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Establishing standards for the digital radiography of archaeological materials

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Karla is an Icon Accredited Senior Archaeological Conservator for Historic England and an Accreditation Assessor. She has worked for Historic England for 20 years and has responsibility for conservation related to terrestrial sites and preservation in situ research. She is the X-ray Imaging Facility manager and is leading on the revision of the HE Guidelines on the X-radiography of archaeological metalwork to include guidance on the use of digital radiography.

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Claire is Archaeological Archives Curator for Historic England and has been working with Archaeological Archives for 20 years, increasingly focusing on data management and digital archiving in response to how documentary archive is produced. Claire is secretary for the Archaeological Archives Forum and a committee member for the European Archaeological Council Working Group for Archaeological Archives, Society for Museum Archaeology and Chartered Institute for Archaeology Information Management Group.

Historic England has employed digital radiography since 2000 and computed radiography since 2010. Our X-ray facility is part of the heritage science laboratories at Fort Cumberland, a key node in the national distributed research infrastructure for heritage science. We are now in the process of upgrading the facility to serve both our needs and those of the heritage sector for large scale, industrial digital radiography.

This paper will present:

- Our experience of 'going digital' to *Digital Imaging and Communications in Non-destructive Evaluation* (DICONDE) files, which are the non-destructive radiography industry standard for handling, storing, printing, and transmitting information in industrial imaging. Covering the selection of equipment to ensuring our results meet the minimum standards required for archaeological materials.
- The research Historic England has undertaken to develop and publish guidance and resources on the commissioning and use of computed radiography and to support practitioners in the management and archiving of digital X-radiographs.
- Our work on the data management of digital x-rays and preparing them for deposition: Due to the instability of metal archaeological finds, particularly ironwork, digital X-radiographs are considered primary data within an archaeological archive and thus their preservation is essential. Currently there is no UK trusted digital repository for heritage data that accepts DICONDE files. We will discuss the implications of this, the concept of what a digital x-ray is, how we make the data accessible to colleagues during a project and ensure its preservation, we will look at the DICONDE metadata template, what machine generated metadata is embedded, how cultural object information can be aligned to it; raising the question as to whether there can and should there be a sectorial standard for this?

From X-radiography to tomography: a quest for the ideal imaging technique for archaeological metal

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Janneke is currently a post-doctoral researcher at the University of Amsterdam, researching marine precious metal artefacts from a shipwreck. She is also a freelance metallurgical researcher, specialised in archaeological metal and its examination from a materials science point of view. She obtained her PhD in materials science and engineering at Delft University of Technology, the subject being the information value of corroded archaeological bronzes.

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Tonny is programme leader metal conservation and researcher at the University of Amsterdam. Initially trained as a goldsmith, followed by a training in metal conservation, he went to the UK to run for ten years the metal conservation programme at West Dean College. Apart from teaching, he researches historical metal working technology and conducted his PhD research into the casting techniques of Rodin bronzes and the development of casting sculpture using sand moulds.

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Ineke is a senior heritage specialist with nearly 20 years' experience in researching cultural heritage materials like (archaeological) textiles and metal, paintings, stone applied in monuments and sculptures, garnets, glass and ceramics. Research focuses on degradation and conservation studies, and on archaeometrical studies. She obtained her PhD in archaeology at the Free University in Amsterdam on the technology of early historical Iron production in the Netherlands.

The surface of archaeological precious metal artefacts contains a wealth of information, especially on surface decoration and other finishes such as platings. However, that same surface is often susceptible to degradation and interventive conservation treatments like polishing can have an adverse effect on the readability of the metal. It is therefore important that relevant information on the object and its context is not lost after excavation.

The focus of this interdisciplinary Dutch project ('AMOR') is to determine different possibilities for optimally extracting technological information before it is lost. X-radiography was too limited in providing relevant information on the construction of several heavily corroded 17th-century metal finds from a recently found shipwreck (the so-called 'Palmhoutwrak'). This resulted in a systematic study comparing multiple imaging techniques: X-radiography, micro-CT and neutron tomography. The implemented research method should lead to the establishment of an optimal post-excavation conservation and research strategy, important for everyone who has to deal with archaeological precious metals.

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Conservation treatment of a copper-alloy bathtub from the Stabian thermal baths in Pompeii

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Eleonora is an Italian Conservator recent graduate at the Academy of Fine Arts of Naples, in Italy. She studied conservation and restoration of Cultural Heritage, specializing in metal, alloy, ceramic, glass and organic material artefacts conservation.
Her professional experience is mostly focused on archaeological artefacts and metals conservation. During her university career, she did several internships one of which was with the National Archeological Museum of Naples in 2017. In 2019 Eleonora had a post-graduation Placement at RAMM in Exeter, England. She just finished to follow a conservation project in Herculaneum Archaeological Site (in Naples, Italy).

In August 2019 a conservation treatment was carried out upon the bathtub (no. inv. 73003) from the second calidarium of the Stabian Thermal Baths in Pompeii, Naples (Italy) dating from I-II century CE, as Master Thesis Degree. The project itself took place within the National Archaeological Museum of Naples - MANN (Italy).

Discovered in fragments in 1856, the find was first treated by artisanal on-site restorers, then acquired by the Archaeological Museum of Naples in 1863. There is no documentation about the bathtub conditions and its first conservation treatment.

For a long time, the find has been displayed in the Museum's Little Bronze Collection until it moved to the MANN storage.

The bathtub was in poor condition and the precarious physical stability of the artefact required the execution of a diagnostic campaign, with generous sponsorship from the Rotary Club of Naples: the use of X-radiography, UV fluorescence, X-Ray Fluorescence and FT-IR spectrophotometry allowed us to identify these critical issues, contributing to the correct planning of the treatment (fig. 1).

The project aim was to recover the formal, static and aesthetic unity starting from a critical scientific study of the artefact, whilst considering how the previous conservation treatment involved its historicity, functionality and aesthetics.

It was necessary to design and realize a mount for the correct handling of the artefact.

The communication between the professional figures of the restorers, the Senior Lecturer and Conservator Marina Vecchi, the archaeologist Dr. Luigia Melillo and the diagnostician Dr. Claudio Falcucci, together with an in-depth archive and bibliographic research, allowed us to outline a very early literature dedicated to metal bathtubs from Roman age, connecting the ones stored in Italy, in Europe and in the USA and carrying out a comparison about the technologies and the previous treatment detected on the artifacts.

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Conservation of a recently excavated anti-resurrections infant coffin from Euston, London

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Lucie is responsible for the conservation of archaeological artefacts from a range of materials, and participates in the management of conservation work for archaeological projects. She also provides conservation advice and support on-site, such as in-situ lifting of fragile objects. She has been involved in prestigious and complex urban sites, acting as conservation liaison with the project team and specialists, and conserving large quantities of material.
Before joining MOLA in 2018, Lucie worked in the Collection Care department at the Museum of London. Lucie has a degree in conservation for archaeology and museums from UCL, and is a member of ICON and ICOM conservation bodies.

In March 2019, an iron coffin was excavated from a large Victorian burial site in London.

The coffin held the remains of an infant and was identified as an anti-resurrectionist coffin. Surviving examples of these are normally found in crypts, so one found in the archaeological record was of significance. Other designs of such coffins were excavated on-site, but complete adult iron coffins have not preserved as well due to large areas of the metal corroding away, resulting in highly fragmented objects.

As the coffin was going to retained and accessioned, conservation was commissioned to stabilise the object for long-term storage.

The coffin was covered in a thick, bulky layer of concreted soil and orange corrosion products, some appearing active. It appeared mostly stable and holding together. The head of the coffin was very fragmented.

The coffin was first cleaned using a power pen, powered by an air compressor. This revealed the original surface of the coffin, along with the remains of intricate decorations. A challenge was the size of the object: it was too large to be x-rayed before treatment, which would normally guide the mechanical clean. The next phase of the treatment will comprise the stabilisation of the actively corroding metal both inside and outside the coffin.

The project presents the current treatment and the difficulties encountered, such as the inherent fragility of the object, how to deal with areas difficult to reach and the ethics of treating an object that was designed to never be opened again after burial.

Terrestrial archaeological ironwork: an assessment of past treatments - Evaluating the long-term performance of past treatments to inform future approaches to stabilisation.

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After obtaining a diploma in Conservation Crafts at Lincoln College I went on to specialise in archaeological conservation at the Institute of Archaeology, UCL London. After graduating in 1990, I started work at the British Museum in the Metals Conservation Section. Then In 1992 left to join the Archaeology and Numismatics department at the National Museum of Wales Cardiff, conserving mixed material, but specialising in the treatment of metals, pottery and the identification of pigments. In 2014, I relocated to the National History Museum at St Fagans, just outside Cardiff, where I now care for the collections on open display in the historic houses.

While undertaking a study to assess the stability of the archaeological iron collection at Amgueddfa Cymru National Museum Wales, an opportunity arose to evaluate the ability of current and past treatments to maintain stability during a prolonged period of storage. Numerous treatments to stabilise the iron had been applied to the collection over the years, if it was possible to evaluate the performance of different treatments this data could then be used to influence future treatment plans.

The aim of the survey was to answer the following questions.

1. How well has our present treatment performed and is it worth continuing?
2. Can the study of the performance of past treatments help inform the development of new procedures?
3. Does passive conservation (storage with desiccated silica gel alone) manage to maintain or provide better levels of stability than active conservation methods?
4. Is it possible that some treatments, no longer in use or favour, are now worth renewed consideration?
5. Can the impact of each stage of treatment be isolated, for example mechanical cleaning, desalination or coating? If so, which if any have the greatest influence on long-term stability?

The resources available to aid the evaluation process included treatment records, X-radiographs and photographs from the conservation archive, dating back to 1973. This data was consulted throughout the study and a total of 1379 objects were examined and assessed.

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Repacking the metal finds from Wharram Percy

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Charlotte studied Medieval History at the University of St Andrews before turning to conservation, completing a Masters degree in the conservation of archaeological and museum objects at Durham University. During her training, Charlotte undertook a 10-month placement at the Royal Armouries Museum in Leeds working on complex interventive object treatments and devising new emergency response training for museum staff. After a brief period undertaking conservation housekeeping as a Conservation Assistant for the National Trust, Charlotte worked for English Heritage leading a project to repack the Wharram Percy archaeological collection. As the 2017/18 Bute/Icon Preventive Conservation Intern with the National Trust for Scotland Charlotte assisted with the upgrade of the Trust-wide environmental monitoring system, worked on writing collection care plans for individual historic properties and supervised and advised on filming and large-scale projects in sensitive historic interiors. Charlotte is currently Preventive Conservator at Spencer & Fry providing conservation advice and training for museums and historic properties and supervising filming in historic locations.

Helmsley Archaeology Store holds archaeological collections from English Heritage sites across the North of England. Extensive archaeological finds from Wharram Percy, arguably Britain's most famous deserted medieval village, form part of the collection. Excavations at the site took place regularly from the 1950s till the 1990s; amongst the finds are a substantial number of metal artefacts, ranging from copper alloy brooches to indiscriminate lumps of iron.

In 2017 the metal finds from Wharram Percy were highlighted for a repacking project. The objects had been stored in finds bags, packed in Stewart boxes with silica gel packets stacked on pallets in the Archaeology Store. The objects had very little support within the finds packets and were crammed into overfull Stewart boxes, some of which were broken. Some larger objects were stored in cardboard boxes as they were too big for the airtight Stewart boxes. The repacking project, which relied heavily on the support of dedicated volunteers, aimed to provide more suitable packing for the long-term storage of the collection using conservation grade materials and to upgrade and update the object records on the English Heritage database to include good quality photographs, correct locations and important data.

The project was successfully completed and can be used to highlight some complexities and considerations about the long-term storage of archaeological metal objects, such as the ongoing commitment needed to maintain correct storage conditions and the space needed to store such a collection, especially after repacking to conservation standards.

The Desert in the Dry Dock: Desiccation on a Grand Scale

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Nicola is a chartered Mechanical Engineer, working as a design analyst and project engineer in the aerospace and nuclear power industries prior to her recent move into heritage conservation. In 2018, she was appointed to the newly created "Ship's Conservation Engineer" post at Brunel's SS Great Britain in Bristol. In this role she is reviewing the effectiveness of the ship's current conservation system, put in place in 2005, and developing a sustainable conservation strategy for the future care of this unique object.

The SS Great Britain was designed and built by the Great Western Steamship Company under the supervision of the Engineer Isambard Kingdom Brunel. Launched in 1843 she was the first ocean-going vessel to be made from iron, allowing her to be significantly larger than had previously been possible. She survived being run aground early in her career and went on to enjoy 94 years of service, thanks to the strength and longevity of this exciting new shipbuilding material and technique. Salvaged from the Falkland islands in 1970, she was returned to the original Bristol dry dock in which she was built, where she has since been almost continuously accessible to the public.

Guided by research at Cardiff University a curator-led, Heritage Lottery Funded programme of conservation was completed in 2005, creating a controlled-climate envelope at 20% relative humidity around the ship to halt chloride-accelerated corrosion. By "slowing down time" in this way, and with minimal intervention, the SS Great Britain Trust are keeping their options fully open to take advantage of whatever future technology might offer to conserve this one-of-a-kind, 98m-long object.

In 2018-19 the desiccation system, and associated monitoring and control, was reviewed and upgraded, with further work now planned to secure the long-term future of the object and contribute to the city of Bristol's aspiration to reach "net zero" by 2030. This paper explores the practicalities and challenges of maintaining a controlled environment on a 100-metre scale, covering the mechanical and electrical systems, control software, plant maintenance and carbon footprint. Audience engagement in conservation has also been vital in securing support and funding for the work, and further public engagement activities are planned alongside future conservation work.

Launching new guidelines for the desiccated storage of archaeological metals: an update to First Aid for Finds

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Nicola is a Senior Lecturer at Cardiff University where she teaches Conservation and Heritage Science with a focus on research methods and analysis. Working closely with practitioners, her research centres on producing evidence-based guidance for end users in conservation practice.

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David is a Professor of Conservation at Cardiff University, where he teaches and researches conservation theory and practice, with emphasis on the corrosion and treatment of ferrous metals. His research into desiccated storage of unstable iron underpinned the conservation of Brunel's iconic steamship SS Great Britain. In 2010 he was awarded the Plowden Medal for his innovative research and for his contributions to the conservation profession.

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Johanna Thunberg is an AHRC-funded PhD candidate at Cardiff University. Her research project aims to provide guidelines for management of archaeological copper alloys and identification of bronze disease. She has a BSc and MSc in Conservation from Cardiff University where her theses focused on the efficacy of storing archaeological metals using microclimates.

This paper introduces new guidelines for the storage of archaeological metals based on research being carried out at Cardiff University (https://www.heritagepreservationguidance.co.uk/). It updates previous, generic guidance on storage box selection and silica gel use such as is offered in First Aid for Finds, which remains a go-to guidance. Advice on silica gel per volume of box in that publication was based on contemporary practice rather than evidence-based data and no guidance on box selection was offered beyond the ubiquitous Stewart Sealfresh.

The advice presented here arises from measuring the leakage rate of six brands of commercial polymer boxes and the impact of different masses of silica gel on the internal environment of boxes. Two external environments were modelled to represent a controlled store at 50% RH and uncontrolled conditions of 80% RH. Supporting cost benefit decision-making in storage box selection and silica gel regeneration cycles, these guidelines will allow managers of archaeological metalwork collections to design bespoke storage protocols which have the potential to extend lifetimes of collections.