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CONTENTS

COMPARATIVE STUDY OF DIFFERENT IMAGING AND CONSERVATION APPROACHES FOR ARCHAEOLOGICAL IRON: CONSERVATION AS A MEANS OF RETRIEVAL OF ARCHAEOLOGICAL INFORMATION

N. Cleeren [1], J. Dhaene [2], M. Peters [3]

[1] Artesis University College of Antwerp
Faculty of Architecture and Design,
Conservation Studies – Centre for Conservation Research (CCR)
Blindestraat 9
B-2000 Antwerp, Flanders
Belgium

[2] Department of Physics and Astromonomy
Centre for X-Ray Tomography
University of Ghent
Proeftuinstraat 86
9000 Ghent
Belgium

[3] Akeleilaan 11
5582GG Waalre
Netherlands

*Corresponding author: natalie.cleeren@telenet.be

Abstract

In this study, different invasive and non-invasive approaches to the conservation of heavily corroded archaeological iron finds are assessed in order to extract as much information as possible from these objects. A survey of the research potential of archaeological finds results in four levels of information that will be considered in every step of the conservation process for iron finds.

Examples of different conservation techniques for iron objects, mostly from burial sites, ranging from standard conventional X-ray radiography, in combination with partial cleaning, to Computed Tomography (CT), are evaluated in regard to the information they reveal that is relevant to the archaeological research. Ultimately, a well thought out balance between common methods and new techniques will result in the most effective approach.

Keywords

archaeological iron, diagnostic cleaning, imaging, CT scanning.

Introduction

The iron finds included in this research were excavated during the last ten years from several Iron Age, Roman and Early Medieval sites in Belgium and The Netherlands [1]. These objects were all subjected to investigative conservation techniques and their research potential was constantly examined and re-examined. The majority of these objects (spearheads, arrowheads, axes, swords, knives, tools etc.) are heavily corroded with no metal core remaining. Their original shape is conserved within the layers of corrosion. This condition gives rise to substantial difficulties when trying to use mechanical cleaning to reach the original surface, also referred to as the 'abandonment surface' by Bertholon, which suggests a representation of the dimensions of the object at the moment when it was interred (Bertholon, 2007).

A sensible approach to the conservation of such heavily corroded iron artefacts is required, as a majority of iron finds are currently being recovered in this precarious condition. In a context of privatisation of archaeological research, the retrieval of information is always urgent and financial resources are limited. The four levels of information were established in close collaboration with the archaeologists involved in the research of the aforementioned sites. Even elaborate techniques, such as μ-CT, can become part of a cost-effective approach when information retrieval is set forward as the main objective of conservation of archaeological iron finds in the first stages of archaeological research.

Conservation as a means of gathering of information

The objective of archaeological conservation could be described as efforts to safeguard those characteristics of excavated objects that make them informative, awe-inspiring or enjoyable (Pye, 2001). During the initial phases of archaeological research, iron finds serve purely as sources of archaeological information. At this stage, the conservator's focus lies mostly in recovering all the information residing in the object.

Archaeologists are first and foremost interested in diagnostic features which place the artefact in a given typological sequence. These features will reveal its age and provenance, information on which most archaeological interpretation is based, together with the stratigraphic context of the finds.

As many of the artefacts considered in this research are retrieved from burial sites, it is important to notice that the presence of different social classes in the community is investigated by exploring their presence in this archaeological record, among which are iron grave goods (Annaert and Ervynck, 2013).

Associated with the iron finds, traces of the initial burial environment are recovered, traces of associated organic finds and organic materials belonging to the object itself. These materials rarely survive in an early archaeological context, and their recovery has become increasingly significant to archaeologists.

Details of metal-working are unfortunately seldom incorporated into current archaeological studies. Metallurgical studies reveal an insight into technological evolution but recede into the background as typological studies will more easily reveal economic and social evolution.

A protocol for conservation treatment of iron finds should consider not only the condition of the finds and their conservation needs, but most importantly their archaeological context and the potential of the objects to reveal additional information through careful selection of the method of treatment. A treatment protocol can be established for every type of archaeological context, depending on specific research questions. During the conservation of the finds that were subjected to this study, first and foremost to uncover the archaeological information that they contain, it became useful to distinguish different levels of information directly connected to the priorities established by the archaeologists.

Four levels of archaeological information

The first and most relevant level of information includes the diagnostic features, such as the original shape and possible decoration, which help to place the object in a well known typology. The detailed identification of organic materials also belongs to this first category (in regard to early Medieval and earlier finds) as they reveal the scarce information on the use of organics that have survived burial.

The second level of information is specific details of shape and decoration that have the potential to become part of the commonly used set of diagnostic features. So far these features are not included in current typological sequences for iron objects, mainly because they have been overlooked and are too difficult to document using common cleaning and 2D documentation techniques. Refining the existing typological sequences remains a priority in archaeological research.

The third level contains mostly technological information, of great interest to the study of technological evolution. This information is currently difficult to link to the date or origin of the finds due to a lack of in-depth research and is currently considered more anecdotal than the information from levels 1 and 2.

The fourth and last level of information deals with the corrosion features of the object and should become increasingly relevant to archaeologists when dealing with the management of archaeological sites. *In situ* preservation has been set out as the preferred option in the Valetta Convention (1992), but unfortunately research on the correlation between soil contamination and the condition of metal artefacts is lacking in Belgium. A few Dutch studies do recommend monitoring of the corrosiveness of soils (Kars and Smit, 2003), but so far fundamental studies on this topic are lacking and this could have substantial consequences for *in situ* preservation of archaeological sites. *In situ* preservation might turn out not to be the best option for long-term preservation of metal, and specifically iron, objects.

The first step in every treatment protocol should be a focus on obtaining level 1 information, to be gathered by partial (diagnostic and investigative) cleaning, in close collaboration with archaeologists and finds specialists. This process will form the basis for possible further interventions.

Common practice – diagnostic and investigative cleaning

In the year 2013, economic reality commits archaeologists and conservators to make choices. Extracting a maximum of information from a large number of objects has become the main priority of archaeological conservation. In 2001, the Flemish Institute for the Archaeological Heritage determined that a period of 24 years was required to fully clean approximately 25,000 iron finds from the site of the Roman Castrum (camp) of Oudenburg, Belgium. This was subsequently narrowed down to 2.5 years by X-raying every object and partially cleaning about two-thirds of the finds (excluding nails). In total, 213 objects were fully cleaned for presentation purposes (Cleeren, 2006). From this moment on, diagnostic cleaning of iron artefacts was introduced in Belgium as common practice.

The distinction between full cleaning (for research and presentation purposes) and diagnostic and investigative cleaning demanded a substantial effort from archaeologists, finds specialists and draughtsmen. Diagnostic cleaning provides the archaeologists with sufficient information on the morphological details to place an object in its typological sequence. Investigative cleaning provides details, such as the highly-valued traces of organics (both level 1 information).

The first premise for successful partial cleaning is a close collaboration between conservators, archaeologists, finds specialists and draughtsmen. It demands intensive knowledge of typological features by the conservator, who preferably has a strong background in archaeology. One of the biggest challenges is to teach draughtsmen to interpret X-ray images. Ideally, the conservator produces the first diagnostic drawings, as shown in Fig. 1.

Important details can be missed when cleaning iron objects. It has to be realised that partial cleaning, together with the information retrieved from two-dimensional X-rays, will never reveal every important morphological detail. As an example, the X-ray of a spearhead from Viesville (Belgium) surprisingly does not show the small copper alloy rim at the bottom of the shaft. Fortunately this area was subject to partial cleaning and this feature was discovered; however, localised elsewhere, it would have been missed (Fig. 2).

Even with extensive, full cleaning, specific morphological (levels 1 and 2) details can be overlooked. During this research, special attention was given to the morphology of iron spearheads. Here the limits of our current approach were reached: classical X-rays do not show the section of the blade. Is it for example diamond-shaped or lenticular? Mechanical cleaning, however meticulously executed, will

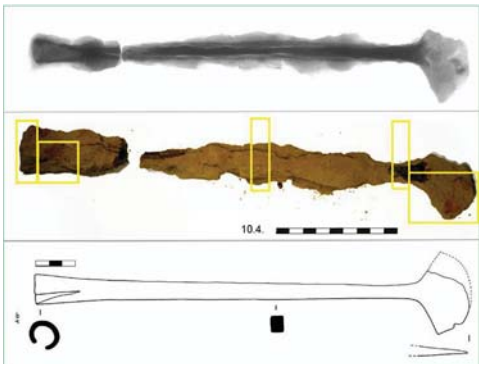

Figure 1: Roman object from the site 'ville d'Anderlecht' à Bliqcui, Belgium (Fouilles 2003 CTRA et ULB). X-ray, zones to be partially cleaned (yellow boxes) and end result (archaeological drawing).

Figure 2: End of the shaft from a spear-head with copper alloy rim, not visible on the X-ray. (site of Viesville/Pont-à-Celles, Belgium). Laurence Baty ©: SPW – Archéologie.

often fail to provide the correct shape of these sections. Even experienced conservators are reluctant to admit that not every morphological detail, not every detail of the 'abandonment surface', can be recovered and are even more reluctant to admit they may, at some point, unconsciously proceed to 'shape' the object according to their own assumptions.

Traces of organic materials can be missed by partial cleaning. 2D X-ray images are restricted to the metal object, hardly showing any less-dense materials. The more an organic compound has mineralised, the more it will show up on the X-ray image. Experienced conservators can distinguish certain organic traces while being aware that additional organic remains may not be visible on an X-ray image. Partial cleaning will only reveal them when visible on the X-ray image, when localised in the areas to be cleaned or of course when they are not fully covered with corrosion products and are visible by the naked eye.

Revealing every informative feature of an archaeological iron object will often require full cleaning. Given the time and budgetary constraints, full cleaning must be warranted and based on the information obtained from partial cleaning, and with reference to the importance of the archaeological context.

How accurate are the data obtained by diagnostic cleaning? Usually the original contours of an object will be more evident on the X-ray image than on the actual object. 181 objects from the sites of Broechem and Viesville (swords, spearheads, arrowheads, axes) were examined after partial cleaning, and 86% (156 objects) showed a 1-3 mm deviation between the measurements of the cleaned areas and the measurements taken by X-ray (scaled to precisely 1:1), and 8% (14) of the X-ray images revealed no readable contours. 4% (7, the better preserved objects) showed an exact correspondence between both, and 2% (4) showed a deviation of 3-5 mm. As far as the drawings (and the archaeological record) are concerned, they are mostly based on the X-ray images and are therefore generally quite accurate, although 3% (5 objects) show a large (3-5 mm) deviation, mainly due to fact that the X-ray was not rescaled when an object was recovered in a small block and during scanning was set above on the X-ray film/ detection plate. Set against the diagnostic features that categorise these objects, a deviation of 3 mm plays no role in their archaeological interpretation. Depending on the type of object, even the 5 mm deviation can sometimes be acceptable (for level 1 information, larger objects). It should also be noted that the original surface has probably moved to some extent, although most objects considered in this research present a consistent even surface. Small lifted areas are easily defined as such and are not included in the drawing of the original contours.

Other non-invasive techniques in the search for more detailed information

In the search for further information, several objects from the Merovingian site of Lent (Nijmegen, Netherlands) were examined by X-ray Computed Tomography (CT) to obtain a 3-Dimensional representation of the objects without any cleaning. Several ensembles of block-lifted grave goods were investigated, still encased in their block of soil.

For the 3D reconstruction, the software package Octopus (Vlassenbroeck, et al., 2007) [2] was used.

The HECTOR scanner - High Energy Computed Tomography Optimized for Research – (Masschaele et al., 2012) at the Ghent University Centre of Computed Tomography (UGCT) was used. A voltage between 180 kV and 220 kV was applied with exposure times around 500 and 1000 ms. The achievable magnification in this setup is around 1/1000 of the size of the object and the voxel size of the reconstructed swords was 0.18 mm. The complete scan is managed by the scanner GUI (Dierick et al., 2010), a programme that controls all of the components of the scanner.

Results from individual finds and block lifted ensembles

A µ-CT-scan of the blade of a spearhead (site of Lent), executed at the University of Leuven *[2]*, reveals a section evolving from a lenticular to diamond shape (and back), a shape that would be difficult for a conservator to determine visually by mechanical cleaning (Fig. 3b). Based upon the information gathered from partial cleaning (Fig. 3b), many conservators may be tempted to 'shape' the blade in a lenticular shape. This level 2 information is not incorporated in any typologies for Merovingian spearheads, not even in the ones that do incorporate data on the section of the blade (Siegmund, 1998).

Visualising sections of the object proves to be useful for interpreting the object and recovery of level 2 information. Technological details (level 3 information), such as the internal structure of the copper alloy pommel of a sword (Fig. 4), are beautifully revealed using the µ-CT technique.

For block-lifted finds, embedded in soil, the results obtained on previously published objects from the Merovingian cemeteries of Lauchheim in Baden-Württenberg, Germany (Ebinger-Rist et al., 2010; Stelzner et al., 2010), both by

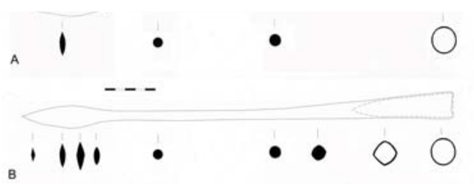

Figure 3: Morphological information gathered from diagnostic cleaning. 3b. Morphological information obtained with µ CT scan (spearhead, Merovingian burial site of Lent (Nijmegen, Netherlands) BAMN (Bureau Archeologie & Monumenten, gemeente/ Nijmegen).

Figure 4: µ-CT scan image of the internal structure of the copper alloy pommel of a sword from the Merovingian burial site of Lent (Nijmegen, Netherlands) BAMN (Bureau Archeologie & Monumenten, gemeente/ Nijmegen). 50 W-1000 ms - voxel size: 50 µm.

X-ray CT and neutron CT, were promising. Relating these techniques to the different levels of information addressed in this paper was the scope of the investigation by μ-CT of the block lifted objects from Lent. More specifically the investigation asked: which level 1 information can be retrieved by μ-CT alone and not by full cleaning, and which information remains difficult or impossible to retrieve using μ-CT?

The following examples show features that would be difficult to reveal by hands-on cleaning of the artefacts. The contours of a sword in its scabbard are revealed on a 2D X-ray image, but not the sword's cross-section (Fig. 5). A scabbard made from organic material with important morphological detail is not easily recovered by mechanical cleaning. Not every surface detail is visible even when meticulously cleaned and using a binocular microscope (40 x magnification.)(Fig. 6).

μ-CT scans of ex situ organic samples can provide detailed images of their internal structure. The wood from an axe-shaft and from the scabbard of a *seax*, from the Merovingian site of Broechem (Belgium), was successfully identified using μ-CT (level 1 information) as being taxa, *Prunus sp*. (a Prunus species) and *Ilex aquifolium* (Holly) (Han et al., 2012).

The most important drawback of non-invasive documentation by μ-CT (XCT and NCT) for block lifted finds is the fact that organic materials may be localised when partly or wholly mineralised, but cannot be examined in full detail for purposes of exact material identification, that is, level 1 information in a block of soil. Investigative or full cleaning of the ensemble remains necessary to fully reveal detail and level 1 information about associated organics. For example, the tiny string attaching a small yellow bead to the handle of a sword was completely missed by the μ-CT scan (Fig. 7).

CT scanning can reveal morphological details, sometimes impossible to uncover by mechanical cleaning. However, these visualisation techniques alone cannot provide all of the information that archaeologists require from these finds, least of all for block-lifted objects.

Cost-effectiveness of different techniques

The cost-effectiveness of the different approaches examined here has been evaluated. For individual finds, the combination of 2D X-ray images with diagnostic cleaning remains the most cost-effective method for retrieving as much level 1 information as possible. The expense of meticulous diagnostic cleaning is, on average, a third of the cost of full mechanical cleaning (considered for both large and small finds and calculated for the finds of Broechem, Bliqcui and Viesville). Some details might be missed and small deviations in shape will occur, but these do not justify the expense of fully cleaning every iron artefact. Microscopic investigation of organic materials remains more cost-effective than the current use of μ-CT.

For object ensembles 'en bloc', the most cost-effective and scientifically interesting approach seems to be a combination of 2D X-ray images and well chosen μ-CT-scans to obtain information that cannot be retrieved by hand, and as a tool to guide the investigative cleaning of these complex ensembles. For the block-lifted objects from Lent (Nijmegen), this approach will be equally expensive as full cleaning for blocks containing swords and several small utensils. Full cleaning will reveal an object ready for presentation, and might reveal some additional details such as the string going through the yellow bead mentioned above, while partial and investigative cleaning in combination with μ-CT will reveal a greater set of morphological information.

In the case of the objects excavated at Lent, the graveyard is of such scientific importance that options for further research through more detailed conservation by further cleaning and 3D documentation is considered, again to reveal mostly level 1 information. Nevertheless, this process will also reveal level 2 and 3 information. Communication is the main key to a successful and budgetary responsible conservation process, and the main objective is the

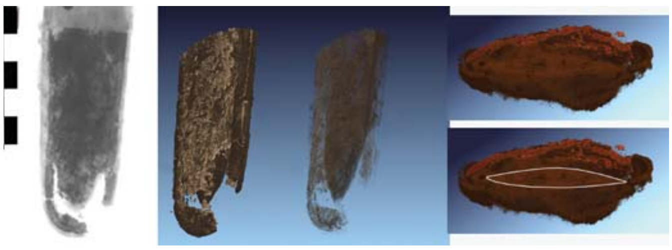

Figure 5: μ-CT scan image of the sword within its scabbard and section (Lent, BAMN (Bureau Archeologie & Monumenten, gemeente/ Nijmegen)) - 220 kV, 85 W, 1000 ms, voxel size: 180 μm.

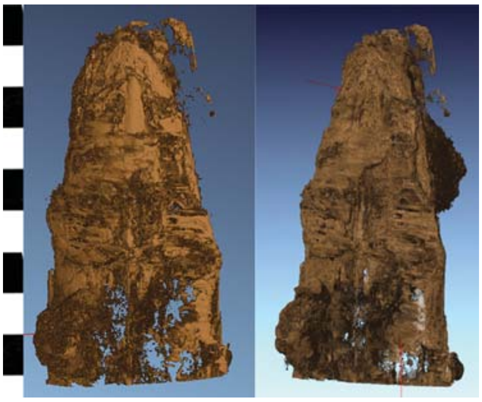

Figure 6: μ-CT scan image of the organic scabbard with surface details (sword, Lent, BAMN, Bureau Archeologie & Monumenten, gemeente/ Nijmegen)) 175 kV, 50 W, 1000 ms, voxel size: 50 μm.

Figure 7: Yellow bead with string preserved. The string is not visible on the μ-CT scan (sword, Lent, BAMN (Bureau Archeologie & Monumenten, gemeente/ Nijmegen

retrieval of all scientific information from the objects. To present these findings to the general public, further more detailed conservation treatments may be undertaken, not by definition prioritising the aesthetic qualities of the object as was usually the case in the recent past.

Conclusion

The use of imaging techniques and hands-on conservation of archaeological objects can be extremely valuable; however, much time and money can be spent on pointless interventions and analysis. Economic reality no longer allows conservators to spend too much time on treatments that will not provide more scientific information. These objects are being preserved in view of the knowledge they can provide.

2D radiography combined with partial cleaning can provide a method that reveals a lot of information in a limited time-span. The information that remains uncovered by this method can be safeguarded for future research. Often, more intensive investigation is considered unfeasible. Nevertheless, in-depth studies using a combination of invasive (partial cleaning) and non-invasive techniques such as μ-CT can be achieved when working in close collaboration with archaeologists, following a well though-out protocol that considers the retrieval of, and need for, different levels of information throughout the conservation process.

End notes

[1] The sites of Blicqui (Iron Age & Roman), Broechem (Merovingian), Viesville (Merovingian) in Belgium and the site of Lent (Merovingian) in Nijmegen, the Netherlands.

[2] http://www.octopusreconstruction.com

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