The Archaeological Information System of the Czech Republic – A Big Solution for Big Data

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Drawing on archaeological research going back many years, a vast collection of data on the development of human society has been assembled. In the Czech Republic, information on archaeological fieldwork and sites has been traditionally archived in the form of registers and card files at the archives run by the Institutes of Archaeology of the Czech Academy of Sciences. Although some data is still being archived in this way, the prevalence of digital content has completely transformed the way in which information is now organised and stored. The paper reports on a solution that has been chosen to comprehensively address this technological shift, mining nearly 30 years of collective experience in managing digital content (text documents, photographs, maps, plans) and overseeing administration and archiving systems. Great attention was paid to finding a technical solution that would align its data model and workflow to suit the nature of archaeological fieldwork practice. At the same time, priority was given to creating an infrastructure that would meet the needs of users while integrating professional and public interests. What follows is a report on the practical measures the Archaeological Information System of the Czech Republic has taken over the past 2 years and outlines future plans of applying big data to contemporary research.

Key words:
Digital Humanities, Research Infrastructures, Digital Culture Heritage, Archiving, Archaeological Information System.

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ARCHAEOLOGICAL ARCHIVING AND ITS ROLE IN RESEARCH INFRASTRUCTURE DEVELOPMENT – A BRIEF HISTORY

The beginning of centralised archaeological archiving in the Czech Republic coincided with the institutionalisation of the field in 1919 and the founding of the "State Institute of Archaeology" (SIA) in Prague. Since 1920, it has served both as a central repository for information on archaeological excavations and as a specialist archive department. In 1942, an independent branch of the SIA was established in Brno (later becoming a separate institute in 1970), leading to the creation of two national institutes for the archiving of archaeological fieldwork in the Czech Republic. Each adopting its own separate agendas, the Institute of Archaeology in Prague oversees information on the Bohemian region, while its counterpart in Brno curates data on the Moravian and Moravian-Silesian regions. Now, roughly seventy years later, it has become possible – aided by the advance in new technologies – to re-merge both archives at a 'virtual' level, and to share and publish the nation's archaeological heritage in a coherent way for the benefit of all users.

BUILDING A RESEARCH E-INFRASTRUCTURE – THE CURRENT STATE OF PLAY

The archives of the Archaeological Institutes of the Czech "Academy of Sciences in Brno" (IAB) and Prague (IAP) – together with various specialised libraries and museum archives – form the primary basis for archaeological

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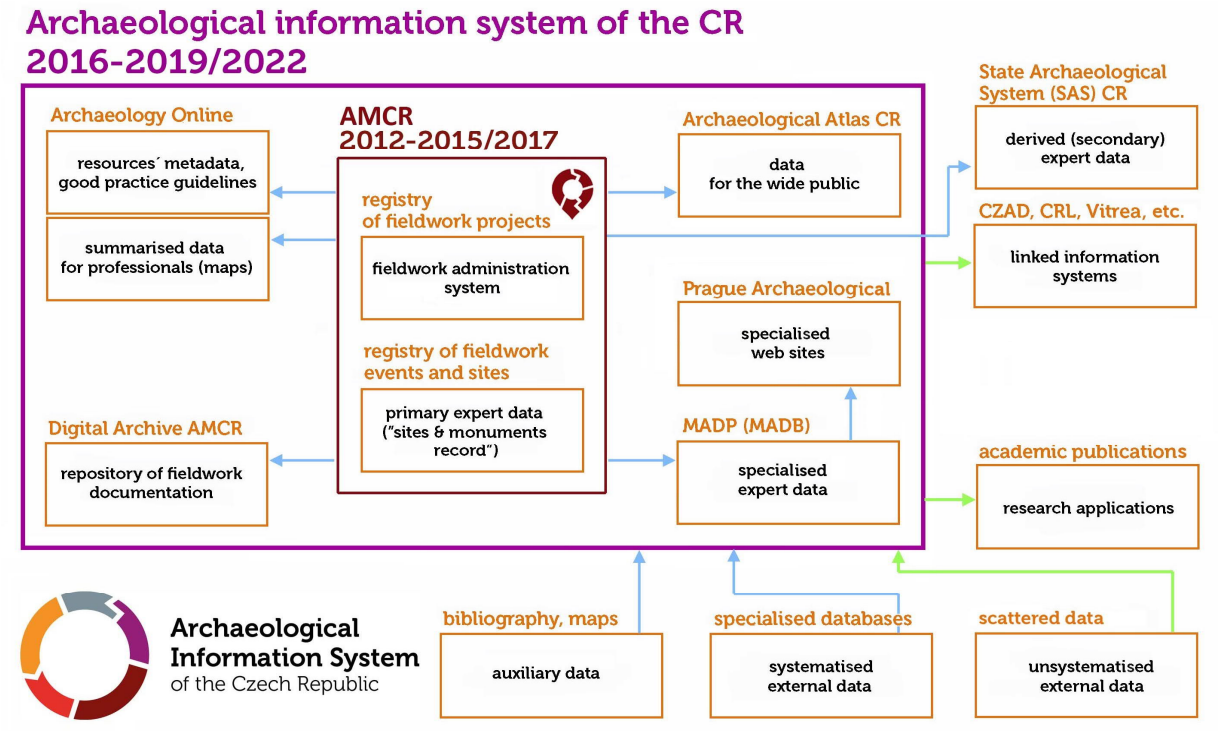

Fig. 1. Scheme showing the interconnection of individual AIS CR applications and data sources (designed by Martin Kuna and David Novák, 2019)

research in the CR. These combined resources are as invaluable to researchers, students and academics as they are to the general public.

Digital archiving of archaeological fieldwork first began in 1989 with the foundation of the *"Archaeological Database of Bohemia"* (ADB), an offline database created by IAP. Even now, with their more sophisticated information system, the ADB's metadata structure and vocabularies have been continuously used as the basis for structuring data registers. In 2002, the IAP launched its *Digital Archive*, the first ever online platform dedicated to managing and accessing archaeological data in the "Czech Republic" (CR); another online platform – *Internet Database of Archaeological Fieldwork* – followed in 2009. A year later, an information system *Digital Archive and Archaeological Fieldwork Evidence of Moravia and Silesia* was introduced by IAB. In 2012, the IAP initiated the project *"Archaeological Map of the Czech Republic"* (AMCR), which resulted in the introduction of the AMCR application in June 2017. Designed as an information gateway for archaeological fieldwork and finds, the AMCR integrates the functions of all the above information systems and platforms. The formation of the AMCR was of significant importance in that it managed to synchronise systems and data on a state-wide level (see further [Kuna 2015]). Nevertheless, it was essential to build on that achievement by creating a framework platform that would integrate all digital resources on Czech archaeology to serve professionals and the general public. Realising that goal required the implementation of a comprehensive and long-term strategy. To that end, in 2015, the *"Archaeological Information System of the Czech Republic"* (AIS CR)[1] was successfully established as an overarching infrastructure project – comprising the incomplete AMCR and other systems in development at the time – and incorporated within *The Roadmap of Large Infrastructures for Research, Experimental Development and Innovations in the Czech Republic for the Years 2016-2022*.[2]

[1] http://www.aiscr.cz/
[2] https://www.vyzkumne-infrastruktury.cz/en/strategy/

THE ARCHAEOLOGICAL INFORMATION SYSTEM OF THE CZECH REPUBLIC – STRUCTURE AND FUNCTIONS

The AIS CR combines a central database with a number of linked application interfaces that serve various purposes and users – the *Archaeological Map of the Czech Republic*, the *Digital Archive of the AMCR*, the *Archaeological Atlas of the Czech Republic*, *Prague Archaeological* and *Archaeology Online* (Fig. 1).

With its modular yet interconnected solution, the AIS CR fulfils multiple purposes: (1) it makes archaeological fieldwork available to the archaeological community and distributes it among licensed organisations; (2) it operates a systematic register for fieldwork results and provides a main source of data, a record of sites and monuments on archaeological heritage care; (3) it boasts a secure long-term central repository of documentation on archaeological fieldwork; (4) it pools, presents and circulates archaeological data and research results for the benefit of professionals and the general public; and finally (5) integrates digital humanities tools as part of archaeological practice.

The **Archaeological Map of the Czech Republic (AMCR)**[3] constitutes the backbone of the AIS CR. It serves two main purposes: Firstly, it operates as an administrative information system for recording ongoing fieldwork activities and ensures that information on archaeological excavations are accessible by organisations licensed to carry out such excavations. Secondly, it collects, saves and shares data on fieldwork results from the 19th century onwards, which effectively amounts to a national archaeological database of all recorded sites and monuments. The AMCR data model and workflow are based on the division of archaeological fieldwork into the following four phases: (1) formulating professional goals and performing spatial planning; (2) conducting fieldwork; (3) carrying out functional and chronological analysis of archaeological excavations; (4) synthesising and interpreting data.

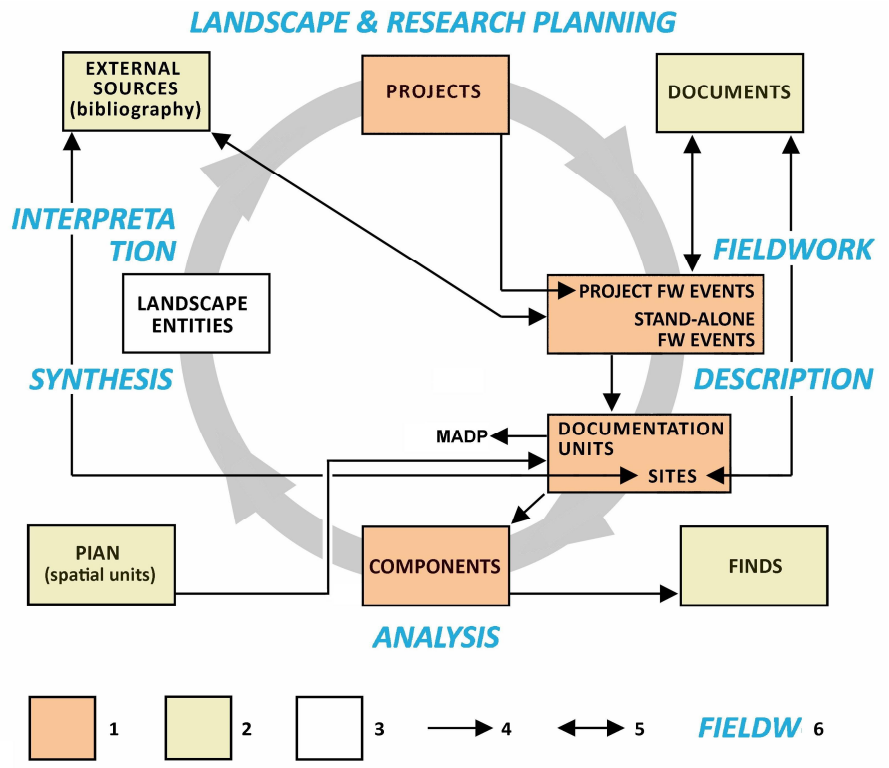

Fig. 2. AMCR workflow based on the archaeological fieldwork model: (1) main categories – data classes; (2) referential data classes; (3) future development categories; (4) 1:N relations; (5) M:N relations; and (6) phases of archaeological fieldwork (designed by Martin Kuna, 2017)

[3] http://www.archeologickamapa.cz/

These phases correspond to respective record categories within the AMCR: (A) *projects* (field interventions of any kind); (B) *fieldwork events* (archaeological field activities and research); (C) *sites* (arbitrary sections of the landscape containing acknowledged archaeological features interpreted as a single site or activity area), *documentation units* (spatial sections of fieldwork events) and *components* (specific areas of previous activity categorised based on historic period); and (D) *landscape entities* (spatially, chronologically and functionally coherent sections of the original landscape). The form and content of these categories are further supplemented by the following groups of data: (E) *finds* (lists of keywords for groups of identified finds); (F) *spatial units* (geospatial features – points, lines and polygons – with differentiated accuracy of delimitation); (G) *documents* (primary and secondary fieldwork documentation); (H) *archaeological documentation points* (a metadata extension to the documentation units); and (I) *external information sources* (bibliographic records) (see further [Kuna et al. 2015]) (Fig. 2).

The case below illustrates the process of registering data in the AMCR (with all important AMCR terms **highlighted**):

> *A single pottery sherd is found by an amateur historian at an as-yet unresearched hillfort previously identified by written sources. A **standalone "fieldwork" (FW) event** is then registered along with this prehistoric **component** of unknown activity, including the pottery sherd **(find)**. As the historian is not sure about the specific location of the find, the **documentation unit** of the FW event is spatially identified using a polygon **(spatial unit)** representing the whole hillfort **(site)**. The polygon of the hillfort is created using both the available LiDAR image and the historic plan of the location, with the **site** represented by basic metadata. To better understand the hillfort, researchers then proceed with a systematic survey incorporating geophysics, an aerial survey and field collections. This results in the registration of another **standalone FW event**, spatially delimited as the precise polygon under investigation. During the fieldwork, the researchers identified Neolithic funeral and Bronze Age settlement **components** (with unknown links to the hillfort) as well as a La Tène-period gate within the wall of the site. According to these new findings, information on the **site** is updated and a new **bibliography** added. Particular emphasis is placed on registering aerial images, including metadata on individual **flight** conditions and the types of features **(shapes)** identified (see [Gojda and Čulíková 2015]). A few years later, a developer announces his intention (via the AMCR webform) of building a house (of basic infrastructure, network connections, etc.) at a location that partly intersects the area of the hillfort. This information is verified by the IAP/IAB and made available as a project within the AMCR. Next, a licensed archaeological organisation **registers** the project and concludes an agreement with the developer to carry out a rescue excavation. The start-date is registered in the AMCR. As the hillfort is already a **listed monument**, the project record is automatically passed to the National Heritage Institute for its own processing. After finishing the excavation, the **FW event** is connected to the project, which lists all identified **components** and a selection of the most significant **finds** as metadata. These are accordingly connected to separate **documentation units**, representing (1) the total excavation area under the house (a polygonal **spatial unit**), (2) a cut for a 1500 m-long electricity cable with negative evidence (linear **spatial unit**) and (3) a single prehistoric pit identified as the location for a planned wine cellar (point **spatial unit**). Within several months, all primary data are summarised in the excavation report and uploaded as one or more PDF **files** forming a **document** along with, in some cases, a selection of photographs, plans and other data described by metadata. After validation, data are archived and made available through the **Digital Archive of the AMCR**. In all of the above cases, **documentation units** may be enhanced by adding data on specific trenches recorded as **archaeological documentation points.***

The system combines data from multiple sources with various types of research, all of which can be subsequently re-used for purposes of research or presentation. All event-based evidence (the fieldwork register) cannot be modified, with each piece of information compiled and saved after each field activity. Site-based evidence, on the other hand, is periodically re-evaluated and updated to reflect the current state of knowledge on specific types of site crucial for further research. Both categories of evidence are primarily interconnected on a spatial basis, complementing each other to create a coherent picture of the historic landscape. Equally important is the ability of the AMCR to oversee administrative processes concerning field activities conducted by licensed organisations and the direct exchange of data with the National Heritage Institute. This multi-data supplier principle influenced the establishment of the AMCR as a system founded on community-based crowdsourcing. Only through consolidating all potential data sources and widespread collaboration can benefit be brought to the wider professional community in service of the common public interest. Similarly, only with a well-informed public can the true value of our archaeological

heritage be fully appreciated, and most importantly, safeguarded. Assisted by new technologies, it has become much easier for the AIS CR to promote and share the aspects of the cultural heritage that fall within its remit.

Accordingly, the provision of Open Access and Open Data is integral to the AIS CR concept. In the Czech context, the publication of archaeological data is limited by the Copyright Act. However, this restriction was recently overcome following a consensus reached between the IAP, IAB and individual data providers on the sharing of metadata and documents. The specific agreements made between the institutions took effect in January 2019, with the archives becoming available under the Creative Commons license (CC-BY-NC 4.0). More than 80% of the available data is already covered by the new licence agreements, with accessibility to the remainder under negotiation.

The AMCR also serves as a repository for digital documents shared using an interface of the **Digital Archive of the AMCR**.[4] Consisting of a web application designed for browsing digital documents archived by the IAB and IAP, the e-archive contains text documents (excavation reports, expert reports), photographs, aerial photographs, maps, plans and other digital data. The plan is to extend its reach as much as possible through the expected introduction of a 3D data library and a register of individual metal detector finds. Not only is the Digital Archive interconnected with the AMCR – from which it indexes data on a daily basis – at a data and user-account level, it also offers unique features such as advanced search tools and options for browsing documents' content. To make browsing data more user-friendly and attractive, the following features are planned to be implemented in the near future: various thematically focused layers (medieval castles, hillforts, burial mounds), rich analytic and harvesting tools, API services and CIDOC-CRM-based endpoints for Linked Open Data.

The AMCR and Digital Archive incorporate five user roles, each assigned different access rights. User rights are cumulative, with each higher role encompassing all lower role rights in addition to higher user-level privileges:

1) *Anonymous*: allows users to browse selected documents and explore and export metadata without the need to register.
2) *Researcher*: tailored to the general scientific community; in addition to anonymous privileges, the researcher can insert data for stand-alone fieldwork events and browse most of the documentation.
3) *Archaeologist*: intended for members of licensed archaeological organisations that need to manage their projects or submit excavation reports and/or other documents.
4) *Archivist*: staff of the IAB/IAP archives authorised to facilitate the monitoring, evaluation and archiving of records.
5) *Administrator*: ICT specialists responsible for batch imports and exports, erasing data, user accounts and glossary management.

Bringing the nation's archaeological heritage closer to the public is the main purpose of the **Archaeological Atlas of the Czech Republic**.[5] Featuring 205 of the best-preserved examples of archaeological sites in the CR (ranging in wide chronological scope from prehistory to the 20th century), the application gives users the opportunity to visualise sites as contextualised points in the general landscape. Visitors to the application are guided through sites of interest, all complemented by brief descriptions (in Czech and in English) and a downloadable file detailing geographic coordinates, photographs, maps and plans. (Fig 3). Since its launch in 2015, the website has been visited by more than 47 000 individual users worldwide.

The web portal **Archaeology Online**[6] is at present a peripheral part of the AIS CR, but is set to be prioritised. It is a gateway presenting digital information sources related to the study of the historic Czech landscape and Czech archaeology. The content is divided into three parts – *Maps, Sources* and *Practice*. The *Sources* section allows users to navigate metadata on existing infrastructures, record-keeping systems and tools as well as web portals. The *Maps* section allows users to search for, and visualise, sample data from selected information sources via simple search criteria such as the type of site, activity and chronology represented as a timeline featuring two sliders. The map allows users to browse data integrated in a single view, either on a small scale as a density raster or on a larger scale as single points with a basic description and a link to the original dataset (Fig. 4). The *Practice* section contains forms, guidelines and best practices for fieldwork, which are all available for download.

[4] http://digiarchiv.amapa.cz/
[5] http://www.archeologickyatlas.cz/en
[6] http://www.archeologieonline.cz/

Prague Archaeological[7] is another web portal incorporated into the AIS CR. Featuring the Map of Archaeological Documentation Points (MADP), the portal is an example of how a central infrastructure can dovetail with an individual project, which, in this case, specialises in datasets on a historically built environment. It provides access

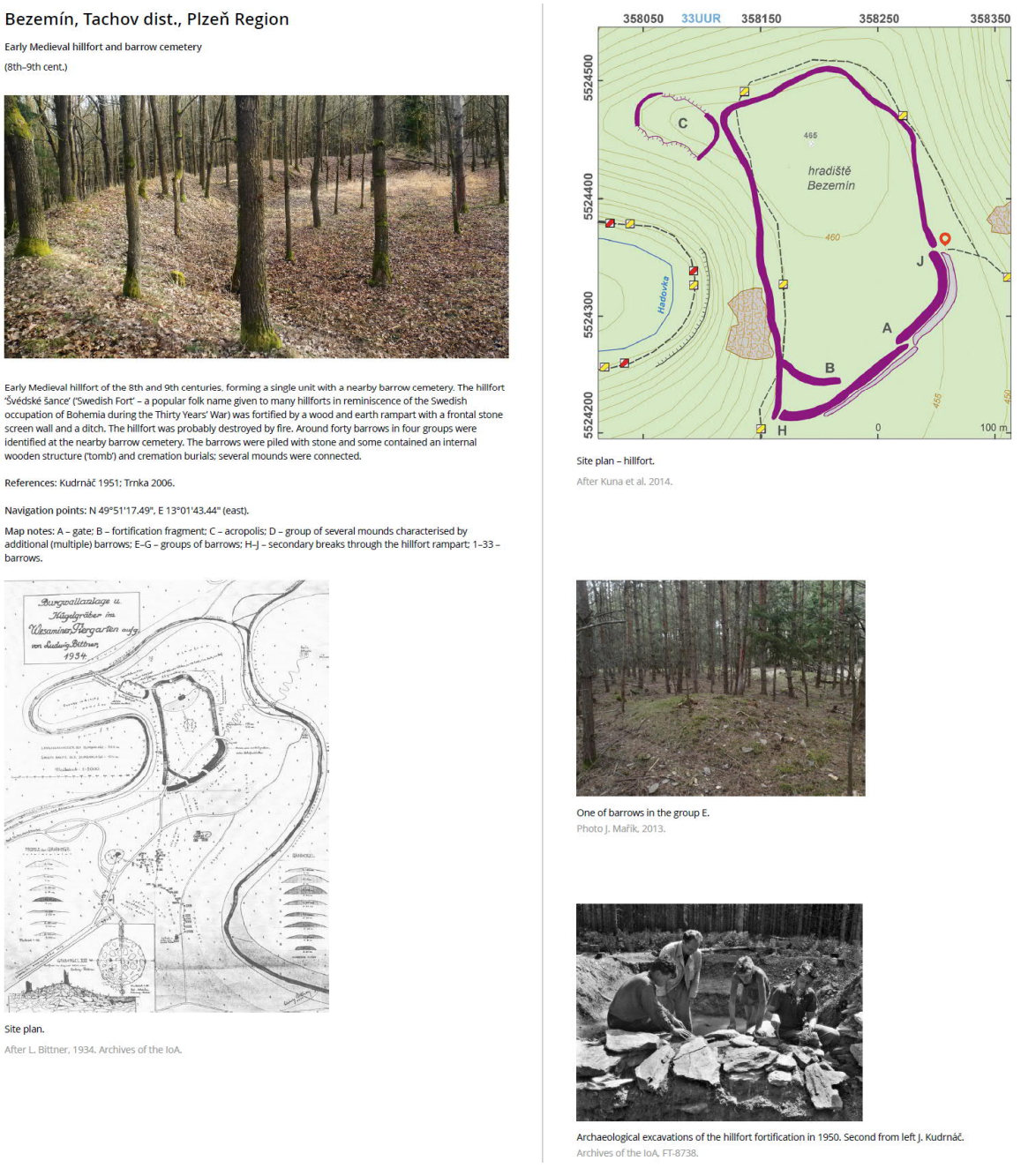

Fig. 3. Downloadable site overview from the Archaeological Atlas of the Czech Republic for the site of Bezemín (Tachov district), featuring an Early Medieval hillfort and barrow cemetery[8]

[7] http://www.praha-archeologicka.cz/
[8] Retrieved February 15, 2019 from: http://www.archeologickyatlas.cz/en/lokace/bezemin_tc_hradiste

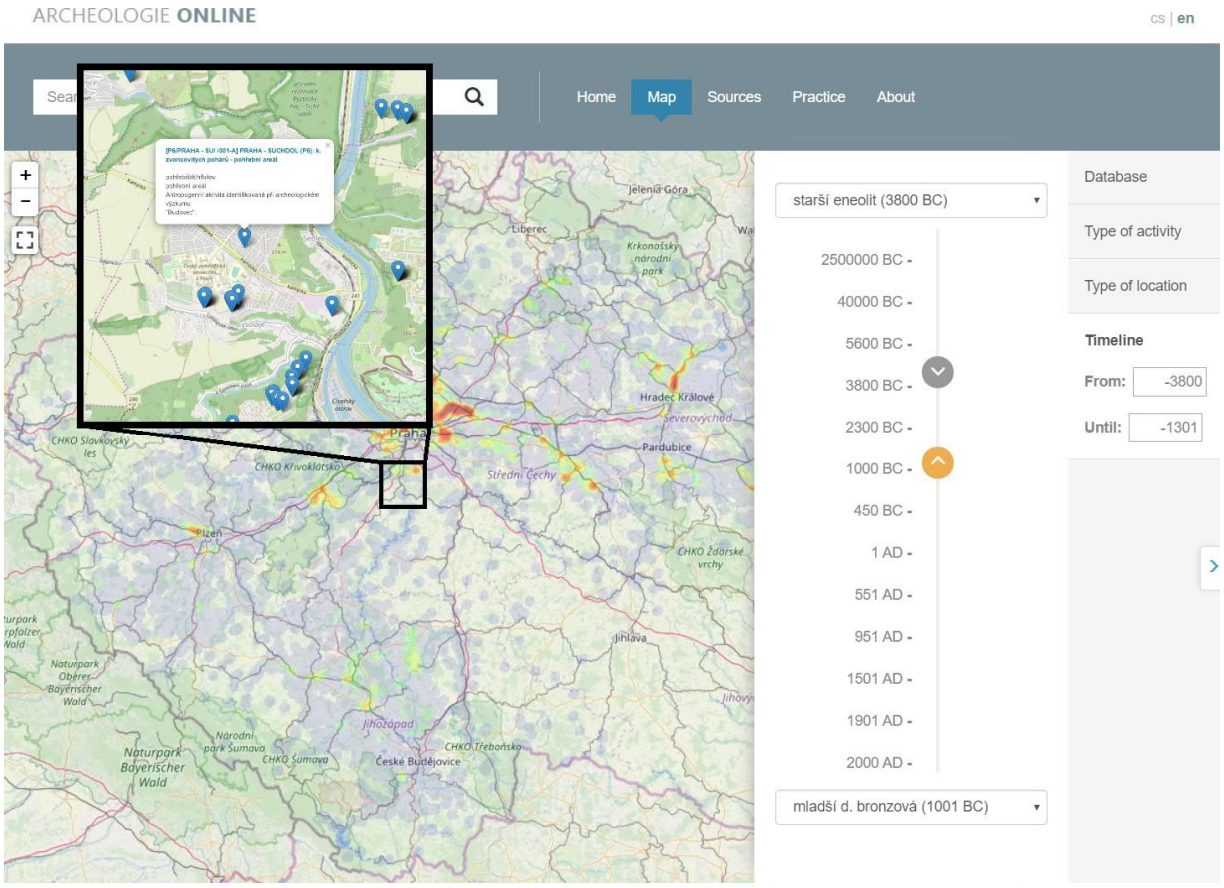

Fig. 4. Portal Archaeology Online – map view showing data as (1) a density map and as (2) specific points with basic descriptions. The map also features basic filtering, including an interactive timescale

to archaeological information on Prague for professionals and the general public (including tourists). Users can take a virtual tour of the Prague underground and follow in the footsteps of those who helped shape the city's history. It enhances AMCR data with its own MADP dataset and presents it together with data collected by other institutions, particularly the National Heritage Institute, through a common map interface. The MADP database is based on an original dataset (assembled by Ladislav Hrdlička), which underwent detailed revisions as part of a grant project completed in 2017 (see [Boháčová et al. 2015]). Ongoing developments to the portal involve optimising the user interface, adding English translations, updating data and introducing several new features.

TECHNICAL FRAMEWORK

The AIS CR's main servers, disk arrays and supplementary network components are located within the IAP's premises in Prague. The solution involves the deployment of development, testing and production environments, backup facilities (including an offline tape storage system) and an off-site backup storage system in Kutná Hora. The main server room is equipped with a fire-resistant door and a security monitoring system. IAB operates its own server in Brno as a storage system for primary digitisation outputs. It also plans on introducing a new off-site backup offering better connectivity to the Prague facilities. The ongoing upgrade of all HW equipment consists of reconstructing the Prague server room as well as installing new servers, disk arrays and a high-quality switch for operating prospective network traffic.

The AMCR server is built on a PHP platform, with all metadata permanently stored in the PostgreSQL database; the PostGIS extension is used to store associated spatial data. The web server is used to manage the database, features a

back-end interface allowing bulk imports and exports as well as APIs for data exchange, and provides supplementary front-end services such as user registration. The AMCR desktop client handles data content, while communication with client applications is mainly operated via XML-RPC protocol. A data repository forms a discrete system-module built on a separate server, which operates the supplementary MySQL database. It is connected to client applications via FTP protocol (AMCR) or directly via a filesystem (Digital Archive). The system architecture syncs with interfaces that use different technologies and software providers while maintaining access to identical data. The AMCR client is built on the Java platform (currently being re-implemented as a web application using Django), the Digital Archive uses the Apache Tomcat/Apache Lucene SOLR platforms and the Prague-Archaelogical interface runs on Apache 2 and Leaflet. Since 2016, all new applications are developed as Open Source (GNU-GPL 3.0 licence) and shared on the GitHub platform.[9]

WHERE WE ARE NOW AND WHERE WE ARE HEADED

The AIS CR is the result of a long-standing vision within the archaeological community of creating a single infrastructure that harmonises the collective experience and expertise of archivists at the Institutes of Archaeology of the CAS. The comprehensive framework put in place has helped to promote coherence and synergy at a state-wide level in the areas of data management, data provision and archaeological research (Fig. 5). The AIS CR has been developing its services across several thematic areas, namely (1) ensuring a proper technical framework, (2) providing comprehensive and high-quality data content, (3) encouraging collaboration within the community; (4) disseminating information on archaeological activities and (5) conducting its own in-house research.

Although the technical framework in place is sufficient, it still stands to benefit from some important upgrades. The modernisation plan envisaged involves securing hardware infrastructure as well as implementing measures for software development, such as completing the existing software interface and providing a web client for the AMCR (currently running as a desktop-based client).

While the AIS CR acquires and processes new data, it also recovers and protects data on previous archaeological excavations and archived research. This data would be scattered or irretrievably lost without the existence of an efficient central storage system. The digitising and indexing of the IAB archive continues together with an in-depth review of the data stored at both institutes. The plan for developing data content at the AIS CR for the coming years involves completing the database of archaeological fieldwork events, further enhancing a database of gradually assembled archaeological sites (reflecting individual types such as castles, hillforts, deserted villages, burial mounds, etc.), processing data from geophysical surveys, expanding data from aerial archaeology, and linking the database of archaeological events with other expert data. Prospective research applications are expected to operate from a planned Linked Open Data/CIDOC-CRM-based interface in order to reconstruct historic landscapes and integrate AMCR data as interpretable landscape entities. These features will allow users to integrate archaeological data with historical evidence and other resources, generating dynamic models of the Czech landscape (see [Novák et al. 2015, 224]). The scope of the infrastructure is being further extended thanks to a number of ongoing national, international and multidisciplinary projects (SEADDA,[10] Archiv-Net,[11] Archaeology from the Sky,[12] INDIHU,[13] etc.). The AIS CR uses Open Data principles and open-source solutions to support the compatibility and accessibility of the information and services it provides domestically, while strengthening its existing international ties with European research infrastructures like ARIADNE (Advanced Research Infrastructure for Archaeological Data Networking in Europe)[14] and the E-RIHS (European Digital Infrastructure for Heritage Science).[15]

Although the AIS CR solution is based on combining one central database with several linked application interfaces, they are only tools. In other words, they have no meaning without the users that avail of them. A series of training workshops was organised for archaeologists, particularly users of the AMCR, to assist in the process of entering

[9] https://github.com/ARUP-CAS
[10] https://www.cost.eu/actions/CA18128/
[11] http://www.archaeologie.sachsen.de/6723.htm
[12] http://www.arup.cas.cz/?p=30489&lang=en
[13] https://indihu.cz/
[14] https://ariadne-infrastructure.eu/
[15] http://www.e-rihs.eu/

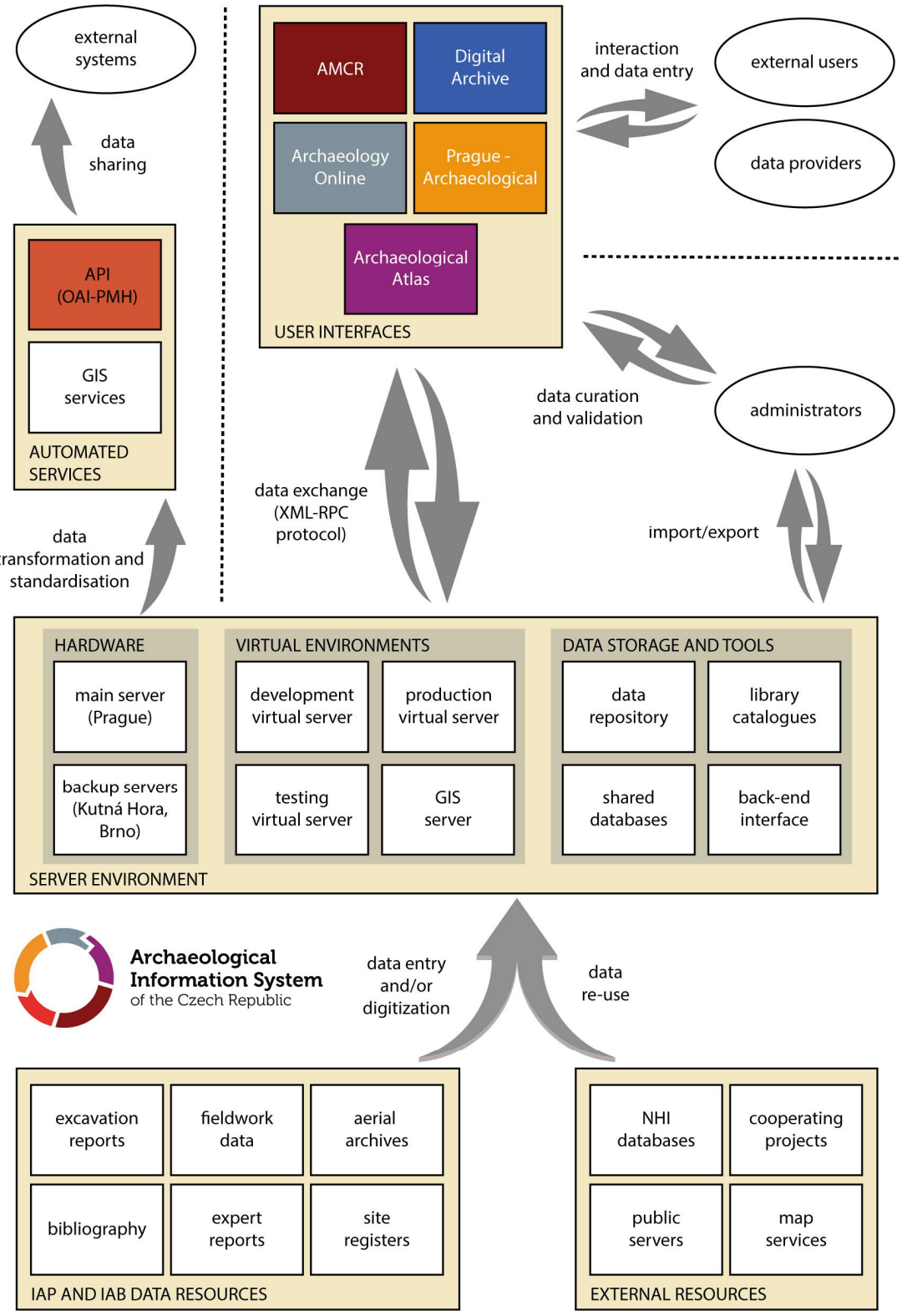

Fig. 5. Visualisation of the AIS CR infrastructure (designed by David Novák, 2019)

current data into the database. The existence of branch infrastructure, which relies on diverse sources of information being shared, is essential for driving further development in the field.

The AIS CR has made steps to enhance its administrative workflow with regard to communication between investors and heritage care and archive departments. Thanks to the introduction of the online form – "Notice of intention to start construction in a territory containing archaeological finds" (obligatory under Act No. 20/1987 Coll. on State Monument Care) – an investor can now submit relevant details, which are then automatically redirected to the AMCR for approval. Once approved by an AMCR administrator (staff of the heritage care department), it becomes a *project* that waits then to be registered by a relevant organisation authorised to carry out the necessary excavations. This is just one example of how the AMCR's virtual environment is able to deliver a streamlined technical solution, which not only simplifies the entire administrative process (dispensing with the need for the investor to download and fill in a form and send by post, while minimising delays resulting from administrator requests to resubmit material) but also helps foster cooperation between developers, companies, investors and administrators of the nation's cultural heritage.

Far from being a system designed exclusively for professional use, the AIS CR is committed to ensuring that information on the nation's cultural heritage is accessible to the public, the effects of which support local tourism and help spatial planning. By providing its users with up-to-date and accurate data on the nation's historical landscape, the AIS CR participates in promoting a positive and proactive approach to the dissemination of cultural information.

With the emergence of e-infrastructures able to handle structured 'big data' and the development of new research tools for their analysis and modelling, the complex research questions that have typically resisted explanation are now easier to answer. The research potential of the AIS CR data has already been documented in a few case studies [Dreslerová 2011; Dreslerová and Demján 2015; Kolář et al. 2015; Demján and Dreslerová 2016], while other studies and projects, particularly those on structural and long-term trends in the development of settlements and the reconstruction of historical landscapes, are underway.

CONCLUSION

Establishing any infrastructure necessitates creating as many structures and platforms as there are activities to support. The construction of a physical public infrastructure, for example, involves attending as much to transport and technical logistics as it does meeting the needs of public services and utilities. Similarly, the potential of a research infrastructure such as the AIS CR – which integrates virtual structures under a unified framework and which offers a comprehensive base for specialist activities – can only be unlocked if it benefits the people who use it. By managing the structures and data that make up the AIS CR virtual research environment, by training users in its correct operation, and by promoting its attractiveness and potential, the AIS CR has taken the first steps on its exciting journey of development. It is hoped that it will continue to provide a nurturing environment for a thriving community for many years to come. With the integration of digital technologies, 'big archaeological data' has become a reality. However, it can only be fully appreciated by society when presented – with the help of specialist expertise – in an easily understandable form.

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