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Article *in* African Archaeological Review · June 2018

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ORIGINAL ARTICLE

Digital Management of Rock Art: the African Archaeology Archive Cologne (AAArC)

Tilman Lenssen-Erz · Eymard Fäder · Friederike Jesse · Joana Wilmeroth

Abstract Archaeology is a costly and object-affine practice requiring sophisticated technical equipment, and therefore is largely initiated and run from industrialised countries. Accordingly, also data and objects are largely lodged in these countries. In rock art, this leads to the paradoxical situation that many motifs and sites with outstanding prehistoric art are better known and more often shown in northern hemisphere urban centres than in the global south rural areas where the art in fact is found. This paper will focus on the possibilities and benefits of a digital archive in making pictures, data and other archaeological source material accessible anytime from everywhere. An open online archive will in the long run flatten the hierarchical order of access to the results of archaeological research and heritage archiving. Today, this is still concentrated in the western metropoles and rarest in African hinterlands. The open access to thousands of pictures will facilitate dissemination of motifs in particular since the distribution of smartphones and network coverage are ever growing particularly in Africa's rural areas. The African Archaeology Archive Cologne (AAArC), being licenced under Creative Commons, provides open access to tens of thousands of rock art photos and to the enormous Brandberg-Daureb Data Base that contains 39,000+ rock art figures. Additionally AAArC stores all kinds of digital archaeological products from across Africa (mainly Sudan, Algeria, Chad and Namibia), including audio and film documentary.

Résumé L'archéologie est un domaine sophistiqué qui nécessite assez souvent un équipement technique important et cher. Elle est donc largement initiée et gérée par les pays industriels. Par conséquent, les données et les objets relevés sont en grande partie déposés dans les pays qui ont financé les recherches. Concernant l'art rupestre la situation est devenue paradoxe, car les motifs représentés et les sites sont mieux connus dans les centres urbains de l'hémisphère nord que dans les zones rurales de l'hémisphère sud à l'origine de ces œuvres. Le présent article focalise sur les possibilités et les avantages d'une base de données de l'art rupestre sur internet. Elle ouvre l'accessibilité - toujours et partout - aux images, aux documents et aux autres sources archéologiques. Une telle archive publique permets d'aplatir l'ordre hiérarchique de l'accessibilité aux résultats des recherches et rends possible l'archivage du patrimoine à long terme. Encore aujourd'hui, même les archives numériques de l'art rupestre se trouvent souvent dans les métropoles occidentales et très rarement dans l'arrière-pays africain. L'accès publique et libre aux milliers de photos et d'autres documents facilite la diffusion du patrimoine même pour les zones rurales d'Afrique, car le réseau internet est souvent parfaitement développé. Aujourd'hui l'AAArC offre déjà - sous les licences Creative Commons - un accès libre aux dizaines de milliers de photos d'art rupestre et à la base de données importante de Brandberg-Daureb avec plus de 39,000 figures. En outre, l'AAArC stocke

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Published online: 12 July 2018

aussi toutes sortes de données archéologiques numérisées et numériques provenant de toute l'Afrique (principalement du Soudan, de l'Égypte, de l'Algérie, du Tchad et de la Namibie), y compris des documentaires (radio et télévision).

Keywords Rock art · Data management · Heritage management · Open access · African archaeology

Introduction

The Internet is no longer optional in scientific inquiry; it is not only the prime tool for research into existing literature, but increasingly also the first choice for the exchange and provision of data and results, to make investigations comprehensible and testable, and to create synergies. Already established research results do not necessarily have to be repeated, but primary data can be re-used for new approaches of analysis.

Furthermore, today's possibilities of digitization open up completely new dimensions in making collections scientifically usable worldwide to fully exploit their potential and importance. The allure of digitization lies not least in the fact that it allows easy access from all over the world (an Internet connection with sufficient bandwidth being all that is needed). This is of great importance especially in the field of African archaeology, as numerous scientific collections are hosted outside Africa, mainly in Europe or North America. Rock art, as a special archaeological resource, is particularly apt for digital representation because crucial information can be conveyed by visual record. It is a field that has taken a technological leap in the digital age.

The African Archaeology Archive Cologne (AAArC) was established to do all this: to make Cologne University's archaeological collections including its important rock art documentation digitally available. The formation of AAArC and its importance for rock art research is described in this paper. After some general remarks concerning Open Access and the digital archiving of rock art, the making of AAArC is discussed. This starts with a short description of AAArC's basis—the collections hosted at Cologne University's Forschungsstelle Afrika (*African Archaeology*)—and is followed by a technical report detailing AAArC's data model and structure. We conclude with remarks on the importance of AAArC for rock art research as well as perspectives for future developments.

Open Access—Challenges and Obstacles

Open Access and open data are familiar keywords at this juncture. Yet, they are still more an ethical claim than far-ranging reality and, with regard to indigenous intellectual property rights and heritage ownership (Hodder 2010; see UNESCO 2017, paragraph 40 and UN 2008) or site protection, not without contestations. The 'Berlin Declaration', which was formulated in 2003 on the initiative of the Max Planck Society and subsequently signed by more than 560 institutions worldwide, calls for:

> 'New possibilities of knowledge dissemination not only through the classical form but also and increasingly through the Open Access paradigm via the Internet have to be supported. We define Open Access as a comprehensive source of human knowledge and cultural heritage that has been approved by the scientific community. In order to realize the vision of a global and accessible representation of knowledge, the future Web has to be sustainable, interactive, and transparent. Content and software tools must be openly accessible and compatible.' (Berliner Erklärung)

Following the Berlin declaration and the supporting institutions, Open Access is widely demanded and regarded as indispensable for research in an increasing digital world. Even if we are conscious of and respect problems with traditional custodianship, intellectual property and copyrights, we believe that a responsible implementation of Open Access can bring about advantages that not only rest with western researchers, but indeed help with the protection and management of cultural heritage resources. Open Access makes available an enormous amount of literature and data not only to scientists, but to everyone worldwide. Participation of the general public in science and research becomes much easier and opens up completely new opportunities of input and accumulation of knowledge (Siegmund and Scherzler 2015, p. 12) which today come with labels such as 'citizen science' or 'crowd-sourcing' (e.g. Ridge 2013; Smith 2014). Rock art in particular offers great potential to involve an interested public in the research process. A good reason to practice Open Access is exemplified by the very object of our research, the tangible and intangible heritage of the African continent. The accessibility of digital tools provides methods for returning the cultural values and findings of our research to their source countries.

However, the readiness of researchers to share data by making it widely and easily accessible to all is often lacking, which is problematized by legal aspects such as copyrights and intellectual property rights. A session at the recent Open Science Bar Camp compiled a comprehensive record of inhibitors to open science (see OSBC 2018). The discourse on the pros and cons of data sharing is vast and manifold, and it is beyond the scope of this article to provide a summary of it. Some orientation is provided in the principles for the handling of research data adopted by the Alliance of German Science Organisations which state that

> '[this] principle [Open Access] shall be balanced against the scientific and legal interests of researchers. The protection of the personal data of participants, patients and others affected by the collected data, as well as obligations to third parties—e.g. cooperation partners—have to be taken into account.' (Principles)

In archaeology, the principles of Open Access conflict with the protection of sites against looting and destruction. Therefore, site coordinates need to be handled as particularly sensitive data, and not only in rock art research. In addition, the regulations of the respective national monument authorities have to be taken into account.

Open Access (open data) initiatives in German archaeology are rather new, whereas the Archaeology Data Service (ADS) in the UK started in 1996 and the corresponding Data Archiving and Networked Services (DANS) in the Netherlands is also well established (Schäfer et al. 2015, pp. 128–129). Comparable initiatives in Germany are more recent (Siegmund and Scherzler 2015, p. 14) so that a central archaeological research data centre, IANUS (IANUS data portal), was fully functional only in 2017. Moreover, data management plans are required only rather recently by German funding institutions. Against the background of the Berlin Declaration, the establishment of digital archives is thus also a reaction to the demands of scientific ethics in the twenty-first century. The main funding institution in Germany, the German Research Foundation (DFG), addresses this with special funding programs and by defining a set of rules and regulations bestowing an important role to data management and re-use of data:

> 'Research data should be made available as soon as possible. The research data should be accessible at a processing stage (raw data or already further structured data) which enables reasonable and useful re-use by third parties.' (DFG-guidelines)

In 2011, the DFG launched a funding program for the 'accession and digitization of object-related scientific collections'. This enabled access to funds for a project to retro-digitise the African archaeological collections hosted at Cologne's *African Archaeology* and led to establishing AAArC, the African Archaeology Archive Cologne (Fig. 1).

Digital Archiving of Rock Art in Practice—Some General Remarks

Every rock art archive is primarily about the visual record so that photographs and/or drawings constitute its main component. Pictures are the easiest objects to start with when establishing a digital archive, because TIFF files—as the generally accepted standard format for long-term digital archiving of pictures (e.g. US National Archives)—allows the inseparable integration of metadata with the digital object. A major problem of archiving photographs and/or drawings of rock art is therefore the 'deep curation', i.e. the level of descriptive detail, in particular of the rock art motifs captured in the photograph. Absolute dating of rock art is notoriously difficult (e.g. Whitley 2011, pp. 75–92) and only in some cases is there scientific dating available for specific rock art motifs or even whole pictures. The problem of motif description is partly based on the fact that with some exceptions (trance hypothesis in southern Africa [e.g. Lewis-Williams and Dowson 1989], Wandjinas (also Wanjina) in Australia [e.g. Flood 1997; Layton 1992], pastoral livelihood in Saharan art [e.g. Barbaza 2015; Muzzolini 1995]), there are few widely accepted standardised terms and conventions in rock art. While missing a device that is common in art history where tools like the *Thésaurus Iconographique* (accessible, e.g. via ICONCLASS) set widely applicable (western) standards for the description of picture motifs, rock art description inevitably turns into a non-standardised process based on the training, experiences and background of the individual researcher. Often even the epistemological 'school' is a powerful filter; an adherent of a universal trance hypothesis will describe a picture based on different features than someone focusing on technology. In cases where institutions such as SARADA or CRAR+M

establish standardised terms for description, they rest with a restricted vocabulary that inevitably cannot be applied universally. Curation not only has to fulfil the purpose of description, but also of structuring the information in the ontological framework of a data model (see examples in Galvin et al. 2017; Kuba 2006; Wiltshire 2013). Whereas a well-structured, controlled and tabular documentation grid eases categorisation and digital curation in terms of efficiency, it can be detrimental for the later scientific use of the recorded data, as it may not be adaptable to specific methods, theories or aspects of research. This is especially true for rock art with its wide range of approaches, for which a purely descriptive text can often address issues with a more thorough perspective (Galvin et al. 2017). A well-suited reference framework thus would attempt to cover a wide range of options and increase usability.

Where funding for infrastructure or detailed curation is missing, then pursuing a dissemination concept with basic structure and affordable depth can be ideal as a starting point (Ruiz et al. 2016; Wäfler et al. 2016; SARADA; Roundhead Database). Another approach may be to provide a platform with a more or less global appeal to which a community of researchers and/or amateurs may contribute (EuroPreArt; Haubt and Taçon 2016). This may also be suitable in cases that specifically target the visiting public (Prehistoric Rock Art Trails; RAMP Rock Art on Mobile Phones), so that the dissemination platforms additionally perform heritage management duties (Figueiredo 2013; Wiltshire 2013). Such applications will require the data model to be adapted to legal requirements of the source data.

The Making of AAArC

African Archaeology in Cologne

Rock art research in Africa has a long tradition at the Institute of Prehistoric Archaeology at the University of Cologne. The first research projects started in 1963 in Namibia and focused primarily on the rock art of the region. Since the early 1980s, the second focal point is the arid regions in north-east Africa (mainly in Egypt, Sudan, Chad and Libya). Both areas had previously been largely *terra incognita* in archaeological research (for the early history of research in northern Sudan, see Hinkel 1979; for Namibia, see Gwasira in prep., *A history and analysis of Namibia's archaeologies*). In addition to rock art, the focus of the various projects was on human-environment relations, which from the very beginning required close cooperation with scientific disciplines such as geosciences, paleo-botany and ethnography. The establishment of the 'Forschungsstelle Afrika' (*African Archaeology*) as a department of the Institute of Prehistoric Archaeology in 1984 also more firmly anchored African archaeology institutionally at the university. The premises of *African Archaeology* also serves to store and preserve the large quantities of data and material produced during the course of numerous projects, including major long-term ones such as

- 'The History of Settlement in Eastern Sahara' (B. O. S.) 1980–1993; (for an overview and further bibliographical sources, see Kuper 1995),
- the Collaborative Research Centre 389 ACACIA (1995–2007); (see Bubenzer et al. 2007 for an overview and further bibliographical sources), and
- the documentation and publication project 'Rock Paintings of the Upper Brandberg' (Pager, 1989-2006).

The aim of AAArC (African Archaeology Archive Cologne, Fig. 1) was and is to make these and further extensive and unique collections housed at Cologne's *African Archaeology* more easily accessible. In a first step, focus was put on photographs as well as written and drawn documentation. With regard to the great share of rock art research in Cologne's *African Archaeology*, AAArC put focus on one of its lighthouse projects with the retro-digitization of the rock art recorded in the Brandberg in Namibia. The basic idea of this archive is that all archaeological assets that can be digitised should become available on a single platform. With this broadness of digital objects, the most likely users of the archive would be archaeologists with specific research interests. Curation of the digital objects therefore aims at enabling use of the data in a primarily academic environment. But the large quantity in particular of rock art reproductions certainly has an appeal to laypeople, too, and may even catch commercial

Fig. 1 This poster was employed to present and introduce AAArC at several congresses. In these exchange forums, AAArC showed that despite the relatively small project size, it has quickly reached eyelevel with well-established open digital archives. (Oliver Vogels)

The **African Archaeology Archive Cologne** (AAA C) is a digital archive. It is based on collections resulting from University of Cologne's research in northeastern and southwestern Africa in the past 50 years. **AAA C** is a repository complying with the principles of open access. Its long term aim is an open research archive where material from other sources and projects can easily be integrated. Ultimately, **AAA C** enables a digital homecoming of complex research data to their countries of origin.

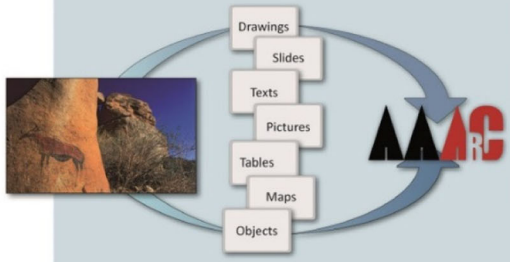
African Archaeology Archive Cologne

Universität zu Köln

iDai.objects arachne

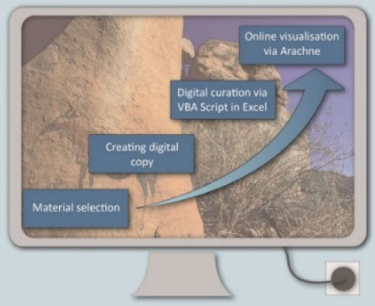
Deutsche Forschungsgemeinschaft DFG

The Material



The rich materials require different approaches of curation: there are materials which can be digitised to images (slides, field recordings etc.), genuine digital images (.tiff, .jpg etc.) and 'non-images' (texts, tables, objects etc.).

The Process

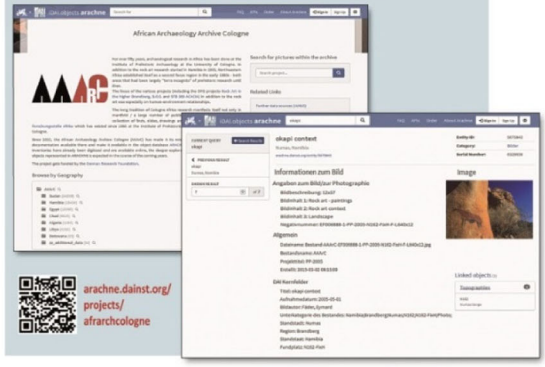


Every digital object is tagged with metadata in 27 categories concerning geography, origin, content and access permission. AAArC metadata is based on established standards (Dublin Core or CIDOC CRM).

The Result

AAA C currently presents about 77,000 pictures of rock art, excavations and objects in Africa's northeast (Sudan, Egypt, Chad etc.) and southwest (Namibia). Pictures are licensed under Creative Commons CC-by-NC. A database embracing information (location, chronology, description, bibliography etc.) on the sites curated in AAArC allow in depth exploration of the data available in **AAA C**, presently for more than 1500 sites.

To guarantee sustainability, **AAA C** is hosted by Arachne, the central object database and archive of the German Archaeological Institute and therewith it is part of the iDAI world. Technical support is provided by Cologne University's Regional Computing Centre (RRZK).



The Future

AAA C provides structures for digital data management where new material can easily be integrated. Close cooperation with IANUS (Research Data Centre Archaeology & Ancient Studies) helps to include non-visual archaeological research data and therewith enlarge the information online accessible.

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interests—a circumstance that we try to manage with a Creative Commons CC-BY-NC-ND 3.0 (Attribution-NonCommercial-NoDerivatives) license.

With this mission, from 2012 to 2017, tens of thousands of slides were scanned, audio and video material was screened and digitised, and data from hundreds of sites were processed for the archive.

As AAArC was not conceived as a rock art archive alone, the data model does not include descriptors or categories exclusively conceived for rock art. Instead, the rock art sites themselves as text-searchable information objects include broad motif descriptions. In addition, the entire database of the Brandberg/Daureb project is provided as an open source (see IANUS) for scholars to download and analyse.

The Development of the Digital Archive AAArC

The technological basis for AAArC (AAArC) was the integration into the already existing online archive Arachne (ARACHNE 4 online), which today is one of the main pillars of the so-called iDAI world (Fig. 2). This is an interlinked network of online platforms of the German Archaeological Institute (DAI, Deutsches Archäologisches Institut, the official state institution for archaeologies outside Germany) with image, bibliographical and geographical databases and the aim to support digital and decentralised research. AAArC uses all these platforms, including IANUS (Research Data Centre for Archaeology & Ancient History; Dally et al. 2013). The latter offers storage and display of all kinds of digital objects: images, databases, and video and audio files.

The initial concept aimed at integrating AAArC in the already existing digital database of ARACHNE and accelerated the archiving process as it removed the need for the creation of a suitable digital infrastructure. However, it was still necessary to design the general structure of AAArC and to develop workflows for the digitization of different archival object classes.

Our objective to use exclusively non-proprietary open source formats and programs has not, however, been fully implemented since it was also important to use formats with integrated metadata. For images, this is made easy through formats such as TIFF or JPEG, whereas for other data-processing formats such as spreadsheets, databases or sensor data, no such standards are yet available. To cover these non-picture formats, AAArC relies on the comprehensive standards of the IANUS repository, which provides highly developed curation templates for every conceivable data format.

Structure of the AAArC Data Model

The metadata model is based on a virtual 'object' that consists of interlinked metadata. The information connected with each 'object' can be divided into four large groups (Fig. 4):

(1) Localisation (e.g. topographical information)
(2) Chronology
(3) Derivatives (e.g. image content)
(4) Project.

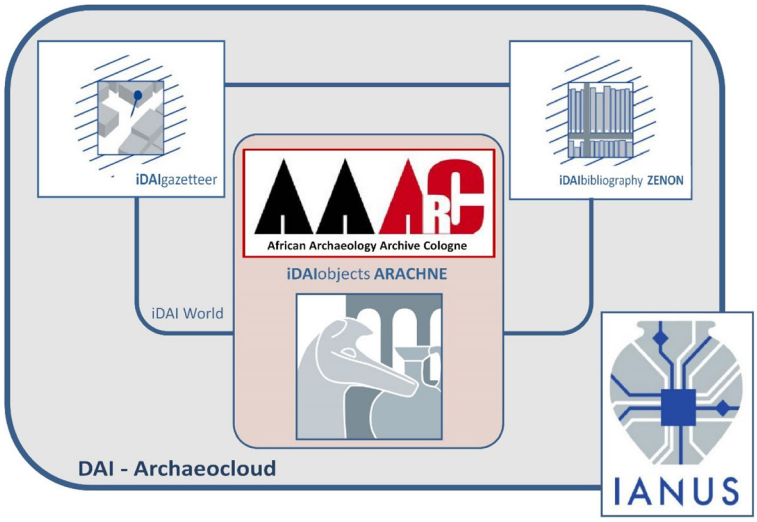


Fig. 2 Schematic chart showing the linked open data concept of the platforms of the iDAI world that AAArC is deploying (Eymard Fäder)

Various standards have been defined by AAArC for its digital archive: from normalised chronology terms, controlled ontology lists and a hierarchical geographical folder structure, to metadata concerning the origin, type and access rights of the digital object. As a measure against coincidental loss of information, technical redundancy is produced by a total of 27 entries that are embedded in every digitised copy by integrated metadata as well as in the file names. They include geographical information on the location of the find, the research project, the date and originator of the digitised copy, as well as a detailed description of the contents (Fig. 3). These are based on established standards such as Dublin Core and CIDOC CRM.

The main structuring element is the *localisation* using the following, hierarchically arranged entities based on geographical location, all of which are linked to coordinates and IDs (Fig. 4):

- country,
- region,
- area,
- site.

In the site description, the archaeological entities 'extension of the site', 'site category' as well as the 'activity' performed are stored. Every input is defined by a controlled vocabulary to guarantee a consistent data representation. For example, the term 'activity' subsumes the standard activities dealing with a site such as 'excavation', 'survey' and 'documentation'. Additionally, the categories 'finds' and 'feature' provide further archaeological data relating to the site. In 'feature', the site subdivisions are classified, while 'finds' contains the quantity as well as the type of finds that were documented on-site.

Information concerning *chronology* is divided into three types of chronological classification (Fig. 4):

(a) occupation phase,
(b) regional chronology,
(c) radiocarbon dating.

The radiocarbon dating of the virtual 'object' is marked only (with Boolean attributes) as existent or not. For (a) and (b), a controlled vocabulary, defined by geoscientific broad-ranging terms such as Pleistocene or Holocene, is implemented to describe the occupation phase and commonly used archaeological terms to describe the regional chronologies. By using broad terms for the occupation phase, the data model provides a coherent dataset and makes semantic comparison of the regionally disparate frameworks of reference possible. The use of relatively few attributes is here preferred over unnecessary individual solutions.

For the class of 'derivatives' our curation process provides their own large set of metadata (Fig. 4). These can be allocated to two categories:

- repository relevant data, and
- the picture content itself.

'Repository relevant data' includes technical data such as material and exposure date, as well as the conventional repository values such as author, title and date of origin. A special function created in response to the huge quantity of digital photographs is the so-called 'favourite filter'. This is a marker to select significant or highly relevant pictures to be shown first in an online visualisation.

In the AAArC data model, the 'picture content' is divided into three different data-subsets where every content value is regulated by a controlled vocabulary (e.g. K1A—artefacts; K3—rock art context; K3M—rock art, paintings; K3G—rock art, petroglyphs; N1—landscape; N2—flora; N4—fauna) and an additional full text description.

The fourth segment is 'project' with a subdivision of 'subproject'. Both categories indicate the research projects in which the respective data set was produced. They are of interest for the history of research and to check for different methodological approaches.

Practical Implementation and Application

A so-called *scan protocol* was developed as the chief workflow tool for curating the digital archive records such as photographs, drawings and documentation sheets. This is an MS-Excel spreadsheet including most of the metadata described above as well as numerous automatic processes using Visual Basic, macros and controlled vocabularies via drop-down menus. Thus, newly created digital objects as well as genuinely digital data can both be catalogued and digitally curated ready for import into the online archive in a single process. One entry in the *scan protocol* regulates the access rights to the images with a relatively conservative

approach. Three categories of access have been defined here: Category 1 images are freely accessible, category 2 images can only be viewed in higher resolution after authenticated registration and category 3 images are only released upon written request and if there is a reasonable research interest. This is necessary to protect, for example, personality rights of pictured people.

A linked MS-Excel spreadsheet, the so-called site gazetteer ('Fundplatzkatalog'), contains all information concerning the archaeological site, activities performed there and finds recorded.

The following workflow describes the standard procedure by which a conventional archaeological work result becomes part of the digital archive:

- Analogue 'old stocks' (e.g. slides, excavation documentation) are scanned or photographed digitally. The latter proved to be very suitable for drawings, excavation documentation and plans, and has the advantage of being faster than scanning. All image files are stored in TIF format.
- For each digitised image, the available information relevant for the metadata is entered in the *scan protocol*. After this, a new file name is automatically generated by applying one of the macros of the *scan protocol*.
- In a further step, the metadata from the *scan protocol* is embedded into the XML header of each digitised copy using another program (EXIFcell based on EXIFutils) (Fig. 5).
- Finally, the *scan protocol* automatically distributes each individual digitised copy into the corresponding geographical folder of AAArC's hierarchical filing structure.
- Afterwards, the digitised images are transferred to the server at the Regional Computing Centre (RRZK) of the University of Cologne that hosts the AAArC/Arachne database, in order to be imported and presented online. The latter is a routine of the hosting archival system Arachne which is the online image database of the iDAI world.

A manual describes this whole workflow in detail and makes AAArC relatively easy to use for everyone. This usability has been tested so far with photographs and documentation of excavations in northern Namibia that were curated and entered into the AAArC archive by the excavator herself (E. Kose). She was able to run the internal processes of the archiving routines virtually autonomously by consulting the manual that describes the process stepwise with convenient screenshots, and to allocate metadata and distribute the images into the folder tree. The final import in the online database of Arachne, and with it the online visualisation is done by Arachne as host. Evidently, with this manual at hand, the comprehensive archival process of AAArC with all its special options (gazetteer, bibliographic database, etc.) can be accomplished even by users unfamiliar with the project.

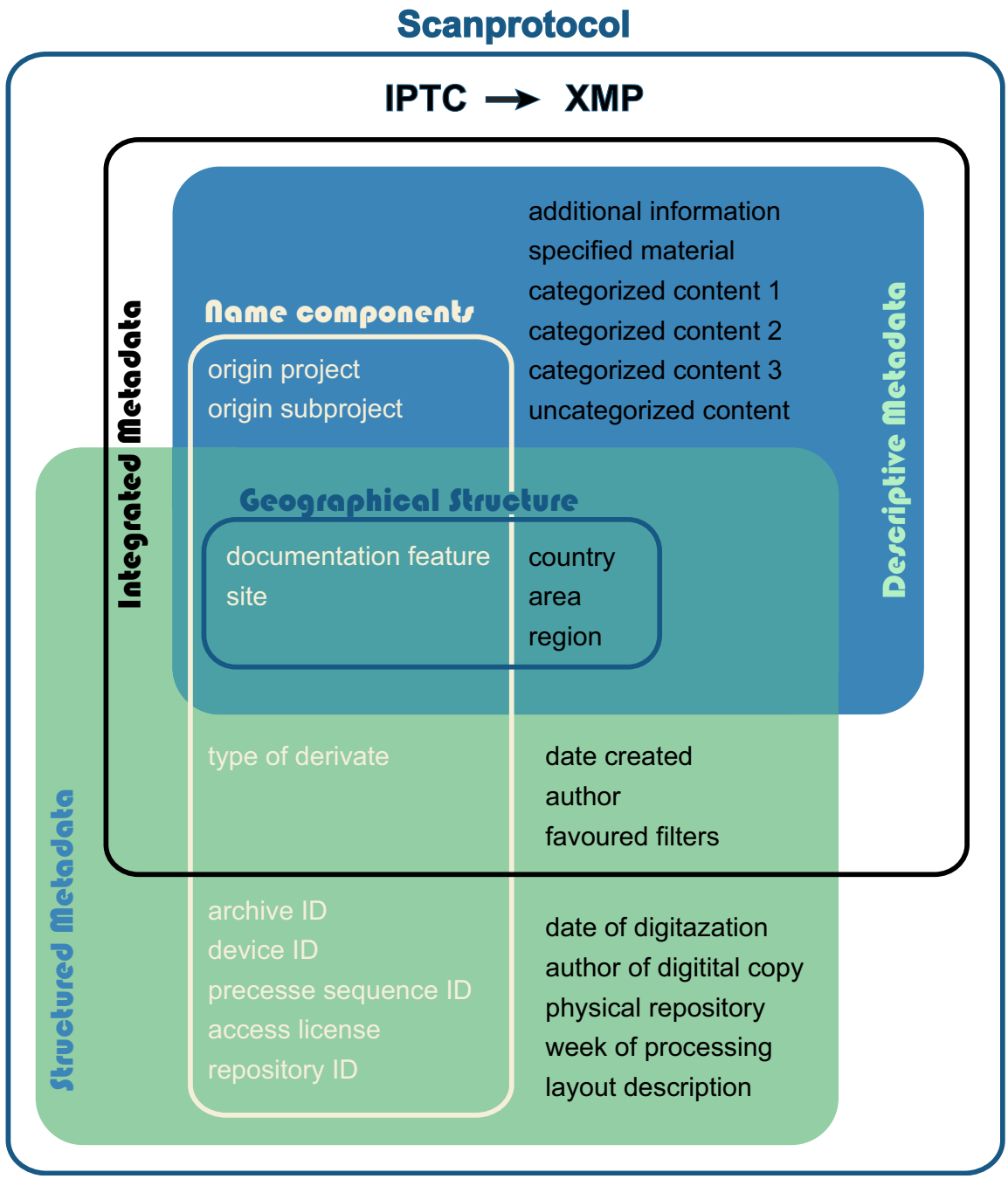
Fig. 3 Graphical representation of the AAArC metadata model for pictures that is handled in this complexity by the scan protocol also illustrating how metadata is linked to the filename. This overlap of metadata and filename is a security measure against data loss if one of the two components is damaged, for example, during a transfer or migration (Eymard Fäder)

Up to now, more than 70,000 images from the various Cologne research projects in south-western and north-eastern Africa are available through AAArC. Rock art constitutes the majority share, comprising over 10,000 photographs of the Brandberg, as well as numerous pictures of rock art sites in Algeria, Egypt, Sudan and the Ennedi Mountains of Chad.

Practical Experiences and Errors

The duration of the AAArC curation process depends on the elaborateness of metadata; some 40–50 digital objects that require detailed individual information can be finished during a normal working day. If metadata is of little complexity and more standardised, about 150 digital objects can be curated during a working day.

These time estimates do not include digitization of analogue objects that can be particularly difficult with older slides, especially if they are in glass frames. Common scanners (e.g. Nikon Coolscan) cannot scan them satisfactorily as the sharpness definition is adjusted to the first surface the measuring beam meets—in this case the glass frame—and as such the image itself will be poorly defined. Therefore, all slides in glass frames had to be transferred to glassless ones. A different unforeseen problem arose with the roughly 3000 Hasselblad photographs that H. Pager took of the Brandberg rock art. Lacking an adequate scanner at the Institute, they had to be scanned by an external company with an original Hasselblad scanner. In spite of repeated attempts, occasional erratic shifts in colour reproduction had to be accepted.



Over the 5 years' duration of the project, digitization of slides became increasingly professionally available, and costs for outsourcing became so affordable that for future retro-digitization, it is recommended to save costs as well as time, and instead seek professional services.

Another practical consideration was to use the language of the documentation or already existing description of images and sites. As a consequence, AAArC contains a mix of German and English descriptions. Notwithstanding the idea of AAArC

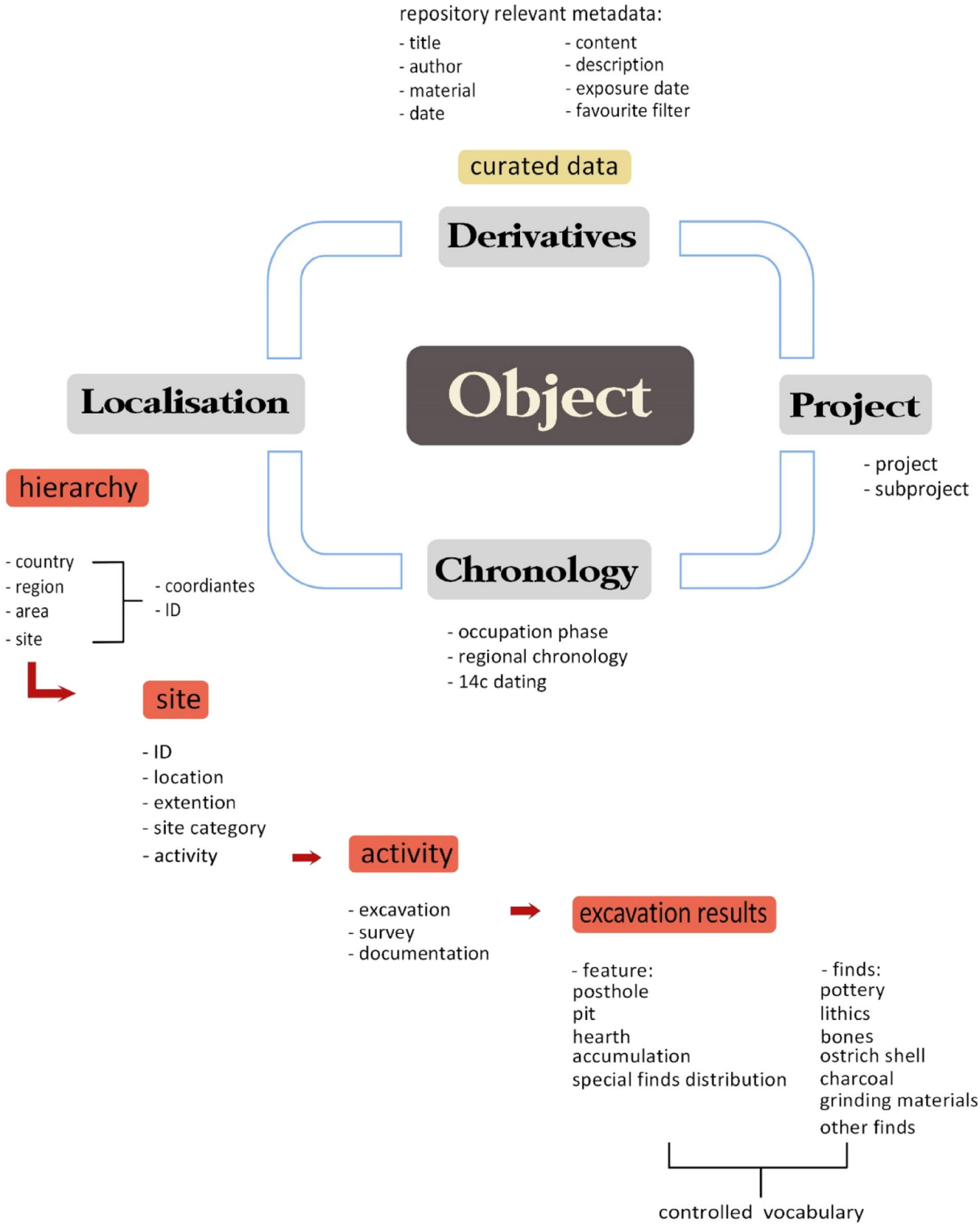


Fig. 4 Graphical representation of the general AAArC data model which encompasses all of the archives data structures (Joana Wilmeroth)

Fig. 5 Metadata of a digital picture highlighting the information that, in XMP format, remains inseparably connected to the digital copy in this way (Eymard Fäder)

being a worldwide usable digital archive, this was considered justifiable as translation tools available online (e.g. DEEPL) allow for reliable translations of German texts.

As a newly setup platform, AAArC was confronted with all kinds of problems, not only practical ones but especially technical ones. From the very beginning of the project, AAArC was to be embedded in and hosted by ARACHNE, in order to keep its own programming requirements as low as possible. But from the start, incremental incompatibilities became apparent; Arachne was originally conceived as a repository for photos of museum exhibits and buildings, so the search for contexts takes precedence using an ontological structure (here defined by object relationships without hierarchical order). Incorporating the hierarchical geographical order of AAArC with its concept of the descending order of the spatial categories (country-region-work area-site-excavation unit) required a number of indispensable adaptations for Arachne. The 'archaeological site'—which is the core unit in AAArC—had to be represented with the so-called topographical object in Arachne. Since Arachne was conceived for the realm of classical antiquity, numerous new entries for archaeological sites corresponding to topographical objects had to be created for AAArC—e.g. 859 units for the Brandberg/Daureb in Namibia. These new entries also had to be included in the iDAI Gazetteer, the site database linked with and defining the spatial ontology for Arachne. Information on hundreds of sites from Egypt, Sudan, Chad and Namibia are now available on so-called topographical objects in Arachne.

As already mentioned, AAArC regulates access rights to the images by the categories mentioned above. However, exact geographical coordinates are, in principal, only disclosed upon justified request by researchers, as regulated through the iDAI-Gazetteer.

Protection, especially against commercial use of the images, is also granted by the application of a Creative Commons license (Ball 2012). A yet-unresolved problem is the fact that the two main platforms of the iDAI world that AAArC uses run under different Creative Commons licensing; while Arachne has a CC-BY-NC-ND 3.0 (Attribution-NonCommercial-NoDerivatives) license, IANUS applies CC-BY_SA 3.0 (Attribution-Share Alike).

The development of AAArC has shown that even if an archive is planned to be fully embedded into an existing structure of the same discipline, extensive developments and programming may still be necessary to find satisfying solutions for the whole project.

However, despite the challenges, the close collaboration with Arachne enabled the successful development of AAArC, because it granted the sustainable integration into the iDAI world. This makes it easier to achieve the desired development of AAArC towards a digital research archive, because AAArC benefits from every further development of the iDAI world.

The Importance of AAArC for Rock Art Research

AAArC was not conceived as solely a rock art digital archive, but as an archive for archaeological sites throughout Africa. Nevertheless, because considerable research efforts especially in Namibia, Algeria and Chad were devoted to rock art, AAArC offers a considerable number of images of rock art in these countries. Due to the integration of AAArC in the iDAI world and the ensuing close cooperation also with IANUS, it was possible to make accessible the complete rock art database for the Brandberg/Daureb containing in-depth analyses of more than 39,000 single figures. In fulfilment of the Open Access principle, this database is downloadable together with an elaborate document on its structure (see IANUS). In view of requests from other researchers, it is anticipated and realistic that AAArC in the near future will become the main data-management infrastructure for new archaeological projects in Africa. Our own research programs from the near surroundings of AAArC aim at data mining and spatial research based on the data available in this archive.

Perspectives

The project AAArC started with the aspiration to become a web-based platform that enables open access to storage and re-use of archaeological data from Africa. This self-imposed claim can realistically be achieved, namely that open digital access enables the indirect return of archaeological finds and findings to their countries of origin, and permits interested parties there to participate in the use of data and further research of their cultural heritage. Close cooperation between western initiatives and local national authorities is needed. A good example for such an approach is the cooperation between the National Corporation for Antiquities and Museums of Sudan and the DAI in digitising the renowned Hinkel Archive for use in site management.

For the moment, AAArC allows to import scientifically curated data in large batches. A further development might be the addition of a publicly accessible interface which also allows single entries made by anyone to be accommodated. One example for such a special restricted access interface is SAHRIS (South African Heritage Resources Information System [Wiltshire 2013]) which is also a heritage management system.

The importance of a better recognition of such work in the scientific community for the further development of digital archives and Open Access cannot be overstated. The principles for the handling of research data adopted by the Alliance of German Science Organisations underlines this by stating:

> 'The provision of research data for further use is a service which benefits the sciences and humanities in their entirety. The Alliance encourages the recognition and support of this additional costly and time-consuming effort.' (Principles)

A final important point of data access is the financial aspect with regard to who pays for the service necessary to grant Open Access and whether there is continuity of financial support or can income be generated through the services themselves. In the case of AAArC, this is still an unsolved problem but the existence and accessibility of AAArC (and also its migration into new systems if necessary) is secured by the embedding in the systems of the iDAI world, independent of projects or personnel provided for this archive.

Acknowledgements We are grateful for valuable comments by two reviewers and the guest editors of this issue of *AAR*. The staff of the iDAI world and particularly its director R. Förtsch were always accessible for us, and without their relentless support and cooperation, AAArC could never have been realised. The figures were executed by the named authors; their development however was a collaborative team effort and their copyright rests with AAArC.

Funding Information The project African Archaeology Archive Cologne was funded by the German Research Foundation DFG (grant number LE 1117/4). Scanning of Hasselblad slides was enabled by funding through the Franz-und-Eva-Rutzen-Stiftung.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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