically attractive proposition.

**The full text of this paper with bibliography is available at
dx.doi.org/10.11141/ia.43.12**

Digital Archaeological Heritage

Edited by Keith May

The Amersfoort Agenda (EAC Occasional Paper No. 10) identifies digital technologies and the expanding phenomenon of online and social media as fundamental aspects of the future of archaeological endeavour. The aim of the 17th EAC Symposium in Brighton in March 2016 was to consider many of the challenges that this agenda raises through an 'observatory' of current digital archaeological practice and emerging or future trends. The unprecedented speed with which digital technologies are developing opens up many new possibilities and challenges for the conduct and presentation of archaeological research and investigation. The digital realm is one which knows few borders and so the sharing of understanding about these new methods, techniques and possibilities across Europe is extremely valuable. The contributions in this volume cover a wide geographical range of European countries from Sweden to Greece and Ireland to Moldova.

The symposium comprised three sessions exploring the digital techniques and related heritage management challenges under three broad topics of 'Measuring and Sensing'; 'Data to Knowledge' and 'Visualizing the Past'. This volume is a collection of extended abstracts for each of the 20 presentations given in Brighton. Given the digital theme, an online volume has been published in Internet Archaeology <http://intarch.ac.uk/journal/issue43/index.html> with open access to a collection of fuller papers which expand further upon these themes.

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