OREA 16

Old Excavation Data

What Can We Do?

Proceedings of the Workshop held at the 10th ICAANE in Vienna, April 2016

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Austrian Academy of Sciences Press

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Picture on the opposite page:
Scanning fielddrawings for the digital Tell el-Daba (Egypt) documentation archive
(photo: Tina Simon 2016; modified by Seta Štuhec 2020).

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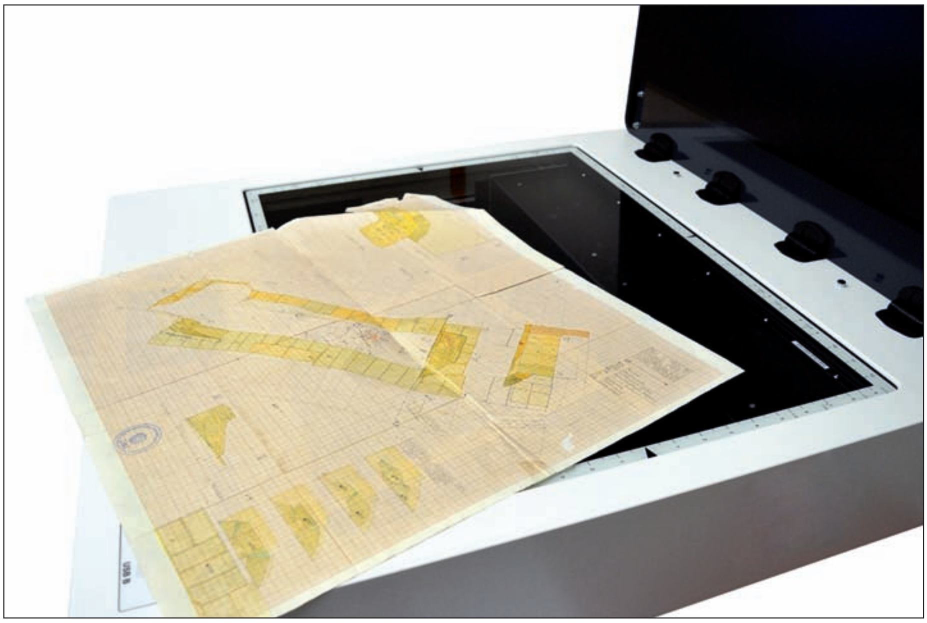

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Preface by the Series Editor

The 16th volume of the OREA series 'Old Excavation Data. What Can We Do?' represents the outcome of a workshop organised by Edeltraud Aspöck, Seta Štuhec, Karin Kopetzky and Matthias Kucera, held on 25th of April 2016 at the International Congress on the Archaeology of the Ancient Near East (ICAANE). The 10th anniversary conference of the ICAANE took place from 25th to 29th of April in Vienna and was hosted and organised by the Institute for Oriental and European Archaeology (OREA) at the Austrian Academy of Sciences. Altogether 800 participants from 38 different countries found their way to Vienna to celebrate the 10th anniversary of ICAANE with eight scientific sections, 28 workshops, round tables, a huge poster exhibition and a special section about 'Cultural Heritage under Threat'.

The editors of this volume used the opportunity to gather experts in Near Eastern field archaeology to raise the question many of us are currently confronted with: What can we do with old excavated data? Edeltraud Aspöck, Seta Štuhec, Karin Kopetzky and Matthias Kucera initiated and organised a workshop focusing on our current challenges in dealing with long-term excavations and the heterogeneous nature of their documentation data. After about two centuries of producing all kinds of archaeological data in analogue and digital formats, the current problems in their long-term storage, archiving and their future accessibility are indisputable. The organisers drew on their own experience working on our project 'A Puzzle in 4D', developed to create a repository for the Tell el'Daba excavations started in 1966. The archive materials of these important long-term excavations in the Nile delta hosted at the OREA institute, represent a characteristic assemblage by means of heterogeneity, quantity and changing practices in documenting archaeological fieldwork. The editors own contribution in this volume demonstrate ways for handling some of the problems, as well as in using the old data to create new and innovative approaches. Finally, Edeltraud Aspöck, Karin Kopetzky, Gerald Hiebel and Matej Ďurčo managed to establish a new framework and workflow procedure for integrating the old Tell el'Daba data into a state-of-the-art repository at the Austrian Academy of Sciences. It remains as the host institution's task to secure the future funding for continuing the long-term digitalisation and data integration into the new Tell el'Daba digital archive.

The editors successfully managed to bring together five different case studies from various Near Eastern regions through six different contributions. They perfectly demonstrate the high degree of variation in dealing with old excavation data by showing different ways in structuring and archiving them, as well as in making them available for the community. However, the very productive discussions during the workshop and the collected papers illustrate the spectrum of potential systems and concepts on the one hand, and the already established standards in data management on the other. Therefore, the present volume does not only offer archaeologists already established and useful data management systems for old excavated data, but also some essential advice for future expeditions in the field. I warmly thank the authors for sharing their expertise and perspectives about the current challenges in dealing with these important sources of cultural heritage, and to Edeltraud Aspöck, Seta Štuhec, Karin Kopetzky and Matthias Kucera for editing the 16th OREA volume.

My sincere thanks for financial support for the 10th ICAANE conference go to several Austrian and international institutions which are the following: The Austrian Federal Ministry of Europe, Integration and Foreign Affairs, the University of Vienna, the City of Vienna, the Vienna Science and Technology Fund (WWTF), the Institute for Aegean Prehistory (INSTAP), the Austrian Orient Society Hammer-Purgstall and the Austrian Academy of Sciences. I would

like to thank Ulrike Schuh for the coordination and editing, Nathan Peld for language editing, Angela Schwab for the layout and the Austrian Academy of Sciences Press for supporting the publications of the 10th ICAANE workshops in the OREA series.

Barbara Horejs
Director of the Institute for Oriental and European Archaeology
Vienna, 13 June 2020

Old Excavation Data – What Can We Do? An Introduction

Edeltraud Aspöck[1]

Archaeological fieldwork is at the heart of the archaeological discipline. An enormous number of excavation projects was carried out over time, steadily increasing our knowledge about the past and producing large archives of documentation. Through new developments in information technology many analogue documentation techniques are now carried out digitally, adding new challenges of long-term preservation. However, digital technologies also present new opportunities when it comes to sharing and disseminating resources from fieldwork archives for re-use.

This book is about the digital integration of resources from archaeological fieldwork projects in the Eastern Mediterranean region and Near Eastern countries. It includes projects that integrate fieldwork resources for providing open data for reuse in new projects,[2] a case study about integration of excavation resources in a GIS for advanced spatio-temporal analysis[3] and the presentation of software solutions for integration of excavation legacy data for analysis, sharing and long-term preservation.[4]

All papers share a concern with the heterogeneity of resources from archaeological fieldwork, and they present different strategies to overcome this challenge. Frequently discussed topics are the specific idiosyncrasies of excavation data facing a digitisation project as well as issues around data modelling and levels of data integration.

With the casual wording 'old excavation data' for the workshop and book title, we refer to all types of resources from previous archaeological fieldwork campaigns, both digital and analogue. Such resources may typically be recording sheets, photos, maps, field diaries and drawings. These can also be referred to as 'legacy data'. Legacy data depends on an outdated piece of software or operating system and often lacks documentation.[5] These data are therefore difficult to access. With archaeological fieldwork being increasingly carried out digitally,[6] it is important to consider that software and formats may be short-lived, and standards of good practice in data management must be observed to guarantee long-term preservation of digital resources.[7]

Because legacy data is present in obsolete formats, the term is sometimes used in a derogatory way; however, this is not the way we see it. When it comes to data from archaeological fieldwork, we deal with important information about our cultural heritage, which because of the destructive nature of excavation in many instances may be irreplaceable. In Near Eastern/Eastern Mediterranean archaeology, where almost two centuries of excavations have produced an abundance of data from thousands of sites over a wide chronological range, it is imperative to take measures for their preservation.

1 Austrian Academy of Sciences, Institute for Oriental and European Archaeology, edeltraud.aspoeck@oeaw.ac.at.
2 Helgestad, this volume; Aspöck et al., this volume.
3 Kucera et al., this volume.
4 Frey, this volume; Prosser – Schloen, this volume.
5 E.g. Schmidt – Bennöhr 2008, 109.
6 E.g. Averett et al. 2016.
7 E.g. IANUS; ADS.

Why We Organised a Workshop on Old Excavation Data

This volume is based on a workshop titled 'Old Excavation Data – What Can We Do?' held on 28th April 2016 at the 10th International Congress on the Archaeology of the Ancient Near East (ICAANE) in Vienna. The idea for the workshop came about as part of our work on the 'A Puzzle in 4D' project, which aims to digitise the resources from the Austrian long-term excavation project at Tell el-Daba, Egypt to make them available online with open access. At the beginning of the project, we analysed Tell el-Daba analogue and digital resources, as well as the excavation and documentation methodology, to find an approach to structure the archive and organise the digitisation process. We faced many questions: How should we organise the data, which standards are in use and which are the most sensible to use? How should we organise the digitisation process of a vast number of analogue resources, including some complicated and deteriorating materials such as colour film negatives? The high number of analogue resources prevents us from digitising all analogue resources during the current project, but which are the relevant criteria for selection of materials? Which software solutions exist for collecting metadata, or information about the digital objects? Which are the most appropriate for our project, and do we need to turn to a proprietary solution? Can we find open source software or should we create our own solution specifically tailored to the needs of the Tell el-Daba material?

These were the most important questions we faced, which did not seem specific to the 'A Puzzle in 4D Project', but any project dealing with digitisation and preservation of resources from long-term excavation projects. Answers to questions of such a practical nature often do not find their way into publications, however, and whilst guides of good practice in digital archaeology address many issues related to best practices of data management, in particular in relation to long-term preservation of digital data, many of the questions raised were very specific to our project and not discussed in these guides. Online research of similar projects suggested that so far each project team had found their own solutions. Hence, with ICAANE arriving, we found the perfect occasion to invite researchers who have worked on similar projects to discuss problems and solutions to digitally integrate, preserve and publish excavation legacy data from sites across the Near

Fig. 1 Photo taken during the ICAANE workshop Old Excavation Data – What Can We Do? on 28th April 2016 (photo: A Puzzle in 4D 2016)

East for reuse by future generations of archaeologists. That we were dealing with a pressing issue was clearly demonstrated by very good attendance of our workshop Old Excavation Data – What Can We Do? despite several parallel sessions with appealing archaeological topics (Fig. 1). The final programme (see below) included presentations on resources from excavations in Iraq (Zaina, Helgestad, Pittman, Van Ess), Turkey and Syria (Prosser – Schloen), Syria (Marchetti), Greece (Frey) and Egypt (Aspöck et al., Kucera et al.). From the ten presentations at the workshop, six contributed to this volume. They discuss challenges for digital integration of old excavation documentation and the conceptual and technical solutions they developed based on archaeological case studies.

Digitising Fieldwork Archives Is for Access and Data Sharing

In the pre-digital age, visiting an archive to consult materials from archaeological excavations was a very time-consuming process. If it was not part of the archival policy to allow researchers to remove relevant documentation or make photocopies of the material, all work had to be carried out in the archive. In such cases, gathering primary fieldwork data involved going through large amounts of descriptions, drawings, plans, photographic materials or other analogue media and taking notes, often by hand, or making Xerox copies and photos. Often, the same material was consulted by multiple researchers, each of whom would make their own copies of the primary data.

With developments in information technology, the collection of data from analogue resources became easier. Researchers can now bring laptops for note-taking and recording data in databases. Digital cameras, scanners and even mobile phones allow taking large numbers of photos without straining a tight research budget, which may have limited the number of analogue photos that could be taken. Visiting archives is still a time-consuming part of the research process – and it needs to be emphasised that familiarising oneself with an archive is not only part of digitisation but also an important part of the research process[8] – but often the same material may be digitised multiple times for different research projects. While the development of new technologies has quickened this process, development of information technology also means that parts of the excavation documentation in an archive may be in digital form, potentially creating problems of access to the information if not curated properly.

The premier advantage of digital field documentation, considering resources born digital as well as digital copies of analogue material, is that resources can be replicated and shared easily between researchers. Hence the onset of digitisation and the internet has brought with it new possibilities for sharing information from previous, and many times much older, excavations. Instead of one researcher after another visiting an archive to collect data, we now have the possibility to make a single copy to be shared limitlessly with colleagues. Informal means of data sharing are frequent in archaeology. Researchers often privately share their data with others with whom they are friendly, based on personal trust that the data are high quality.[9] Because standards of data management in archaeology are rather informal, there is usually a lack of documentation of the data, which makes it necessary that the data are explained privately between colleagues. Sharing data via online platforms reaches a broad audience, however, requiring the data to be organised and documented adequately and consistently for others to understand. Archaeologists can then recognise that the data is of good quality and the information provided is reliable. Ideally, for archaeologists to develop trust in datasets for re-use, data should have sufficient metadata

8 Whether it is an analogue or a digital archive, an important part of the research process is to learn about the organisation of the archive and the methods used to collect data. This information is necessary to evaluate the data and avoid the de-contextualisation and misuse of information. See also Frey, this volume; Zaina, this volume.

9 Kansa – Kansa 2013.

describing the research context, i.e. about how the research process was performed.[10] This includes information about the methods of data collection and recording as well as about the person who conducted the work.

If online excavation archives are open access, researchers do not have to travel to distant places any more to carry out research on a specific site. With worldwide access to the internet, open fieldwork data allows archaeologists from any location, independent of their background, to carry out research on a specific site. This also includes single researchers with little or no funding, who may find it hard to afford multiple trips to museums and archives housing data from their site. This was one of the main challenges for re-using data from older excavations from the perspective of a single researcher, which was discussed at our workshop by F. Zaina.[11] Therefore provision of open data makes researchers more equal, and freely available data is seen as part of the democratisation of knowledge. On a more critical note, however, it has been argued that like with open access to publications, open data reproduces existing power structures because only affluent institutions have the necessary funds to perform the task of digitising large archives of excavation records and developing the necessary online platforms for their dissemination.[12] The availability of high quality records from excavations, rich with information and documentation, facilitates the research of a site when students and scholars looking for material to answer their research questions consult the resources and analyse them. We would argue that in Near Eastern archaeology, however, where sites are often excavated by foreign institutions, the provision of open data from field campaigns might be a way to give back to the states and communities where the fieldwork has been carried out.[13]

Different reasons led to the digitisation of excavation resources from the projects presented in this book:

- Access to excavation resources: Analogue excavation records must remain on site, so digital copies were required for researchers to carry out research year-round
- Digital re-unification of resources from a site that are currently spread across several museum collections
- Danger of loss of information because of deterioration of analogue carrier material, e.g. photo negatives
- Integration of analogue and digital excavation data for research
- Provision of open data

Online Sources for Archaeological Fieldwork Data from the Eastern Mediterranean and Near East

Several of the projects that were presented at the workshop and in this book provide open access to their online excavation archives to allow researchers to analyse or re-analyse individual contexts and records. In the landscape of online resources, such projects represent a minority.[14]

Generally, we can distinguish different types of online resources connected to excavation data. Several webpages aggregate information on archaeological sites and fieldwork projects, and they can be consulted to identify sites which would answer a particular research question. Examples are Fasti Online,[15] an online site database of excavations throughout the area of the Roman Empire

[10] Faniel et al. 2013; compare also Witcher 2008.
[11] Zaina, this volume.
[12] Bevan 2015; Aspöck 2016.
[13] Porter 2010.
[14] AIAC 2014.
[15] Fasti Online.

since 2000; the DEFC App[16] on Neolithic sites in Greece and Anatolia; and the TAY project,[17] which presents information on Turkish archaeological sites. The MEGA-Jordan webpage is an open access GIS for the inventory and management of archaeological sites there.[18] The amount and types of information available on these sites varies depending on the objectives of the project but also the information generally available from an archaeological site. Hence, the results might be just basic information such as location, name and period, but often there are bibliographic references, information about the institutions and people responsible for a site and links to related online resources. An exception to these examples is the DEFC App, which goes beyond resource discovery and allows researchers to explore data related to finds.[19] A starting point to identify resources from excavations that would be useful to answer a specific research question is to query such online databases.

It should also be mentioned that some institutions and projects provide collections of useful links to resources on Near Eastern archaeology such as the Electronic Texts and Ancient Near Eastern Archives (ETANA) project,[20] a multi-institutional electronic publishing project. The Digital Near and Middle Eastern Studies (DNMS)[21] webpage of the Centre for Near Eastern studies of the Philipps University of Marburg, Germany, also hosts an archive of digital resources. The Ancient World Online (AWOL) blog informs readers of new open access resources for the ancient Near East and Mediterranean regions.[22] Browsing online Near East archaeology resources indicates, however, there are more resources on ancient texts rather than archaeological fieldwork data.

In several European states a central institution is responsible for collecting and archiving excavation data, and documentation must be deposited at that institution after the end of an excavation project.[23] In other countries, full excavation archives containing data on finds, stratigraphy and scientific reports are available with open access, which allow researchers to analyse or re-analyse individual contexts and records.[24] Fieldwork in Near Eastern/Eastern Mediterranean archaeology is frequently carried out by institutions foreign to the countries they are working in, such that there may be no official policy about long-term archiving of resources from fieldwork projects. For example, on the webpages of the ETANA project,[25] we read under ‘Archaeological Projects’ that a need to access archaeological data from excavations was identified during the conception of the website. “While individual archaeologists and dig sites were posting data on the web, there was, and still is not, an agreed upon archival storage mechanism or site”.[26] There is no access to archaeological projects from this site, so it seems that inclusion of archaeological resources has not yet been completed.

Hence, at present in the field of Near Eastern archaeology it is very much down to the initiative of individuals, projects, site directors and institutions whether the documentation of an excavation is deposited in an archaeological data archive and whether it will be made available open access. The American data archive Open Context holds a significant number of excavation records from all over the world, but it is particularly rich in records from Near Eastern sites.[27] Open Context is a data publisher, and data can be explored and cited to the item level – each potsherd has its own URL.[28] This highly granular data dissemination is different to other repositories, where a whole

16 DEFC App; Aspöck – Masur 2015; Andorfer et al. 2016; Štuhec et al. 2016.
17 TAY.
18 MEGA-Jordan.
19 Aspöck – Masur 2015; Andorfer et al. 2016; Štuhec et al. 2016.
20 ETANA.
21 DNMS.
22 AWOL.
23 Fentress et al. 2016.
24 E.g. the British Archaeology Data Service ADS; or the e-depot for Dutch Archaeology EDNA.
25 ETANA.
26 ETANA.
27 OPEN CONTEXT.
28 Kansa – Kansa 2013.

excavation dataset may be considered one item, with one set of metadata for the whole package that has to be downloaded before research. Via the Open Context website, it is possible to explore excavation archives to the level of individual contexts and finds. The webpage is easy to query and includes several interfaces for data visualisation and download.

Idiosyncrasies of Archaeological Fieldwork Data: Challenges for Data Integration

The shared topic of all papers in this volume are the challenges in digitally integrating diverse analogue and digital resources from archaeological fieldwork projects. Resources from archaeological fieldwork are very heterogeneous, which complicates their digital integration.[29] The time and effort needed for digital integration of excavation data – be it from excavations of one or several sites – is often underestimated. During the process of digital integration many important decisions have to be made, and digitisation can be a valuable part of analysis.[30]

Heterogeneous fieldwork data results from a lack of an accepted standard methodology and recording system for archaeological fieldwork. It is a product of different research traditions in different archaeological subfields, and the situation is unlikely to change in the future. Many idiosyncrasies of excavation data are described in the chapters of this book and were discussed at the workshop:

- Different excavation methods were used across different sites, or they do not comply with a modern standard of stratigraphic excavation principles.[31]
- Excavation methodology of a long-term excavation project changed as methodologies evolved over time.[32]
- Projects at a site were carried out by several teams that came from different states, and hence excavation documentation is in different languages.[33]
- Generally, even if documentation is in the same language, different terminology was used for recording and describing the results.[34]
- Different classification systems were used among different teams and researchers, e.g. different find typologies or ways of periodisation.[35]
- Data were organised inconsistently; for example, jewellery is grouped with other jewellery in one dataset and with decorative items in another.[36]
- Fieldwork at a site started with analogue documentation and was over the years increasingly carried out digitally; hence the same type of resources exists in different formats (i.e. analogue, digitised surrogates of analogue resources, born digital ones).[37]
- There are different versions of documentation of the same physical object, for example the same find was drawn and reconstructed differently by different people and at different times.[38]
- Digital data exists in a plethora of file formats, many of which are obsolete or special proprietary formats that may be unreadable in the near future. Granularity of data from different sites varies and complicates creation of a data model for resources from many different fieldwork

29 E.g. Allison 2008; Plaza 2013; Felice – Fratta 2016.
30 Witcher 2008.
31 Kucera et al., this volume.
32 Aspöck et al., this volume.
33 Prosser – Schloen, this volume.
34 Aspöck et al. 2016; Prosser – Schloen, this volume.
35 Aspöck et al. 2016.
36 Prosser – Schloen, this volume.
37 Aspöck et al., this volume.
38 Aspöck et al., this volume.

projects, i.e. from some sites there is very little information available, whilst from other sites there is a full excavation archive according to modern standards. Analogue recording forms do not have the constraints of a database, and archaeologists eager to document may add many observations in a non-standardised way and in unusual places such as on photos.[39]

- Some forms of analogue documentation, such as diaries from fieldwork, resist formalisation because they can be very irregular due to handwritten accounts of several individuals and even occasional photos and sketches.[40]

Another problem for data modelling derives from the nature of the archaeological evidence: Archaeological evidence does not produce the same regularity of observations known in other scientific fields or in business, for example in a database of business customers.[41] Instead, some finds or archaeological features may occur only once, and others may be so plentiful that quantification is difficult, buckets of potsherds for example. As a result, archaeological databases based on a standard relational data model and software, e.g. Microsoft Access, use a case-tailored data representation – because few archaeologists are experts in data modelling – and may have a large number of cells, many of which may be empty because some observations were only made a limited number of times.

Approaches to Modelling and Integrating Archaeological Excavation Data

The authors of the articles in this book propose different solutions to the problems outlined above. The way they have taken to data integration has been determined by the aim of their respective project, for example: What will the digital resource be used for? Who is the audience – individuals, one or several research teams, or will it be provided openly via the internet and should therefore be understood on a global level to enable its re-use? Another decisive factor has of course been the financial and personal resources and constraints of a project.

J. M. Frey advocates that the digital archive should replicate the structures of existing analogue excavation archives rather than create a new way of organisation.[42] He argues that most excavation archives already function as an analogue form of a relational database. Hence, the software Archaeological Resource Cataloging System (ARCS)[43] for digitising and cataloguing excavation archives focuses on the archival document rather than its archaeological information. J. M. Frey rightly argues that scholars have always had to familiarise themselves with the recording system of a particular project if they wanted to research a site in-depth and make informed conclusions. He points out the danger of using de-contextualised information and drawing the wrong conclusions. The archivist was always only responsible for showing the researcher where to find resources, but not extracting and summarising the content on their behalf. The software ARCS allows using the digital archive in a similar way to an analogue one. It is open source and aims to facilitate integration of legacy data also for projects with limited funds. Data can be exported for archival storage at a data centre.

M. Prosser and S. Schloen introduce the item-based approach and the Online Cultural and Historical Research Environment (OCHRE) software, an XML database that allows for deeper integration of the data.[44] They discuss the pitfalls of the relational data model and argue that OCHRE's item-based data model is more flexible than the relational data model and particularly useful for the heterogeneous data archaeologists create. OCHRE records each unit of observation

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39 Frey, this volume; Helgestad, this volume.
40 Frey, this volume.
41 Prosser – Schloen, this volume.
42 Frey, this volume.
43 ARCS.
44 OCHRE; Prosser – Schloen, this volume.

as a discrete database item, which can be recorded independently of any other item. Every database item can be identified and described with various properties, even if they only apply to that item. Because of this flexibility the item-based approach has shown to be particularly useful to integrate data from several excavation projects with many different organisational systems. OCHRE also serves as a repository for all project data and is secured by the Digital Library Development Center at the University of Chicago.

E. Aspöck and colleagues also find the relational data model too inflexible to model the complex relations in a long-term excavation project among the documentation, its analogue and digital derivatives and the physical reality it documents.[45] They use semantic technologies for data integration and the CIDOC CRM ontology[46] as the conceptual background. This allows modelling the resources of the Tell el-Daba excavations to create a network of information that is able to represent the complex relations among the different entities. Using an international standard increases the chances for preservation of the metadata semantics in the future as well as the interoperability of the data.

B. E. Helgestad introduces the Ur Digitisation Project, which integrates information about objects from the ancient site of Ur that are currently dispersed over several museum collections.[47] Via the Ur webpage users can not only query and download integrated museum records, but additionally objects have been recorded in the database along with the integration of information found on excavation documentation regarding the archaeological context. In this case, the digital resource goes beyond what a traditional analogue excavation archive does by bringing together all the related material, as the data is indexed and relationships are auto-generated.

F. Zaina presents the perspective of a single researcher dealing with old excavation data. Working on resources from the excavations at the Near Eastern site of Kish in Iraq, which are held at a number of different archives, he outlines the problems a single researcher encounters during the research process, ranging from funding to institutional support. He introduces the research protocol and open online repository Mesopotamia Exploration Survey (MES), which he used for data organisation, analysis and storage. Zaina relates his experience to the theory of archive archaeology and highlights that when re-using archives, a researcher needs to have in mind the archive creators, their background and aims, as well as the background of the scholars that have previously been engaged.

M. Kucera and colleagues introduce an archaeological information system (AIS) for integration of resources from an early, pre-digital fieldwork campaign at Tell el-Daba, Egypt.[48] The AIS consists of a geographical information system (ArcGIS and ArcScene) interfaced with a stratigraphic sequencer (HMC+) for spatio-temporal analysis. They demonstrate how the AIS facilitates the reconstruction of missing stratigraphic information. As a novelty, the stratigraphic sequencer allows allocating stratigraphic units to time intervals. Hence, temporal analysis of the dataset can be carried out via time intervals, which is an advantage to previous sequencers, which were restricted to simple temporal relations.

Digitising: Organisation, Difficult and Vast Amounts of Material

One question that was discussed during the workshop was whether the digitisation of analogue material should be carried out in-house or done by professional companies. This is of course primarily a question of financial resources, but not only. Some projects have had parts or all of

45 A Puzzle in 4D; Aspöck et al., this volume.
46 Le Boeuf et al. 2015.
47 Ur Online; Helgestad, this volume.
48 Kucera et al., this volume; A Puzzle in 4D.

their digitisation done by professional companies.[49] Although this may look like a quick and easy solution, much effort by the responsible archaeologist is required to achieve satisfactory results. The process starts with getting test scans of the same archival material from several companies and evaluating them. This step already requires the responsible archaeologist to familiarise themselves with different scanning equipment as well as criteria for evaluating the test scans, information and prices of several companies. If original excavation documentation is digitised by a private company, overseeing the transport of archival material is also important. Similarly, having someone supervise the beginning of the scanning process at the private company has turned out to be beneficial in order to see ensure all instructions are understood and the material is handled properly.[50] A similar experience was had by the author when handing over a small batch of photographic material to a private company. Not all the instructions were carried out by the company, because they had not been fully understood and we only found out when we saw the results.

In this volume, B. E. Helgestad outlines the advantages of digitising archival resources internally. Besides avoiding the many administrative and logistic challenges when resources leave an institution, institutions benefit from the skills and expertise developed when digitisation is carried out in-house, and equipment can be re-used for other projects. Additionally, the project staff maintains full control over the process and can adapt workflows if necessary. Also, the digitisation workflow is fully integrated with all other parts of the project. From the experience with the 'A Puzzle in 4D' project the author can only support all these points.[51]

Some projects had to deal with difficult material such as old photo negatives. For example, the archive of the excavations at Uruk at the German Archaeological Institute contains photo negatives of all ages, formats and materials.[52] Many of these negatives have already deteriorated, and their preservation is endangered. Hence, the original negatives cannot be used by researchers anymore, and the original negatives need to be protected. In a project with the University of Applied Sciences in Berlin the photographic material of the Uruk excavations was evaluated to identify the different types of photographic materials, find which types are endangered and how to identify them.[53] They developed different workflows for the digitisation of these negatives and standards for conservation of the original material to prevent further deterioration.

Processing digital project resources is part of the digitisation process. Files from fieldwork projects may exist in a series of obsolete or proprietary formats. It may be a challenge to access these data, and the help of a professional, such as a data specialist at a data repository, may be necessary. However, for those data that can be accessed, a series of guides advise on good practices and digital file formats suitable for long-term preservation.[54] It should be the aim of any digitisation project to use such formats, which can then ideally be used with most software solutions and hence is the precondition for re-use of the data. For cleaning and systematising data, free and simple tools are also available.[55]

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49 For example, a small batch of photographic material from Tell el-Daba had to be digitised quickly at the beginning of the project and was therefore given to a private company; parts of the Uruk maps and old archive material at the German Archaeological Institute (pers. comm. Margarete van Ess 2016).

50 Pers. comm. Margarete van Ess 2016.

51 The webpage of the 'A Puzzle in 4D' project (https://4dpuzzle.orea.oeaw.ac.at/archive) contains documentation of the project and information about the scanning process.

52 Pers. comm. Margarete van Ess 2016.

53 Bartels – Jüster 2011.

54 E.g. ADS; IANUS.

55 Prosser – Schloen, this volume.

This Book: Archaeological Case Studies and Archival Material

In this book, approaches to the integration of resources from archaeological fieldwork are presented with archaeological case studies. J. M. Frey discusses the integration of resources from Isthmia in Greece, a site where fieldwork has taken place since the 1950s, revealing evidence from prehistoric to modern times, but which is famous for the sanctuary of Poseidon as the site of the Isthmian games. M. Prosser and S. Schloen discuss three case studies, all based in Turkey and Syria with evidence ranging from the Neolithic to the Byzantine periods, where research in most cases started in the early 20th century with the exception of one site (Zincirli), which has been researched from the 1880s. Aspöck et al. and Kucera et al. work with the resources from the excavations at Tell el-Daba in Egypt, a site with evidence from the 12th to 18th Dynasties (early 2nd millennium BC), which has been excavated since 1966. Fieldwork at the site of ancient Ur, with evidence dating from 5500 to 300 BC, started in the mid-19th century, and the resulting resources are being united for the first time in the Ur online project reported by B. Helgestad. F. Zaina works with material from the excavations at ancient Kish, Iraq, many of which date to the first three decades of the 20th century.

Hence, most fieldwork-records of the projects discussed in this volume are from the early 20th century, but some are up to 160 years old. Dealing with archival data from older or long-term excavations also means that we are dealing with material from different eras of archaeological fieldwork. These resources also are a testimony of how archaeological fieldwork has been carried out over time. They show how archaeological features were recorded and categorised and how they were analysed and interpreted. This has important implications for those who work with these archives: they must consider the different theoretical and methodological backgrounds to the creation of the resources in comparison to contemporary archaeology. In particular where there is textual evidence, such as from many parts of prehistoric Eastern Mediterranean, information from texts may have heavily influenced the recording, categorisation and interpretation of the evidence.[56] For the same reason fieldwork archives also serve as sources about how archaeological thinking, knowledge and research practices developed, and their study can therefore contribute to our understanding of research history and epistemology of archaeology.[57]

Such information is hidden in field diaries, recording forms, photographs and illustrations. Hence, we have encouraged the contributors to this volume to illustrate their articles with examples from the archival material with which they are working. These images may reflect research practices of archaeologists in the past that are different from today. For example, at the excavations at Ur in the 1920s, photos of 'street scenes' were taken of excavation workers posing in the streets of ancient Ur.[58]

Coming from a different era of archaeological research, these photos also have their own aesthetic, differing from today's more standardised excavation photos. In this sense, this volume marries technological approaches to integrating legacy data with a presentation of insights into the riches of our old excavation archives. The latter should serve as a reminder that these old archives are valuable and rich resources that can be brought to a new form of life through digital technologies. It is also important, however, that they are not forgotten in the midst of the current hype around technological developments for archaeological fieldwork.

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56 Compare also Allison 2008; Witcher 2008.
57 Baird 2011; see Zaina, this volume.
58 Helgestad, this volume.

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The ARCS Project: A 'Middle Range' Approach to Digitised Archaeological Record

Jon Michael Frey[1]

Abstract: Just as they did with other technologies in the past, archaeologists have readily adopted and adapted a wide range of electronic tools to aid them in their collection and analysis of archaeological data. While this digital revolution has already begun to yield positive results, especially for projects that were born digital in the past decade, it is less clear what should be done with the older forms of documentation for projects with longer histories of archaeological exploration. With this in mind, and with an eye towards the growing costs of digitisation and storage, researchers at Michigan State University created the Archaeological Resource Cataloging System (ARCS). This open source, web-based program, developed with funding from the National Endowment for the Humanities, enables archaeological projects to manage collections of digitised documentation either for research or migration to a digital repository. From the beginning, the ARCS team has been guided by the philosophy that it is better to improve upon rather than replace methods and tools already in existence. This guiding principle applies as much to the desire to collaborate with archival solutions and linked open data initiatives as to the effort to emulate the experience of being present in an actual paper-based archive.

Keywords: Archives, digital archaeology, legacy data, open source software, archaeological metadata

Over the past few years, the archaeological world has seen explosive growth in the number and popularity of surveys and excavations that have gone 'paperless' in their field recording and data storage procedures.[2] To be sure, this digital revolution holds great promise in its ability to quicken and simplify the way archaeologists collect, analyse and share the information that informs their interpretations of the past. At the same time though, in our collective excitement over 'going digital', which is often coupled with a fair amount of anxiety over selecting the best combinations of off the shelf and custom-built software and hardware, we seem to have forgotten about the vast quantity of evidence that has been collected by archaeological projects in the past and is now stored in museums and archives around the world. The fate of these more traditional plans, illustrations, photographs and field notes should be a source of concern not just for those whose research combines records of past and present fieldwork, but also for those who are responsible for the maintenance of archaeological data in its 'born digital' form. It is a curious irony that a whole body of archaeological documentation, which for some projects has survived in remarkably good condition for close to two centuries, has recently come to be seen as deficient in comparison to the use of software and digital files that must be updated and migrated every few years in order to remain accessible.[3] Indeed, whether our archaeological predecessors have just as much to teach us about the effective long-term organisation and maintenance of archaeological recording systems as they do about the ancient peoples and places documented therein is worth considering.

The Archaeological Resource Cataloging System (ARCS) project seeks to bridge this gap between analogue and digital recording practices.[4] With the support of National Endowment for the Humanities Digital Humanities Startup (2011) and Implementation (2014) grants, a team of software designers, archivists, archaeologists and student programmers from the Ohio State University

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[2] Ellis – Wallrodt 2011; Paperless Archaeology. For examples of digital methods and techniques in archaeology, see: Kansa et al. 2011; Roosevelt et al. 2015; Averett et al. 2016.

[3] Jeffrey 2012; Dallas 2015.

[4] ARCS Online; Frey 2014; Frey et al. 2015.

Excavations at Isthmia, the Michigan State University College of Arts and Letters and the MATRIX Center for Digital Humanities in the Social Sciences has created an open source web-based software solution designed to enable archaeological projects to organise and share digital copies of the documents stored in their archives. While the following discussion aims to showcase some of the program's more noteworthy features, calling attention to the fact that many of these innovations concern not just the digitisation of documents in an archive but also the processes that made for their effective use in their original paper-based form is perhaps even more important. In this way the ARCS team can be said to have situated itself in a 'middle range' between technology and tradition by holding fast to the idea that, in the case of pre-existing excavation archives at least, it is far better to replicate than to replace the recording systems that are already in use.

Design Principles

While the ARCS project has grown in size and complexity over time, its initial inspiration lies in an effort to solve a relatively simple yet frustrating problem. As at many archaeological projects in the classical world and Near East, all records from past 50 years of research at the Ohio State University Excavations at Isthmia must remain on-site year-round. This restriction, enacted in an effort to preserve critical evidence concerning the context of the objects and monuments uncovered at the site, often serves as a significant impediment to research conducted by scholars outside of Greece. Thus, when the digitisation project began in 2009, the initial goal was merely to provide archaeologists with off-season access to electronic copies of the field journals from the excavation. Yet even by the end of the first season of digitisation, it had already become apparent that simply storing electronic copies of archival documents on personal hard drives was not a

Fig. 1 Archives at the Ohio State University Excavations at Isthmia (photo: J. M. Frey)

significant improvement in terms of universal access to the data. Instead, members of the excavation team began to think about ways in which digital migration might actually be used to improve the utility of this archive for a wider professional and public audience. Additionally, while many aspects of the software evolved organically as the ARCS team evaluated critically what could and should be accomplished, the development process as a whole has been guided by a limited set of design principles.

First it was important that ARCS enhance rather than replace an already strong system of record keeping that had been developed over several decades at various archaeological projects in Greece. This is because most excavation archives already function as an analogue form of a relational database. Pages in field journals, individual descriptions of artefacts, line drawings, photographs and ground plans are all connected to one another through the use of consistent naming conventions or supplemental notes. While all these different documents must work together in order to recreate the lived experience of an archaeological investigation, it is nevertheless possible to use any of these forms of documentation as a point of entry into the record-keeping system. The ARCS development team saw great value in maintaining both this organisational structure as well as the type of interactivity that is a benefit of work at a physical archive. Thus, ARCS utilises an interface that encourages users to browse by type the various archival documents, which in the system are called ‘resources’. To be sure, a search utility is provided to allow one to find a specific resource, but it is hoped that users will continue to scan through digitised pages of a notebook or electronic copies of index cards in a catalogue of finds and in so doing, preserve an older tradition of identification through visual recognition. Incidentally, this form of electronic browsing holds the added benefit of producing unintended discoveries, which may not be so readily yielded by means of a keyword search.

In addition, just as a researcher who makes use of the Isthmia archive in person will regularly gather and consult several different document types at once, the ARCS program makes it possible

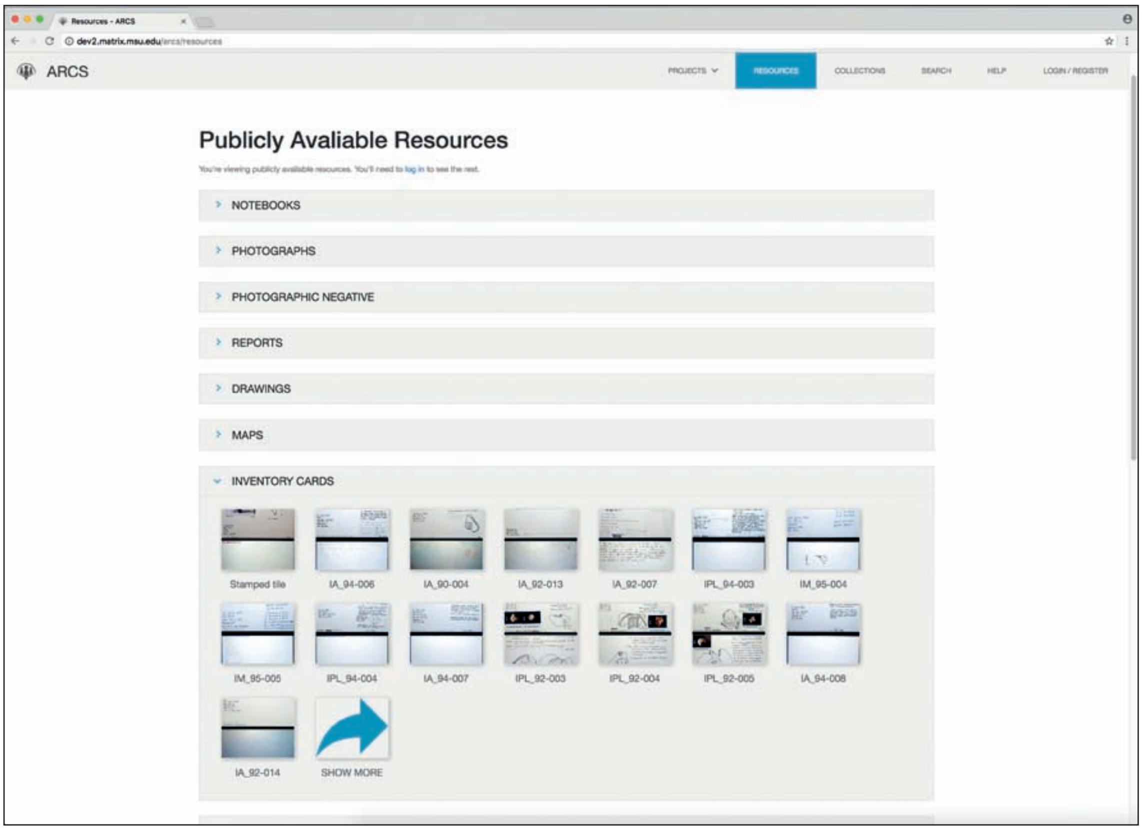

Fig. 2 Screen capture of ARCS program showing resources sorted by type (courtesy of MATRIX)

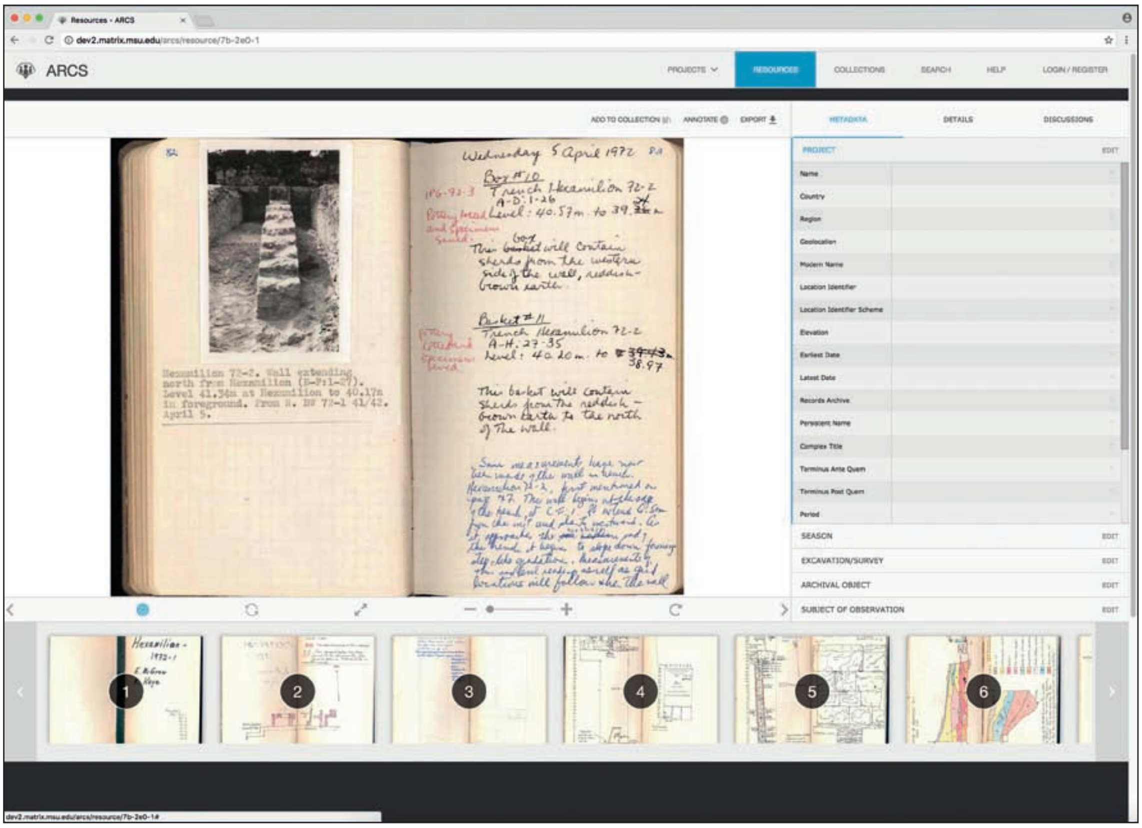

Fig. 3 Screen capture of ARCS program showing resource view of a field journal (courtesy of MATRIX)

to create collections of resources that can be saved and shared with other members of a research team by means of stable Uniform Resource Identifiers (URI). Actually, each individual resource has a unique, stable URI, which is an essential component of participation in linked open data initiatives.[5] Finally, because another advantage of work at an actual archive concerns the ability to draw on the institutional knowledge of more experienced researchers and specialists, resources are provided with their own discussion forums. Here individual users can ask the ARCS community questions concerning specific resources and collections in order to resolve issues involved with interpreting the documents from past seasons' fieldwork.

The idea of supplementing but not replacing the archive applies to the individual forms of documentation as well. For example, field journals, which serve as the principal record type within the Isthmia recording system, are remarkably complex and dynamic documents. From the written narratives to the sketch drawings of artefacts and archaeological features to the photographs pasted onto random pages, these field journals defy attempts to generate an accurate copy in machine-readable format. What is more, the fact that each journal is a living document that continues each season to be supplemented with descriptions and discussions penned in several different hands makes the automation of content processing, such as optical character recognition or even manual text encoding for that matter, especially difficult.

Thus, our approach has been to augment an image of the original document with additional information to help in identifying and understanding its content. This is done in a number of ways. Users can add transcriptions and translations should a certain resource prove difficult to read. They can also tag the resource with keywords that will help to generate more effective search results in the future or create hyperlinks to other documents within and outside of the system

5 Heath – Bizer 2011. On linked ancient world data, see Elliott et al. 2014.

through an annotation utility. All of these tools, however, are supplemental to the display of the document itself, which must be experienced in a way that replicates as closely as possible its original appearance. For while it is clear that well-structured digital data can provide significant insights into the evidence collected through fieldwork, utilising information that has been separated from its unique documentary context can lead to misinterpretations.[6] To this end, by emphasising the visual representation of an archival document over a transcription of its content, the ARCS program enables users to recognise at a glance changes such as handwriting or colour of ink that may not be so readily noticed in encoded text.

Limited Budgets and Unique Needs

Another goal of the ARCS project has been to create an open source software solution that can be adapted to match the unique needs, organisational schemes and limited budgets of smaller archaeological projects. When one surveys the digital legacy data landscape, a number of projects already show the way forward with software built to address their own specific goals. Yet many older or inactive excavations and surveys lack sufficient funding, time and personnel to create their own custom-built solutions. Moreover, the unique idiosyncrasies of archaeological recording systems in different parts of the ancient world make it prohibitively difficult to copy the structure and source code from one project to another. Therefore, ARCS follows an approach that seeks to achieve modest goals by means of an intuitive user interface that imitates the interactivity of common operating systems and web applications. Thus it should be possible for the average user to begin to work with ARCS without any specialised training.

In addition, ARCS facilitates the batch upload of digitised documents as they are generated, either with or without supplemental metadata. Thus, projects can build their digital collections when they have sufficient time, personnel and funding. Moreover, because many research centres do not have a team of dedicated archivists and have always depended on the assistance of students in training or volunteers, ARCS has been designed to support a crowd-sourced approach to improving the accessibility and utility of a project's digitised legacy documentation. The ARCS design team has made an effort to simplify and streamline interactions with resources and collections so that a user can make improvements to the system with minimal distraction even while conducting research. In addition, all users of the ARCS program are given unique accounts so that individuals can be assigned different levels of access to sensitive information and, perhaps more importantly, be recognised for their efforts. The ARCS system also allows users to report errors in the upload and display of digitised resources that can be fixed by higher level administrators at a later time. All error reports and edits are logged in ARCS, thereby ensuring a degree of version control for each resource.

In the end, in spite of the team's efforts to create an easily adopted software solution, the greatest challenge in making the ARCS program available to a wide array of archaeological projects concerns the lack of a uniformly accepted set of standards for recording archaeological discoveries.[7] While such diversity is inevitable, given the number of places and periods that are under study, this nevertheless complicates the structure of the underlying database (ARCS is built upon the KORA Digital Repository and Publishing Platform[8]) to the point of rendering even simple searches for evidence across sites and repositories nearly impossible. At the same time, requiring any project to translate its organisational scheme and terminology into a completely new data

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6 Huggett 2015, 89–93.

7 Kintigh 2006, 573–575; Faniel et al. 2013. For an account of the difficulties involved in normalising archaeological vocabularies, see Kansa et al. 2014.

8 KORA.

structure and ontology simply to make use of ARCS would doubtless discourage adoption and use of the program.

Again though, as with the creation of the ARCS interface, this problem was addressed by emulating the structure and organisation of archaeological archives more generally. For better or worse, the archaeologists who created these archives designed them to function well for their own specific sites but not necessarily on a larger scale. Moreover, the initiation of a new excavation often represented an opportunity to innovate and improve upon whatever recording system was most familiar to the project organisers, so that it is most unlikely to find two projects that collect their evidence in the exact same way.

In this tradition, scholars wishing to engage in cross-project research that goes beyond the identification of an individual artefact for comparanda has always been required to familiarise themselves with the unique aspects of each project's recording system before using its archive. At the same time, it has always been the responsibility of the archivist to assist the researcher in locating and retrieving specific documents, but not to extract and summarise the contents of those records on their behalf. While such traditions may slow the research process, they nevertheless serve the purpose of ensuring that scholars gain a better sense of the nature of their evidence before drawing their conclusions. With the prospect of big data extraction and analysis in archaeology on the near horizon, we should consider the potential drawbacks of a project-agnostic approach to archival information.[9] To be sure, working with non-compatible recording systems is one of the time-consuming complications that digital archaeologists seek to solve through the creation of uniform data collection standards and practices. Yet imposing standard terminologies and organisational schemes on legacy archives, especially when such translations are conducted in the absence of a specific research question, increases the chances that we will misuse the information we extract.

As a result, the ARCS team decided on a much more modest approach to legacy data that focuses upon the archival document itself rather than the archaeological information it contains. This dramatically simplifies matters, for in contrast to the vast array of systems for the classification of artefacts and monuments, the tools of archaeological record keeping are quite limited in number. Until very recently, excavators and surveyors alike have consistently documented the progress of their work on bound journals, paper reports, film photographs, maps and illustrations. For ARCS to function in the model of a traditional archive, the system must reliably deliver these documents so that researchers may discover for themselves what information they contain.

In order to achieve this more restricted goal, the ARCS team developed a metadata scheme that records as much information as possible about the archival object and its digital surrogate. ARCSCore, an adaptation of the ArchaeoCore schema, is organised in several nesting levels, beginning with general information about the project, then moving to specific seasons of fieldwork.[10] Next there is a level for describing the relevant details concerning a discrete unit of survey or excavation within a season. At the most detailed level is found information regarding each individual document, its electronic surrogate and finally the subject of observation that this document describes. In generating this last set of fields, the ARCS team attempted to avoid designating specific systems of classification. Instead, projects are encouraged to define their own terminology in order to aid the retrieval of information according to their system of documentation.

As a result of these decisions, an unmodified ARCS system will be much more effective at generating results for searches focused on certain periods of fieldwork, documents and individuals than a specific type of artefact. For example, ARCS will allow a scholar to gain rapid access

9 Bevan 2015; Cooper – Green 2016. Note also the recent conferences on big data in Archaeology at the Leiden Centre of Data Science (12 May 2017: <https://www.universiteitleiden.nl/en/events/2017/05/18th-lcds-meeting-big-data-in-archaeology> [last accessed 18 Dec. 2019]) and the McDonald Institute for Archaeological Research (27–28 March 2019: <https://erikgjesfjeld.wixsite.com/big-data-archaeology> [last accessed 18 Dec. 2019]).

10 ARCSCore.

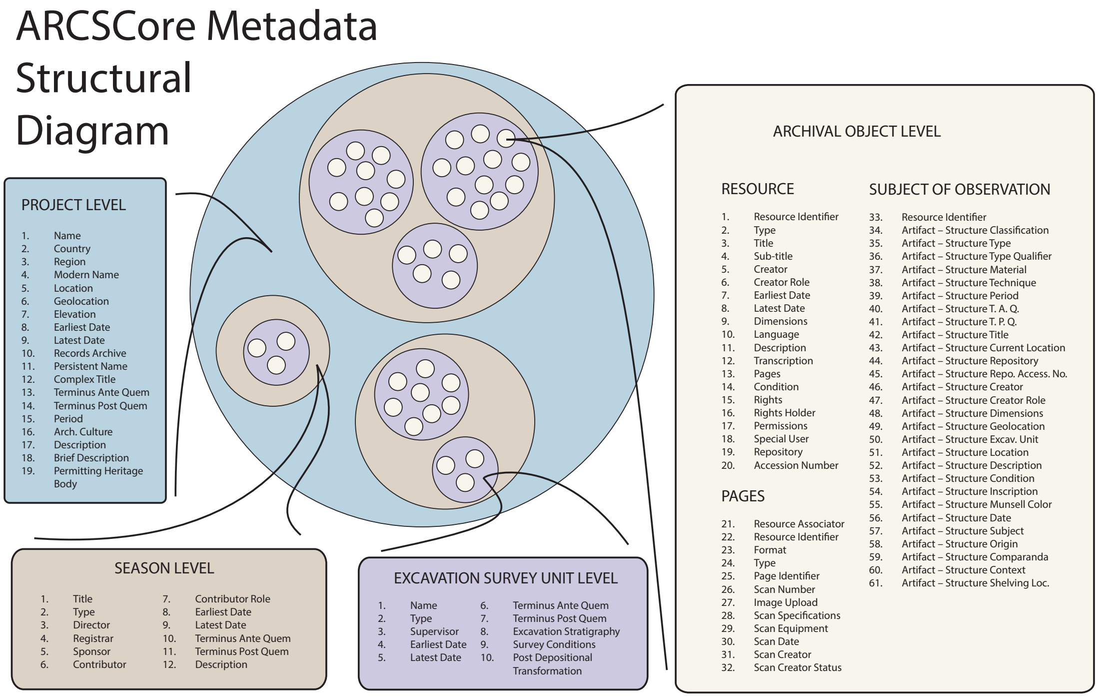

Fig. 4 Chart illustrating organisation of ARCSCore metadata scheme (graphics: J. M.Frey 2017)

to all objects catalogued in 1975 or all field journals penned by the project director. With small modifications such as the creation of a controlled vocabulary database in ARCS for subjects of observation, it will also be possible to retrieve all documents that mention the discovery of Latin inscriptions or Greek amphorae. However, it should be kept in mind that the results of such a search will not necessarily be machine-readable data. Rather, researchers will still be responsible for interpreting for themselves the contents of the documents they have retrieved.

To be clear, the ARCS team is not opposed to ‘big data’ style analyses and is currently in the process of building an import/export utility to accommodate the transfer of structured data into the ARCS system and out again for use in statistical and geospatial analyses or, even more importantly, for secure archival storage through services like tDAR, ADS or DANS.[11] At the same time though, it is hoped that simple keyword searches will not be an end unto themselves, but will function instead as a point of entry into a network of relationships that have been created among documents within a fully annotated ARCS catalog. Furthermore, we expect that this approach will allow a wider variety of archaeological projects to participate in the digital revolution in archaeology in a way that respects their often unique record-keeping systems.

ARCS at Isthmia

Although the ARCS program is still under development, researchers at Michigan State University and Ohio State University have already had great success in using this software as a teaching and research tool. In the classroom, students benefit from experiencing in a more direct way the primary archaeological documentation that lies behind the polished facts and interpretations that they are normally asked to accept at face value. For archaeologists in training, the opportunity to examine documents from the excavations or surveys where they will be conducting fieldwork

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[11] tDAR; ADS; DANS.

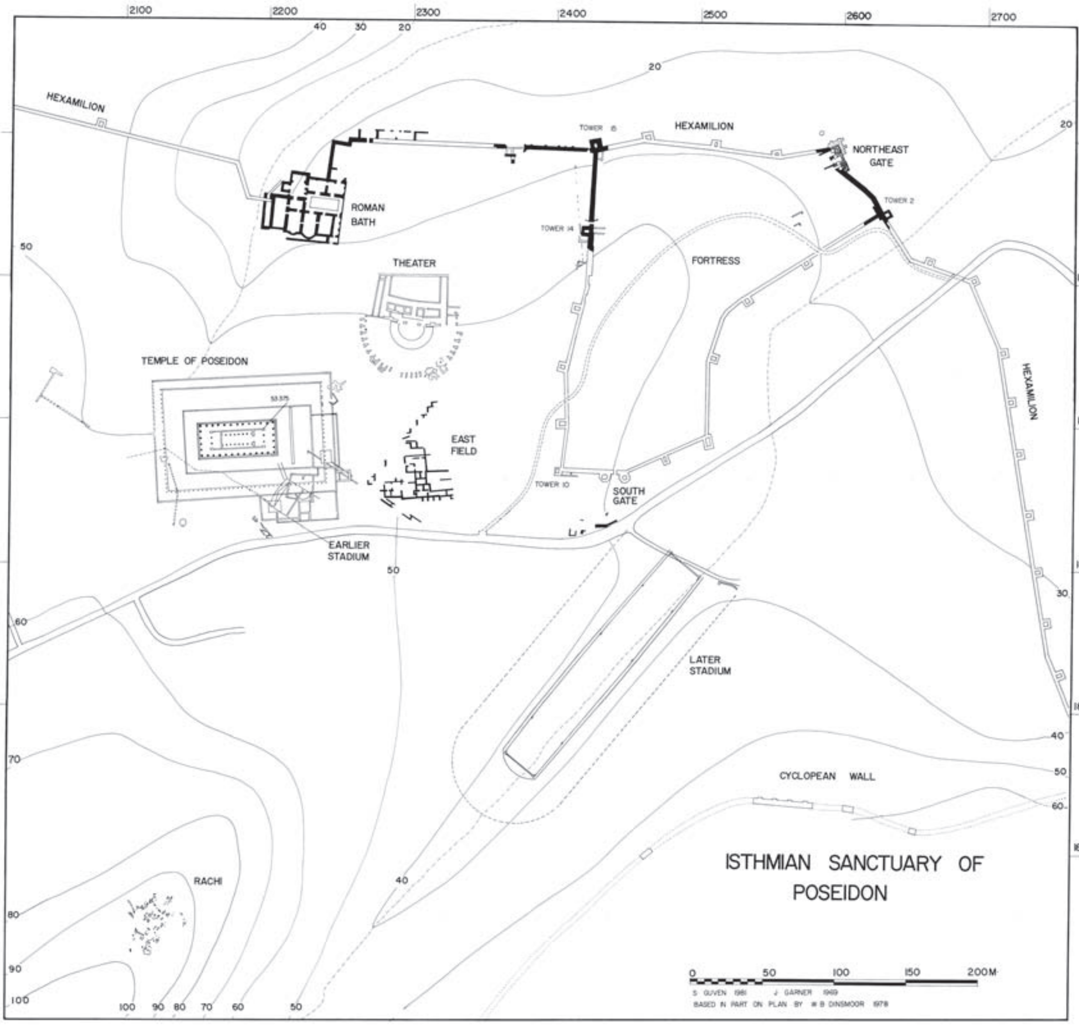

Fig. 5 Plan of Sanctuary of Poseidon at Isthmia (courtesy of the Ohio State University Excavations at Isthmia)

gives them time beforehand to familiarise themselves with the way a system of documentation works and more importantly doesn't work. Indeed, there is no better way to teach a student how to take effective notes in the field than to have them evaluate someone else's field journal. Most significantly in terms of research, archaeologists are already using ARCS as an effective tool for processing information from excavations that have taken place at one site in central Greece since the 1950s but remains incompletely published to this day.

The Sanctuary of Poseidon at Isthmia, located on the eastern side of the Isthmus between northern and southern Greece, was famous in antiquity as the site of the Isthmian Games, which along with the more well-known Olympics formed part of the quadrennial Panhellenic cycle of athletic competitions. As a result, in addition to its temples and altars, the site also featured a theatre, stadium and bathing/exercise facilities, all of which were extensively remodelled or, in the case of the stadium, replaced in Hellenistic and Roman times.[12]

The site is also famous in antiquity as a common meeting place for Greeks to respond to threats such as the 5th century BC Persian invasion[13] or receive important news like the Roman

[12] Broneer 1973.
[13] Herodotus, *Histories* 7.172.

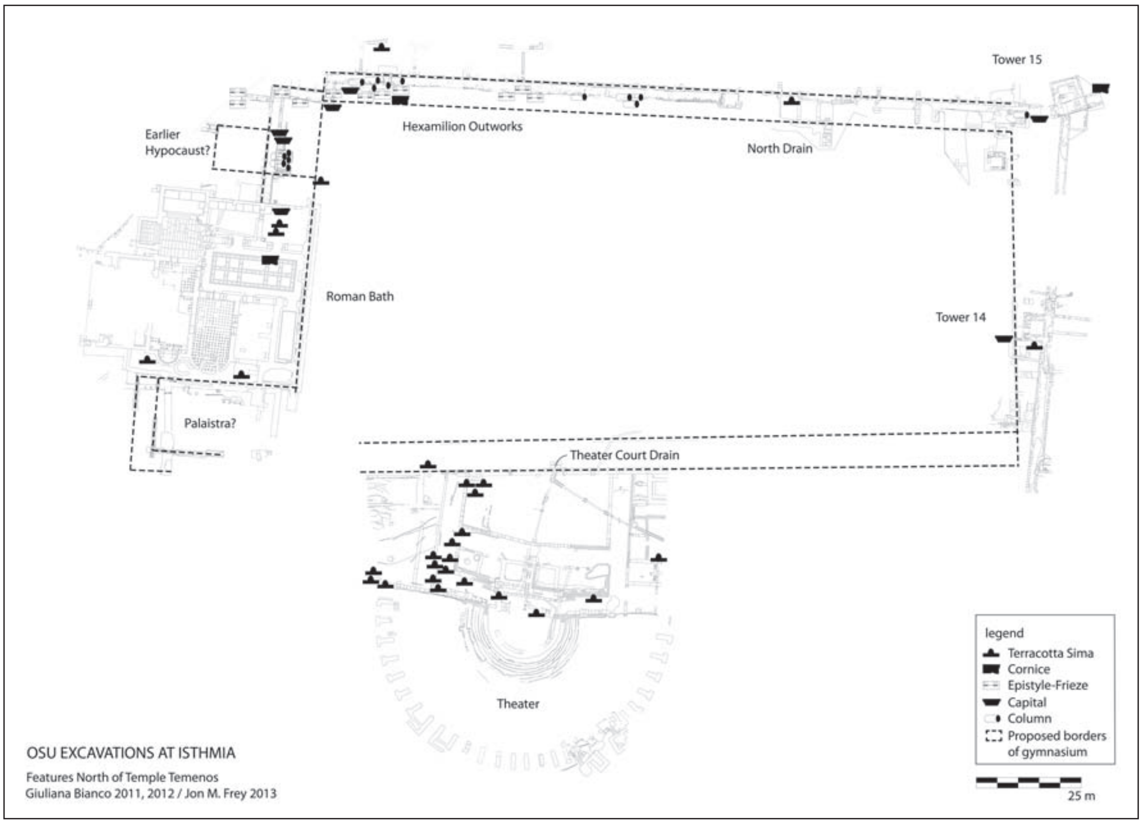

Fig. 6 Plan of lower sanctuary at Isthmia showing the locations of finds and proposed location of gymnasium (courtesy of the Ohio State University Excavations at Isthmia)

general Flamininus’ declaration of the freedom of the Greeks from Macedonian rule in 196 BC,[14] a pronouncement that was repeated by none other than Emperor Nero in AD 66.[15] In the early Byzantine period, following the dissolution of the games, Isthmia served an equally important role as the location of a fortress connected to a nearly six-mile long barrier wall that spanned the isthmus and was intended to protect all of southern Greece against the growing threat of barbarian raids.[16] So many of the sanctuary’s monuments were recycled for use in building these defences that the earliest modern investigations at the site mistook the fortress for the temple precinct.

The actual location of the Temple of Poseidon was established in 1952 when Oscar Broneer from the University of Chicago began systematic excavations in the village of Kyras Vrysi. In subsequent seasons, exploration of the temple temenos, both stadia, the theater, the Roman bath and its Greek precursor, as well as the fortifications continued under Broneer’s direction and that of his successors, Paul Clement at the University of California Los Angeles, Betsy Gebhard at the University of Chicago and Timothy E. Gregory at the Ohio State University. These transitions in leadership often brought with them changes in procedures for record keeping so that the available documentation of the site is marked by a complexity that discourages analysis of the entire site across space and over time. Thus, the publication of sculpture, lamps, coins and other artefacts sorted according to type have preceded larger scale synthetic studies of the monumental landscape of the sanctuary. However, as the research team at Isthmia transitions from fieldwork to

14 Plutarch, *Flamininus* 10.3–5.
15 Suetonius, *Nero* 24.
16 Gregory 1993.

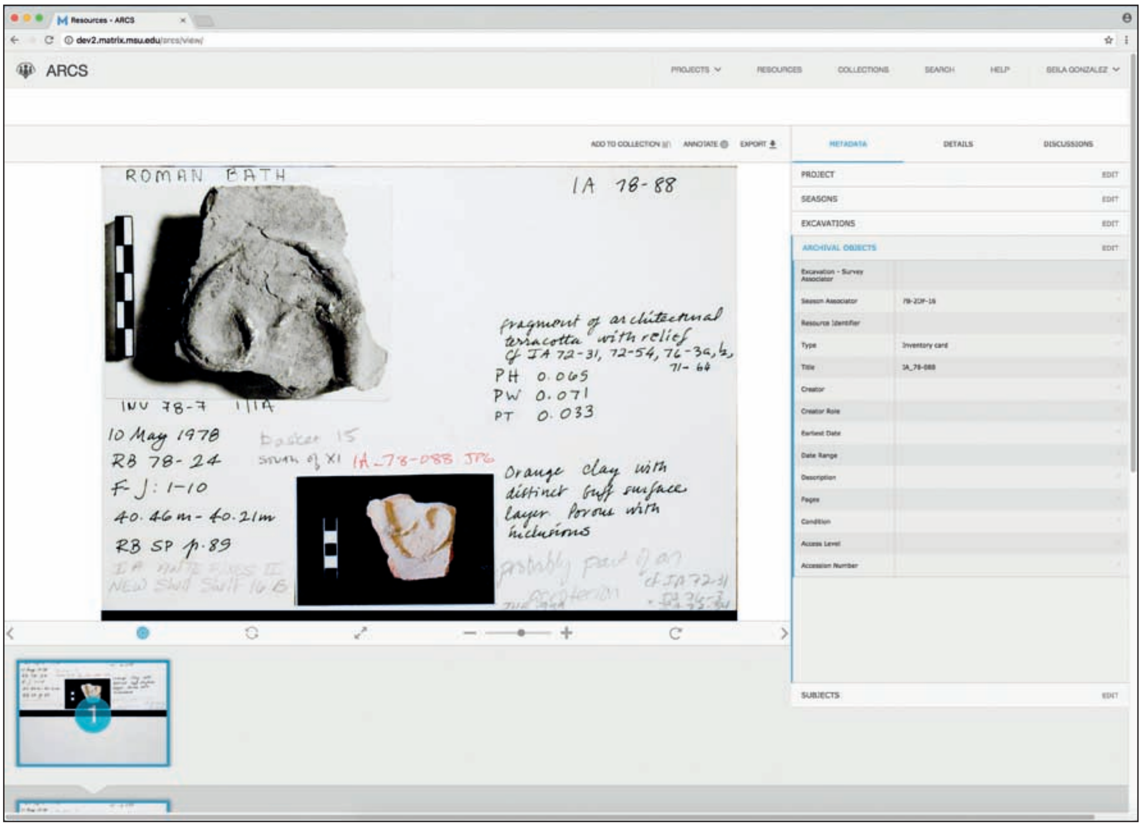

Fig. 7 Screen capture of ARCS program showing sima misidentified as an acroterion (courtesy of MATRIX)

archival research, a reinvestigation of the excavation records is beginning to reveal exciting new insights into the layout and history of the site.

For example, through a closer examination of the field journals, plans and catalogued artefacts that formed a part of the ongoing work to digitise the contents of the Isthmia archives, researchers have now been able to recognise connections among features that were excavated in seemingly isolated locations. What had once been interpreted as parts of the early Byzantine fortress in one location, the Roman period theatre courtyard in a second place and a staircase of indeterminate date in a third are now understood to be part of an enormous Roman period gymnasium/bath complex ringed by a Doric style colonnade.[17]

At roughly 175 × 70m in size, the rectangular plan of this facility is remarkably similar to a feature that is thought to have existed at Olympia.[18] Furthermore, because the distance of the north and south sides is equivalent to the length of a Greek stade, it is likely that the colonnades along these sides actually belonged to the same type of covered running track known from the excavations at Delphi.

This reinterpretation of the extant evidence was largely confirmed through the discovery of similarly shaped fragments of a terracotta sima at each of the separately excavated areas. This element, which functions as an elaborately decorated gutter along the roofline of monumental classical era architecture, would have given a sense of visual uniformity to the separate buildings lining large central open space. The ARCS software was instrumental in recovering this information, as excavators since the 1950s have classified these fragments variously as

17 Frey – Gregory 2016.
18 Wacker 1996.

antefixes, simas or simply unknown objects. A visual scan through the catalogs, which often took place remotely though the ARCS system, allowed archaeologists to recognise mistakes in interpretation and assign various examples of the same decorative moulding to trenches excavated all around this colonnade. Once properly identified, these artefacts were retrieved from storage for further study and in some cases even repaired from joining fragments. It is likely that this search for evidence could not have achieved the same result had we relied upon keyword searches of transcribed documents instead.

Conclusion

It is indeed an exciting time to be a field archaeologist, as surveyors and excavators now enjoy ready access to digital tools and techniques that previous generations of scholars could hardly have imagined. At the same time though, in the midst of our understandable enthusiasm for speeding and simplifying the process of discovery, analysis and dissemination of archaeological information, it is worth pausing to consider whether certain innovations are attempting to reinvent some archaeological recording procedures that were tested and perfected generations ago. This is a particular concern at ongoing archaeological projects that must make difficult decisions as to which innovations to implement in their fieldwork and which traditional practices to preserve.

These considerations have always been central to the design and implementation of the ARCS project, which, it is hoped, will enable projects with long histories but short budgets to take part in the digital movement in archaeology on their own terms. The ARCS team is currently in the process of implementing the system at excavations in Greece, Cyprus and the northern Black Sea coast to test the flexibility of the software, metadata scheme and database in other archaeological contexts. The next phase of the project involves the creation of an automated installation utility to assist projects lacking an information technology specialist to configure their own version of ARCS. The ARCSCore metadata scheme is freely available for anyone to use and modify to suit their own needs. Anyone interested in making use of ARCS to organise and share their own archival documents is encouraged to contact the author.

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Unlocking Legacy Data: Integrating New and Old in OCHRE

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Abstract: Given the proper tools and a clear view of the goal, it is entirely possible to unlock legacy data for use in current and future research. In our work with archaeology and philology projects at the Oriental Institute of the University of Chicago, we have come to expect that database projects usually begin with a set of pre-existing legacy data from excavation paperwork, to top plans, to supervisors' notes. These data are valuable and often the basis for the project going forward. A certain amount of conversion and janitorial work is necessary to convert the data to a digital format. Each project must decide how much of the legacy data to convert and how detailed the data should be. The item-based approach of the OCHRE database allows a project to itemise their data to the finest degree needed. These highly granular data are organised by a combination of hierarchies, links and other strategies. Once digitised and properly organised, these data become part of the larger network of research data. In this context, value is added by integrating resources of various formats (GIS, photographs etc.). Once fully integrated, the data – both new and old – can be leveraged for research and presented in dynamic and interactive online formats.

Keywords: OCHRE, graph database, legacy, integration, archaeology, philology

Introduction

We find ourselves at a peculiar point in history. While clearly working in the digital era, we are still near enough to the pre-digital era that we continue to rely upon and interact with information predating the digital revolution. We are straddling that important watershed moment called the digital revolution. On our side of this historical watershed, we have at our disposal powerful computational tools to aid our research. Aerial photography, digital total stations, tablet computers and databases – all things that used to be too expensive or too technical – are all now common and widely available for use in archaeological field work. Most research now leverages at least some set of computational tools. However, most research is based also in part on information that predates the digital revolution. This remains the central issue: archaeological and philological projects often face the challenge of integrating data from a previous decade or even century. At the very least, our research would be enriched if we were able to incorporate related data from previous research projects. One may even argue that we have a responsibility to include these previous data. But legacy data typically are different than born-digital data in form and structure. As such, we are faced with the problem of how to incorporate information from the previous side of the historical watershed; in other words, an era when the use of databases was not common in the humanities and published research took the form of printed papers and volumes. For some researchers, their immediate reaction is that a current or proposed project would simply lack the time and resources to digitise and incorporate information from previous research. Even an earnest and thoughtful approach might lead one to conclude that a given set of legacy data simply reflects a different approach to describing the research, an approach that would not align neatly with the current research project. As such, even if one were to digitise the legacy data, it would still not align with the approach employed by the current project. With this realisation, a

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researcher may be tempted to conclude that any attempt to integrate legacy data might derail the goals of the current project. These are common conclusions, especially in the humanities, where researchers rarely agree on descriptive terminology and certainly rarely use the same tools and methods for collecting data.

These defeatist conclusions may have been understandable in the early years of the digital revolution; however, database applications have evolved to address these precise problems. Whereas in a previous era a database may have been limited by a data model that required tables to be joined by common fields, current technological advances make it possible to use a data model that is better suited to the unique nature of humanities research data and which specifically supports the desire to integrate legacy data. With this technological hurdle no longer impeding the task of integrating legacy data, researchers now need only apply themselves to the task.[3] We hope to demonstrate that with the appropriate tools and strategies – specifically a data model that allows for the integration of disparate datasets – and with a clear view of the goal, legacy data can be unlocked and can play an active role in an ongoing research project.

Case Studies

Before discussing the data model and strategies that make this task possible, the following examples demonstrate the successful integration of legacy data by some of the projects using the Online Cultural and Historical Research Environment (OCHRE).[4] Like most research projects, these all began with various sets of legacy data – some in the form of printed materials or even in the form of handwritten records. Other projects started with spreadsheets and tables from relational databases. These projects also faced the problem of integrating images from slides, prints and digital media as well as maps and top plans, both in print form and in GIS formats generated in programs like ArcMap.

The first example, Tell al-Judaidah, is a site excavated by Robert Braidwood and the Oriental Institute in the 1930s.[5] It is one of the largest sites in the Amuq valley in southern Turkey and has a long occupational sequence from the Neolithic to the Byzantine Period. The Oriental Institute later returned to the site in 1995 after a bulldozer exposed a significant mudbrick structure.[6] In the years that followed, Dr. Lynn Swartz Dodd continued studying the small finds and organising the data of the excavations using OCHRE. She was faced with handwritten records and photographic slides from the excavations in the 1930s, to which she would need to add her own digital images and observations. The process of digitising the original handwritten documents and images was a fairly simple matter of scanning them. A simple scanned document, however, does not magically become data. Dodd and her team used tools in OCHRE to create live hot spot links that associated object photos with the handwritten documents describing where the objects were recorded and described.

Figure 1 shows a scan of the handwritten excavation record from the 1934 season. The yellow polygon areas on the left side of the scan represent live links to the images of the items in question. Item 4Z is shown in the picture, which itself is a scan of a slide produced in 1934. Professor

3 We do not wish to understate the resources necessary to convert, upgrade, correct, and generally curate a legacy data set. We flatly reject, however, the assertion that such a task is impossible.

4 OCHRE is a computational platform, supported by the ODS of the University of Chicago, and available to academic research projects everywhere. The OCHRE application is free to download (cf. OCHRE Data Service). Projects register with the ODS for data hosting, technical consulting and support, and legacy data conversion services. To read more about the ODS and how to start an OCHRE project, see <https://ochre.uchicago.edu/> (last accessed 18 Dec. 2019).

5 Cf. Braidwood – Braidwood 1960.

6 Cf. Yener – Wilkinson 1996.

Fig. 1 Tell al-Judaidah scanned document and object photograph in OCHRE
(courtesy of the Tell al-Judaidah project of the Oriental Institute)

Dodd and her research team continue to curate the legacy data, adding their own analysis and photographs.

One of the more extensive case studies in which the ODS has participated is the Computational Research on the Ancient Near East (CRANE) research project. This project seeks to provide a framework for studying archaeological data from various sites throughout the Orontes watershed region of Syria and Turkey. At the project's inception, team members assembled research data from excavation and survey projects including the Homs Regional Project, the excavations at Tell Acharneh, the Neubauer expedition to Zincirli and the excavations at Tel Tayinat.[7] Each project brought with it a variety of legacy data, including digital data recorded in spreadsheets and relational database programs. The initial task for this project was to export the data from the old relational databases and prepare it for import into OCHRE. As we describe below, OCHRE allows each project to retain its own nomenclature. In other words, none of the projects were forced to change their data to match the recording methods of another project. The end result is data from various projects that can be queried and viewed together. For example, as of the current writing, a simple query for 'jewellery' across all CRANE projects returns 302 results. If we add 'material' as a search criterion, we can search for metal jewellery, a search that narrows the results to 102. We can search more specifically for metal jewellery which is further described as gold. A search for 'gold jewellery' returns 8 results, a mixture of pendants and bracelets from different sites. Had the various sets of legacy data from these projects not been centralised in OCHRE, this sort of query would have been extremely difficult.

In addition to data related to excavation details and small finds, the CRANE sub-projects each have a significant collection of GIS data. Typically, this type of legacy data would remain isolated and available only in the GIS program in which it was created. However, OCHRE provides a method for integrating all GIS data into the project database where it can be used along with other project data. Each of the separate sub-projects has its own set of top plans and shapefiles,

[7] The Homs Regional project is directed by Graham Philip (Durham University). The excavations at Tell Acharneh were carried out under the direction of Michel Fortin and Elisabeth Cooper (Université Laval). The Neubauer expedition to Zincirli is co-directed by David Schloen (University of Chicago) and Virginia Herrmann (Universität Tübingen). The Tayinat Archaeological Project is directed by Timothy Harrison (University of Toronto).

but the unifying CRANE parent project, which hierarchically contains the individual site projects, also includes a set of GIS data that will play an important role in the modelling of ancient climate data, which pertains to the study as a whole. Researchers are currently gathering climatological data for the Orontes watershed area of interest. This GIS data will serve as one component used in addressing the question of human impact on the environment through agricultural and pastoral subsistence practices. Information such as soil types, land cover by tree species and vegetation, although created in ArcMap and stored as GIS shapefiles, can be used as part of a broader investigation that includes core project data in OCHRE. In short, OCHRE reads and integrates GIS data produced in standard programs like ArcMap or QGIS. This tight integration of OCHRE data and external geodata means that a project can continue using the features of their preferred GIS program, while also gaining the advantage of integrating GIS data with the rest of their data.

The third and final case study comes from the Ras Shamra Tablet Inventory, a project co-directed by Miller Prosser and Professor Dennis Pardee. This project began with a single Microsoft Word document recording the find spots of all the inscribed objects from Ras Shamra–Ugarit.[8] This simple list of thousands of objects and their find spots was converted into a hierarchical system of organisation representing the spatial relationships among the excavation areas and the archaeological finds at the site of Ras Shamra. Each inscribed object finds its home in the database at the lowest level of the hierarchical path which represents the most specific context known for that object. For example, RS 6.021, an inscribed stele, is found in the following hierarchical organisation.

The Site of Ras Shamra
    > The Acropolis
        > Temple of Dagan
            > Topographic Point 715
                > RS 6.021

This object is situated in the broader scope of the site, inheriting its context from its place within the hierarchy. The project is currently integrating legacy data from printed publications, including architectural plans and other maps that specify find spots. These printed maps are scanned and georeferenced in ArcMap, then added as resources in OCHRE.

Figure 2 displays the data about the stele and shows its find spot on the georeferenced archaeological top plan.[9] Note that OCHRE makes every effort to respect the spirit of legacy data, not requiring more than can be accurately stated, nor requiring that it conform to modern standards. An older standard of recording might have indicated that the stele was 'outside the main entrance to the Temple of Dagan'. Today we would use a high resolution instrument to capture exact coordinates at a high degree of precision. OCHRE provides sufficient flexibility and a variety of recording methods so that legacy data can be represented appropriately.

The more primary task of the Ras Shamra Tablet Inventory is the creation of reliable text editions, including text transliterations, commentary and object photographs where available. These various datasets come from many sources: text editions from Pardee, digital images produced by members of the Mission de Ras Shamra and a variety of printed sources. The result is an interactive text edition that includes epigraphic commentary, lexicographic analysis, translation and images.

Figure 3 shows a view of an administrative text written in alphabetic Ugaritic (RS 15.022+). The digital image includes outlined letters, each of which links to the respective letter in the transliteration.

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[8] Cf. Bordreuil – Pardee 1989.

[9] Callot 2001, 167, fig. 44.

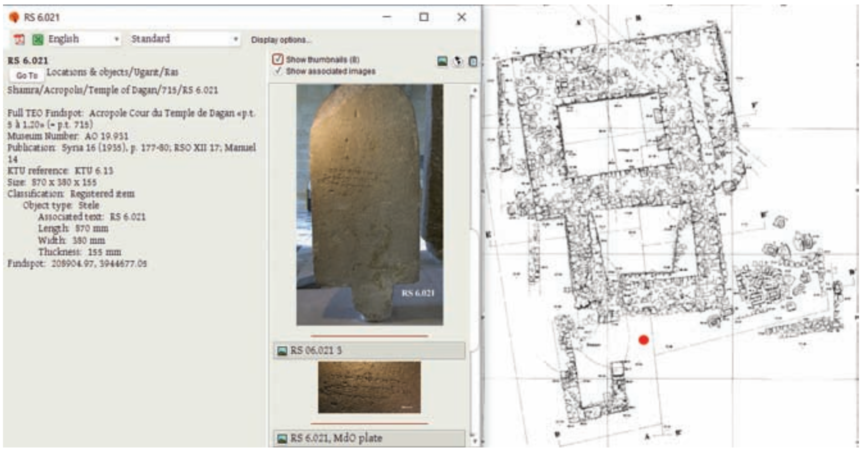

Fig. 2 Ras Shamra Tablet Inventory, RS 6.021 find spot in OCHRE
(© The Ras Shamra Tablet Inventory; image © The Mission de Ras Shamra/PhoTÉO)

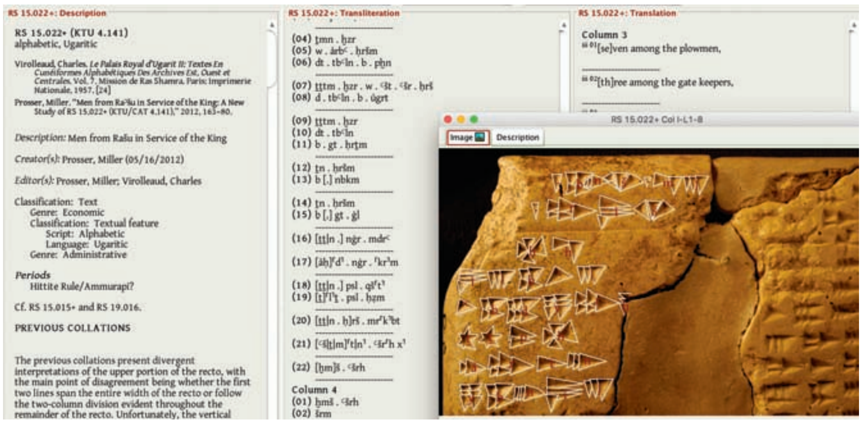

Fig. 3 Ras Shamra Tablet Inventory, RS 15.022+ in OCHRE
(© The Ras Shamra Tablet Inventory; image © The Mission de Ras Shamra/PhoTÉO)

OCHRE Data Service

The current authors are core members of the OCHRE Data Service (ODS), a team of scholars and technical experts who support various research projects using the OCHRE platform. In the realm of digital humanities, we are equal parts *digital* and *humanities*. Schloen, a computer scientist, is the OCHRE developer. Prosser earned his doctorate in Northwest Semitic Philology at the University of Chicago. This combination allows us to understand the research questions asked by our research colleagues and apply computational solutions not typically available to scholars. Researchers using OCHRE work in a broad range of topics and locations, from archaeological field work in Israel, Syria, Turkey and Niger to detailed philology projects involving languages such as Akkadian, Aramaic, Egyptian (hieroglyphic and Demotic), Elamite, Hittite, Old Assyrian and Ugaritic. Our users are located all over the world, from Los Angeles to Toronto and from Be'er Sheva to Tübingen.

Because we work within an institution and a field of study with a long and rich history, we have seen every imaginable type of legacy dataset. One of our frequent and primary tasks is to help researchers integrate legacy data into their active, digitally based research project. As we consult with researchers and advise on computational strategies for modelling research data, we apply lessons we have learned over the years. Because we deal with legacy data on a regular basis, we can save a research project time by avoiding common pitfalls. Whether it is something as simple as the proper strategy for naming digital images and organising them on a remote server or something more difficult like strategies for recording uncertainty and disagreements in the data, ODS can provide recommendations for best practices. Certain strategic missteps early in the process can make the integration of legacy data more difficult than necessary, but with some guidance and the right tools, the once impossible task becomes possible. The OCHRE database environment is uniquely suited to this task.

Initially conceived in 1989 for the purpose of gathering data to do prosopographical analysis of the personal names mentioned on the Ras Shamra tablet inscriptions, OCHRE has grown to accommodate many types of data and support many different research goals. Whether representing the cuneiform signs on these ancient tablets from Ras Shamra, the typeset manuscript of a Shakespeare folio or the inked cursive of the letters of Charles Darwin to his contemporaries; whether describing the paleoclimate of the Orontes watershed region in south–central Turkey or last season's excavation at Tel Keisan in Israel; whether collecting inscriptions on stones in medieval South Indian temples or inscribed coins from ancient Greece, OCHRE's flexible, item-based data model provides structures without strictures. Data, both legacy and born-digital, from over 50 active projects to date, representing over 8.5 million database items, are integrated and managed by OCHRE in a native XML database[10] secured and supported by the Digital Library Development Center at the University of Chicago.[11] From the start, the OCHRE system was designed to handle both variety and volume of data, and its many successful use cases prove the model.

Dealing with Large Data Sets

At times we may find the prospect of dealing with legacy data too daunting because the size of the legacy data is so vast. No doubt, a mountain of data can be intimidating, but with the appropriate tools for cleaning up and systematising the data, the task is not so different, whether the dataset includes 100 or 15,000 items. Free and simple to use tools such as Advanced Renamer and OpenRefine make the data janitorial task easier than it would be otherwise.[12] The former can rename thousands of files at once, removing characters that are typically not valid in file names or imposing order to make files more sensibly sortable. The latter is a powerful tool that helps the user refine spreadsheets with thousands of rows of data. Its built-in features allow quick and easy correction.

When free tools are not enough to solve all issues in a legacy dataset, ODS has the experience and some customised tools to help in the janitorial process. Especially for philology projects, whose legacy data may predate the Unicode standard, ODS has created custom upgrade utilities to convert old documents to current formats and meet the Unicode standard. Most of the writing systems of the ancient world have been added to the Unicode standard, but some only in recent years, which leaves some of our colleagues with documents that were created with customised non-Unicode fonts. In a recent effort to solve this problem at the Oriental Institute, ODS converted tens of thousands of old Microsoft Word documents to Unicode. Documents containing text transliterations can then be imported into OCHRE with the knowledge that the character encoding and display will be the same for all viewers.

The OCHRE database environment has no limit to the number of legacy items it can accept. Flexible import and synchronisation tools allow legacy datasets to be ingested into current projects. We have added thousands of images at once, automatically linking them to other database items where possible. We have imported tens of thousands of faunal remains items from old

10 Tamino, from Software AG.

11 DLDC.

12 Advanced Renamer is freeware developed by Kim Jensen. OpenRefine (formerly a Google product) is an open source and free tool.

spreadsheets. Through this semi-automated import process, these faunal remains were converted from a single spreadsheet into tens of thousands of database items, ready to be viewed, queried and analysed in various ways.

OCHRE

Without attempting to present a complete history and survey of the evolution of databases, we will observe simply that it is important to recognise that there is no single approach to modelling data in a database. Of the various ways to structure data, most are familiar with the relational data model.[13] This is the underlying structure of many database platforms made for the business world. In this model, data are recorded in a series of tables which are related by key fields. The related fields define how information in one table is associated with information in other tables. The related field is typically something that occurs in all related tables, like a customer number, an object ID or some other common datum. With the proper configuration, this data model can be made to work for archaeological data; however, it is inherently limiting and difficult to modify as research progresses. Tables are well-suited for recording highly regular data like invoice details or names and addresses, but they are not the best structure for recording highly irregular data such as faunal remains, pottery classification or text transliteration. When applied to these types of data, the table will either include a cumbersome number of columns, each of which records a sparse amount of data, or a limited number of columns, each of which contains a cumbersome amount of data. In our experience, this data model is difficult to apply to humanities research data.

Itemisation and the Item-Based Approach

The OCHRE data model uses an item-based approach to organising data. Instead of recording data in tables, OCHRE records each unit of observation as a discrete database item. Data is not stored in tables, but this need not induce panic. Items can be reorganised, combined, collected and represented in tables for ease of viewing, analysis or exporting. The important distinction is that in the OCHRE data model, a table is a derived data structure instead of the primary data structure.

Because the item-based data model is not as commonly known, it requires some introduction. Imagine if you could treat each of your artefacts, faunal remains, or botanical samples as its own thing. Each object the archaeologist finds, sign the philologist reads or image the photographer produces – each stands as its own discrete thing, a database item. Instead of grouping items together in categories, some of which are artificial, a database item can be recorded independently of any other thing. One does not excavate a collection of like items from the ground. An archaeologist always hopes to stumble upon a cache of objects, of course! Even so, items are typically excavated one at a time. The item-based data model conveniently parallels this reality. In the real world, things exist as individual items. This simple innovation, that every thing is its own item, is the basic premise of the item-based data model.[14] This approach often feels very natural to the archaeologist who is trained in dealing with individual artefacts.[15] To be clear, in this data model an object such as a pottery vessel, tablet, bone or any other small find is what we call an item.

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13 The foundational work on the relational model is Codd 1970.

14 From a technical perspective, the implementation of an item-based data model is better suited to what is known as a graph database rather than a relational database.

15 In cases in which the archaeologist wishes to record a collection of items without itemising each item, OCHRE can treat the collection as an item. For example, it is common to treat a set of non-diagnostic pottery sherds as a collection. They are important in their collective count and weight, and a researcher will never comment specifically on any single sherd.

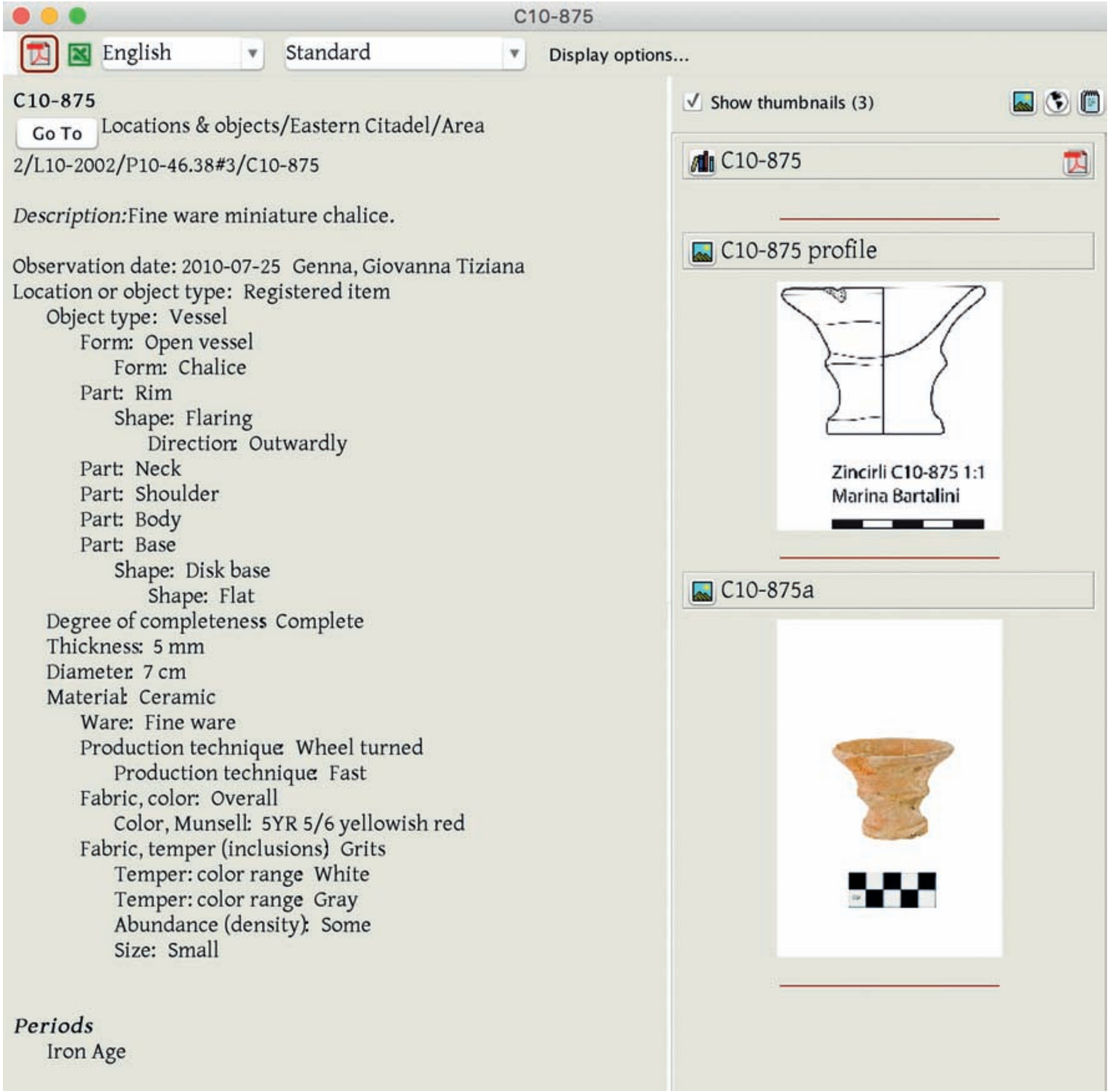

Fig. 4 The Chicago-Tübingen Archaeological Project in Sam'al, the OCHRE entry for vessel C10-875 (© The Chicago-Tübingen Archaeological Project in Sam'al)

The word 'item' also refers to various other data points such as architectural buildings and rooms, modern and ancient people and even periods of time. All of these things are distinct database items. The item-based approach simply refers to the strategy of recording information as distinct items. The process of itemisation may be characterised by batch conversions of spreadsheet tables into many discrete items, dividing larger blocks of data into discrete units or simply the task of entering new information as items from the start. At first reading, the process may sound overly technical, but it couldn't be simpler. Any given thing, a minimal meaningful unit of observation, is an item.

Even PDFs and image resources are database items. In the case of PDFs or other documents, the project is free to decide the degree to which the text of the document is itemised. For example, some archaeological projects decide to keep intact the daily journals produced by area supervisors; they will link a digital copy of the PDF to the database item representing the relevant area. Another project might divide the paperwork into daily journals by excavated locus and link the smaller PDFs to database items representing the relevant loci. While further atomising or itemising the document into smaller units may provide more flexibility for linking the document in highly surgical ways, it is often impractical to do so. In cases such as this, OCHRE provides a method for referencing the specific page of a PDF in a discrete database link so that the user has the flexibility of referring to specific parts of a larger document without having to overextend the idea of itemisation.

In the OCHRE approach, every database item can be identified and described by properties. Ceramic vessels frequently are described by their fabric characteristics, vessel type, decoration and other qualities. Every item can be described with properties that apply only to that item and not to an entire table or class of items. Properties themselves are database items that are applied individually and only as necessary. If a ceramic vessel has a specific decoration, then the properties required to describe that decoration can be applied. If it is a plain vessel, then these individual properties do not apply. To be clear, it is not that the property describing the decoration is left blank for a plain vessel, but that it is not even present when unnecessary. Figure 4 shows the properties for a specific vessel from Zincirli. Note that there are no blank fields. The observer recorded only the properties that applied to this specific item.

One of the greatest challenges to integrating datasets with heterogeneous origins is the typical misalignment of organisational systems. One project may have grouped all jewellery in one table. Another project may have grouped jewellery together with other decorative items. While it might be difficult to align data from two projects using a relational data model, it is much more difficult to integrate data from multiple projects when some of them are highly detailed site-based excavations and others are more cursory surveys. As described briefly above, this is precisely the type of legacy data that has been integrated in the CRANE project. In short, the item-based approach makes this possible because it unlocks the data from the restrictions of the table structure. Once each data point stands as a discrete database item, it can be properly organised and related to any other database items. Within the CRANE project, for example, any small find can be defined with properties that allow the item to be related to all like items, whether the item was found deep in a modern excavation context, lying on the top of an ancient tell or in the handwritten record of an historical field journal.

Organising Items

What do we do with all these items, if not organise them in tables of like items? As already hinted above, OCHRE organises millions of database items in hierarchies. A hierarchy is simply a tree-like structure for recording data. At each level of the hierarchy, the data may branch into any number of sub-branches. On a very basic level, each child item in the hierarchy has only one immediate parent, but a parent may have an unlimited number of child items. This strategy presents a potential limitation: how do we record the location of an item that appears in two conceptually distinct hierarchies? To overcome this apparent limitation, OCHRE allows any given database item to be contextualised in multiple hierarchies. A database item is not limited to a single hierarchical context. It can be reused in as many contexts as needed. In practise, this means that any given locus of excavation for an archaeological project can be recorded in a hierarchy that represents a configuration of excavation units like grids and squares, but it can also be contextualised in a separate spatial hierarchy that represents the ancient architectural system of neighbourhoods, buildings and rooms. In what can be called a polyhierarchical strategy, the locus exists as a single item with a unique identifying number but is contextualised within two hierarchies. The important point here is that the locus is not represented by two separate database items, but rather a single database item organised in two hierarchies. In Figure 5, we see two spatial hierarchies from the Neubauer expedition to Zincirli. Notice that L08-5019 appears as part of a room (on the left) and in its original excavation context (on the right).[16] This database item happens to represent a wall.

16 The Zincirli nomenclature system uses L in an item name to represent a locus. Other projects use their own terminology such as lot or level or unit.

Fig. 5 The Chicago-Tübingen Archaeological Project in Sam'al, a wall (L08-5019) in two hierarchical contexts (© The Chicago-Tübingen Archaeological Project in Sam'al)

When it was initially excavated, the archaeologists could not yet determine its place within the ancient architecture, so it was recorded in an excavation context. After further excavation, the same database item representing this wall was organised secondarily within a hierarchical structure of ancient buildings and rooms.

A hierarchy can represent spatial organisation from region to site, area, grid, square, locus or finegrid, for example. Each level of the hierarchy is contained by its parent item and contains its child item(s). Recalling the example above of the stele from Ras Shamra, the database item that represents the site of Ras Shamra is the parent item to all of the excavation areas on the site. The acropolis of the site, one of the child items of the Ras Shamra item, is also a parent item to more specific areas, each of which is the parent to the various topographic points, which are in turn the parent items to all of the registered items found at each point. This system of hierarchical containment proves to be a very powerful and highly flexible approach to organising spatial data.

Time periods can also be represented in a hierarchical organisation. A sequence of historical periods or archaeological phases when organised into a hierarchy defines the relationship between each nested level of the hierarchy. The order of the periods in the hierarchy defines the chronological order of the periods or phases. Also, if one period in the hierarchy is the parent of other periods, this indicates that the parent item is a broader period that is further divided into sub-periods represented by the child items. Iron Age IIA and IIB are both periods contained by the higher level item Iron Age II, which is contained by the higher level item Iron Age. On a practical level, this allows the user to specify the period of an item without having to over-specify. A given small find, for example, may be identifiable only generally as dating to the Iron Age. Another might be tagged more specifically to the Iron Age IIA period. The hierarchical arrangement of periods allows the user to query for a specific sub-period or a broad period. A query for all items from the Iron Age would find items identified at the highest level as well as all items tagged specifically to any of the periods contained within the Iron Age. In contrast, a query for items dating to Iron Age IIA would find only items from that specific period, excluding any items identified only generally as dating to the Iron Age. A project can define as many period hierarchies as necessary. Typically, archaeological projects include a general outline of historical periods, but may also include regional and site-specific phasing systems or even political outlines. This flexibility is particularly important when capturing legacy data whose details were not captured to the modern scientific standard but are broader or vaguer, yet no less important. We capture what we can without needing to over-specify and without needing to conform to current expectations.

Hierarchical organisation provides a limitless and flexible solution for organising database items regardless of their source, whether born-digital or non-digital and current or legacy. Because the structure of a hierarchical organisation can be revised easily to reflect new and updated understandings of the data, it is uniquely appropriate for archaeological research. New loci and architectural features can be added to existing structures, or new arrangements of existing hierarchies can redefine the related database items. Legacy data can be added to existing structures or can supplement existing data to add missing branches. For example, site-based excavations like Tell Keisan and the Jaffa Cultural Heritage Project have integrated the excavation data from areas exposed by previous teams.[17] Where these areas overlap with the current expedition, the two can exist in the same structure. Otherwise, the new and legacy areas may exist as separate sibling items in the broader hierarchical structure that represents the entire site.

Taxonomy and Thesaurus

In OCHRE, variable-value pairs defined in a project taxonomy are created to represent the descriptive properties of database items. A new project may choose to adopt variables and values established by other projects, but they are also free to customise their project taxonomy to fit their own project needs or accommodate terms from legacy data. Again, hierarchical structure is used to organise the taxonomic values, which themselves are also database items. The taxonomy variable ‘Vessel type’ is the parent of various child values such as Bowl, Juglet, etc. The taxonomy is flexible both in its organisation and the specific terminology used.

We have argued that the item-based approach solves the problem of the misalignment of legacy datasets by freeing data from the strictures of tables, but what about cases when the legacy dataset uses a completely different nomenclature than the current project? As is well known, there is a great deal of variation in the field of archaeology. In fact, we may have already used certain terms that are foreign to the reader. Some projects do not use the term locus, or terms for an excavated unit of soil may be bucket, pail or some term derived from a local dialect (e.g., goufa). In the case where a legacy dataset uses different nomenclature, OCHRE provides a mechanism for creating a thesaurus of terms. Any given variable or value in the taxonomy can be equated with another item in the taxonomy. If one site uses ‘area’ and another uses ‘field’, neither project need adopt the other’s nomenclature. In an ideal world, one might hope that common standards might be agreed upon, but in the real world this seems unlikely. Even so, we would still be faced with legacy data that was collected before such an ideal intellectual détente had been achieved.

[17] The current excavation at Tell Keisan is directed by David Schloen (University of Chicago) and Gunnar Lehmann (Ben-Gurion University). The Jaffa Cultural Heritage Project is co-directed by Aaron Burke (UCLA) and Martin Peilstöcker (Johannes-Gutenberg Universität, Mainz, Germany). Cf. JCHP.

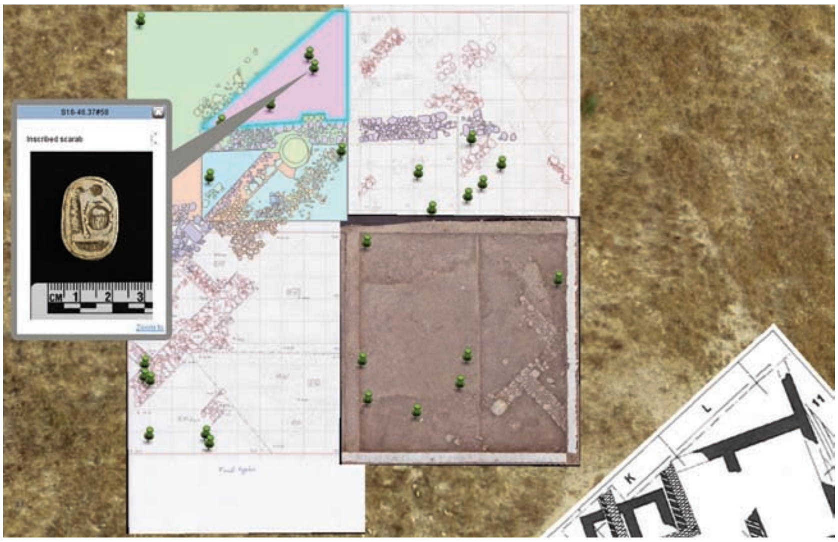

Fig. 6 Tell Keisan GIS view in OCHRE (© Tell Keisan Excavations)

Data of Different Types

OCHRE is a comprehensive data management system. Regardless of the type of data, the goal is to integrate all data in one place. This applies to digital images, PDFs, shapefiles, raster images, drawings, 3D imagery and files of any variety of other formats. The Ras Shamra Tablet Inventory has acquired and integrated legacy datasets from several different sources. The first major set of digital images included the thousands of digital images produced by the epigraphic team of the Mission de Ras Shamra during various research trips to the National Museums of Damascus, Aleppo and the Louvre.[18] Another set of legacy data comes from digital scans of maps and top plans published by the Mission. These were georeferenced in ArcMap and added to the project. From the recently acquired set of research photographs produced by John Ellison during his dissertation research in Damascus and Aleppo, over 10,000 images in all were imported and linked to the database items representing the tablets pictured.

On another front, the CRANE project is currently upgrading and integrating GIS data collected over the years in various formats. In a way, the project created its own set of outdated data simply by using a wide range of GIS collection methods and utilising different technologies as they improved over time. Not all legacy data comes from outside sources as it turns out! Site maps, top plans and shapefiles, georeferenced to the spatial framework of the project's excavation area, can be catalogued in OCHRE and viewed alongside core project data using OCHRE's tightly integrated GIS features. With the right tools in place, the project's geospatial data can contribute to the ongoing picture of the excavation.

One of our core principles of data management is to reduce the number of independent datasets, or inversely to integrate all data sets. OCHRE thus serves as a repository for all of a project's data. This is true as much for legacy data as for all other types of data. In the specific case of GIS data, the goal is that any item in the OCHRE database with spatial information can place itself on a map. Figure 6 below illustrates a view from the Tell Keisan project with selected architectural features drawn in ArcMap. Find spots of small finds, shown as green pushpins, which are live links to object photographs, scanned top plans and part of a scanned map from the previous

18 Photography credit goes to Dennis Pardee, Robert Hawley, Carole Roche-Hawley and Miller Prosser, with image copyright belonging the Mission de Ras Shamra/PhoTÉO.

expedition to the site are visible. This single view shows the complete integration of various data types, digital and non-digital as well as newly collected and legacy.

Conclusion

A clear vision of the desired outcome, a team of determined and hardworking colleagues and the right computational tools are the components that make it possible to integrate legacy data with current project data. The ODS works with its research partners to define the desired outcome and directs project personnel on any janitorial work that may be required to upgrade legacy data. In terms of computational approaches, experience has taught us that OCHRE's item-based data model is more flexible and powerful than the relational data model, especially for dealing with the unpredictable and heterogeneous data that archaeologists and philologists create. In the end, it is satisfying and rewarding when a project unlocks the value of its legacy data and can then begin to incorporate this information into its continuing research.

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The Ur Digitisation Project: Delving into Woolley's Legacy

Birger Ekornåsvåg Helgestad[1]

Abstract: The Ur Digitisation Project is an ambitious collaboration between the British Museum and the Penn Museum to create a comprehensive online resource of all relevant information from Leonard Woolley's excavations of Ur. Since July 2013, teams at both museums have been digitising objects and archives. The archives are housed in the British Museum and include tens of thousands of pages of excavation notes as well as over 2000 glass negative photographs. All this information is brought together and interrelated in a contemporary and complex web resource that is open to all. This paper includes a very brief history of Ur and highlights some pertinent aspects of its excavation. The Ur Digitisation Project itself is discussed in the last section. The focus in this paper is on the archival part of the project. It was presented at ICAANE in April 2016, referring to the state of the project at that time. The project receives lead support from the Leon Levy Foundation, with additional support from the Kowalski Family Foundation.

Keywords: Ur, Leonard Woolley, digitisation

The world's first museum was located in the Sumerian city of Ur according to the interpretation of Sir Leonard Woolley, Ur's main excavator.[2] He uncovered a Neo-Babylonian room with objects from various points in the city's illustrious history:

"The room was a museum of local antiquities maintained by the princess Ennigaldi-Nanna (who in this took after her father [Nabonidus], a keen antiquarian), and in the collection was this clay drum [U.2757, BM 1927,1003.9], the earliest museum label known, drawn up a hundred years before and kept, presumably together with the original bricks, as a record of the first scientific excavations at Ur…"[3]

Ennigaldi-Nanna was not only a princess, but also the High Priestess of Nanna. Her 'museum' was located near the temple and next to what Woolley identified as a school, emphasising the location as one of learning and education.[4] This 'learned' passion for the history of Ur and the understanding of the city as worthy of such study were revived millennia later with the modern archaeological excavations of the site. They are expressed nowhere clearer than in Leonard Woolley's many publications, including the ten Ur Excavations volumes[5] and his books on the Sumerians[6] and Ur.[7]

Following in these very formidable footsteps, two and a half millennia after Ennigaldi-Nanna created her 'museum' and 80 years after Woolley ended his excavations, teams at the British Museum and Penn Museum are collaborating to digitise all germane objects and documents from Ur. The aim is to reunite and digitally publish the finds and archives in an exhaustive and innovative manner. The information produced is incorporated in an extensive online resource[8] that unites the digitised material. This resource is unique in its scope and ambition, is freely available and will

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1 The British Museum, Project Curator: Ur Project, bhelgestad@britishmuseum.org.
2 Woolley – Mallowan 1962, 17; Woolley – Moorey 1982, 251–252.
3 Woolley – Moorey 1982, 252.
4 Woolley – Mallowan 1962, 17.
5 In volume order: Hall – Woolley 1927; Woolley 1934; Legrain 1936; Woolley 1955; Woolley 1939; Woolley 1974; Woolley – Mallowan 1976; Woolley 1965a; Woolley – Mallowan 1962; Legrain 1951.
6 Woolley 1965b.
7 Woolley 1938; Woolley – Moorey 1982.
8 Ur Online.

generate new avenues of research to enable all to explore the finds and records from this extraordinary ancient city.

This chapter starts with a very brief history of Ur, and then highlights some pertinent aspects of its excavation. The Ur Digitisation Project is discussed in the last section. The focus is the digitisation of the archival material. This paper was presented at ICAANE in April 2016, referring to the state of the project at that time.

The City of Ur

Ur is located in southern Iraq, about 170km northwest of Basra and about 300km southeast of Baghdad. It is near the Euphrates River. As the Persian Gulf extended much further inland during the period of Ur's settlement than it does today, the city had access to the sea.[9] This region is the Sumerian heartland, where we also find other important cities such as Larsa, Uruk and Eridu. The ruins of the latter are visible from atop Ur's Ziggurat.[10] These sites can arguably be called the world's first cities. The largest among them was Uruk. By the start of the 3rd millennium, it had grown to a size of c. 600ha from c. 250ha.[11] In terms of population, it was also in a "...category of its own",[12] with possibly as many as 40,000 inhabitants around 3200 BC.[13] Compared to this Ur was rather more modest in size. Wright writes that it probably grew from about 10ha in the Late Uruk period to 50ha in ED III of the mid-3rd millennium BC.[14]

Beyond being amongst the world's earliest cities, Ur was also occupied for a long period, from at least 5500 until about 300 BC. More importantly, it was considered ancient and significant by its inhabitants and their Sumerian contemporaries.[15] Old cities were revered in southern Mesopotamia, with their standing much influenced by the status of their tutelary god and perceived antiquity. Institutions in younger but ambitious settlements would rework theologies to be placed on "equal footing with the older cities".[16] Ur's tutelary god was Nanna-Suen (Sîn), and his most important sanctuary was the é-kiš-nu-gál Temple located in Ur. This is where the above-mentioned Ennigaldi-Nanna was a high priestess. Nanna was a popular god in Mesopotamia, although always subordinate to the principal gods of the pantheon.[17]

Ur and Nanna's fortunes rose and fell over the millennia; regardless, both remained important throughout Mesopotamian history. Ur grew into a significant city–state during the 3rd millennium, and it rose to the rank of imperial capital around 2100 BC. After the fall of the Ur III Empire just a century later, it functioned as a major city within the long series of empires that followed. In most of these periods, construction and restoration work were conducted on Ur's various monuments.

The last significant restorations at Ur were undertaken by Nabonidus, the last Babylonian king, father of Ennigaldi-Nanna and the keen antiquarian mentioned above. His activities in the city had a particular focus, as described by Woolley below:

"The activities of Nabonidus at Ur are easily explained by his fanatical enthusiasm for the Moon god in whose service he had been brought up … everything that concerned Nannar was of interest to Nabonidus."[18]

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9 Kennett – Kennett 2006.
10 Woolley – Moorey 1982, 12.
11 Nissen 2001, 173.
12 Pollock 2001, 187.
13 Nissen 2002, 7.
14 Wright 1981, 326–327.
15 Tim 2014, 20.
16 Goodnick Westenholz 2001.
17 Klein 2001.
18 Woolley – Mallowan 1962, 1.

Following the Persian conquest (539 BC), Cyrus also undertook some work at Ur.[19] The city's eventual demise is described by Woolley as caused by a combination of factors, particularly the shifting riverbed and changing trading patterns, as quoted below:

"The drying-up of the old river-bed, progressively from the Neo-Babylonian period, meant the stoppage of water-borne traffic, the ruin of the whole elaborate system of irrigation, and the end of agriculture; there was not the energy or the capital for the installation of a new system, and the starving city had no longer any reason for existence. Gradually the inhabitants moved away to other homes, the houses crumbled, the wind sweeping across the now parched and desiccated levels brought clouds of sand which they dropped under the lee of the standing walls, and what had been a great city became a wilderness of brick-littered mounds rising from the waste."[20]

The Ur Excavations

Except for the above-mentioned restoration and collecting activities of kings such as Nabonidus, archaeological exploration of the "wilderness of brick-littered mounds"[21] that Ur had become started in 1854. That year the British Museum employed J.E. Taylor, the British Consul at Basra, to investigate southern Mesopotamian sites. Following Taylor's investigations was a hiatus, although the site was not forgotten, and an expedition from the University of Pennsylvania visited Ur towards the end of the nineteenth century.[22] In 1918, there was a renewed effort at the site, first by R. Campbell Thompson, then by H.R. Hall. The main excavation, however, started in 1922. From then onwards, annual seasons took place for the next 12 years. They were led by Sir Leonard Woolley and jointly sponsored by the British Museum and Penn Museum.

The success of the excavations was not only due to the splendour of the ancient city's remains; it also started at an auspicious time. Woolley's expeditions between 1922 and 1934 encapsulate the moment when early large-scale explorations gave way to the advent of modern scientific excavation techniques. By this time, he had also developed his methods with an increased emphasis on recording. This is evident in the letter quoted below that he wrote to G. B. Gordon (Director of the Penn Museum) concerning his new assistant Max Mallowan:

"My new assistant, Mallowan, is shaping well and is very keen on his job: he is of course quite inexperienced and lacks certain qualifications which he will have to acquire before he can rank as really competent - foe [sic] one thing, he has not the remotest idea of drawing, which is a serious handicap."[23]

This emphasis means that the vast scale of the finds he recovered is contextualised by an abundance of documentation, including notes, drawings and photographs. The British Museum houses most of these records. As part of the Ur Digitisation Project these indispensable resources are being digitised, indexed and cross-referenced.

The timing of Woolley's excavations also meant that it was the first archaeological exploration in Iraq that under the terms of the new Antiquities Law (1924) divided its finds between the Iraq Museum and the excavators. It initially involved Gertrude Bell travelling to the site to select objects for the Iraq Museum.[24] Today about half the objects are housed in the Iraq Museum, with the other half shared equally between the British Museum and Penn Museum. There are also smaller collections in other institutions. An unfortunate consequence of the distribution of the excavated material, however, is that corpora of objects are divided and often found across three or more museums.

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19 Woolley – Moorey 1982, 259.
20 Woolley – Moorey 1982, 263.
21 Woolley – Moorey 1982, 263.
22 Woolley – Moorey 1982, 13.
23 Woolley 1925.
24 Asher-Grev 2004, 173–174.

Although the excavations unearthed much that was already familiar, an abundance of riveting and unique finds was also unearthed. Woolley's team uncovered Ur's famous Ziggurat complex as well as urban areas with streets, alleys and densely packed private houses. They also excavated over 2000 graves from several periods. Amongst them are the c. 16 royal graves with rich inventories of masterfully crafted artefacts created using a variety of precious materials. These monuments also contained macabre evidence of large-scale human sacrifice. They are entirely without parallel, and evidence of such practices has not been found elsewhere in Mesopotamia. Here were kings and queens buried with what Woolley described as "ghastly pomp".[25] The graves included oxen-driven carts, jewellery, musical instruments such as those in figs. 4 and 5, weapons and as many as 72 individuals interred with the primary royal occupant. These monuments provide key insights into core aspects of Sumerian life and society, including crucial information about the period's warfare, music, food, drink, customs and institutions.

The graves together with the other areas of the site provided a mass of information, and their co-occurrence in a city is exceptional. Also, the many thousands of cuneiform tablets found at Ur further improve our understanding of the city and its inhabitants. Covering a period of about two millennia, these fascinating ancient documents enable a broader understanding of society and concomitantly provide very focused glimpses into life in the city.

Having so much diverse material from such an expanse of time presents a wealth of research opportunities. Such research, however, is dependent upon availability, which is what the Ur Digitisation Project provides, enabling investigations hitherto impossible. The resource created by the project not only provides the core data but also interrelates and contextualises information from across corpora.

The Ur Digitisation Project

The most exiting aspect of the Ur Digitisation Project is the rare opportunity it provides to reunify dispersed information. Not only are the collections from the three museums, the British Museum, Penn Museum and Iraq Museum, integrated in one digital resource, but also the different categories of objects are consistently recorded to produce a coherent dataset. The broader aim is to store data on all pertinent objects from Ur, and this reunification is the primary purpose of the project. It makes possible the exploration of all information from Ur in one location and provides access to entire corpora located in multiple museums. This includes everything from the cuneiform tablets mentioned above to the many thousands of pottery sherds from Ur. The teams at the British Museum and Penn Museum work in collaboration, though with differing approaches as appropriate for the respective institutions. The computer programmer is managed collectively and spends time at both museums. This loose organisation has proved very flexible, ensuring that each team has been able to capture the data they deem most relevant. Collaborations with additional institutions also incorporate information from their collections.

Besides the information from modern museum records, the same resource also incorporates archival data from the excavations. The three main types of such data are the excavation notes (Fig. 1), catalogue (Fig. 3) and photographs (Figs. 2, 4–8). The documents in the first two categories include both written descriptions as well as illustrations. There are also different types of photographs. These categories include excavation photographs with context labels (Fig. 2), photographs of excavators at work (Fig. 7), the various activities surrounding the excavations (Fig. 6), portraits and object photographs with excavation number labels. Another interesting category is photographs of streets with local workers posing as if they were still in use, such as in Fig. 8. Woolley also named them based on the familiar streets of Oxford and placed signs along

[25] Woolley 1938, 28.

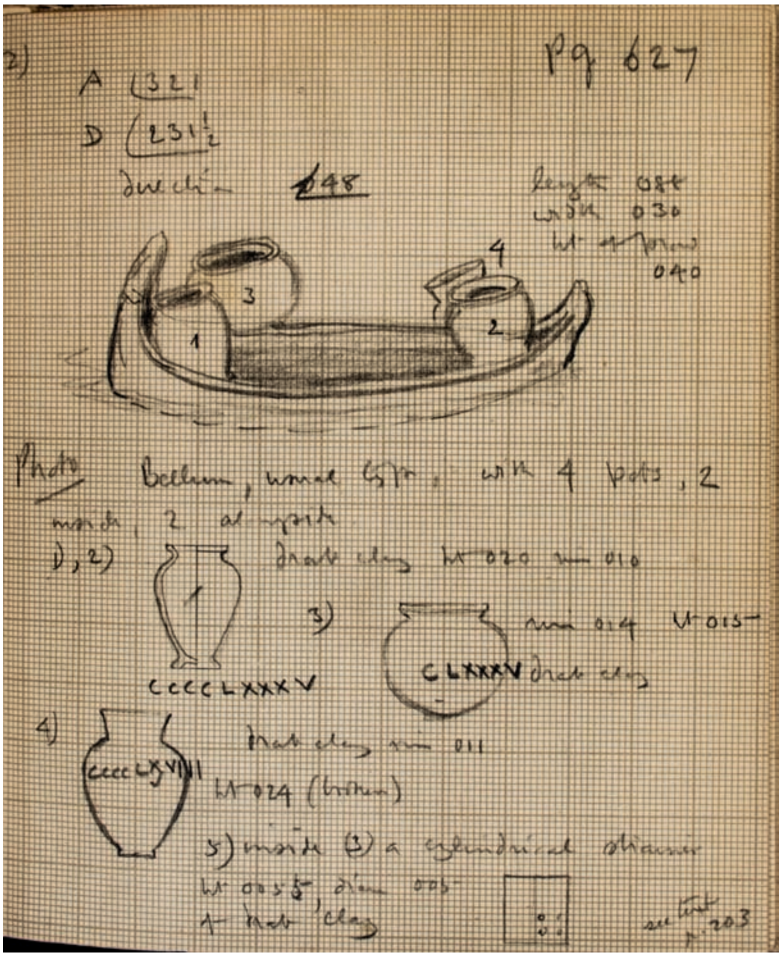

Fig. 1 Excavation-note entry for the bitumen-boat and vessels found in PG/627, shown on photograph Fig. 2 (© Trustees of the British Museum)

Fig. 2 A model boat made of bitumen (bellum) with ceramic vessels in situ in grave PG/627, see drawing Fig. 1 (© Trustees of the British Museum)

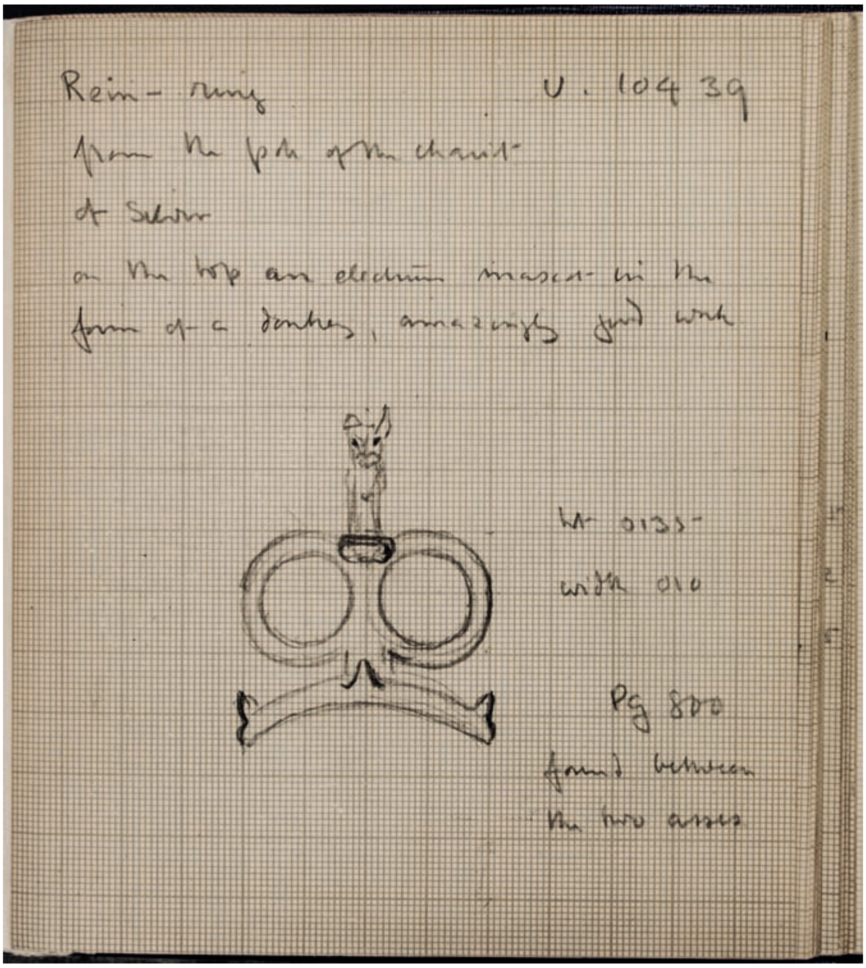

Fig. 3 Excavation-catalogue entry for U-10439 (British Museum 1928,1010.122) a silver rein-ring (© Trustees of the British Museum)

Fig. 4 Leonard Woolley holding the plaster cast of the lyre from grave PG/1151. Woolley pioneered a technique where plaster was poured into the hollows left by the decayed wood, preserving the original shape of the object – here the sound-box of the instrument – whilst also keeping parts made of non-perishable materials in place such as the copper cows head. (The Plaster Lyre – Iraq Museum number IM8695) (© Trustees of the British Museum)

Fig. 5 Three lyres in situ in what Sir Leonard Woolley named "the Great Death Pit" (PG/1237) where five male and 68 female retainers were laid out in rows. (The Gold Lyre – Iraq Museum number IM8694; The Silver Lyre – British Museum 1929,1017.2; The Boat Lyre – Penn Museum 30-12-253) (© Trustees of the British Museum)

Fig. 6 Leonard and Katharine Woolley recording finds brought by the workers (© Trustees of the British Museum)

Fig. 7 The excavation of the Mausoleum. The carts in the background were used to remove soil (© Trustees of the British Museum)

Fig. 8 'Street scene' with posing workers (© Trustees of the British Museum) the streets and outside houses. These signs combined with the actors make the city really come alive in the photographs. They also highlight Woolley's considerable skill as a communicator.

As all this information is fully integrated in the digital resource, a search for a specific object will hence not only produce a modern up-to-date museum record and a recent photograph but also any pertinent archival resources. The latter includes any mention of the object in the excavation notes, a catalogue entry and any photographs taken in the field or at the excavation house. With a single search, finding documentation for, or 'tracking', an object from the moment it was unearthed through registration in the excavation catalogue to the current museum record is possible. The inclusion of descriptions from multiple sources, drawings and photographs both modern and archival, presents a visitor with a mass of interrelated data that otherwise would have been very time-consuming and logistically impractical or even impossible to collate. This information also provides context such as find spots revealed only in photographs or relationships highlighted in group photographs. Archaeological context is also described in the excavation-notes and catalogue.

As the notes and catalogue primarily were written with pencils on frequently smudged millimetre paper (Figs. 1 and 3), the exact wording of a record is often open to interpretation. It was decided to include photographs of all pages, and not only transcriptions, or indices of their pertinent data to facilitate such interpretations. In essence, if there was any mark made by a pen or pencil on a page, it was photographed. Blank verso pages, however, were not included, whilst simple sketches, lines and doodles were. Also, illustrations are often included in both the notes and catalogue and exist in complex relationships to the text. These relationships can frequently not be reproduced without photographs of the entire document. For example, illustrations often contain numbered objects with references to these numbers in the text (e.g. Fig. 1). A visitor to the web resource will hence be able to personally investigate digital copies of all original archival material rather than just transcriptions and interpretations of this material. It is essential, however, to also produce indices to make the information searchable and correctly relate a record to other data. This means that the information from various archival sources must be indexed in a consistent manner so that the different museum registration systems correspond with that of the archives. The most basic such relationship is between the excavation numbers (u-numbers) that were given to objects in the field and the museums' registration numbers. Only with an extensive set of indices is it possible to fully integrate archival and museum object information. For example, archival material such as Figs. 4 and 5 can be displayed when someone searches for the museum numbers of these instruments corresponding to their current display in the respective collections.

It was decided at the start of the project to conduct also all archival digitisation internally. Three of the advantages of this approach are listed below.

1. The archives do not leave the museum. The project hence avoids the many administrative and logistical challenges related to moving items as well as ensuring that storage and treatment outside the museum are satisfactory.

2. Skills and knowledge are developed internally. Also, equipment can be reused, or new equipment can be acquired for future re-use. The Ur Digitisation Project also provides an opportunity to involve students from various universities.

3. The project staff maintains full control over the process and can amend and improve it as the project evolves. Also, the digitisation process remains fully integrated with the other aspects of the project.

The two primary archive digitisation tools used are a photography setup and a flatbed scanner. The former is a simple copy stand with four lamps and a standard Nikon digital single-lens reflex camera. The setup also includes a piece of perspex held by the operator and used to flatten the page being photographed. A remote control for the camera has also proved crucial. This equipment is cost efficient and easy to use, and new operators can be trained quickly. It does, however, require two people to work together, as operating it singlehandedly is difficult. All the paper records are digitised in this manner.

For the digitisation of glass negative photographs, we use a flatbed scanner. The only customisation we have made is constructing a frame for the negatives. As with the paper digitisation setup, the scanner with frame is easy to use so that operators can be trained quickly and uniform results can be achieved.

The project fully integrates data collected from our current museum records with that captured from digitised excavation notes, catalogues and photographs, as well as other sources. This creates opportunities for comparative studies otherwise made difficult by a lack of access. Entirely new sets of information are also produced when the data included are successfully indexed, and relationships are auto-generated. A simple search for an object has the potential to present material never before seen together. All this material, including the images, is freely downloadable in standard formats so that it can be used by anyone. The images are published under a creative commons license, enabling free use for non-profit purposes. Even the code for our resource is openly available, and we hope other projects will be able to use this code and further develop it. The project's web resource should hence provide unique opportunities for new original research, enabling researchers from any location to investigate digital copies of all original archival material as well as comprehensive information on all the relevant museum objects and the relationships that exist among them.

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Back to the Archive: The Challenge of Old Excavation Data from Ancient Mesopotamia

Federico Zaina[1]

Abstract: The analysis of scientific archives has emerged in the previous decades as an important element in the study of archaeological sites. While the theoretical and practical roots of this approach date to the early 1960s, the onset of the digital era provided the real breakthrough by enhancing and quickening data collection, elaboration and sharing through different media. In the paper, using a case study of ancient Kish, an important capital of Southern Mesopotamia, I will show how a single scholar can contribute to the study and reconstruction of an old excavation. The paper will raise the specific challenges affecting single scholar research. A working protocol will be proposed and evaluated based on the case study of the ancient Mesopotamian site of Kish.

Keywords: Archive archaeology, old excavation data, single researcher, working protocol, Mesopotamia, Kish, open access, replicability

The present work draws on the author's PhD research carried out using European and U.S. archives of the archaeological site of Kish[2] in order to allow single researchers to approach archaeological archives and design efficient strategies for such study.

After a brief introduction of the theoretical debate behind the emerging field of archive archaeology, I focus on some practical issues including the organisation of a proper working protocol for single researchers dealing with old excavation data. An overview of the development of methodological approaches to the study of old excavation data in the Near East since 1960s onward is followed by the definition of challenges and strategies concerning single researcher projects, eventually defining a possible working protocol developed in the frame of the Bologna OrientLab open projects. In the last paragraph I make explicit my approach through a case study of the ancient Mesopotamian site of Kish in central Iraq.

Theories and Debates around Archive Archaeology

In the last decades new theoretical approaches and greater accessibility to sophisticated technologies boosted the interest for archaeological documentation and artefacts housed in both public and private institutions. The relevance of this new trend has been stressed by J. Baird,[3] stating that "the study of archaeological photographs – and materials – and archaeological archives can contribute to our understanding of the history and epistemology of archaeology". Particularly relevant are the interests and scopes related to this practice, which extend well beyond the traditional reconstruction of unpublished archaeological contexts to include the history of the archaeological research itself.

This academic phenomenon gave birth to what has been defined as 'archive archaeology'.[4] A wealth of mostly theoretically-oriented papers attempted to explore this subject with the aim of better understanding its potential and strategies to efficiently deal with archaeological archives.[5]

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2 Zaina 2011; Zaina 2015a; Zaina 2015b; Zaina 2016; Zaina forthcoming.

3 Baird 2011, 427.

4 Baird 2011; Swain 2012.

5 Lucas 2010; Baird 2011; Swain 2012; Hicks 2013; Baird – McFayden 2014.

This led to diverse definitions of archive archaeology and multiple points of view from which it can be addressed. According to J. A. Baird and L. McFayden,[6] archives should not be considered as static entities but rather subjects themselves, meaning that "the form of archive itself, is something that has direct relationship to the creation, form and possibilities of archaeological knowledge". Archives comprise different levels of information, from 'raw data' (plain photos, artefacts, etc.) to notes and sketches where excavators provided their own interpretation, often "fitting the ancient structure in a known schema".[7] Therefore, it is of the greatest importance to keep in mind how the organisation and past use of many archaeological archives is due to the archaeological knowledge and strategies in use at that time.[8] Understanding the background and mind of the archive creators and reconstructing the excavator's personalities, including their purpose and the results, are critical. While a growing number of papers seek to fully explore and define the theoretical framework of archive archaeology, this practice has certainly shown all its potential through the internet and a wide range of new digital tools. Indeed, since the early 2000s a dramatic increase in the number of online digital archives has resulted at the initiative of public institutions like museums and universities. Access to at least parts of these digital archives through the internet has dramatically cut both the time and costs of scientific research. This is particularly significant as far as single researchers are concerned.

Previous Strategies and Current Trajectories in the Scholarship on the Ancient Near East

Almost two centuries of excavations in the Ancient Near East produced an exceptional amount of data from hundreds of sites. Thanks to the continuous development of recording methodologies and the technological advances of the last century, the way data have been collected, stored and treated has changed considerably.

The area discussed in this paper, modern Iraq, has been one of the most densely explored since the dawn of archaeological research in the Near East. However, investigations carried out prior to the onset of World War II suffered from outdated excavation and recording methodologies and most of the results can no longer be verified. The situation has worsened during the last two decades due to the dramatic decrease of international projects, which further affected scientific advances in the study of ancient Iraq.

Since the early 1960s the reappraisal of old excavation data stored in museum and university archives has become part of the archaeological research agenda in the Near East. As a result, a growing number of what H. Martin[9] called "academic kind of salvage excavation" were undertaken by various institutions and scholars with different aims and results. To better understand what were and are still the main trends, I would broadly distinguish between two main types of archive archaeology projects in the Near East: 1) team-based projects, 2) projects carried out by single researchers. The former are composed by multidisciplinary groups of researchers including one or more academic institutions, generally supported by generous regional, national or even international grants, and dealing with entire sites and sometimes regions. Several years or sometimes a whole decade is the average time to provide final results.

On the other hand, single researcher projects usually span over a short time and have to deal with less funding. In addition, single scholars have to face the simple fact that they would hardly be able to process an entire site and the bulk of data that came from the excavation.

In this sense, different strategies have been applied by scholars, with the most challenging type of single researcher project certainly regarding the albeit rare reconstructions of the

[6] Baird – McFayden 2014, 16–18.
[7] Baird – McFayden 2014, 19.
[8] Baird – McFayden 2014, 16; Beyer – Stahl 2015, 20.
[9] Martin 1988, 2.

archaeology and history of entire sites. This has been the case of ancient Sumerian cities like Fara/Shuruppak,[10] Jemdet Nasr[11] and Bismaya/Adab.[12] Another and probably more widespread type of studies concerns researches focused on certain part of sites or selected classes of finds. These include among others the study of C. Beuger[13] on the pottery assemblage from the temple of Ishtar at Ashur excavated at the beginning of the 20th century and the stratigraphic and chronological reassessment of the Early Dynastic cemetery of Tell al-Ubaid by H. Martin.[14]

The digital era provided a step forward in the study of archaeological archives. Beside the classical paper-based researches, new solutions represented by online databases were explored. Numerous archives have been digitised and shared through online projects, which became especially valuable for materials and documentation coming from certain countries in the Near East affected by detrimental political situations. Indeed, public and private funding was successfully won by teams working to preserve, share or study materials and documents mostly kept in Western museums and other institutions and coming from countries where their cultural heritage was in danger. To this end, since the early 2000s, many digitisation and archiving projects of old excavation data with different aims and methodologies were launched. This is particularly emblematic for Mesopotamia, which recently received the attention of several large research initiatives sponsored by museums and academic institutions.

The structure and purpose of these projects may vary significantly. Classic online databases are usually dedicated to specific sites or museum collections, for example Kish,[15] Ur[16] or the Diyala expedition sites.[17] Multifunctional platforms include the international CRANE project[18] and the Turkish project TAY,[19] and those additionally providing editorial support for publishing researches carried out using databases as in the case of the British ArchAtlas Project[20] or the US Cuneiform Digital Library Initiative,[21] and the Italian platform OrientLab.[22]

Challenges and Strategies for Developing a Single Researcher Approach

Advances in the study and accessibility of archaeological archives have favoured the emergence of numerous old excavation data projects. But what can an individual researcher do in front of large amounts of documentation?

First, there are a number of issues occurring during the research to be addressed or simply to be kept in mind:

1. Funding: Most of the articles addressing archive archaeology have underestimated this problem, taking for granted the ability to raise the necessary funds for this type of research. In some cases it is possible to understand the amount of funds through some reports[23] or online databases.

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10 Martin 1988.
11 Matthews 2002.
12 Wilson 2012.
13 Beuger 2005.
14 Martin 1982.
15 Field Museum; Ashmolean Museum.
16 Ur Online.
17 Diyala Project.
18 CRANE Project.
19 TAY Project.
20 ArchAtlas Project, <https://onlineshop.shef.ac.uk/product-catalogue/faculty-of-arts-and-humanities/archaeology/archatlas-donation> (last accessed 6 June 2020). The ArchAtlas Project is currently offline and depending on donations.
21 CDLI.
22 OrientLab.
23 See Hicks 2013. With regards to Near East among others the Oriental Institute of Chicago provides open access online annual reports including the state of projects and funds, cf. Oriental Institute Annual Reports.

While large-scale projects aspire to substantial grants, individual researchers are used to sailing into more troubled waters. The most attractive and achievable ways include fully funded PhDs or postdocs, national or university grants or specific schemes provided by private foundations and donors.[24] In most cases, however, overhead costs typical of such researches are not included in grants.

2. Copyright and permission to publish: Different policies and degrees of accessibility are applied to copyright of both documents and artefacts depending on the museum and institution.
3. Expensive analyses: A third problem concerns some expensive analyses such as archaeometry that cannot be easily supported by single researchers. In some cases, however, carrying out low cost analyses thanks to the support of internal funding schemes (see below) or occasional external calls is possible.
4. Feedback: Although solitary research usually helps to improve the scientific independence and breadth of scholars, some issues lurk. Apart for supervised researches including PhDs and postdocs, single researchers need more feedback since they do not benefit from the expertise provided by research groups, especially when structural problems emerge.

With these problems in mind, it is then necessary to define a research protocol and timetable. In this paragraph, I illustrate the results of more than ten years of researches conducted by the chair of Archaeology of the Ancient Near East at the University of Bologna. Indeed, since 2002 many students have been involved in old excavation data collection and analysis in the frame of the BA and MA classes held by N. Marchetti.[25] Since 2009 this approach was transferred into an online open source and open access repository called Mesopotamia Exploration Survey (MES) within the OrientLab platform[26].

OrientLab is a project grounded on concepts of inclusivity by fostering different disciplines "contaminating each other through shared objectives and views", replicability because "social sciences may be deemed scientific when they allow the possibility of verifying each intellectual process at each step" and openness through accessibility, integration and feedback.[27] The platform is an open access tool divided into two main sections: web projects and publications. The former includes three exhibitions and EU project websites, a GIS platform and four online databases all concerning the cultural heritage of the ancient Near East. The publication section provides editorial solutions for data dissemination related to the web projects and beyond.

In this frame, MES represents a user-friendly tool to store, organise and perform researches based on old excavation data from different perspectives, including those focused on particular regions, sites and material cultures (Fig. 1). Any user upon accreditation can create new projects. Images, documents and other information can be uploaded and managed according to their scopes. Some of these projects later became BA, MA and PhD theses. Furthermore, numerous papers were presented over the years at workshops and conferences or published in various scientific peer-reviewed journals. Among these are papers dealing with the sites of Khafajah,[28] Kish,[29] Ur[30] and Nippur.[31]

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24 Recently online crowdfunding platforms are also emerging as potentially useful tools to get funding, especially in the US and UK (cf. DigVentures). However, while for several fields and subjects this practice has been successful, in the humanities it is still underdeveloped.

25 See Marchetti 2006; Marchesi – Marchetti 2011.

26 OrientLab.

27 For the description of the philosophy behind the OrientLab project see <https://www.orientlab.net/#orientlab/Inclusive> (last accessed 18 Dec. 2019).

28 Guerri 2008.

29 Canullo 2010; Zaina 2011; Zaina 2015a; Zaina 2015b; Zaina 2016; Zaina forthcoming.

30 Benati 2013; Benati 2015a; Benati 2015b; Benati – Lecompte 2016a; Benati – Lecompte 2016b.

31 Scazzosi 2014; Scazzosi 2016.

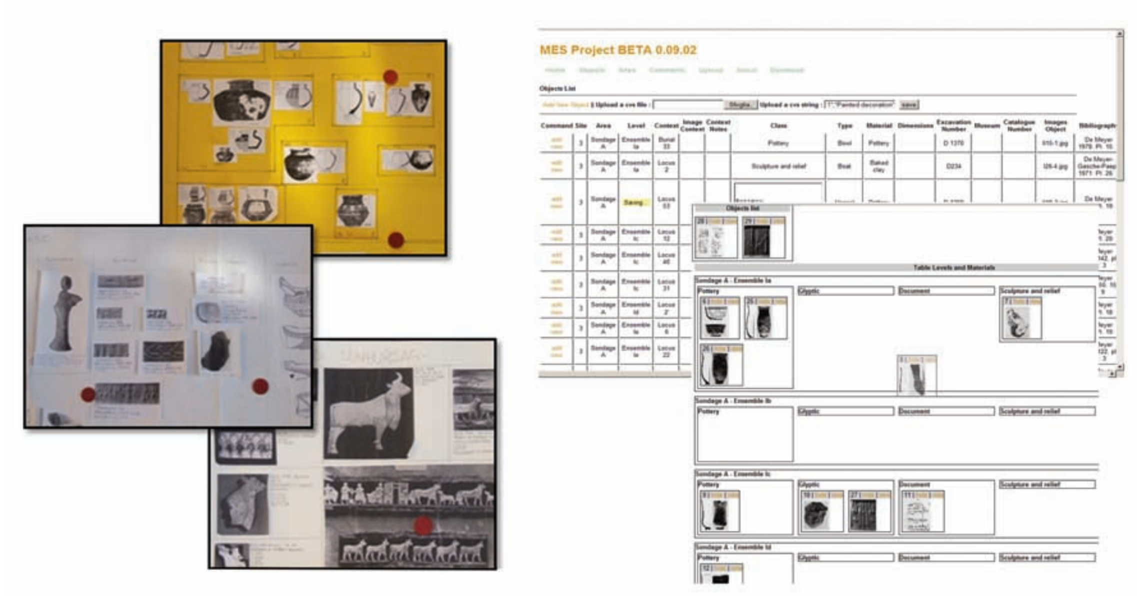

Fig. 1 From paper to the web. The open access platform MES (source: www.orientlab.net)

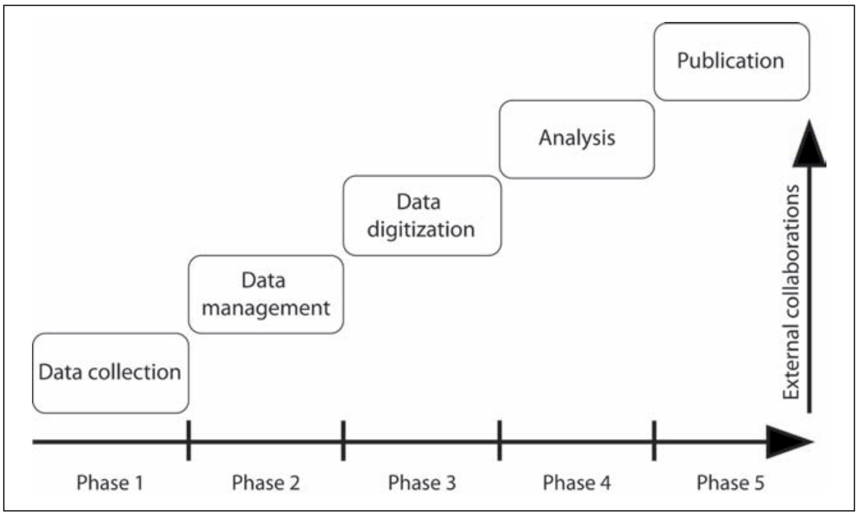

Fig. 2 The OrientLab.net platform provides support for both data management and open access publications (source: www.orientlab.net)

In order to complete the research cycle, in addition to the technical support for storing and organising raw data, the OrientLab platform provides various solutions for data dissemination. These include two open access peer-reviewed monographic series, OrientLab and OrientLab Series Maior, and an occasional publication series focused on the Gaziantep region in Turkey, GR-POP.[32] Since its introduction a proper research protocol was designed, tested and when necessary changed in the frame of the OrientLab approach. This protocol considers five main steps (Fig. 2):

Step 1 – Data collection: This phase consists primarily of the research in archives or on the web and the documentation of artefacts from museum collections.

[32] OrientLab publications are all scientifically directed by N. Marchetti, cf. <https://www.orientlab.net/pubs/> (last accessed 18 Dec. 2019).

Step 2 – Data organisation: It is mandatory for the single researcher to organise the data into well-designed and easily accessible databases. The number of databases and their organisation depends on the type of project.

Step 3 – Digitisation: Plans, sketches, drawings and other written documents are digitised. For example, new maps are created from old drawings, maps and or sketches using CAD or GIS software and the graphic support of Adobe Photoshop® or Adobe Illustrator®.[33]

Step 4 – Data analysis: Once organised and digitised, raw data are ready to be processed according to the purpose of the research. This step also includes, when possible, laboratory analyses.

Step 5 – Data dissemination: This can take the form of peer-reviewed articles or monographs. In the case of the OrientLab platform additional content such as databases will be uploaded also and made available through copyleft in order to allow data replicability.

Case Study: Tell Ingharra/Kish in Central Iraq

As observed by McG. Gibson[34] the ancient city of Kish in Central Iraq, "held an extraordinary position" in the formative periods of Mesopotamian civilisation. Located along the Euphrates River in the centre of the Mesopotamian alluvium, the city was occupied for approximately 5000 years, from the 4th millennium BC until the Islamic period (Figs. 3–4).[35]

The integrated use of historical sources and archaeological evidence allowed the recognition of the 3rd millennium BC as the most flourishing period of the city.[36] After impressive urban growth from the beginning of the 3rd millennium BC,[37] Kish emerged as one of the most influential polities of the region,[38] with its kings extending their hegemony over much of Central and Southern Mesopotamia.[39]

This flourishing period came to an end after some violent episodes including the conquest of the city by King Enšagkušu'anak of Uruk,[40] which can be tentatively associated with the evidence of destruction recorded in many excavation areas at the site.[41] The city's hegemony was thereafter rapidly overshadowed by the emergence of Sargon I, founder of the Akkadian empire, around 2350 BC.[42] Both archaeological and historical evidence indicate that these events eventually led to a slow decline during the following centuries.[43]

Given the history and extensive archaeological explorations, the ancient city of Kish represents a perfect case study for both large teams and single researchers. It was explored at different times between the 1910s and 1930s, but the excavation and recording methodology applied were outdated and the results were not comprehensively disseminated.[44] To fill this gap, from the early 1960s several projects were initiated. Of paramount importance were the works by P. R. S. Moorey and McG. Gibson, which paved the way to other researches carried out from the 1980s until today.[45]

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33 In order to cut the costs of software it is also possible to use open source tools such as QGIS, Gimp etc.
34 Gibson 1972, 1.
35 Moorey 1978, 180–181.
36 Algaze 1983/84; Gibson 1972; Moorey 1978; Zaina 2016.
37 Zaina 2016.
38 Yoffee 2005; Butterlin 2013.
39 Marchesi – Marchetti 2011, 97.
40 Frayne 2008; Marchesi – Marchetti 2011.
41 Zaina forthcoming.
42 Moorey 1978, 171.
43 Moorey 1978, 171–172.
44 Langdon 1924; Mackay 1925; Mackay 1929; Watelin – Langdon 1934.
45 Recent researches on 3rd millennium BC Kish include Algaze 1983/84; Breniquet 1984; Clayden 1992; Gregoire 1996.

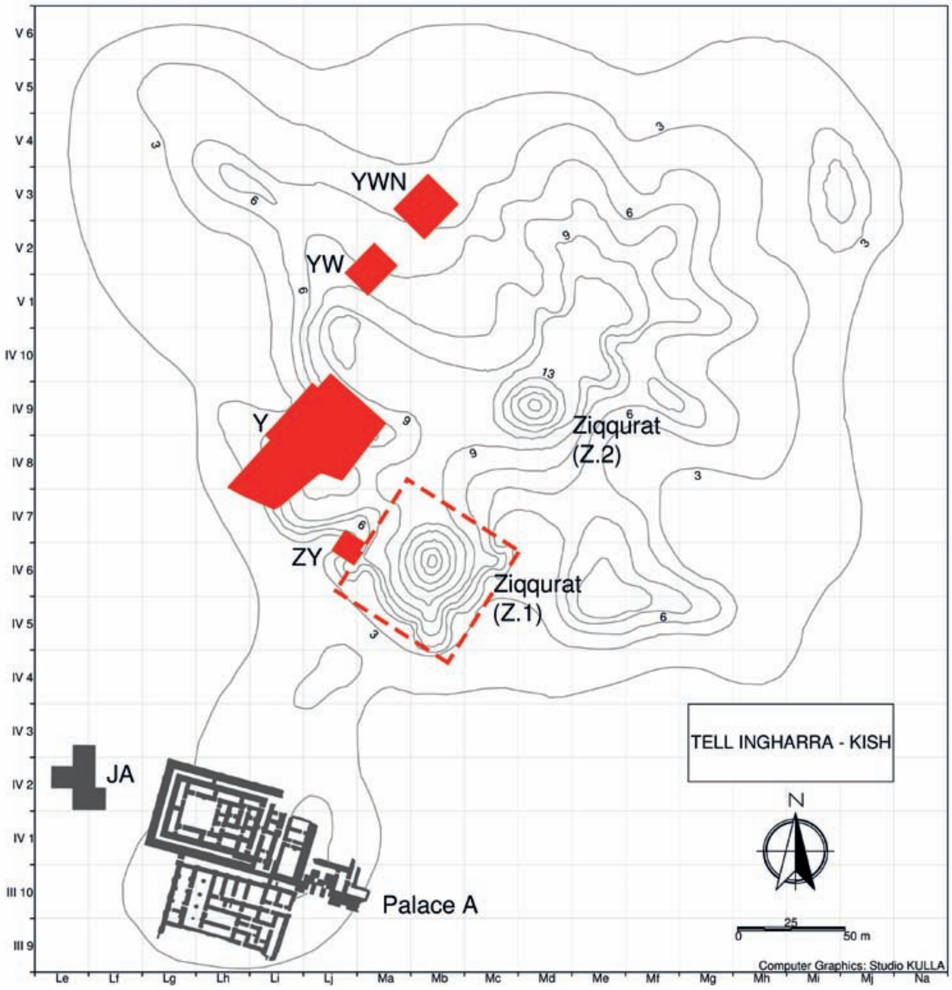

Fig. 3 New topographic map of Tell Ingharra/East Kish (Zaina 2016, 433, fig. 1)

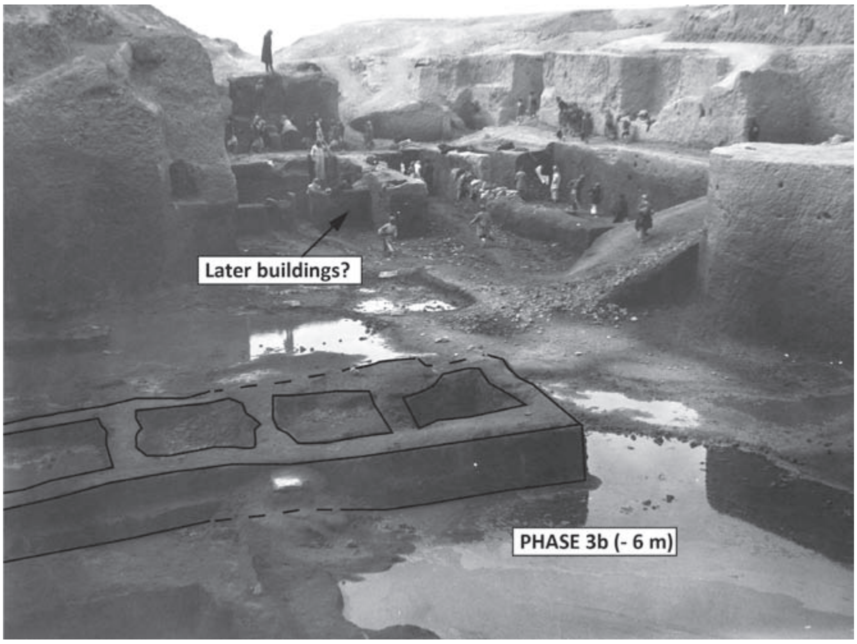

Fig. 4 General view of Tell Ingharra/East Kish from South-west
(© Ashmolean Museum University of Oxford)

Indeed, the aim of their studies was to provide a reassessment of the previous excavations through a general stratigraphic and chronological analysis. As stressed by Gibson himself,[46] however, further work was necessary to fully understand the archaeology and history of the site.

The research I have carried out on Kish since 2007 started from the issues and questions left unsolved by these previous studies. The project was gradually enlarged during my BA (2008), MA (2011) and eventually PhD (2015) studies.[47] Due to the impossibility to approach the whole site, I had to select one part of the site, focusing on the 3rd millennium BC levels, as a case study. This choice was made for several reasons:

1. The 3rd millennium BC is one of the most important periods in the history of Kish.
2. Levels of the 3rd millennium BC are the most extensively excavated at the site.
3. Data from the excavation areas[48] considered are quantitatively and qualitatively sufficient to propose a new analysis of this period.
4. Excavations in the areas revealed different types of contexts including domestic, religious and public secular buildings as well as graveyards.

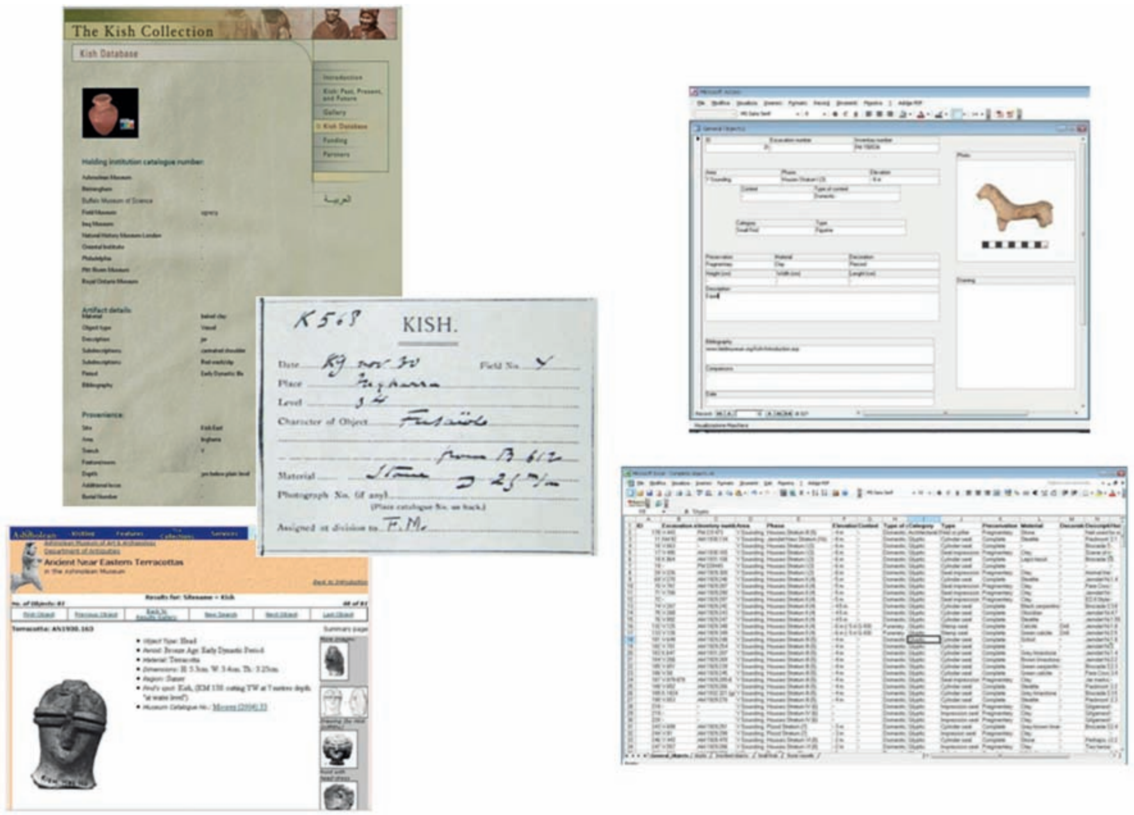

Fig. 5 Data collection. Integrating information from different sources into a general digital open access database (© Ashmolean Museum, University of Oxford)

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46 Gibson 1972, 116.

47 From 2010 it was financially supported by a two-month grant (2000€) from the Alma Mater Studiorum University of Bologna to carry out research visits in the US and then by a three years fully funded PhD (2011–2015, approx. 13,000€ per year) by the Sapienza – University of Rome. Additional grants were also provided for participating in conferences and workshops by the Université Paris 1 – Panthéon Sorbonne (2013–2014, approx. 600€) and for further researches in museums and libraries by Sapienza – University of Rome (2013, approx. 1200€).

48 The areas considered in my research are the Y, YW and YWN soundings at Tell Ingharra, area A and JA to the southwest of it and area P and JP to the northwest of it. For more details on the excavation areas and the selection criteria see Zaina 2016.

The first step included the collection of all documentation, both written documents or photos and materials. To this end, between 2010 and 2015, 15 research visits in several international museums including the Ashmolean and the Pitt Rivers Museums of Oxford, the Field Museum of Chicago, the Louvre Museum of Paris and the UCL stores in London were carried out. The total amount of objects for which information has been collected reached almost 9000 items, and among these almost 900 have been newly described, drawn and photographed. In addition, the entire documentation has been analysed, and all the information useful for the project has been collected. As a result, 235 letters and notebooks and more than 1000 photos of fieldwork activities and finds have been documented. This serves as an example when understanding the background and mind of the archive creators as well as their aims and results became crucial in order to choose what to select and study as well as how to interpret it.

Information collected during the research visits were organised in a Microsoft Access database including eight tables organised according to the type of context or the type of object. These two variables were selected on the basis of my main research needs. Each table was designed to contain a number of fields to provide specific information.[49] Despite the potential of multi-table databases, however, these have been often transformed and used as Excel spreadsheets in order to meet requirements for data sharing with certain museums or academic institutions (Fig. 5).

Graphic documentation was then digitised. Old maps, drawings and sketches of the site and the areas included in the study were newly drawn with the support of a professional topographer. CAD and GIS software were used for digitisation and geo-referencing, while Adobe Photoshop® or Adobe Illustrator® were used for graphics. Newly geo-referenced topographic maps of Kish and detailed maps, plans and sections of the areas excavated at Tell Ingharra were produced (Fig. 6). It was also possible to create new 3D reconstructions of some areas such as Palace A as well as digital elevation models of selected sectors of the site, like the area of Tell Ingharra.

The previous steps confirm J. A. Baird and L. McFayden's idea[50] that archives are not static entities, but their form can change or evolve, in this case from hard copies to digital and from raw sketches to processed data.

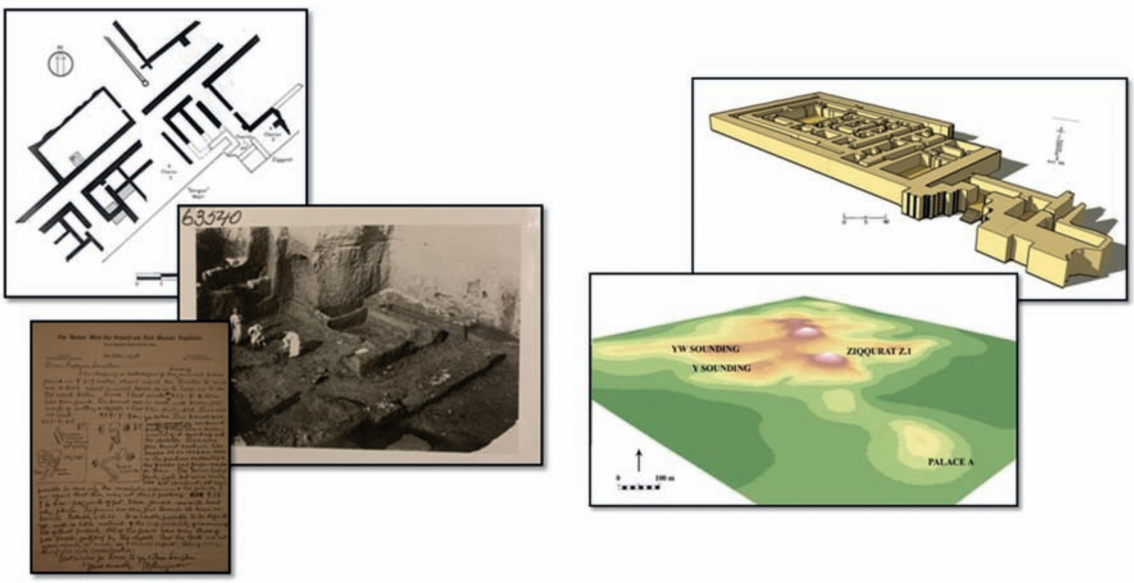

Fig. 6 Data digitisation. From sketches and drawings to digital geo-referenced maps and plans (© Ashmolean Museum, University of Oxford)

49 Zaina forthcoming.
50 Baird – McFayden 2014, 16–18.

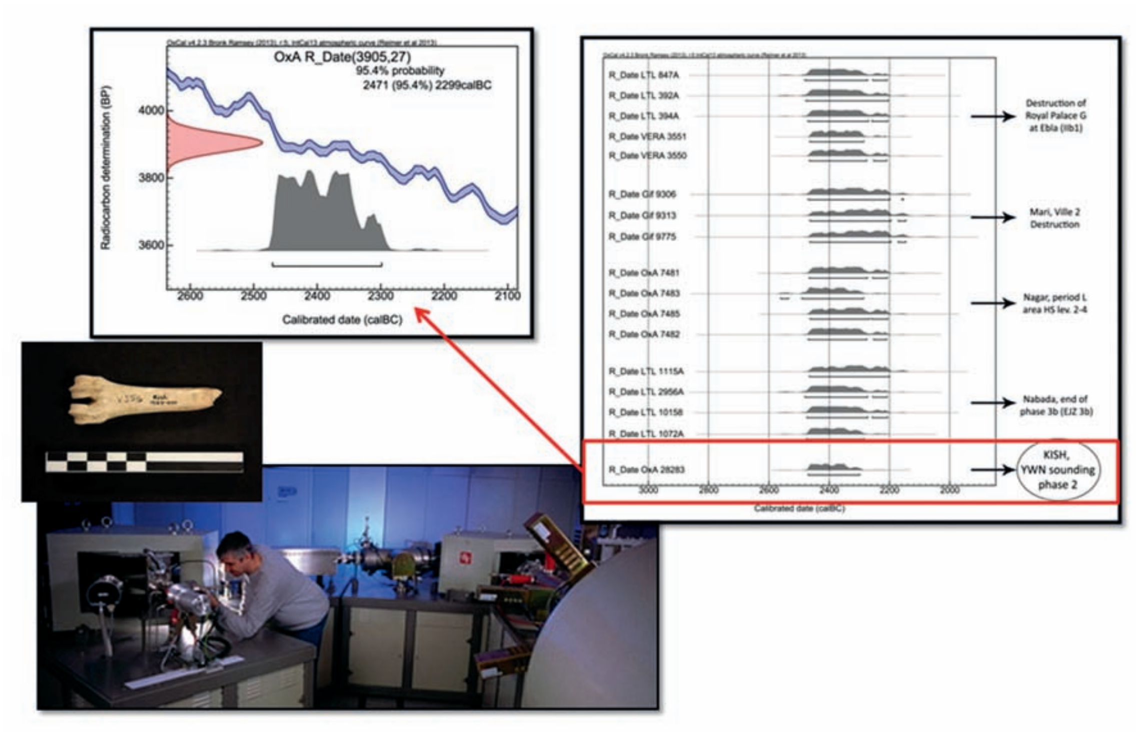

Fig. 7 The role of external collaborations. Radiocarbon analyses on stratified samples from Kish carried out at the Oxford Radiocarbon Accelerator Unit (© Ashmolean Museum, University of Oxford)

The fourth step, data analysis, proposed a new reconstruction of the 3rd millennium BC occupation at Kish.[51] Some interesting data regarding the urban and architectural development of the city emerged, and such evidence also allowed outlining some major episodes in the early history of the city, with the first significant occupation dating to the Early Dynastic I period (2900–2700 BC) and the monumentalisation of the Early Dynastic IIIa (c. 2600–2450 BC) as two key periods.[52]

During the research period additional support and cooperation with other colleagues helped to improve the project results. The first was active collaboration with two philologists[53] for the study of the epigraphic finds. The second collaboration was arranged with the Ashmolean Museum of Oxford and the team of the Oxford Radiocarbon Accelerator Unit (Fig. 7). Thanks to an internal grant (3600£)[54], we submitted in 2013 some stratified bone finds for radiocarbon dating.

The last step of the protocol, the publication of data using digital open access support, can be considered as vital at least as much as the paper-based study. In line with the OrientLab philosophy, different strategies of data dissemination and sharing have been implemented. First, in order to maximise feedback and foster debate, since 2014 the *Session* of Academia.edu[55] was used to gather comments and critiques as well as articles to be published.

Once the research is completed, a final report on the 3rd millennium BC areas from Kish will be published in the online series OrientLab Series Maior, and it will be downloadable for free from the platform OrientLab.net. Additional raw data concerning lists of materials will be provided through the same platform in order to allow research replicability. With this strategy, the OrientLab project hopes to reach the largest number of students and scholars.

51 Zaina 2016, 440, tab. 1.
52 Zaina 2016, 442–444.
53 Gianni Marchesi from the University of Bologna and Aage Westenholz from the University of Copenhagen.
54 John Fell Fund Small Schemes of Humanities of the University of Oxford.
55 Academia.

Conclusions

This article illustrates the potential and problems arising when single researchers must deal with old excavation data. The growing field of archive archaeology and corresponding debate provide the theoretical background to allow single researchers to carry out such protocol efficiently. When approaching an archaeological archive one should keep in mind not only the objects or documents kept, but also the archive creators and their background and purposes as well as those of the scholars previously engaged. Therefore attention should be paid to a wide number of intertwining variables in order to have an inclusive understanding of the subject. In addition, we must always remember the ever-changing nature of archives, which cannot be considered as static entities[56] but rather something that may be subjected to reshaping and processing by different scholars in different periods. In this frame, a paramount role has been recently played by the media, chiefly the internet with the emergence of online open access databases of small and large collections.

The case study of Kish and the five-step protocol described must be considered as an attempt made by single researchers to scientifically deal with archaeology archives in the digital era. By illustrating the OrientLab open projects and focusing on the case study of the ancient Mesopotamian site of Kish, I attempted to show the feasibility of this procedure and suggested different ways to meet goals and overcome issues.

Acknowledgements: The new project on Kish was conducted under the supervision of Nicolò Marchetti (University of Bologna) since 2007 and I would like to express my gratitude for his guidance and support. I am particularly grateful also to Paul Collins (Ashmolean Museum, Oxford), Jack Green (Corning Museum of Glass, Chicago) and to Jim Phillips and Karen Wilson (Field Museum, Chicago) for their permission to study the unpublished documentation and materials from Kish. Thanks are also due to Aage Westenholz for his fruitful critiques and suggestions. Any errors are my own. A slightly different version of this article was published in the journal Mesopotamia (F. Zaina 2018, Delving into Archaeological archives, a Single-researcher Approach. The Case Study of Ancient Kish (Central Iraq), Mesopotamia LIII, 1–14).

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A Puzzle in 4D: Archiving Digital and Analogue Resources of the Austrian Excavations at Tell el-Daba, Egypt

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Abstract: Since 1966 Austrian excavations have taken place at Tell el-Daba in Egypt, an archaeological site revealing evidence from a society with contacts to many parts of the Eastern Mediterranean dating to the 12th–18th dynasties (early 2nd millennium BC). After 50 years of fieldwork campaigns, the Tell el-Daba archive at the Institute for Oriental and European Archaeology (OREA) at the Austrian Academy of Sciences (ÖAW) contains a huge and heterogeneous resource of digital and non-digital photographs, plans, drawings and written documentation. The 'A Puzzle in 4D' project aims to provide long-term preservation for the rich archaeological resources of this long-standing Austrian excavation project. The project is also a case study for the development of a repository for archaeological data at the Austrian Academy of Sciences. In this paper we provide an overview of the archaeological results of the excavations at Tell el-Daba and then describe the resources that were created throughout the excavations as well as the challenges we face preparing these resources for archiving. We introduce our data model and the requirements for the system architecture. We use the CIDOC Conceptual Reference Model (CRM) to model our data.

Keywords: Egypt, Tell el-Daba/Avaris, long-term excavation, legacy data, digitisation, archiving excavation data, CIDOC CRM

Tell el-Daba is an archaeological site situated in the eastern Nile delta regions of Egypt that has revealed archaeological evidence from the 12th–18th dynasties (early 2nd millennium BC).[5] Excavations at Tell el-Daba have shown the presence of a wealthy society with contacts to many parts of the Eastern Mediterranean. A unique connection to Minoan culture has been identified through the discovery of thousands of fragments of Minoan style wall paintings in two of the Tell el-Daba palaces, depicting e.g. scenes with bulls and bull-leapers, which have become a trademark of the site (Fig. 1).

Since 1966 excavations at Tell el-Daba have been carried out by Manfred Bietak for the Austrian Archaeological Institute (ÖAI), resulting in records from 50 years of fieldwork campaigns.[6] The archaeological discipline has seen major changes during this period of time, most notably a shift from analogue to digitally-born data caused by developments in information technology. As a result, the Tell el-Daba archive at OREA contains a huge and heterogeneous resource of digital and analogue photographs (Fig. 2), plans, drawings and written documentation.

Today, the preservation of parts of the datasets and information on Tell el-Daba is a major challenge to the institute. The negatives of black and white photos from earlier fieldwork campaigns are deteriorating and showing damage due to their age. Data loss may occur due to fragmented legacy research data (e.g. digital site maps) and incompatibility of formats as well as loss of knowledge about the spatial and temporal relationships of archaeological entities.

The aim of the 'A Puzzle in 4D' project is to provide long-term preservation for the rich archaeological resources of the Austrian Tell el-Daba excavation project.[7] The project is a case

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[5] Bietak 1991a; Czerny 1999; Czerny 2015; Hein – Jánosi 2004; Forstner-Müller 2008; Müller 2008; Schiestl 2009.
[6] Bietak 1996; Bietak et al. 2001; Bietak et al. 2012/2013; Bietak – Forstner-Müller 2006.
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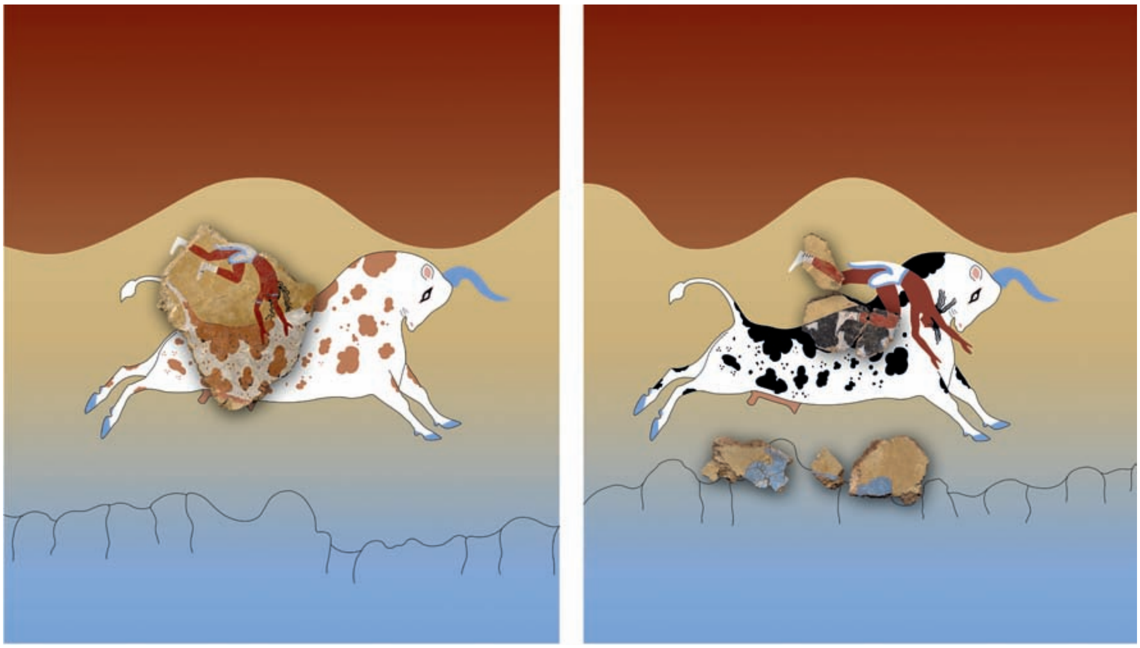

Fig. 1 Bull leaping frieze from area H/I (reconstruction)
(drawing: M. A. Negrete Martínez after Bietak et al. 2007, fig. 60)

Fig. 2 Excavations in area A/II in the year 1980 with the village of Tell el-Daba in the background
(M. Bietak, © ÖAW (ÖAI/OREA) archive)

study for the development of a repository for archaeological data at the Austrian Centre for Digital Humanities and Cultural Heritage (ACDH-CH), at the ÖAW. Digital and non-digital excavation data will be enriched with metadata and prepared for long-term archiving and open access online publication. In this paper, we report the ongoing work on the Tell el-Daba archive. We

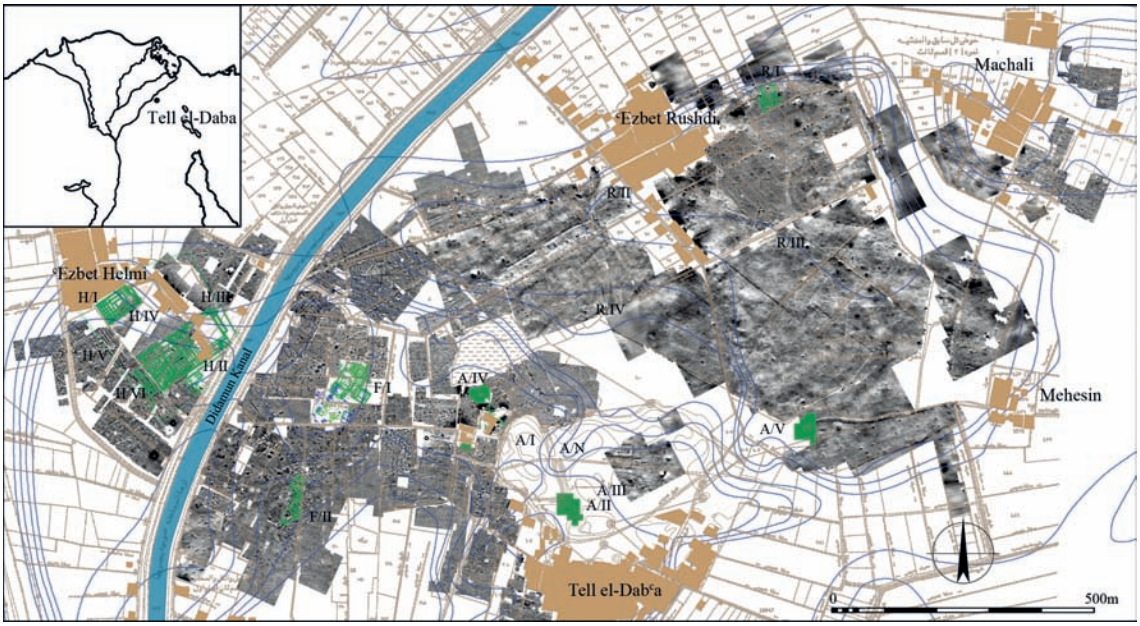

Fig. 3 Geomagnetic map of Tell el-Daba with excavation areas marked in green (© ÖAW (ÖAI/OREA) archive)

provide an overview of archaeology at Tell el-Daba and the resources resulting from 50 years of excavation. An outline of the challenges of the project is followed by a description of our work so far, including a preparatory phase, data modelling and testing of software.

After 50 Years of Excavations at Tell el-Daba: Archaeological Results

The archaeological site of Tell el-Daba, ancient Avaris, is situated on the eastern most of the five ancient Nile branches. Today the tell lies on the Didamun canal about 7km north of the modern town of Faqus in the Egyptian province of Sharkiyya (Fig. 3). Twenty phases of occupation at Tell el-Daba covered nearly 900 years of Egyptian history from the early 12th dynasty (c. 1980/70 BC)[8] to the early Ptolemaic period.[9] With a size of about 2.5km², it was one of the largest towns in the Eastern Mediterranean during the first half of the 2nd millennium BC, when the site was one of the most important trading centres in this area.

From 1966 to date, with a short interruption due to the Arab–Israeli war from 1970–1975, the site was investigated by the ÖAI under the directorship of Manfred Bietak and his successor Irene Forstner-Müller. During that period, fieldwork took place in nine different areas, revealing a continuous stratigraphy from the early Middle Kingdom to the New Kingdom (c. 1980/70–1410 BC)[10] (Tab. 1). With its mixture of Egyptian and Near Eastern Bronze Age culture, Tell el-Daba is important for chronological research in the region providing a link between Egyptian and Near Eastern chronologies.[11] Research on ancient Egyptian culture highly benefits from the excavations at Tell el-Daba, as the site reveals evidence about all aspects of human life in an ancient harbour town, from temples and palaces to simple living quarters and cemeteries (Fig. 4).

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8 Czerny 1999.
9 Lehmann 2015.
10 After Kitchen 2006.
11 Bietak 1991b; Bietak 2013; Kopetzky 2010.

	Dynasties and Kings	**absolute Chronology (after: Kitchen 2000/2006)**	**Tell el-Daba Phases**
	12th dynasty	c. 1980/70–1800/1790 BC	
	Amenemhat I		N
	Senwosret I		Hiatus
	Amenemhat II		M
	Senwosret II		L
	Senwosret III		K
			I
			I
Middle Kingdom	Amenemhat III		H
	Amenemhat IV		
	Sobeknorfu		
	13th dynasty	c. 1800/1790–1650/40 BC	G/4
			G/1–3
			F
			E/3
Second Intermediate Period	**15th dynasty** = Hyksos kings	c. 1650/40–1530 BC	E/2
			E/1
			D/3
			D/2
	18th dynasty	c. 1550–1295 BC	
	Ahmose		D/1
	Amenophis I		
	Thutmosis I		
	Thutmosis II		
	Hatschepsut		
	Thutmosis III		C/3
			C/2
New Kingdom	Amenophis II		
	Thutmosis IV		
	Amenophis III		
	Amenophis IV		
	Semenchkare		
	Tutanchamen		
	Ay		
	Horemheb		C/1
	19th & 20th dynasties = Ramesside Period	c. 1295–1070 BC	B
Third Intermediate Period			Hiatus
Late Period	**26th dynasty** = Persian period	664–525 BC	A/3
			Hiatus
Ptolemaic Period		332–30 BC	A/2
Roman Period			A/1

Tab. 1 Egyptian chronology and the phases of Tell el-Daba (Kopetzky 2017)

At Tell el-Daba a planned settlement dating to the early Middle Kingdom (c. 1970 BC) is the first preserved archaeological evidence (Fig. 5). Founded at the eastern frontier of the Nile delta, it was built as a bulwark against nomads from the east but at the same time was very likely

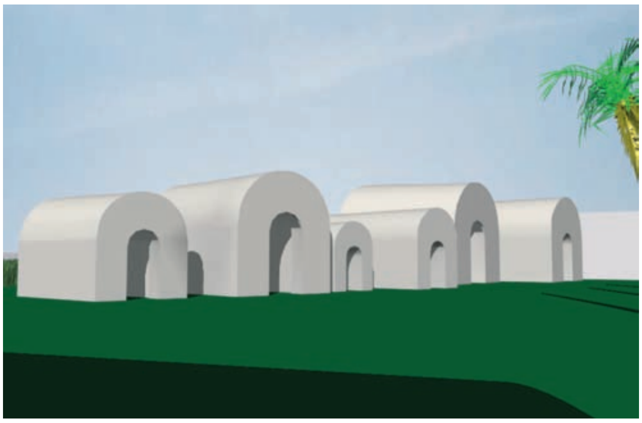

Fig. 4 Reconstruction of early 13th dynasty tombs in area F/I (Schiestl 2009, pl. 32/a, courtesy of Robert Schiestl)

used as a starting point for expeditions and a trading outpost.[12] After a short hiatus the town was extended, and an enclosed settlement with houses arranged in insulae was built (c. 1900 BC). Parts of these buildings were replaced by a temple founded by King Senwosret III in the first half of the Middle Kingdom (c. 1870 BC).[13] After Senwosret III, people from the Near East who can be identified by Middle Bronze Age material culture settled in Tell el-Daba (c. 1825 BC). They conducted trade between Egypt and the Levantine coast and brought with them a new way of life and foreign beliefs. Evidence of these can be found in the architecture and burial traditions. In the following three centuries, a unique culture from traditional and incoming influences developed at Tell el-Daba that was specific to the north-eastern Nile delta and today is known as the Hyksos culture. The city of Avaris transformed into one of the most important ports in the Eastern Mediterranean as well as a transshipment centre for Egypt.

During the last quarter of the Middle Kingdom (c. 1790/80 BC) a palace-like mansion was constructed with a garden and tombs, which testify to the wealth of its owners (Fig. 4).[14] It seems that at the end of the Middle Kingdom (c. 1710/1700 BC), an epidemic struck the city and killed a large part of its population. In the following Second Intermediate Period, Tell el-Daba and a part of the eastern Nile delta separated politically from the Egyptian crown and formed the Kingdom of Avaris. In one part of Tell el-Daba a cultic centre emerged with a series of temples of Near Eastern and Egyptian layouts surrounded by large cemeteries.[15] Huge villas show the economic success of the inhabitants of Tell el-Daba at that time (c. 1700–1650 BC).[16] The following period is known as the Hyksos period (c. 1650–1530 BC). The names of the Hyksos kings, the ‘lords of the foreign countries’ were documented by Manetho, an Egyptian priest, who wrote the first Egyptian history in the 3rd century BC. At Tell el-Daba the Hyksos kings constructed a huge palace of Near Eastern style.[17] The residential areas were densely populated, with tombs partly built under the houses and used as family crypts.[18] In this period trade with the Levantine regions and other parts of Egypt declined,[19] whilst exchange of goods with Cyprus boomed.[20] After the conquest of Avaris by King Ahmose, the first ruler of the New Kingdom (c. 1530 BC), the Egyptians expanded the harbour and most likely based their naval fleet there.[21] Large Egyptian-style palaces were now constructed at the area which is now Ezbet Helmi (Fig. 6). An important discovery was that the wall paintings in these palaces are very similar to those found in the palaces of Minoan Crete (Fig. 1). This shows a unique connection between Egyptian and Minoan culture at that time. A massive fortification wall was built on top of the palaces in the middle of the New Kingdom.

12 Czerny 1999.
13 Czerny 2015.
14 Schiestl 2009.
15 Bietak 1991b; Müller 2008; Forstner-Müller 2008.
16 Bietak 1996.
17 Bietak et al. 2012/2013.
18 Hein – Jánosi 2004; Forstner-Müller et al. 2015.
19 Kopetzky 2010.
20 Maguire 2009.
21 Bietak 2017.

Fig. 5 Two units of the planned settlement in area F/I – n/17
(M. Bietak, © ÖAW (ÖAI/OREA) archive)

Relicts of the Ramesside era are found all over Tell el-Daba, whether it be the massive enclosure wall of the Seth temple, vineyards, pits or slipper coffins. Finally, in the early Ptolemaic period the construction of tower houses, the ancient Egyptian equivalents to modern skyscrapers, represents the last chapter of the more than 17 centuries of rich history of Tell el-Daba.

Excavation Resources: analogue and digital data

During the last 50 years, over 80 excavation and study seasons have been undertaken at Tell el-Daba, first by the University of Vienna and from 1973 by the ÖAI. The vast majority of resources is kept at the archives of the OREA Institute in Vienna and smaller collections are held by ÖAI in Vienna, at their Cairo branch, and at the excavation house in Tell el-Daba.

The excavation methodology at Tell el-Daba, a combination of excavation in arbitrary spits and stratigraphic removal, has remained unchanged throughout the 50 years of excavation.[22] A major change in the documentation methodology occurred in 1996 on the other hand, with the introduction of the locus system. The locus system is often used in Near Eastern archaeology and was introduced by Mortimer Wheeler.[23] In many instances a locus corresponds to the definition

22 Aspöck et al. 2015.
23 Aspöck et al. 2015.

Fig. 6 Plan of Palaces F, G and J and building L in Ezbet Helmi (plan: N. Math, © ÖAW (ÖAI/OREA) archive)

of a stratigraphic unit, but generally a locus is defined at each excavation.[24] At Tell el-Daba, the surface of each new excavation area was defined as Locus 1 (L1). Further changes in the documentation methodology took place as part of technological advances in the field, as increasingly digital documentation methods have been used. For example, the first computer has been used on site to maintain a simple database from the late 1980s. Since 2000, analogue cameras have slowly been replaced by digital ones, field drawings have been digitised using AutoCAD during the post-excavation process and in 2004/5 a Microsoft Access database for field protocols was created and has been in use since. Therefore, after 50 years of excavation, the Tell el-Daba archive at OREA consists of a large and heterogeneous set of analogue and digital resources (Tab. 2). In some instances, one type of resource exists in different formats, i.e. analogue, digitised (scans) and born digital. For example, the field protocol, which contains the descriptions of archaeological features, exists in paper format, scans and partly as entries in a database. Parts of the field drawings have been digitised using AutoCAD, some have been scanned, whereas others still exist as paper copies only (Fig. 8). Also some of the analogue photos from the earlier campaigns (black and white negatives or colour positives) have been digitised as part of previous research projects.

[24] Masur et al. 2014.

Analogue resources (estimates)	Digital resources
• 45000 slides • 15000 photos • 200000 black & white and coloured film negatives, of which about 2/3 are of 36×24mm format and the rest are 6x6 cm film negatives • 10000 field drawings consisting of plana, sections and details on millimetre paper • 4500 drawings in ink based on field drawings and maps as well as reconstructions • 15200 pencil find drawings on special artists' paper • 8000 find drawings in ink on tracing paper • 5 files of field protocol	• field photos (from 2003) • find photos (from 2001) • databases of wall paintings • database of field protocol (from 2005) • databases of animal bones, flint, botanical remains, 14-C samples, seal-impressions • data of geophysical investigations (geomagnetic, georadar) • data of 3D-scanning of area H/III • videos

Tab. 2 Tell el-Daba resources curated at OREA, ÖAW (© A Puzzle in 4D 2017)

The Challenges of Archiving Resources from a Long-Term Archaeological Excavation

As we have seen above, 50 years of excavation at Tell el-Daba created a huge amount of heterogeneous digital and analogue resources (Tab. 2). A series of challenges arose for the digital archiving of these resources, including conceptual and technical tasks as well as establishing a retention policy.

One of the first challenges we faced was to decide which resources would be given priority in our project. As we have seen in the previous section (Tab. 2), the legacy of around 50 years of excavation is a huge resource, impossible to process in its entirety within this project. Therefore, we had to identify information and resources which may be endangered, for example because of deteriorating carrier materials or the danger of loss of contextual information about finds or features. Endangered materials included film negatives from the 1960s, when excavations started and which show evidence of damage. Hence, photos from the earlier excavation campaigns were given priority for digitisation in this project. Notably, our first case study represents the purely analogue era of fieldwork, and a second one characterises when digital documentation methods were also in use to see how analogue traditions were carried over into the digital age.

A somewhat related issue is that several Tell el-Daba resources existed in multiple forms, which requires the establishment of a policy to decide which resources are preserved and in what way. Parameters for which resources should be selected for long-term preservation concerns documents with multiple versions, such as those created during the post-excavation process of digitising plans and drawings. Deciding which versions of data should be preserved was necessary, and specifically so-called preservation intervention points had to be defined.[25] For example, pottery was drawn in pencil on cardboard during Tell el-Daba excavations (Fig. 7). In most cases these pottery drawings are reconstructions of pots based on pottery sherds. At a later stage, these drawings were converted into ink drawings either by drawing directly on the cardboard over the pencil drawings or by using tracing paper, which preserved the original pencil drawing. The ink drawings were fit for publishing. A large number of these ink drawings had already been scanned into a digital format. Therefore, in some cases information about the same pottery find had been documented in three different analogue and digital formats. In some cases, however, researchers disagreed about the reconstruction of sherds, and therefore pencil and ink drawings may contain differences, or there may be different ink drawings of the same pencil drawing. This is just one example in which defining parameters and ways to preserve

[25] ADS.

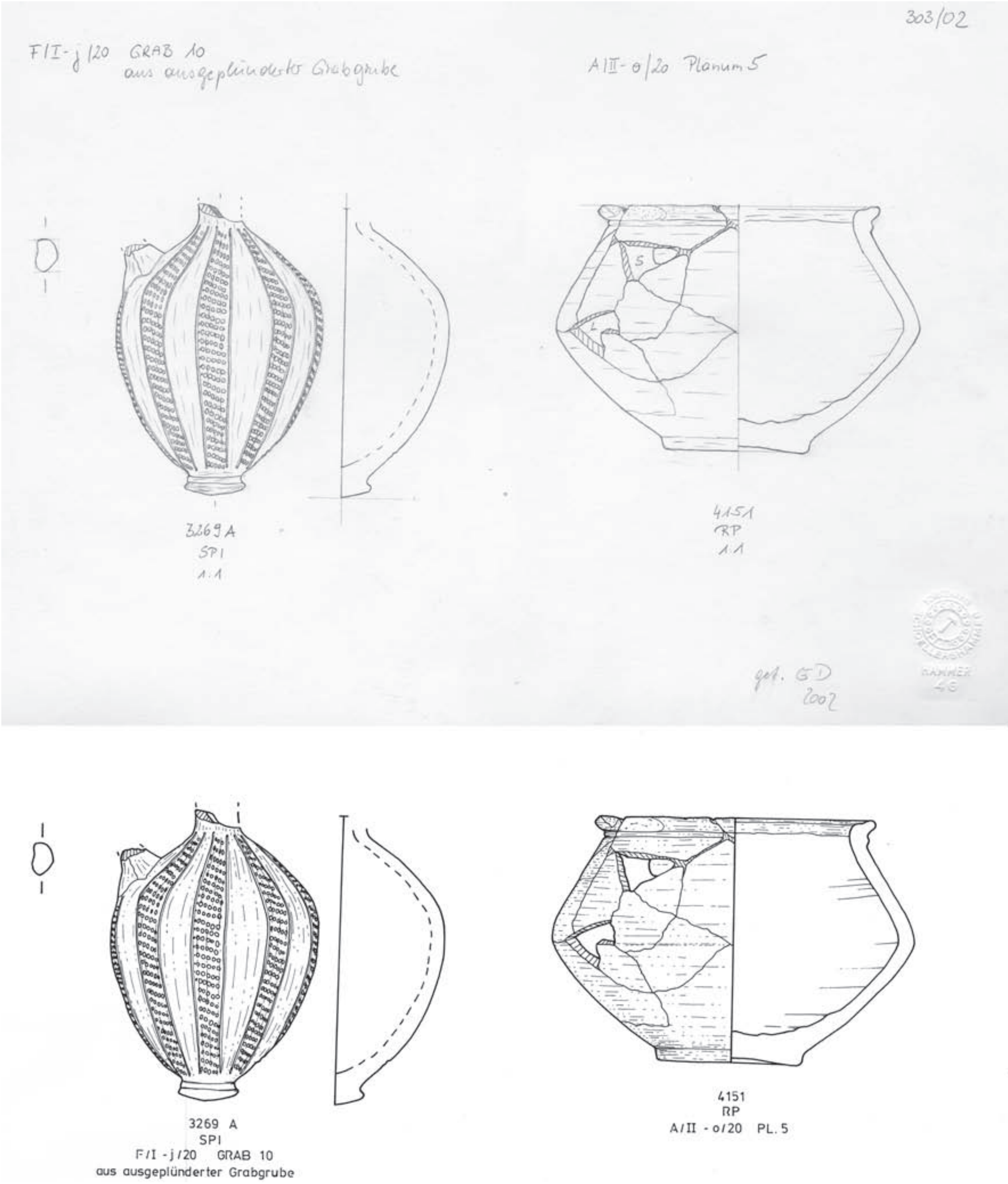

Fig. 7 Examples of field drawing of finds in pencil and in ink
(drawing: K. Kopetzky, © ÖAW (ÖAI/OREA) archive)

different formats and versions of one particular finding must account for multiple interpretations in order to avoid loss of knowledge.

As Jon M. Frey has nicely put it in his contribution to this volume, the resources of most excavations already function as an analogue form of a relational database.[26] The documents work together, but it is also usually possible to use any form of documentation as a point of entry to the recording system. The same holds for Tell el-Daba, where the documentation of the

[26] Frey, this volume.

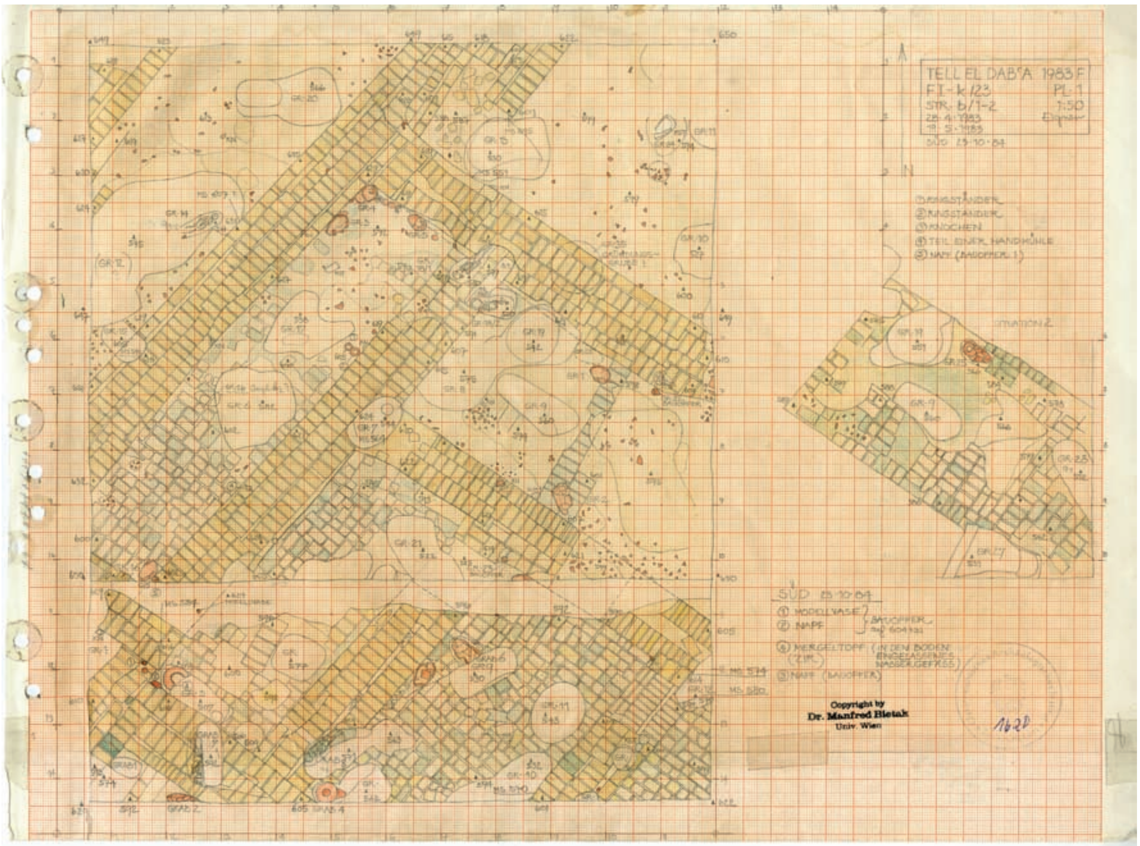

Fig. 8 Field drawing of square F/I – k/23 planum 1
(drawing: D. Eigner, © ÖAW (ÖAI/OREA) archive)

excavation process in the various types of resources (Tab. 2) is connected through consistent naming conventions of excavation areas and finds. The challenge was to understand how the physical reality of the excavations at Tell el-Daba was represented in the documentation of the excavation process. This provided the basis for the creation of a solid data model for the recreation of the Tell el-Daba archive, which currently is a mix of analogue and digital resources, in a purely digital form allowing to retrieve resources based on their metadata. We found, however, that data modelling was complicated by a series of factors. For example, analogue recording methods did not have the standards for entering data into a database, meaning that documentation handwritten by a large number of persons and teams over half a century of fieldwork did not always follow consistent protocol. For example, excavators may have put additional information on some resources, such as additional drawings of evidence discovered in a later campaign may have been added to a field drawing from a previous season, or several related field drawings were sometimes stuck together at a later stage to create an oversized map. Other concerns are potential omissions in the data. The conceptual challenge of the project was to create a data model that allows for all the complex relations between the different entities – and for all potential exceptions. For example multiple finds may be documented on one documentation item, but also one find may be documented by many documentations (N:N relationship). Different excavation campaigns were connected to some archaeological features. Excavation of for example a wall may have started in an earlier campaign but was completed in one of the subsequent campaigns, sometimes many years later.

Another information integration challenge was the combination of analogue and newer digital resources with the goal to integrate them in order to be able to retrieve information no matter if the original documents were analogue or born digital. As described above, some types of resources may exist in several types of formats.

Next to the major intellectual task of defining a sound conceptual model, we needed to choose the right serialisation format to encode the metadata. There is large consensus that the long-term readability of metadata is best supported if information is structured according to existing standards and available in a structured, self-contained, human-readable serialisation format. This means that even though one will use any specific application with its internal data representation for data entry, it is crucial that this information can be retrieved without loss of information, ideally in an RDF- or XML-based serialisation, following well-established metadata standards like e.g. Dublin Core, LIDO, METS/MODS or CIDOC CRM.[27]

A similar but much more complex problem lies with the data itself, such as where there is a plethora of file formats for different kinds of data, many of which are opaque proprietary formats that may be rendered unreadable in the near future. Here we relied mainly on recommendations for archiving various document types and enumerating safe and problematic formats issued by various national research agencies and repositories.[28]

The 'A Puzzle in 4D' project is a case study for the development of a repository for archaeological data at the Austrian Academy of Sciences. Technological challenges concerning long-term preservation of digital resources involved aspects of data entry, storage and retrieval, or submission, archival and dissemination according to the Open Archival Information System (OAIS).[29] With respect to data entry by far the largest or most resource intensive task was the systematic cataloguing of the material, i.e. entering structured metadata for tens of thousands of individual documentation items and the archaeological objects they represent. A related aspect was the ingestion process, which must be a validating batch processing task able to handle large amounts of data and ensure correct linking of resources with corresponding metadata.

Finally, once the data was safely stored and archived, it also should be made accessible to the research community in a useful way. For us, this meant especially the possibility for deep semantic search in the data, i.e. discovery systems that allow queries based on the conceptual model to retrieve digital objects and information about their respective research/excavation context. Rich features should be implemented to browse through the material, i.e. creation of relations between related objects as links that allow connecting related finds, areas, documentation objects, involved persons, study seasons, etc.

Obviously, with all these challenges we were not alone and a growing number of repository solutions are readily available as technical solutions for exactly these tasks. There are the well-established domain-specific repositories for archaeology, most prominently the Archaeology Data Service[30] and institutional repositories as well as a growing number of generic repositories for research data. While these services are certified to provide reliable archiving options for research data, they usually consider as one item a whole dataset; i.e. they handle a collection of materials as a binary black box minted with metadata for the whole package, usually without a possibility for deep searching and browsing inside the package/dataset. This means that a researcher interested in for example a pottery find from a specific period would need to download the complete package, make sense of the inner structure and try to find her way through it to identify the maybe small but important piece of information of interest to her.

For deep searching and browsing we experimented with existing archaeological database systems, which promise a certain amount of standardisation and interoperability. In particular we explored Arches, which, building on CIDOC CRM as the underlying data model, sounded very promising for our needs.[31] With Version 3.0, however, we encountered major problems in getting

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[27] Le Boeuf et al. 2015.
[28] ADS; UK Data Service; IANUS; BDA; DARIAH-DE.
[29] OAIS 2012.
[30] Condron et al. 1999; Richards 2006.
[31] Aspöck – Masur 2015.

the system running and unsurpassable obstacles in adapting the default setup to the specific needs of our project.[32]

Our Approach to Archiving Tell el-Daba Resources

The 'A Puzzle in 4D' project is a collaborative project among archaeologists, data specialists and technicians. Only a few have prior experience working on Tell el-Daba and knowledge of the archaeological evidence from the site, method of excavation and documentation. For this reason, we started our project by compiling a document we called 'The essential guide to Tell el-Daba'.[33] This document contains introductory information necessary for archaeologists, technicians and student assistants to start working on the Tell el-Daba resources within the project. It will also be a resource for those who later use the archive.

In the next step, digital and analogue files were analysed to identify the different types of resources, which information they contained (e.g. description of archaeological evidence in a square) and the characteristics of the respective information carriers (e.g. a 150 ppi scan of paper sheets now stored in Egypt). Digital files were ordered according to a set of criteria, for example time (a folder on autumn season 1977) or topic (geophysics data, animal bone data). We identified and removed duplicate files, but left the folder structure unchanged.

We collected so-called 'locus names', i.e. names of types of archaeological evidence such as pit or grave, for a Tell el-Daba thesaurus. For example, when a new excavation area was chosen at Tell el-Daba, its surface was always defined as Locus 1 (L1). Tombs, pits, floors and any visible archaeological feature are given locus numbers. Locus names and numbers appear across all types of Tell el-Daba resources. Locus names became the basis for the controlled vocabulary for metadata entry, which formed the basis for the project thesaurus.

User requirements for the Tell el-Daba archive were defined in focus group meetings with the OREA Tell el-Daba research group. A future generation of researchers and new projects will have the greatest benefit from the archive. Generally, resource discovery will be the priority (e.g. to find all resources from a specific area, see below). For ongoing research projects, however, contextual information such as the position of pottery finds, including altimetric data, would be useful to compare similar finds across different contexts and excavation areas. The Archaeological Information System (AIS) developed as part of the 'A Puzzle in 4D' project will be able to provide detailed contextual information on loci excavated in squares of excavation area F/I.[34]

A suitable case study area was selected for the development of the AIS, data model and workflows for digitisation and archiving, as well as for standards for metadata and semantics. Area F/I-j/21 was chosen because it contained types of archaeological evidence representative for Tell el-Daba (residential buildings, a palace, tombs, etc.). F/I-j/21 was excavated in 1979 and 1980, and the documentation at excavation was still fully analogous. Additionally, no copyright issues limit usage of resources from this excavation area, which was one of the crucial criteria.

Data Model

In order to organise and integrate the metadata of digital and analogue resources that are created in the course of the project a data model is needed to structure the metadata so that it is possible to retrieve resources related to specific archaeological research questions. Entity relationship models have been used widely to model archaeological data in relational databases like Postgres, MySQL

32 Aspöck et al. 2016.
33 Aspöck – Kopetzky 2015.
34 Kucera et al., this volume.

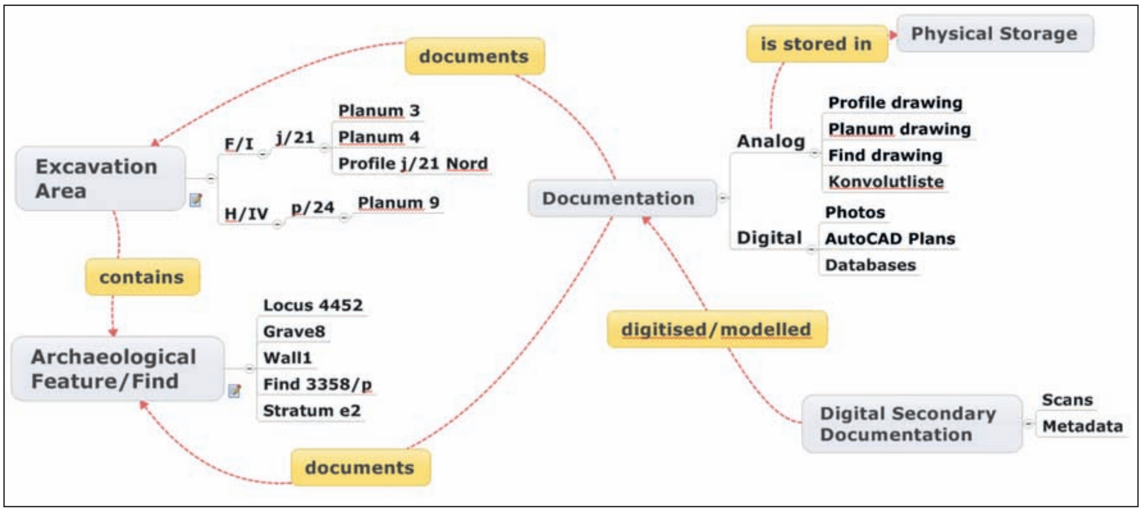

Fig. 9 Main categories of data model representing physical reality, documentation and digitising processes (Hiebel, Aspöck and Kopetzky 2017)

or MS Access. Recently, with the advance of semantic technologies, the use of ontologies as data models has increased in archaeology.[35]

We decided to use the CIDOC CRM ontology[36] as a conceptual background to model Tell el-Daba resources, the physical reality they document and the process of creating digital documentation from analogue sources. The CIDOC CRM is an ISO standard for cultural heritage documentation and was extended in the past few years to model archaeological excavations (CRMarchaeo), scientific observation (CRMsci) and digital provenance (CRMdig).[37] Through these extensions and the CIDOC CRM as a core ontology it is possible to create a network of information that is able to represent the complex relations that are created when the physical remains of activities in the distant past are excavated and documented and the documentation is digitised.

Analysing the available documentation and the process of digitising analogue sources we identified five main categories, which are distinct in their nature. These are:

- Excavation areas
- Archaeological features and finds
- Documentation (analogue or digital)
- Physical storage
- Digital secondary documentation

Figure 9 shows these main categories together with examples of types of documentation and the main relationships between them.

In very simple terms it can be said that the physical reality of archaeological features and finds from specific excavation areas is documented in analogue and digital documentation. We differentiate between features and materials created in archaeological times (the distant past) and features and areas created at the time of excavation by the archaeologists (e.g. excavation areas, squares). The CRMarchaeo extension models this differentiation in a detailed way. In the ‘A Puzzle in 4D’ project the documentation of archaeological features/finds and excavation areas will be processed to make it available in a digital format and to create homogeneous metadata that answers the following questions:

35 Binding et al. 2015.
36 Le Boeuf et al. 2015.
37 CIDOC CRM.

- Which files document an *excavation area*? For example, which resources document the archaeological evidence and finds in area F/I, square j/21, Planum 3?
- Which files document *archaeological features/finds of a specific type*? For example, which resources do we have from tombs?
- Which files document a specific *archaeological feature/find*? For example, which resources document tomb 5 and walls in area F/I, square j/21?
- Which archaeological *features/finds of a specific type* are documented *in a specific area*?

In order to create homogeneous metadata, we had to define processes to create identifiers for the instances of our main categories. Therefore, we had to find in what context a piece of resource was unique to add the corresponding contextual information to the file name. For example, a tomb number (e.g. 'tomb 5') is unique within a square (e.g. square 'j/21'), which is unique to a specific area (e.g. area 'F/I'). Finally, adding our shortcut for the site Tell el-Daba created the unique file name for this specific digital object (e.g. 'TD_F/I_j21_tomb5'). Hence, for the excavation areas and archaeological features and objects the naming conventions established within the Tell el-Daba excavation and documentation methodology produced unique identifiers if contextual information could be added.

System Architecture and Test Implementation

To create, manage and query metadata and digital documents of the Tell el-Daba excavation documentation we identified five main components within the system architecture (Fig. 10).

The goal is to develop a system with open and specified interfaces between its components. The leading idea is that the data are the most important asset of the system, and it should be possible to choose different software products for each system component and, if necessary, replace them individually to improve specific processes.

For the test implementation we chose Microsoft Excel for metadata entry and management of the controlled vocabularies. The reasons were that we found the flexibility offered by Microsoft Excel an advantage compared to other systems and we could immediately start the metadata entry process. The Excel worksheets had to be customised to allow the entry of several identifiers in one

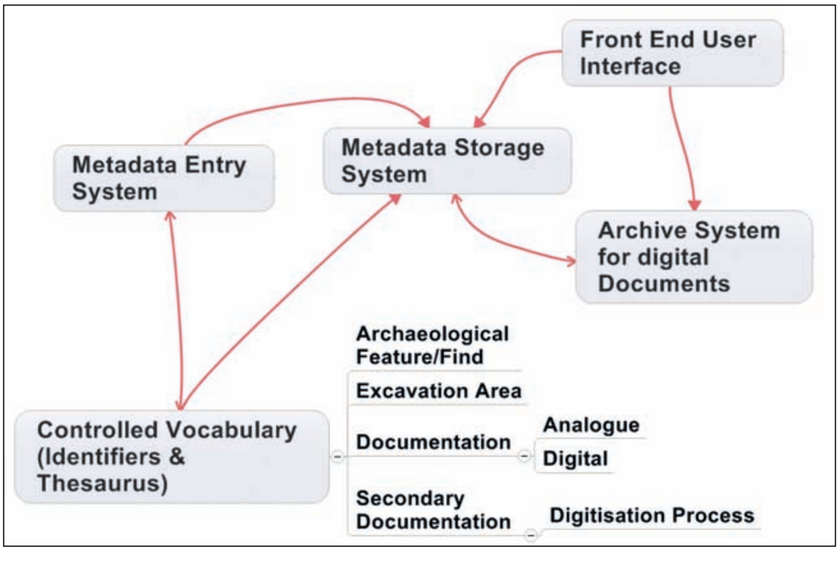

Fig. 10 Main components of the system architecture to create, manage and query metadata and digital resources of the Tell el-Daba excavation documentation analogue (Hiebel, Ďurčo and Aspöck 2017)

field from a dropdown menu to represent 1:n relations. This was realised using Visual Basic macros and Excel data validation functionality.

We used KARMA,[38] an information integration tool, to map metadata and vocabularies to the CIDOC CRM data model. Figure 11 shows how the metadata was mapped to the formal definitions of the CIDOC CRM ontology.

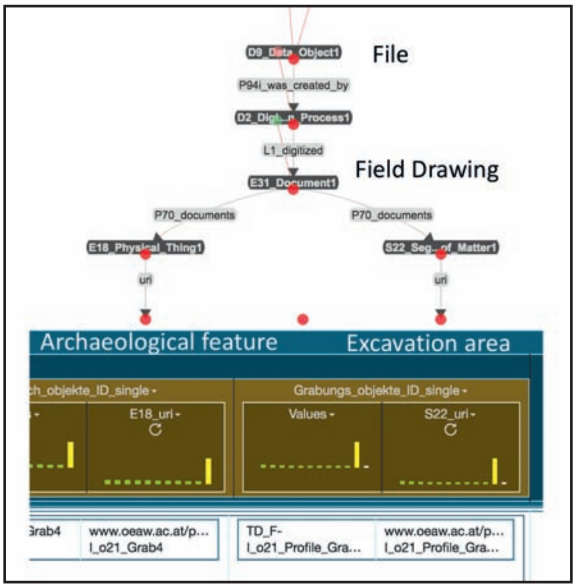

Fig. 11 Using the Karma tool to map the digitisation of a field drawing to CIDOC CRM and CRMdig (Hiebel 2017)

KARMA created a knowledge graph to represent the information and exported it in Resource Description Framework (RDF), a standard model for data interchange on the internet that is able to relate logical statements within a network.[39] RDF is the foundation of the Linked Open Data (LOD) cloud, in which datasets are linked to each other on a global level.[40] The thesaurus portion of the controlled vocabularies was created with the KARMA tool as well and represented in Simple Knowledge Organization System (SKOS), a data model of the semantic web community for sharing and linking knowledge organisation systems such as thesauri, taxonomies, classification schemes and subject heading systems.[41]

After the mapping process, the RDF data was ingested in a triplestore, which is a database to store and query RDF data. In the triplestore the linking of the resources (single described entities like a specific excavation area or the created SKOS concept of a 'tomb' from the archaeological thesaurus) took place, hence integrating metadata of different digital resources such as field drawings and photos. Resources were either linked on a class level (because they belong to the same CIDOC CRM class, e.g. 'document' or 'physical thing'), on the SKOS concept level (because the same thesaurus term was attributed to them, e.g. 'field drawing') or on an individual level (because they describe the same excavation area or archaeological feature/find, e.g. 'Site Tell el-Daba, area F/I, square j/21, Planum 3'). The correct linking in the triplestore was dependent on the creation of the right identifiers for instances of excavation areas, archaeological features/finds, analogue and digital documentation and secondary digital documentation. The data in the triplestore can be queried using the SPARQL[42] query language. To test the system and workflow we ingested the RDF representation of the metadata (created through mapping in KARMA from the tabular data in Excel files) of scanned field drawings and photos of the excavation areas F/I and A/II and created queries according to the requirements defined during data modelling. The results showed that this approach works.

One of the queries created a de-normalised export of data including excavation areas, archaeological features/finds and documents with their types and filenames. The query is listed below:

```
PREFIX p4d: <http://www.oeaw.ac.at/puzzle4d/>
PREFIX crm: <http://www.cidoc-crm.org/cidoc-crm/>
```

[38] ISI.
[39] W3C 2014.
[40] LOD.
[41] W3C 2009.
[42] W3C 2013.

```
PREFIX crmsci: <http://www.ics.forth.gr/isl/CRMsci/>
PREFIX crmdig: <http://www.ics.forth.gr/isl/CRMdig/>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX geo: <http://www.opengis.net/ont/geosparql#>

select distinct ?areal_label ?planquadrat_label ?planum_label ?e18_label ?e55_e18_prefLabel ?s22_label ?e55_s22_
prefLabel ?e31_label ?e55_e31_prefLabel ?filename ?e22 ?e18 ?e31
where {
?d9 crm:P94i_was_created_by ?d2 .
?d2 crmdig:L1_digitized ?e31 .
?e31 rdfs:label ?e31_label .
        optional {
        ?e31 crm:P2_has_type ?e55_e31 .
        ?e55_e31 skos:prefLabel ?e55_e31_prefLabel . }
        optional {
        ?e31 crm:P70_documents ?e18 .
        ?e18 rdf:type crm:E18_Physical_Thing .
        ?e18 rdfs:label ?e18_label .
                optional {
                ?e18 crm:P2_has_type ?e55_e18 .
                ?e55_e18 skos:prefLabel ?e55_e18_prefLabel . }}
        optional {
        ?e31 crm:P70_documents ?s22 .
        ?s22 rdf:type crmsci:S22_Segment_of_Matter.
        ?s22 rdfs:label ?s22_label .
                optional {
                ?s22 crm:P2_has_type ?e55_s22 .
                ?e55_s22 skos:prefLabel ?e55_s22_prefLabel . }}
        optional {
        ?s22 crm:P89_falls_within ?s22_areal .
        ?s22_areal crm:P2_has_type <http://www.oeaw.ac.at/puzzle4d/E55/S22/Areal> .
        ?s22_areal rdfs:label ?areal_label}
        optional {
        ?s22 crm:P89_falls_within ?s22_planquadrat .
        ?s22_planquadrat crm:P2_has_type <http://www.oeaw.ac.at/puzzle4d/E55/S22/Planquadrat_Schnitt>.
        ?s22_planquadrat rdfs:label ?planquadrat_label}
        optional {
        ?s22 crm:P89_falls_within ?s22_planum .
        ?s22_planum crm:P2_has_type <http://www.oeaw.ac.at/puzzle4d/E55/S22/Planum> .
        ?s22_planum rdfs:label ?planum_label}
?d9 rdfs:label ?filename .}
```

The result was imported to Microsoft Excel, and a filter was used to search excavation areas, archaeological types and resource types for retrieval of documents and filenames representing graves in a specific excavation area (Fig. 12). With this test we could show that our approach was able to answer the questions we defined earlier.

The same exported data was used to implement a prototype of a web-based front end that accesses a SQL database, proving that the modular approach centred on a sound conceptual model helps to prevent a technological lock-in. During the project, the digital resources themselves resided on a shared file server. At the end of the project, the digital resources will be transferred to the new FEDORA-based ÖAW repository ARCHE.[43] Figure 13 shows the individual components of the prototype system architecture.

43 FEDORA; ARCHE.

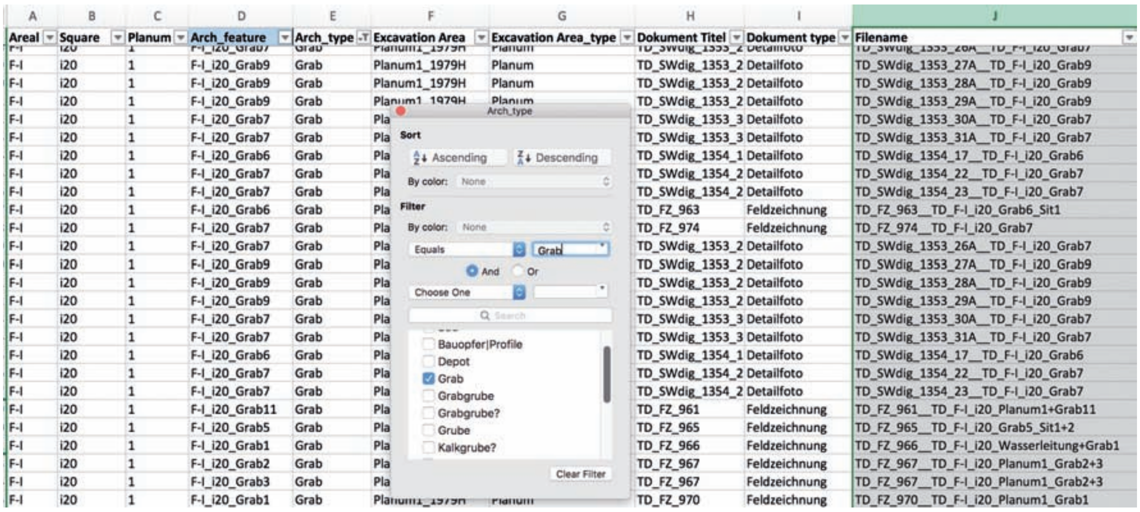

Fig. 12 Query results in MS Excel using filter function to show all documents and files that represent graves in a specific excavation area (Hiebel 2017)

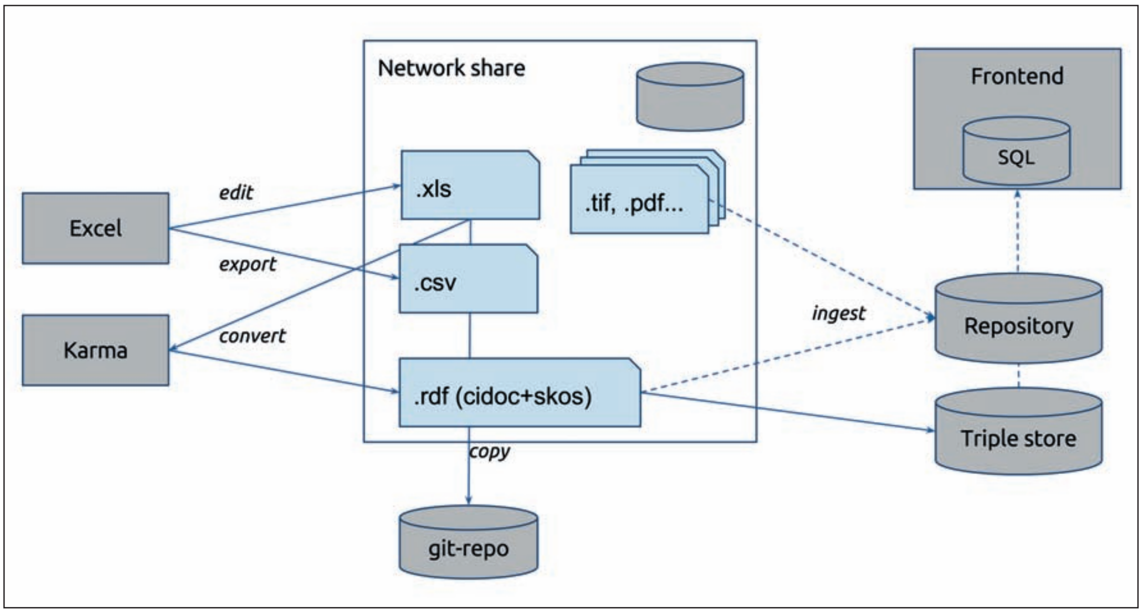

Fig. 13 Components of the prototype system architecture (Ďurčo, Hiebel and Aspöck 2017)

Concluding Remarks

In the first year of the project we have gained a thorough understanding of the Tell el-Daba excavation and documentation methodology, allowing definition of the data model and metadata fields. Metadata fields and their relations to each other were defined to represent all crucial information contained in the resources and relate the thousands of single documents to each other. To encode our metadata, we chose CIDOC CRM to represent the complex relations that were created as archaeological remains were excavated over a period of 50 years and documentation practices changed, most notably from analogue to digital. Using an international standard increases the chances for preservation of the semantics of the metadata in the future.

On an implementation level we have developed an approach to create, manage and query metadata information for the Tell el-Daba excavation documentation based on the CIDOC CRM data model. We used tools and specifications of the semantic web community for our test implementation, and so far, we were able to answer our questions.

We believe we have addressed the main challenges on a conceptual level and achieved an implementation level for the digital documentation of old excavation data in combination with new digital data. At the time of publication of this paper, which coincides with the near completion of the A Puzzle in 4D project, the digital resources are transferred to the ÖAW repository ARCHE.[44]

Acknowledgements: Information about the progress of the 'A Puzzle in 4D' project and access to the Tell el-Daba archive is provided on the project homepage <https://4dpuzzle.orea.oeaw.ac.at/index/>. The 'A Puzzle in 4D' project has been made possible through funding from the Nationalstiftung für Forschung, Technologie & Entwicklung (DH 2014/12) and it also received support from the EU FP7 project ARIADNE (FP7-INFRASTRUCTURES-2012-1-313193). We thank Manfred Bietak, Sabine Ladstätter and Irene Forstner-Müller for their support and engagement during the project.

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The Tell el-Daba Archaeological Information System: Adding the Fourth Dimension to Legacy Datasets of Long-Term Excavations (A Puzzle in 4D)

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Abstract: Archaeological research relies on the documentation and analysis of archaeological entities in space and time, i.e. the stratigraphic ordering of these units, resulting in a stratigraphic sequence. A GIS-based Archaeological Information System (AIS) organises archaeological entities and associated attributable information according to its specific three-dimensional geographical position based on the framework provided by a Geographical Information System (GIS). To compile a stratigraphic sequence of these entities located in space, the GIS-based AIS must be extended by a fourth dimension – time. The paper presents the associated extension of ArcGIS (ESRI) by a stratigraphic sequence composer with an integrated interval-based time model as the basic digital environment for spatio-temporal analysis of archaeological excavation datasets. The long-term excavation at Tell el-Daba, Egypt was chosen as a case study to evaluate the applicability of various digital analysis tools using a geo-referenced 4D AIS on non-digital and incomplete excavation datasets. As most existing archaeological excavation datasets are based upon long-term inconsistent and analogue data, it is crucial to integrate and handle such data to ensure their accessibility for state-of-the-art archaeological spatio-temporal data analysis.

Keywords: GIS-based archaeological information system (AIS), 4D GIS, spatio-temporal analysis, legacy dataset, comparability, Allen's interval algebra, stratigraphic sequencing tool

Most archaeological datasets rely on legacy data recorded throughout previous decades and even centuries. In fact, most archaeological data and information are based on long-term excavations and surveys that include inconsistencies due to evolving documentation systems and missing data due to arbitrary excavation. Especially since the introduction of the principles of archaeological stratigraphy in 1979[9] archaeological methodology has seen basic changes in the paradigm, resulting in major developments in applied documentation techniques and basic theoretical concepts enforced by the advent of geographical information systems (GIS).[10]

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9 Harris 1989.
10 Neubauer 2004.

Considering the fact that archaeological excavation results are always interpretative and depend on the applied methods,[11] the issue of intra-site and inter-site comparability of results based on the various methodological approaches applied becomes prevalent. Especially the aspects of intra-site integration of stratigraphic sequences and their inter-site comparison are of vital importance. With respect to the spatial and temporal properties of every archaeological entity an archaeological information system (AIS) for the organisation, display and analysis must be GIS-based[12] and extended to 4D.[13]

The digitisation of analogue excavation archives is crucial for comparability with new digital datasets achieved through state-of-the-art methodologies (e.g. stratigraphic excavations, digital recording techniques, geo-archaeological and morphological sampling). Redundancy is increased regarding the preservation of the data. To increase comparability and reproducibility of results a standardised workflow for the digitisation, interpretation and spatio-temporal analysis of the data is necessary. The aim of the project 'A Puzzle in 4D' is to develop and apply workflows and techniques to digitally preserve, archive and interpret legacy data using the example of the excavations at Tell el-Daba (TD).[14] Furthermore the possibility of reconstructing undocumented and missing information will be examined according to a procedure best described as 'reverse excavating'. Reconstruction of the workflow of the original excavation and translation into a stratigraphic sequence datasets can be completed and the reliability of given datasets evaluated. Major scientific tasks are the digitisation of the Tell el-Daba legacy datasets, metadata and semantic enrichment, the development of strategies for data archiving and open source access according to international standards, the development of a 4D AIS, virtual reconstruction, visualisation and dissemination.

The development of a GIS-based 4D AIS will secure comparability of the Tell el-Daba legacy datasets in accordance with stratigraphic theory and methodology, a task mainly undertaken by the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology (LBI ArchPro). Best routines for every task will be evaluated and standardised. We will show that the AIS will enhance and simplify further archaeological interpretation. Respective results will be reproducible in respect to the confirmability of the origin of the archaeological information.

Within this paper we present: (1) the basic applied principles and rules for the segmentation of space into stratigraphic units (SU), resulting in spatio-temporal relations displayed by a stratigraphic sequence; (2) the basic design and components of a GIS-based 4D AIS recently developed and (3) an initial suggestion for a standardised workflow for digital segmentation and archaeological interpretation optimised for the Tell el-Daba dataset.

The Case Study of Tell el-Daba

Tell el-Daba is an archaeological site located approximately 150km northeast of Cairo in the fertile Nile delta and has revealed archaeological evidence from the 12th to 18th dynasties (early 2nd millennium BC).[15] During the 15th dynasty it was the capital city of the Hyksos. The area of the ancient town covers about 2.5km². Since 1966 excavations were conducted by the Austrian Archaeological Institute (ÖAI) under the direction of Manfred Bietak. Around 50 years of active fieldwork campaigns have been carried out, resulting in an enormous amount of field protocols, drawings, photographs and prospection survey data. The excavations uncovered mainly residential buildings, tombs and temples illustrating the contacts of a wealthy society to many parts of the eastern Mediterranean. The site is also famous for Minoan style wall paintings reconstructed

[11] Kucera – Löcker 2007.
[12] Arroyo-Bishop – Lantada Zarzosa 1995.
[13] DeRoo et al. 2014.
[14] Aspöck et al. 2015; Aspöck et al., this volume.
[15] Bietak 1970; Bietak 1975; Bietak 1991; Bietak 1996; Bietak 2010; Bietak et al. 2001; Bietak et al. 2007; Kopetzky 2010. For a summary see Aspöck et al., this volume.

out of thousands of fragments. Reconstructions show scenes with bulls and bull-leapers, indicating a unique connection to Minoan culture. The excavations have been carried out with a mixed methodology of excavating in spits biased by observable artificial surfaces such as walls and floors.

Since the start of excavation, the applied methodology stayed the same to ensure consistency in the dataset. Documentation methodology changed however in 1996 with the introduction of the so-called locus system at Tell el-Daba. In many instances a locus corresponds to the definition of a stratigraphic unit, but generally what a locus is defined individually at each excavation. Further changes in the documentation methodology took place as part of technological advances in the field, as increasingly digital documentation methods have been used.


Fig. 1 Situation at the excavations in TD in 1979. One-metre-wide bars separate the squares (15×15m) of area F/I (OREA archive)

Excavations at Tell el-Daba have taken place in five areas (Ezbet Helmi (H/I-VI), Ezet Rushdi (R/I-IV), Catana (E/I), Tell (A/N+A/I-V), Feld (F/I-II)), which are subdivided into quadratic trenches (squares) of usual sizes of 10×10m or 15×15m. The squares were separated by bars of 1m width for the purpose of documentation of cross-sections. Each square was excavated in spits, resulting in a dataset which consists mainly of a handwritten record (including sketches), drawings (levels, details and cross-sections of scales 1:50, 1:20 and 1:10) and photographic documentation (B&W, RGB and slides). The main observed archaeological structures have been also interpretatively drawn in a generalised map (ink drawing) and partly digitised with AutoCAD (Intergraph). During the first campaigns a relative grid, which was geographically referenced and embedded within the global WGS84 coordinate system throughout a geodetic survey in 2008, was used for positioning.

For the development and testing of an AIS, which had to be optimised for digitisation, segmentation and analysis of the Tell el-Daba dataset, a subset of the data was chosen. Area F/I has already been analysed and interpreted archaeologically to allow comparison of the newly gained results with the existing archaeological interpretations. Archaeological structures documented in the respective area date from the first half of the 15th Dynasty (1650/40–1530 BC) to the late 12th Dynasty (1980/70–1800/1790 BC).[16]

In the uppermost levels of the area a temple was found dedicated to stratum a/2 (first half of the 15th Dynasty) followed by a villa belonging to stratum b (middle of the 13th to the end of the 12th Dynasty). Due to different utilisation phases of the villa stratum b was subdivided into b/3 to b/1. Within stratum b offering pits were also documented.[17] At a deeper level the ruin of a huge building, most likely a palace or villa from stratum c (beginning of the 13th to the end of the 12th Dynasty) was found as well as the palace/villa itself, belonging to stratum d/1 (early 13th to late

16 See Aspöck et al., this volume, table 1.

17 Müller 2002.

Fig. 2 Overview of square j/21 (level 3), area F/I in 1979 (OREA archive)

12th Dynasty).[18] Like the younger villa this building was subdivided into two utilisation phases d/1.1 and d/1.2 and respective tombs.[19] An earlier level yielded the Mittelsaalhaus belonging to stratum d/2 (early 13th to late 12th Dynasty) and including the workmen village[20] of stratum e, which dates to the 12th Dynasty. The mentioned strata are linked to the superordinate Tell el-Daba phases E/2 to N/1–3,[21] The temporal model of the described sequence of strata related to archaeological phases was the basis for the subsequent temporal analysis.

For detailed analysis a single trench (square j/21) was chosen to represent most types of observed archaeological features and structures.

For further analysis several specific levels of 40 additional squares displaying the palace and surrounding infrastructure of strata d/1 were added to the subset. The legacy dataset includes

[18] Eigner 1985.
[19] Schiestl 2009.
[20] Czerny 1999.
[21] Bietak 2013/2014.

analogue data (photographs, slides, cross section drawings, level drawings, detail drawings, field protocols, overview maps and topographical maps) and digital data (CAD technical plans, satellite imagery and topographical data). All these data were taken into account for developing a standardised digitisation and segmentation procedure[22].

Basic Principles of Segmentation

The first step within a comprehensive digitisation process was to transfer the various data sources, i.e. photographs, maps, sketches, lists, notebooks etc., into appropriate digital formats for further use in the GIS-based AIS.

The extraction of the relevant archaeological entities or SU from analogue or digitised excavation maps was based on digitisation using basic GIS functionality. Every SU, i.e. deposits and surfaces,[23] was characterised by its geographic position and extent. Surfaces were defined by their immaterial topography, whereas deposits bear material components such as artefacts, composition, texture etc.

Deposits and surfaces can be described further based on their spatial and temporal relations. From the analysis of spatial relations, i.e. superposition, a basic stratigraphic sequence according to the principles of archaeological stratigraphy[24] was derived. This sequence must be refined based on the temporal relations of all units. Since every archaeological entity could be defined temporally as a time span or interval rather than a point in time or event, a temporal analysis of the dataset must be carried out based on time intervals, advancing the event-based concept of simple temporal relations (earlier, later and contemporary). For this reason interval algebra as suggested by Allen[25] was introduced, as also recently shown by Drap et al.[26] As archaeological stratigraphy is based on 4D entities, it deals first of all with the analysis of spatio-temporal relations of archaeological stratigraphic units to derive the formation of the respective stratification. Only spatio-temporal analysis is capable of illustrating the changes of an archaeological site or landscape. For defining temporal relation a physical superposition (i.e. the entities may not be in direct physical contact) of SU is not necessary. This approach is similar to the monitoring of various processes that change the attributes or shape of volumes in time, e.g. earth slides, flooding and mining.[27]

GIS-Based AIS

The main focus of the research and development done by the LBI ArchPro was the design and implementation of the different components of a GIS-based AIS. Because of the geographical character of archaeological excavation information, the appropriate framework is provided by a GIS. Based on the LBI ArchPro's long-term experience of the application of ArcGIS (ESRI) for the interpretation and analysis of archaeological data and also with respect to basic compatibility with other software, ArcGIS Desktop 10.2 was chosen. In contrary to CAD software a GIS

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22 The term 'digitisation' could be firstly used for transferring analogue into digital data. In this case a 1:1 projection of the illustrated information has to be achieved. Secondly it also describes the process of generalising this information e.g. if a drawing of a pit is reduced to its outline in drawing a polygon around it. This can also be called vectorisation of selected parts of the data. If this is the case, the digitisation results in the segmentation of an area or space.

23 Neubauer 2007; Traxler – Neubauer 2008.

24 Harris 1989.

25 Allen 1986.

26 Drap et al. 2017.

27 Kurte – Durbha 2016.

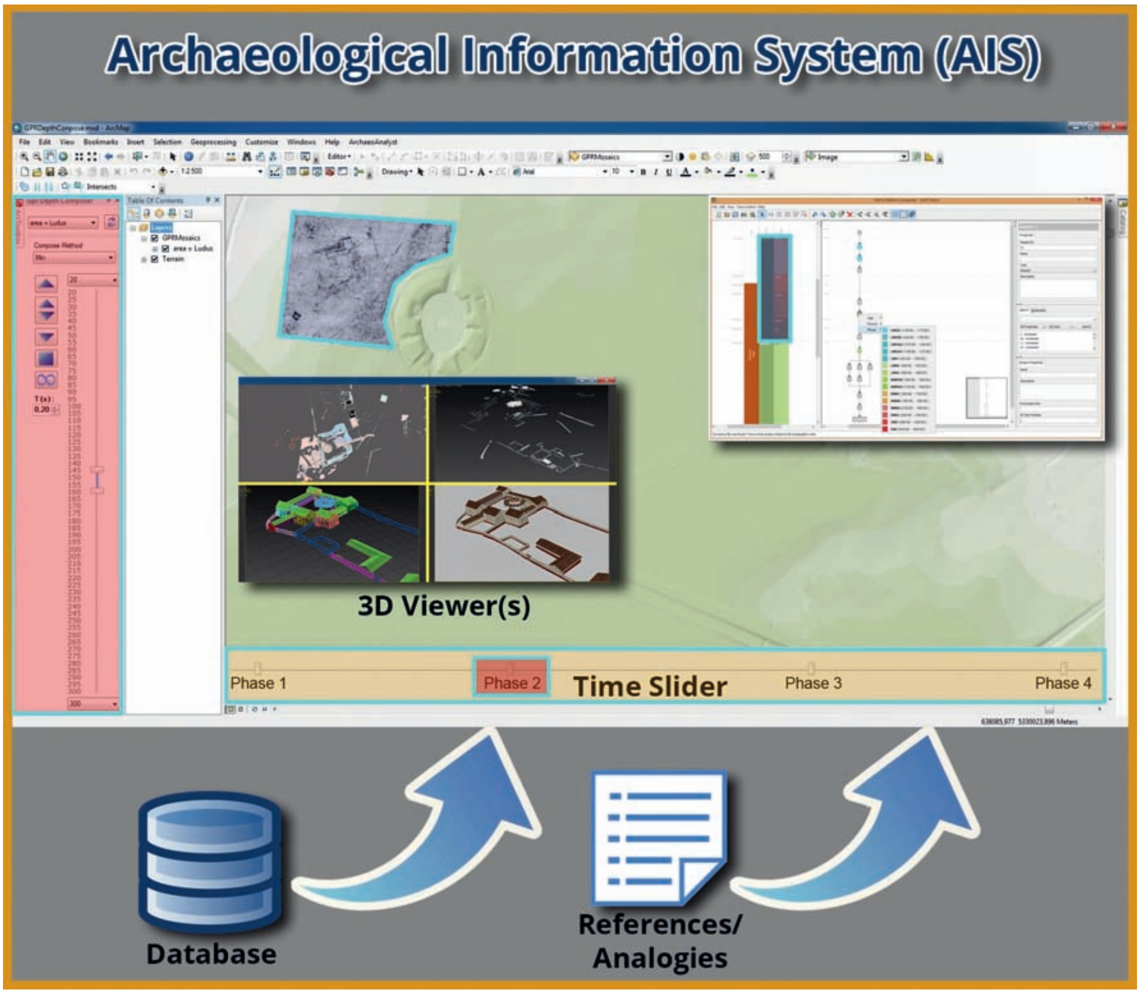

Fig. 3 Basic structure of a GIS-based AIS. It combines spatial and temporal information stored in a Geodatabase. Display, analysis and interpretation of the datasets are done within a GIS environment (LBI ArchPro)

is also capable of dealing with various types of information, e.g. information based on raster datasets, feature classes but also textual information. It is the most appropriate environment to segment space and correlate the generated areas or volumes with embedded archaeological information. A GIS provides an enormous set of various spatial analysis and data query tools. It is perfectly suited to analyse and display the spatial superposition of archaeological entities. For the digitisation and interpretation of 2D based information, e.g. drawings, photographs and maps, ArcMAP 10.2 was used, whereas for 3D visualisation ArcSCENE 10.2 proved to be perfectly suited for the Tell el-Daba dataset. Although initially a separate 3D viewer had been developed on the basis of true 3D, the 2.5D representation capabilities of ArcSCENE were sufficient. As 3D objects were derived from a few cross-sections and level drawings, the reconstructed geometry was very simple, and a 3D viewer was unnecessary. On the contrary datasets based on recent 3D data capturing techniques (e.g. image-based modelling[28] and terrestrial laser scanning[29]) bear more complex 3D geometry. A voxel-based approach for archaeological biased segmentation of space and further temporal analysis of geospatial processes is preferable.[30]

28 Doneus et al. 2011.
29 Doneus – Neubauer 2005; Neubauer 2007.
30 Jjumba – Dragićević 2016.

For temporal interpretation and display of SUs a stratigraphic sequencing tool had to be integrated into the AIS. For this purpose, the Harris Matrix Composer (HMC) had to be modified according to the specific demands of an interval-based temporal interpretation of the data. The first version of the HMC had been developed and released in 2007 (HMC V2.0b) to display the spatial superposition of SUs.[31] This early version provided the possibility for periodisation of groups of SUs but without a consistent temporal model.[32] To meet this requirement, the HMC was modified, and an interval-based time model was integrated, resulting in HMC+. For a spatio-temporal analysis of the dataset in the AIS the stratigraphic sequencer HMC+ was interfaced to ArcGIS. Currently the functionality is being tested and optimised. Whereas it is basically possible to create in each software (ArcGIS and HMC+) new archaeological entities with different identifiers, a unique identifier for each of these entities is necessary. Therefore, a hierarchical model of data input had to be defined and optimised for standardised digitisation, segmentation and the interpretation workflow. To prevent double-naming and contradictions, data input not according to the hierarchical model and standard procedure will be restricted by the AIS. Depending on the specific demands and possibilities of the digitisation workflow, principal properties of the basic (analogue) datasets, observed reliability of the datasets and archiving concept, a geodatabase (GDB) prototype has been developed. All digitally recorded SUs will be stored within this ArcGIS GDB and related to all available archaeological information. The GDB will store raster classes (based on drawings, topographical models, aerial imaginary, photographs, etc.) and feature classes (point, line and polygon) together with respective attributable information to guarantee data queries and display and correlate specific spatial information with the temporal information stored in HMC+. Once the data is digitised, segmented and embedded, the AIS should be capable of guaranteeing more efficient study of documented archaeological information. On this basis an interpretation of the spatio-temporal correlations of SUs, including concepts of functionality covering large areas, could be done and visualised.

Digitisation and Segmentation

Three tasks for the implementation of the legacy dataset of Tell el-Daba into the proposed AIS can be distinguished. (1) The analogue data has to be digitised. This procedure has to be optimised to the most practical resolution for each dataset. (2) The digital data has to be geo-referenced for import into the GIS-based AIS. (3) The data has to be segmented digitally according to specified and well-defined rules.

A GIS project was set up according to the geographical coordinate system used in Tell el-Daba since 2008.[33] All geographic transformations were based on this coordinate system. For a general overview of the area and to ensure control of the uploaded and geo-referenced data, aerial and satellite imagery were included. All drawings (level drawings, cross-sections and detailed drawings) were scanned, partly assembled in Adobe Photoshop and geo-referenced in ArcGIS 10.2. Rectification of the drawings was tested but proved not to be relevant in terms of accuracy.

Most maps were drawn in the scale 1:50, which corresponds to a resolution dependent on the thickness of a line drawn by a pencil or crayon. Based on this a precision of more than 5cm has to be taken into account, whereas accuracy depends on the respective archaeological setting, the skills of the drawer and used recording equipment. It should be expected within a range of approx. 5–10cm. For the data of square j/21 we decided to digitise all features, including single bricks, artefacts and bones with polygons. The digitisation of every brick was opposed by some

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31 For further information and to download trial version refer to Harris Matrix Composer.

32 Traxler – Neubauer 2008.

33 Kurtze 2008.

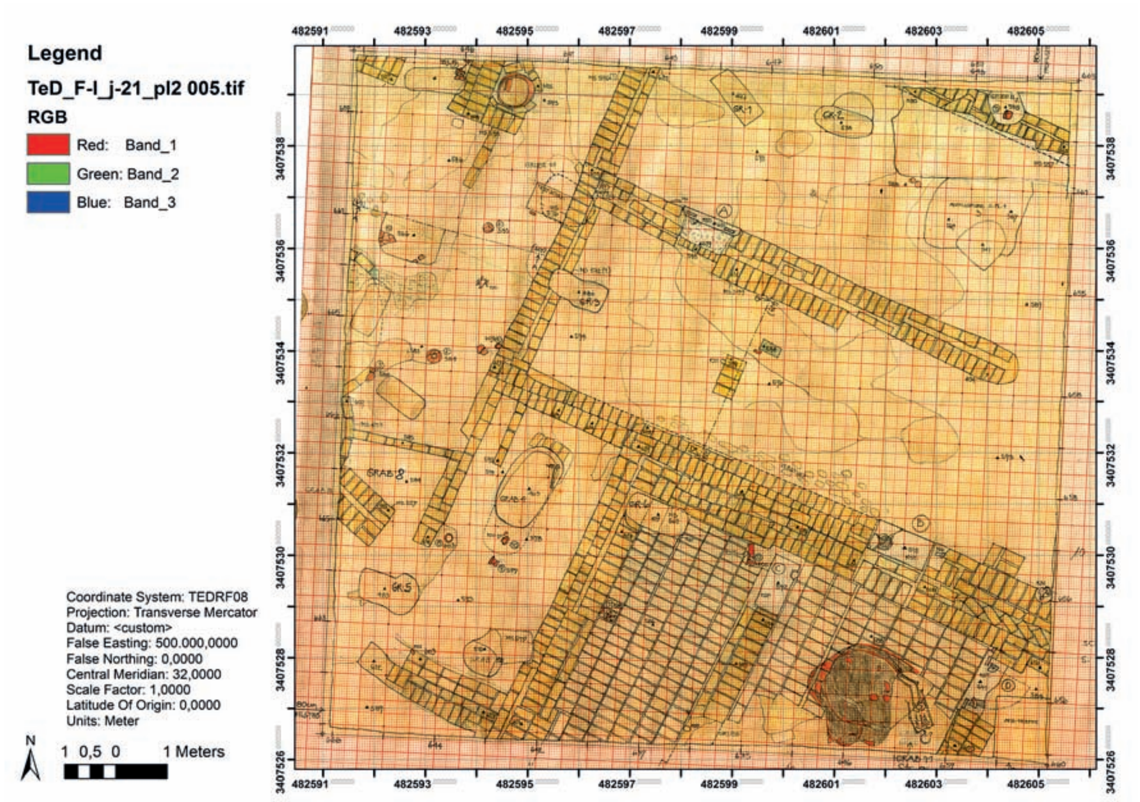

Fig. 4 After digitisation level drawings in the scale 1:50 are imported and georeferenced for further treatment in GIS. The drawing of level 2, square j/21 (LBI ArchPro)

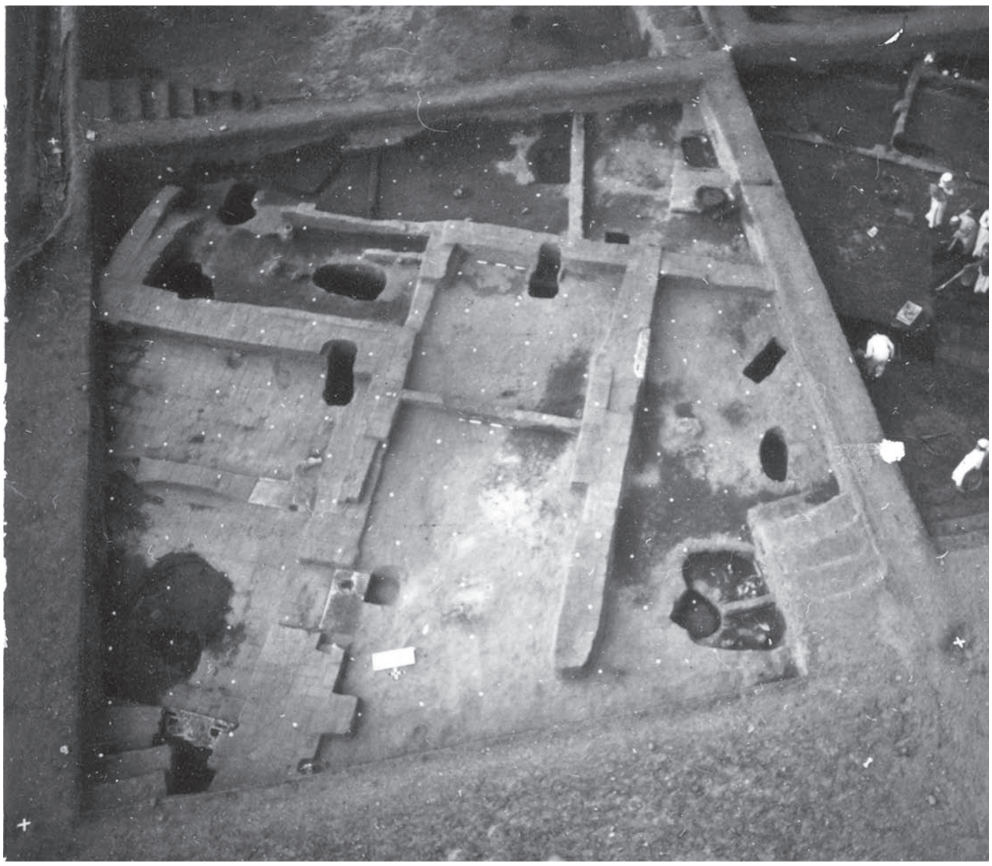

Fig. 5 Overview image of level 2, square j/21 (OREA archive)

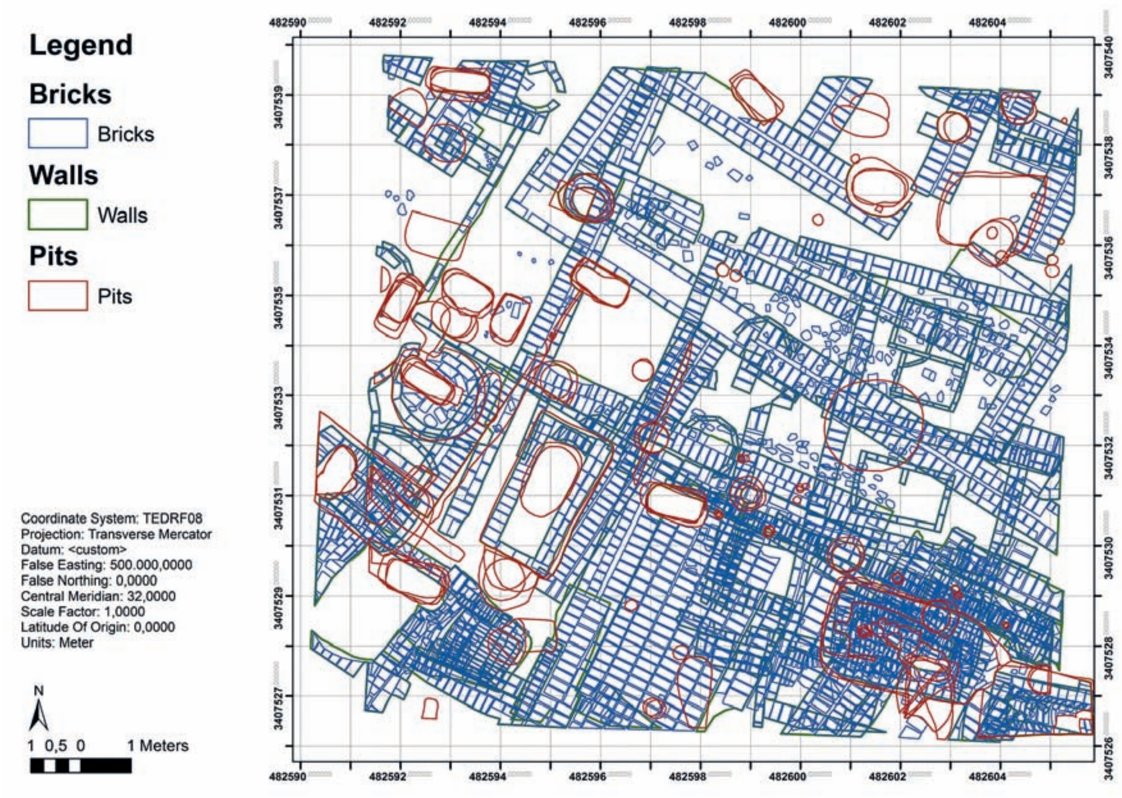

Fig. 6 Digitised bricks, walls and pits of all levels of square j/21 (LBI ArchPro)

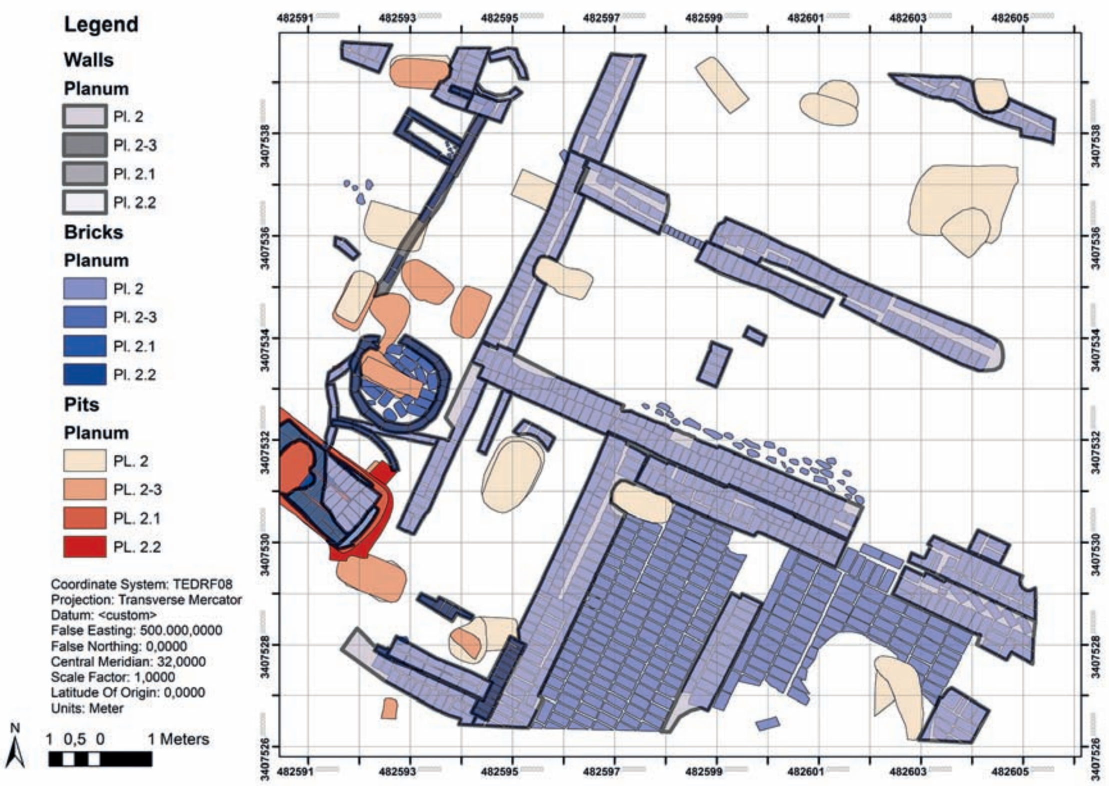

Fig. 7 A schematic map of pits, walls and bricks documented on level 2, square j/21 (LBI ArchPro)

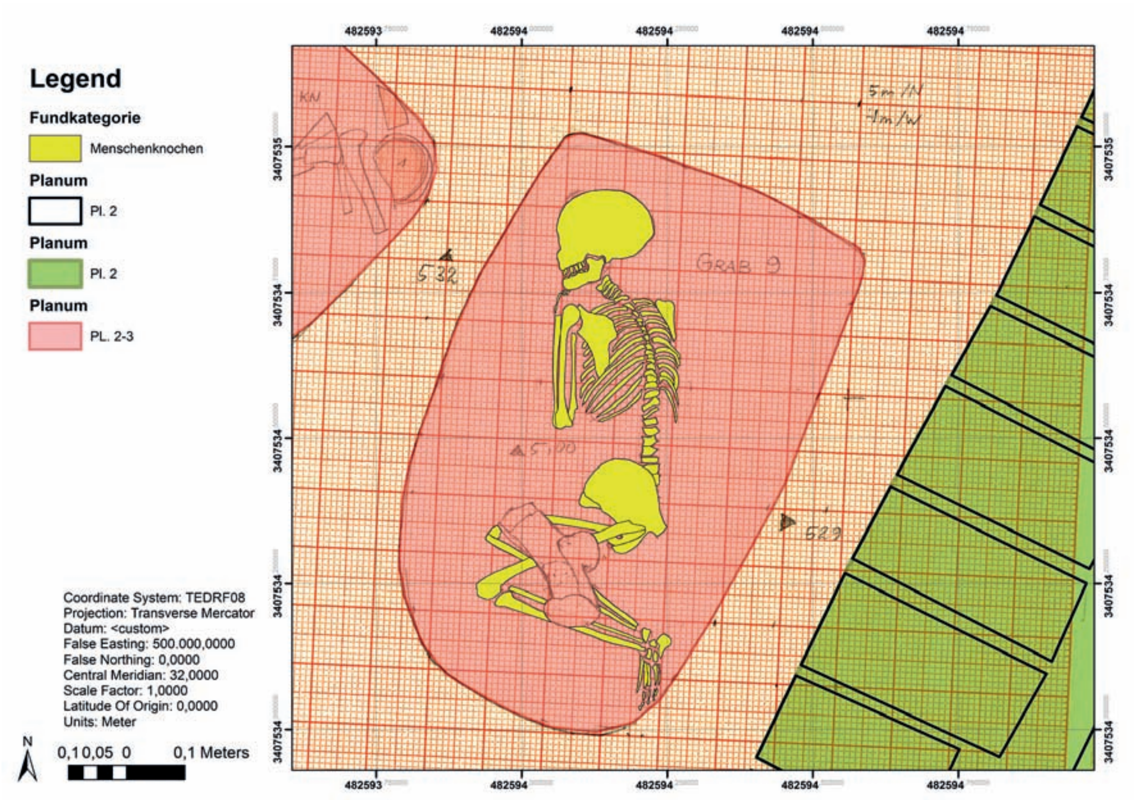

Fig. 8 Digitisation of a field drawing. Grave 9 in square j/21 (LBI ArchPro)

Fig. 9 Photograph of grave 9, square j/21 (OREA archive)

as an enormous expenditure of time and hardly achievable for the whole area regarding cost and time efficiency. Additionally, a single brick within a wall bond is rarely seen as a single SU in archaeological interpretation. Nevertheless, the analysis of the type, material and location of a brick specifies the functionality and spatial relations of a wall, information that is recorded in drawings. The question of whether to digitise only walls or also bricks is dependent on the expected degree of confirmability and reproducibility of gained archaeological interpretations through a quantitative approach. To investigate the benefits and advantages many approaches were evaluated.

The segmentation and vectorisation of the data was done in ArcMAP 10.2, resulting in polygons for every observed feature.

The extension of the features in z-direction was derived from measured heights in the drawings and educated guesses, e.g. the thickness and size of bricks are more or less comparable. At first all types of analogue but also digital data of one square (j/21) in area F/I were integrated in the AIS and all features digitised. In the second step, information regarding a specific phase (stratum d/1.1) of the whole area of F/I was digitised, representing the presumed structures of the palace, surrounding infrastructure and graves mentioned earlier.

For the development of a GDB all information on hand was collected and included within the attribute tables of every feature class. On the basis of the collected information data was classified according to thematic separation of different feature classes, including SUs (walls, pits and layers), bricks, building parts and finds. Additionally, a separate feature class was created to mark the position of the sections. Each attribute table of the different feature classes displays archaeological information about a feature derived from the drawings (e.g. the used colour code indicates specific material), the field protocol, cross-sections and photographs. Further attributes hold available metadata, e.g. source, filename or identifiers of documents and archaeological and excavation objects. One important source of information was personal communication with the Tell el-Daba researchers at the Institute for Oriental and European Archaeology (OREA).

The main aim of providing detailed information in these attribute tables is to guarantee reproducibility of archaeological analysis and interpretation of results as well as prepare the data for the following archiving process (e.g. adding identifiers that comply with the metadata format developed by OREA). The attribute tables provide the basis for the design of the Tell el-Daba-specific GDB which will be used to digitise further areas of Tell el-Daba excavations for stratigraphic analysis. So far the digitised dataset of square j/21 consists of nearly 4,500 recorded features separated into the aforementioned six different feature classes.

For testing and developing the described workflow procedures as a basis for spatial and temporal expert analysis in a 4D AIS within a larger area, another subset of the data was chosen. All data available from a specific archaeological phase was digitised, namely Tell el-Daba phase G/4 (stratum d/1.1), represented by a palace and tombs in area F/I. This subset consists of the data of 40 squares (i/20-23, j/20-23, k/19-23, l/16-21, m/17-20, n/17-21, o/16-21 and p16-21), including square j/21.

All relevant field drawings were collected, scanned, imported and geo-referenced in ArcGIS according to the Tell el-Daba coordinate system. In most cases, only one arbitrary level, planum, representing stratum d/1.1 was considered. Additionally, the general AutoCAD map and a generalised overview map (ink drawing) of the stratum were imported and geo-referenced. Based on previous experiences regarding the digitisation of all bricks in square j/21, only the outlines of the walls were vectorised. Since digitisation of every single brick requires much time, whether comparable results could be derived on the basis of a reduced digitised dataset was also questioned.

As for j/21 a GIS database containing more or less the same columns for data and metadata was established. If available, additional information deducible from cross-sections, the handwritten record and publications was embedded in the database. So far more than 500 features numbered consecutively with respect to the already digitised dataset have been listed in the database.

The digitisation process, including the recording of heights indicated in drawings and cross-sections, results in volumetric features. Archaeological information concerning every feature is available in the database. Based on these properties the spatial superposition of observed features can be derived and SUs defined. A stratigraphic sequence of all recorded features is yet to be done. For this purpose flexible visualisation and display of single volumetric features are crucial.

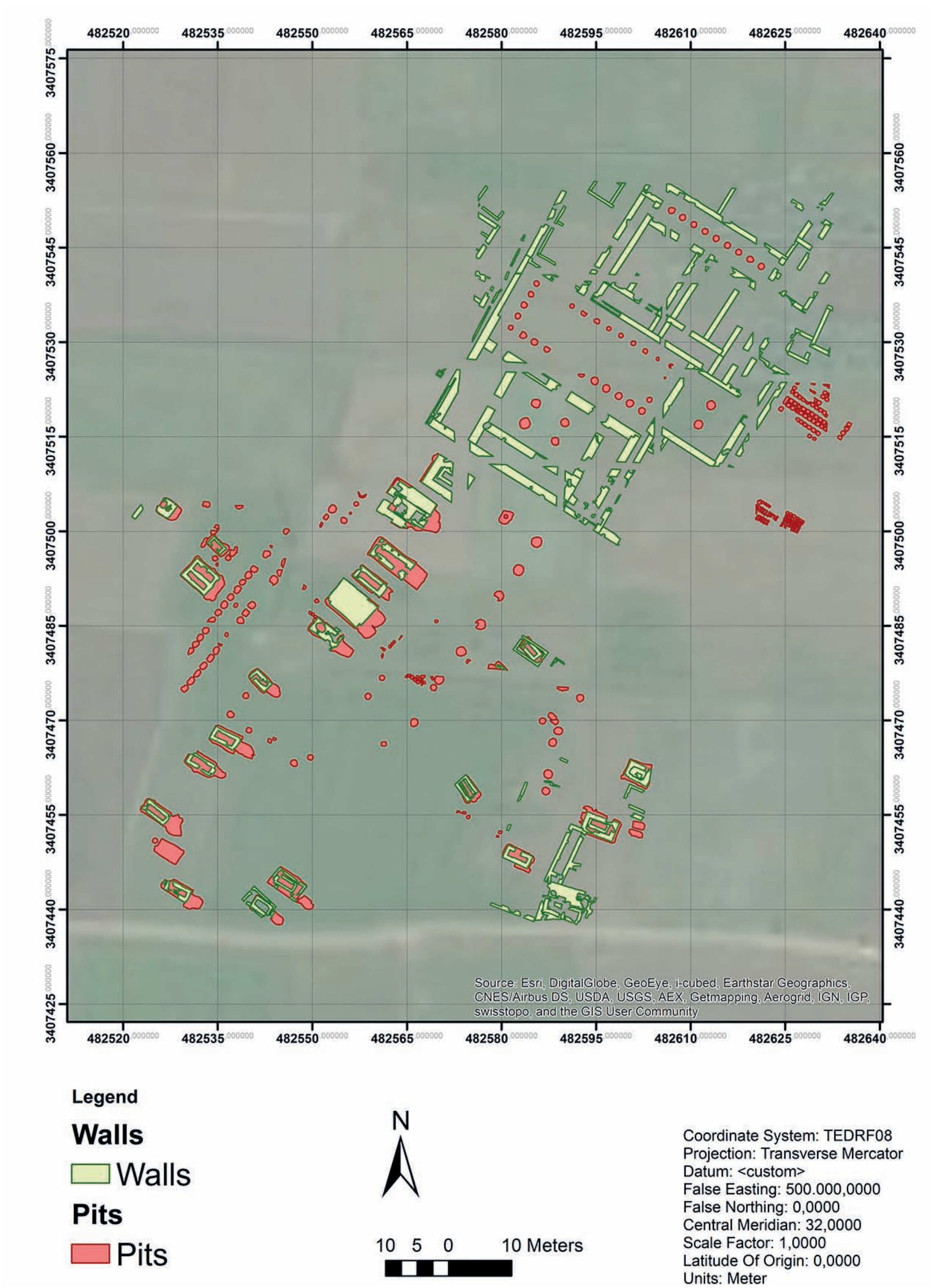

Fig. 10 Phase map of stratum d/1.1 displaying pits and walls of the respective squares (LBI ArchPro)

Visualisation – Spatial and Temporal Relation

Within each feature class of the database of both subsets the attributes' extrusion and base height for volumetric representation are included. These are relevant for the display of digitised features and structures as volumes in ArcScene 10.2. This depiction mode allows the visualisation of entities from different arbitrary documentation levels in 3D at the same time. Displaying and visualising spatial superposition of recorded 3D volumes is a powerful tool for archaeological interpretation from which SUs can be specified. The stratigraphic sequence is generated within by HMC+ software.

As a matter of fact, a feature might be recorded within several drawings that all represent the same SU. In this case it had to be merged into one SU. According to the observed spatial superposition of the digitised features a stratigraphic sequence was generated. The cross-sections were used to gain additional information about 'missing' SU. As the excavation was carried out in discrete levels of approx. 20–40cm apart, most of the stratigraphic information between these levels had been removed. In this sense the Tell el-Daba dataset was incomplete regarding the loss of surfaces

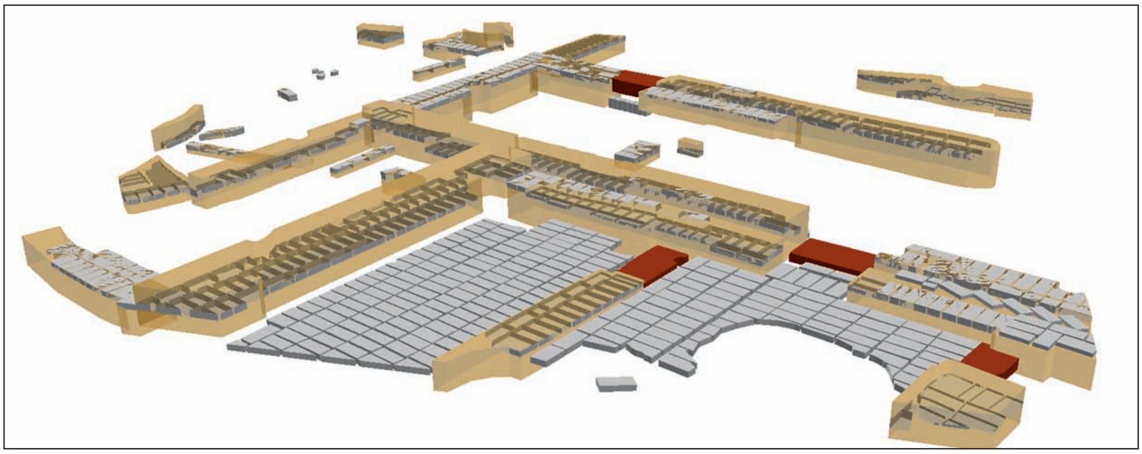

Fig. 11 In adding height information indicated in the drawings, structures could be extruded to generate volumetric stratigraphic units. This simple geometry is sufficiently displayed in ArcScene (LBI ArchPro)

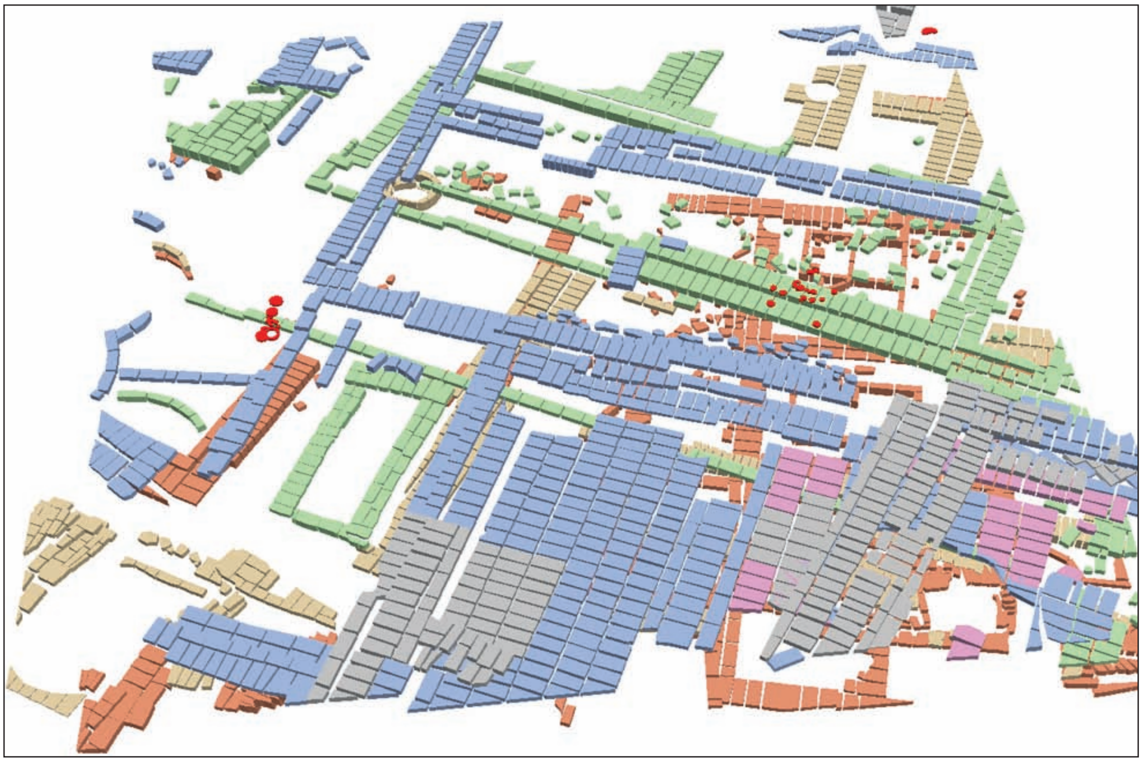

Fig. 11a Spatial superposition of bricks belonging to different archaeological phases (LBI ArchPro)

and enclosed volumes due to the selective excavation process. The infill of a room was removed for example down to its presumed floor. When a room was artificially separated by a trench or occasionally cut purposefully by an additional cross-section, the archaeological evidence of the stratigraphic sequence lost within these volumes became visible. Parts of lost sequential information could be reconstructed through the analysis of the cross-sections (e.g. primary and secondary use and decay of a structure could be observed and represented within a stratigraphic sequence).

For further investigation of spatial relations and to display additional information, e.g. from sections, complex tomb constructions were visualised with the free software SketchUP (Trimble). These detailed reconstructions were made for three tombs and a cellar recorded in square j/21. Using SketchUP all drawings (details, side views and sections) can be displayed at the same time according to their geographical position. Based on these drawings 3D models of the specific structures were derived. The surfaces could be textured according to colour codes or a more realistic texture. Finally, each 3D model can be imported into ArcScene for further analysis of the stratigraphic sequence.

Once the spatial superposition is represented correctly within the stratigraphic sequence, the temporal attributes of each SU can be set according to the specifications of HMC+, which base strictly on the principles of stratigraphy. Each SU can be either assigned to an archaeological phase or defined by specific start and end dates. It is therefore possible to run a query regarding temporal and spatial attributes. To observe the functionality, use and decay of the features for expert archaeological interpretation, the display of different assumed phases is extremely helpful. The temporal relations allow displaying features, which are not in direct spatial superposition. This is crucial for the analysis of the relation of different structures spread over a large area (e.g. houses in a settlement).

For a better depiction of archaeological interpretations and reconstructions simple but meaningful software called Arch4DInspector was developed. It basically allows the user to switch between all archaeological data used in the modelling process while observing a reconstructed 3D model on top. The interface consists of buttons that allow the user to enable and disable different types of information transparently layered on top of each other, a slider for depicting the 3D model through time and a button that orbits the camera around the data and 3D objects for better inspection. Suggested reconstructions and spatial and temporal relations of different phases could be displayed online.[34]

Results

So far more than 5000 archaeological features have been digitised in ArcGIS 10.2. During this process several factors were monitored. One of the main issues of the project is to develop a standardised digitisation workflow, which is crucial for complete and redundant digitisation and later interpretation of the Tell el-Daba legacy dataset. All necessary individual operations were defined based on the demanded skills of the person in charge, which was necessary for effective planning of the project to digitise and spatially segment the whole Tell el-Daba dataset.

An initial database was designed to determine the design of the GDB, which is among the recent tasks of the project and still under development. Data formats, syntax and filenames of feature and raster data have been defined according to the archiving routines carried out by OREA.

Several structures were digitised in 3D using SketchUp. The resulting 3D objects illustrate the situation as they were found when excavated or an idealised view representing a moment during their use. Whereas the former could be time-consuming, a simple 3D model is mostly sufficient for further proper analysis to generate a stratigraphic sequence. These models could be easily

[34] Torrejón-Valdelomar et al. 2015.

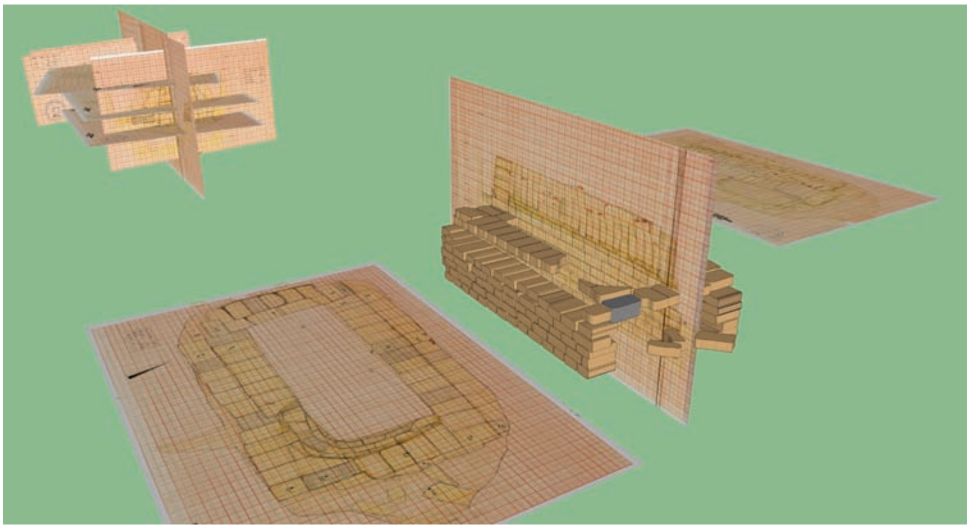

Fig. 12 Drawings of cross sections are displayed in SketchUP to reconstruct archaeological structures. Grave 13 of square j/21 (LBI ArchPro)

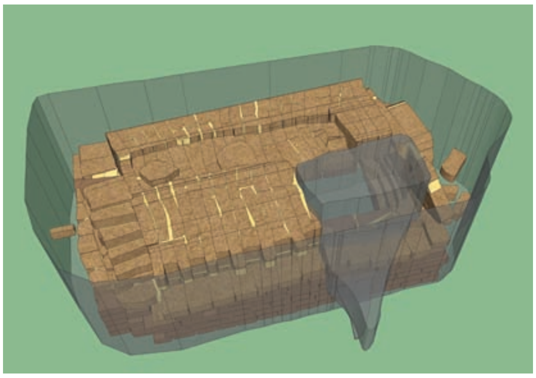

Fig. 13 Remodelling of grave 13 in SketchUP (LBI ArchPro)

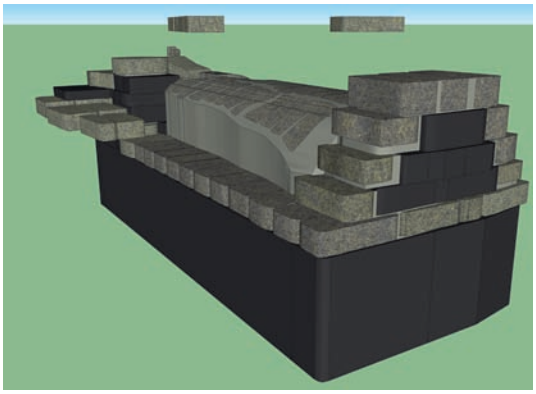

Fig. 14 Idealised reconstruction of grave 13 (LBI ArchPro)

Fig. 15 Grave 13 as it was found during excavation (OREA archive)

derived within the AIS by extruding the digitised features according to their observed height, as height measurements from drawings are stored in the GDB. This is necessary to reconstruct the spatial component of the stratigraphic sequence also within areas where this information had been lost due to the excavation process. Arch4DInspector proved to be a very handy tool to dis-

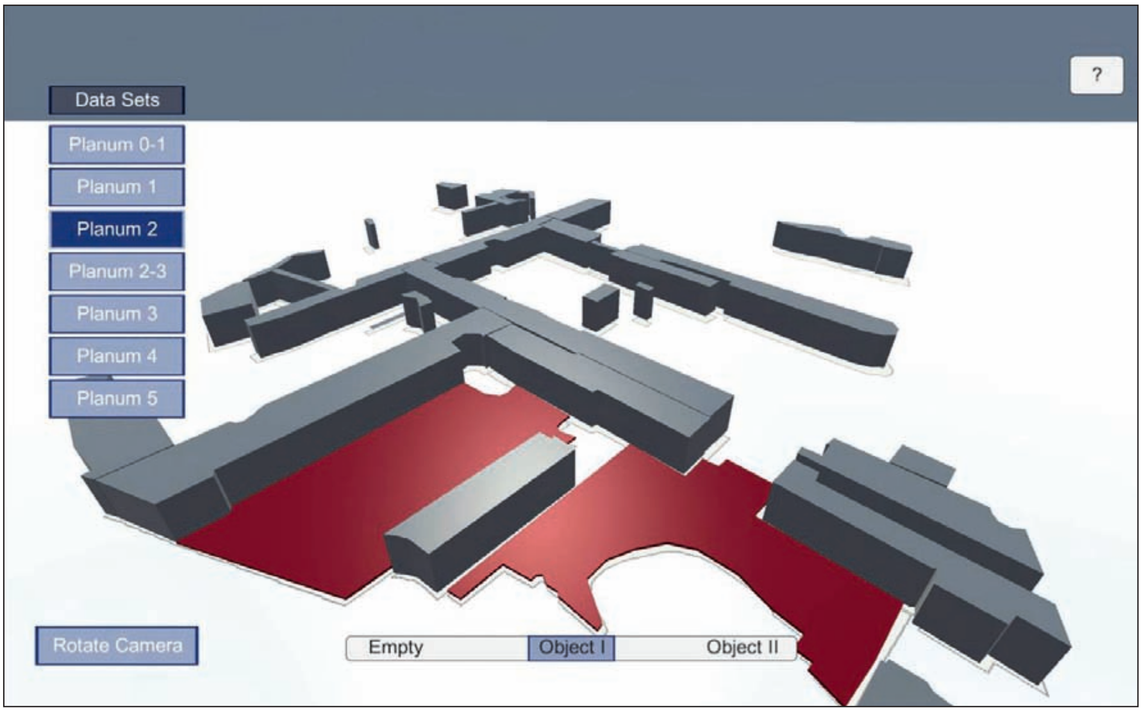

Fig. 16 Screenshot of Arch4D. This tool allows displaying 3D models together with additional information (e.g. drawings as base layer). It is also a web-based viewer (LBI ArchPro)

play basic source information from drawings of levels and cross-sections together with simple reconstructed volumes to visually control spatial consistency. The hypothetical character of the reconstructed volumes must be emphasised.

After the digitisation of the selected subsets, namely square j/21 and area F/I, the spatial and temporal superposition was examined and reconstructed, leading to a mathematically valid stratigraphic sequence.[35] For this purpose the software HMC+ was updated and complemented with a temporal model based on time intervals. Based on observations regarding the reconstruction of the incomplete legacy dataset qualitative guessing of the reliability of the various data sources could be derived. The sections proved to be an important qualitative pool for further information about undefined SUs.

The average precision and especially accuracy of the data are not quantifiable. Precision regarding the spatial resolution is related to the scale of the drawings and the recorded situation, resulting in an estimated error range of 5–10 cm. Contradictions within the legacy dataset, e.g. physically impossible spatial superposition of SUs documented in the cross-sections and the level drawings respectively, could be detected through analysis of the reconstructed stratigraphic sequence.

For the reconstruction of a valid stratigraphic sequence the suggested structure of an AIS, including ArcGIS, HMC+ and a GDB, specified to the demands of the Tell el-Daba project proved to be very efficient. In setting up a GIS-based AIS every item of the digital archive will be specified by its geographical location, as the basis for further archaeological interpretation of the dataset as well as for a comprehensive virtual reconstruction of the site.

35 The validation of a stratigraphic sequence is mathematically argued. As the primary stratigraphic information is lost through archaeological excavation, the stratigraphy represents the observed stratification of the archaeological site and is therefore always interpretative and hypothetical. The hypothetical stratigraphic sequences derived from the spatial and temporal analysis supported by the GIS-based AIS are valid in respect to the laws of stratification.

Conclusions

Legacy excavation data are in most cases incomplete compared to recently derived datasets. Regarding the complete description and segmentation of an archaeological stratification, volumes must be reconstructed where data are missing. A stratigraphic sequence has to represent the whole excavated archaeological volume, i.e. complete stratification. An AIS strongly represents possibilities for remodelling unrecorded information. This process can be described as reverse excavation in comparison to the term reverse engineering, where from a real model an idealised one is deduced.

In transforming the legacy dataset according to present-day methodology in a standardised and well-documented way the new data and results become comparable with other datasets. Comparability is indeed one of the central demands when analysing data and proposing new archaeological interpretations and theories. These results must be also reproducible and comprehensive. These traits become possible by the organisation's introduced system and correlation of archaeological information within a GDB. During the digitisation of the data and spatio-temporal analysis, resulting in a stratigraphic sequence, the reliability of specific properties from the different sources was observed. For example, some section drawings were idealised in order to highlight observed correlations. This has to be taken into account when trying to describe and define the accuracy of digitised data.

The components and specifications of the GIS-based AIS facilitate the analysis and documentation of the spatial and temporal properties of every SU. Each documented SU is uniquely identified by its geographical location, which also refers to its spatial superposition. Temporal properties of archaeological features, structures and processes are interval-based. Allen's interval algebra mathematically defines the relations of intervals and is therefore perfectly suited for the analysis of respective temporal relations. In this way the description and analysis of spatial and temporal properties allow interpreting archaeological information in 4D.

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