A partnered approach to Anglo-Saxon grave finds: Locating and protecting diverse values of archaeological iron by integrating conservation and archaeomaterials processes at UCL Institute of Archaeology

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Abstract

This paper illustrates that integrating archaeometallurgical sampling into the conservation process can facilitate collaborative research across specialisms in higher education (HE); safeguard the significance of archaeological iron; and provide optimal conservation training. Preparing postgraduate conservation students for professional practice is essential, yet critical learning experiences involving challenging stakeholder dialogue can be difficult to manifest authentically. Institutional policies such as engaging students with research, exposure to current developments, and fostering partnerships between staff and students add additional demands. Using the management of ferrous Anglo-Saxon grave finds at UCL Institute of Archaeology (IoA) as a case study, this paper demonstrates how collaborative research and ambitious learning objectives for conservation students can be facilitated within existing staff obligations and coursework loads, with beneficial outcomes for archaeological iron objects.

Objects including a spearhead, knife, shield fittings, belt buckles, and brooches were excavated by the People of the Heath on Main Down (July 2023) and conserved by year 1 MSc students at the IoA. Conservation progressed in partnership with archaeological science colleagues to facilitate research exploring iron sources in the assemblage. This paper outlines the conservation treatments, analytical results, and insights gained from collaboration.

Keywords

archaeology, Anglo-Saxon, iron, conservation training, sampling, scanning electron microscopy (SEM)

Introduction

This paper presents a holistic answer to seemingly disparate challenges of locating capacity for collaborative research across specialisms in higher education (HE); negotiating significance safeguarding for archaeological iron; and providing optimal learning experiences in postgraduate conservation training.

In vocational postgraduate conservation degrees, the requirement to prepare students for future working life is paramount, and there is much discussion concerning how this is best achieved and the many challenges therein (e.g. Manti et al. 2011, Hindin 2015, McGinn 2017, Pearlstein 2017, McGinn 2021, von der Goltz 2022, Sloggett 2022, Wuebold et al. 2022). Important learning outcomes include understanding of professional history, contemporary roles, and associated theoretical principles; recognition and prediction of degradation mechanisms and implications for object significance; method selection and implementation (interventive and/or environmental) to manage existing or prospective undesirable material changes; best practice laboratory conduct and use of equipment; and appreciation of the impact of conservation decision-making on heritage values and relationships. Students must develop competency in the design and implementation of strategies to resolve problems. These aspects provide a fundamental baseline, with students ideally also exposed to authentic stakeholder dialogue—navigating challenging compromises firsthand. Degree programmes are further

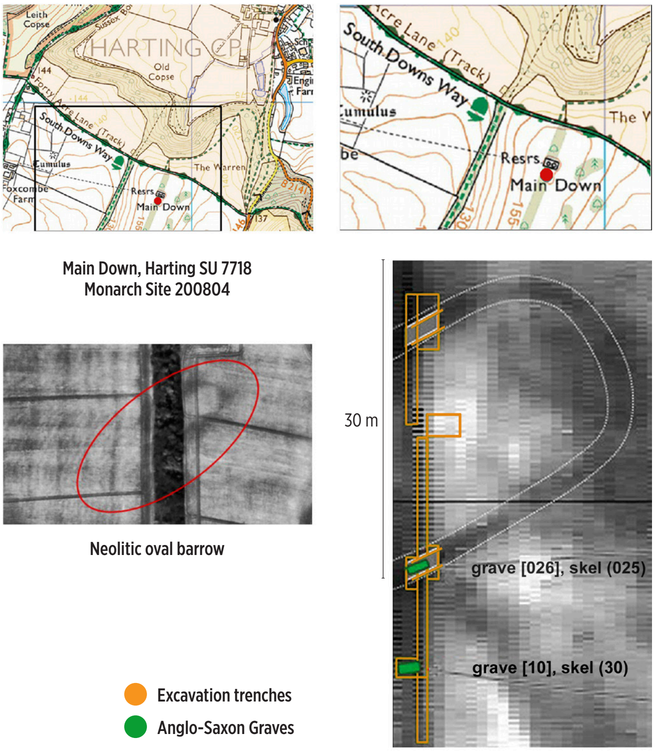

Figure 1 Map and geophysical resistivity survey indicating the location of the graves from which the objects were excavated. Adapted from images provided by Dr Stuart Needham, with thanks to Dom Escott and team

obligated to meet the demands of institutional pedagogical policies; at University College London (UCL) the principles of the Connected Curriculum education framework: engaging students with research and enquiry; exposing them to the latest developments in theory and practice; and creating a dialogue of partnership between staff and students (Fung 2017, 182; Davies and Pachler 2018). These complex learning experiences can be difficult to manifest in practical training.

At the UCL Institute of Archaeology (IoA) comprehensive vocational training is provided through a three-year package: the MA Principles of Conservation (one year) and the MSc Conservation for Archaeology and Museums (two years). In the first year MSc interventive object work module, students study approaches to needs diagnosis, problem solving, decision-making and application of conservation processes in the IoA labs before completing 10-month work placements in the second year where they expand these skills in varied professional contexts. Students are allocated a range of objects for treatment in MSc1, which often form ongoing partnerships with loaning institutions that allow projects to develop over time.

The conservation team was contacted by Dr Stuart Needham concerning Anglo-Saxon iron grave finds encountered in a trench excavated by the People of the Heath team to assess a potential Neolithic oval barrow on Main

Figure 2 Examples from the assemblage as received which were later selected for sampling. From top left: Shield umbo, belt buckle, shield studs, spearhead. Adapted from images provided by Sydney Betancourt, Carolyn Keene, Liu Liu, and Fanxuan Fu

Down (Needham and Anelay 2021a and 2021b) in July 2023 (Figures 1 and 2). Requiring stabilisation and preparation for prospective display the objects were ideal for student conservation training. Following consultation with archaeomaterials colleagues, it was clear they also presented an exciting research opportunity to consider the range of iron sources present within a single assemblage and to add to the corpus of blade samples, furthering contemporary understanding of blacksmith decision-making and traditions (Charlton 2015).

Anglo-Saxon and other examples of early medieval ironworking are known for the technical skill needed to produce high quality iron and steel items. Existing research reveals diverse approaches to steel blade manufacture including variation between urban and rural sites (Welton 2016, Blakelock 2021). Little, however, is known about the structure of smithing traditions and decision-making, and less about the production and distribution of primary iron. Though corrosion mechanisms vary across alloy compositions, manufacturing processes, and burial environments (Fell and Williams 2004, Saheb et al. 2013, Grousset et al. 2016, Nordgren 2016, Grevey et al. 2020), significant degradation of iron during internment is common. After excavation, delays and limitations of stabilisation processes (passive or interventive), mean corrosion may continue (Liu et al. 2004, Thickett et al. 2008, Thickett 2012, Walker 2020), and there may not be the resources or systems in place to access extant metallurgical information before it is too late. Ethical concerns and the desire to protect objects from material losses incurred through sampling are also paramount. Permissions are guided through established protocols and procedures, with requests assessed according to key factors including the nature of analytical project and academic justification; methods of analysis/examination and sampling; and explanation of how outputs will be utilised. There are valid concerns that this process is not always sufficiently robust and can cause problematic outcomes for objects of questionable acceptability (Henderson and Manti 2008). These issues may be emphasised when sampling occurs in isolation—neither guided by nor resolved through conservation.

Academic and teaching HE staff are often expected to produce significant research outputs, commonly requisite for career progression. In the social sciences, interdisciplinary collaborative work is an established form of knowledge production with increasing efforts for accommodation within formalised processes of quality evaluation (Fontaine 2015, IDAP 2022). At UCL, all seven Research Domains are cross-disciplinary and designed for 'fostering interaction and collaboration' (UCL 2024). Yet even when organisational cultures and structures support collaborative work, challenges remain (Lowe and Phillipson 2009, Okraku and McCarty 2021). Despite the increase of academic staff employed in HE in the UK (HESA 2024), capacity can present a barrier to fostering the new relationships that collaborative work entails, and to creating and managing projects which occur outside existing workloads (Whitchurch et al. 2021, Paitaridou et al. 2024).

Using the management of ferrous grave finds at IoA as a case study, this paper illustrates facilitation of collaborative research within existing staff obligations; achievement of ambitious educational experience for students without increasing coursework loads; and that these processes can support credible outcomes for archaeological iron objects.

Methods

Figure 3 shows the project sequence and Table 1 the conservation processes. Objects were individually allocated, thoroughly researched and assessed by students to establish significance and condition, and a project leader was identified. Individual treatment proposals were generated, with an additional section of potential loss compensation should that object be approved for sampling. The student leader liaised with Dr Needham to approve treatment proposals. After initial cleaning, a collaborative meeting identified objects suitable for sampling with number, size, and location of losses negotiated (Table 1).

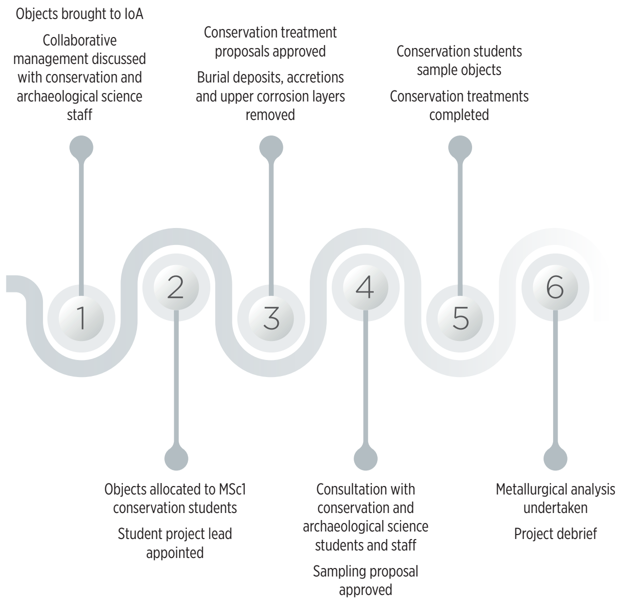

Figure 3 Project Timeline. Key stages from Sep 2023 to June 2024

Table 1 Details of conservation processes performed on the assemblage. N.B. not all processes were applied to all objects

	Conservation Processes
Research	Literary, stakeholder dialogue, benchtop microscopy, X-ray
Cleaning	Mechanical methods + softening with industrial methylated spirits (IMS). Brushes (stencil, hog hair bristle) + netted museum vacuum, glass bristle brush, bamboo stick, Garryflex, Akapad sponge, dental tools, pin vice with fine gauge sewing needle, scalpel, Dremel 4000 with a diamond wheel point, Swam-Blaster Micro Abrasive Blaster (white fused alumina F240 44.5 micron), 0–1 powder power level, 40–50 PSI (pound per square inch) pressure, vulnerable areas protected with cling film and FrogTape
Consolidation	Iron: 3% w/v Paraloid B-44 in xylene; wood/organics: Klucel G 1%–5% w/v in ethanol
Sampling	Wedge or cross-sections cut with Buehler IsoMet 1000 Precision Sectioning Machine
Reconstruction	40%–60% w/v Paraloid B-48N in acetone, 60% 1:3 Paraloid B-72 and Paraloid B-44 w/v in acetone mixture
Loss compensation	Microballoons + 20%–30% w/v Paraloid B-72 or Paraloid B-48N in acetone or 50:50 IMS and acetone; Japanese tissue + watercolours + Araldite 2020 or Hxtal NYL-1 epoxy resin, pigmented 3% w/v Paraloid B-72 in acetone (black iron oxide, burnt sienna, burnt umber, raw umber, raw sienna, titanium oxide, yellow iron oxide), acrylic dispersion paints (ivory black, Black Liquitex, cadmium free red)
Corrosion inhibition	2.5% tannic acid in deionised water (pH 2.2–2.4) (+ ferric tannate reduction in air abrasive)
Coating	3% Paraloid B-44 w/v in xylene, final coat + fumed silica
Packaging	Stewart/archival card boxes with Plastazote, Tyvek and indicating silica gel, relative humidity (RH) indicator strip

Figure 4 The spear after preliminary cleaning and sampling showing revelation of corrosion stratigraphy and metallic structure. Adapted from image provided by Fanxuan Fu

A sampling proposal was approved by Dr Needham before conservation students sampled their objects with a maximum specimen size of 2 cm^2 for the spear (Figure 4). Conservation treatments were then completed (Table 1). Packaging incorporated specimen block retention with each object for future analyses.

Meanwhile, samples were analysed by an MSc Archaeological Science: Technology and Materials student for their dissertation. Specimens were mounted in epo-set resin and polished to 1µm or smaller finish. Uncorroded metal in the specimens was investigated using a 4% Nital etchant to reveal microstructure (especially to estimate carbon content, identify evidence of quenching, and evaluate blade manufacturing methods). Mounted specimens were carbon coated and examined by a scanning electron microscope (Zeiss Evo 25) equipped with dual Oxford Instruments Ultimax 65 energy dispersive spectrometers. Analysis was conducted at 20KV with beam current optimized with a cobalt standard and deadtime measured ~40%. All spectra were generated from 1.5 million X-ray counts using process time 4 and quantified using the factory calibration. Data quality was estimated using the BCR-2 basalt reference material with accuracy and precision for major and minor elements measuring <5% relative. Corroded specimens were searched for remnant microstructure to address metallographic questions noted above. Large area mapping coupled with feature analysis provided a high-resolution image of the entire section and detailed chemical analysis of slag inclusions. The limit of quantification (LOQ) for most elements is approximately 0.1 wt%, with accuracies and precisions typically below 5% relative except when elements are near the LOQ. Statistical data analysis compared slag inclusions between objects to estimate the number of distinct iron sources represented.

Results

The embedment of sampling within a coherent conservation treatment including loss compensation plan was valued by the stakeholder and strengthened the sampling proposal. The conservation presence during sampling decision-making resulted in only some objects being sampled, and only a single specimen cut from those that were. X-ray supported condition assessment reduced risk of fragmentation during cutting, minimised damage by locating existing cracks utilised in lieu of fresh cuts, and increased assurance of valuable data obtainment by identifying metallic cores (Figure 5). Pseudomorphic organic replacements and extant wood were identified and protected through consolidation, covering, and/or adapting the location of sampling.

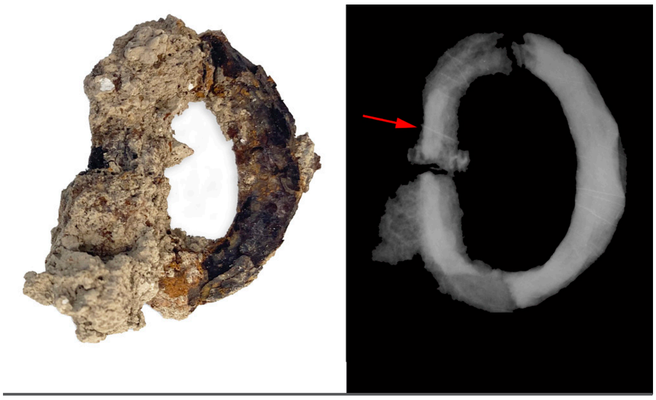

Figure 5 X-ray (right) confirmed justification for this sampling attempt and directed location by identifying the metallic core. Adapted from image provided by Carolyn Keene

The conservation students undertaking the sampling were practitioners with in-depth knowledge of weak points and mindful of best-practice handling. As conservation processes were designed around the analysis, any inadvertent losses were filled and risk of retreatment avoided through delay of reconstructions until after sampling (Figure 6). The bespoke packaging assured not only specimen retention and object-sample association, but also preservation as the desiccated dark storage environment reduced degradation mechanisms of both the metallic sample and the resin.

Analytical

Assessment of the shield boss, grip, buckle, and brooch metallography conformed to expected compositions of ferrite with low levels of sporadic pearlite—a microstructure

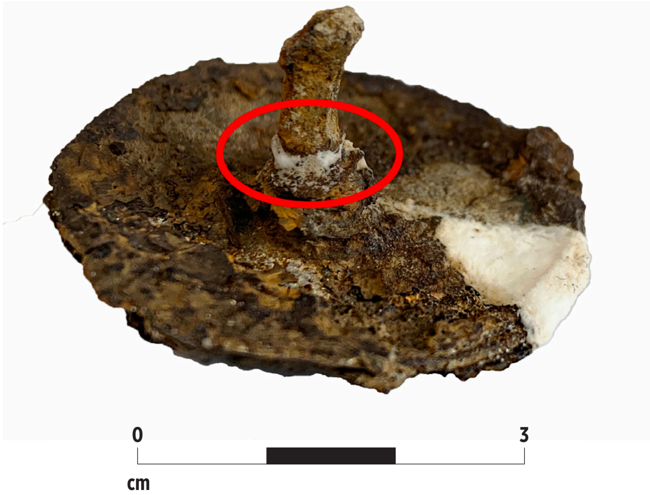

Figure 6 Reconstruction of this stud appendage was delayed until after sampling. Loss compensation for the sampling area is also shown. Adapted from image provided by Liu Liu

desirable for objects where toughness and malleability are key performance requirements. Slag inclusion distribution also indicated material that had been drawn and bent but not extensively refined (Figure 7).

The spear metallography also matched expectations for desirable performance characteristics of a bladed weapon. Approximately one-third of cross-section was composed of eutectoid steel (~0.8 wt% C, Figure 7) and grades into hypoeutectoid steel (~0.3–0.6 wt% C) along one edge and to the blade point. There was no evidence of welding or piling within the section. This suggests the production of a steel blade that lost carbon during smithing, perhaps through successive repairs or resharpening events.

The knife, bar, and stud however, revealed unexpected results. The knife had a large grained ferritic structure with no evidence of steel anywhere within the cross-section. Most knives of early medieval origin are expected to have a steel edge (McDonnell 1989). Similarly, the bar cross-section revealed a piled structure with a steel component quenched to martensite. The bar had no obvious function or parallels, so why it was made of steel and subsequently quenched remains a mystery. The stud was found to sit atop a bronze sheet. Copper corrosion was noted during

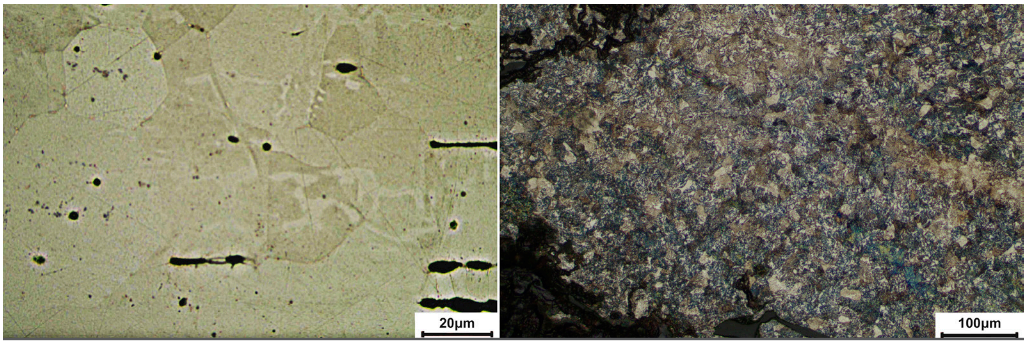

Figure 7 Left: Shield boss section etched with 4% Nital showing ferrite grains and phosphorus ghosting. The distribution of slag inclusions suggest working to flatten the edge of the boss. Right: Eutectoid composition of the spear after etching with 4% Nital

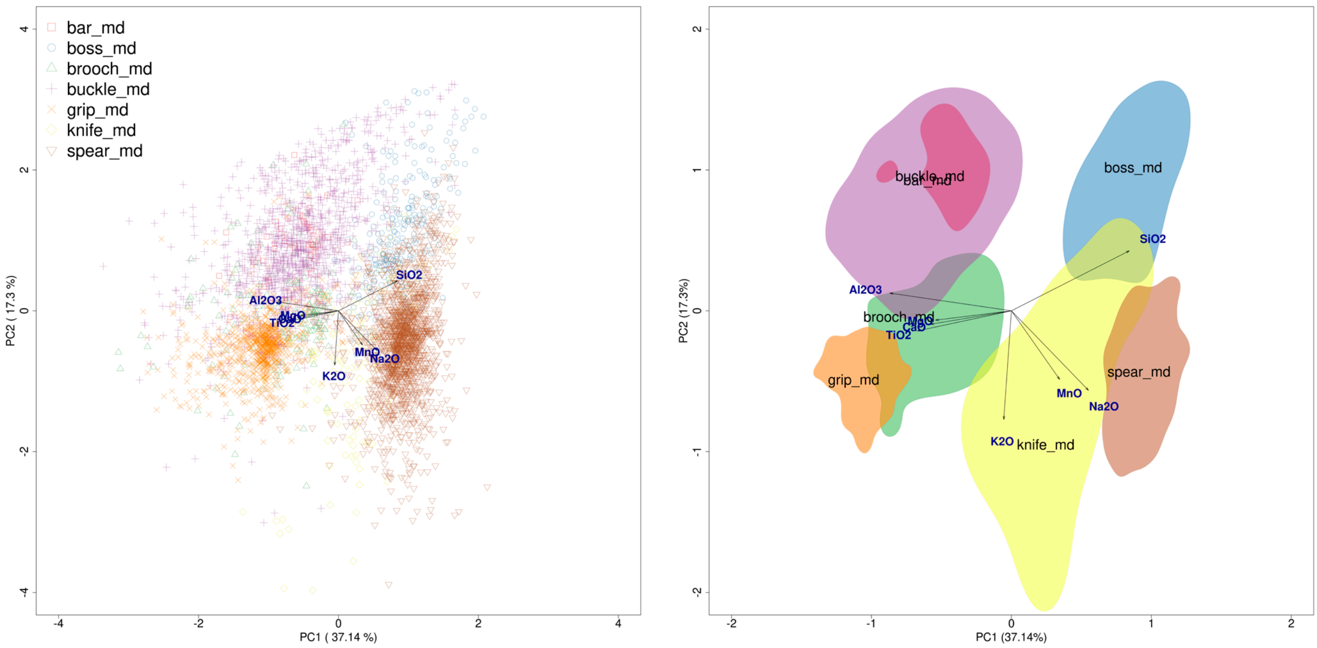

Figure 8 Principal component biplots of slag inclusion chemistry. The plot on the left shows the plot of all inclusions while the plot on the right highlights the inclusion concentration of each object using 50% density contours.

Object		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	MnO	FeO	BaO
Bar (n=52)	x̄	0.1	0.4	5.3	16.9	1.1	0.2	0.0	0.7	1.1	0.2	0.2	73.9	0.0
	s	0.1	0.2	2.8	9.7	0.5	0.1	0.1	0.5	0.6	0.1	0.1	13.8	0.0
Boss (n=285)	x̄	0.3	0.2	1.6	13.8	5.2	0.0	0.0	0.4	0.8	0.1	0.0	77.6	0.0
	s	0.1	0.1	0.6	4.3	2.5	0.1	0.2	0.2	0.3	0.1	0.0	5.7	0.0
Brooch (n=188)	x̄	0.1	0.6	1.3	7.9	1.0	0.1	0.0	0.5	1.0	0.0	0.1	87.3	0.0
	s	0.1	0.2	0.6	4.9	0.8	0.2	0.1	0.4	0.6	0.0	0.0	7.3	0.0
Buckle (n=1148)	x̄	0.0	0.2	2.0	8.3	1.2	0.1	0.1	0.3	1.0	0.1	0.2	86.5	0.0
	s	0.1	0.1	1.0	4.3	1.5	0.3	0.6	0.2	0.6	0.1	0.1	6.4	0.0
Grip (n=977)	x̄	0.2	0.8	4.4	14.4	2.5	0.3	0.0	0.9	2.0	0.2	1.6	72.5	0.1
	s	0.1	0.3	1.8	4.4	1.5	0.4	0.3	0.4	1.1	0.1	0.6	7.1	0.1
Knife (n=127)	x̄	0.3	0.2	3.2	15.4	6.7	0.5	0.0	1.1	1.1	0.1	1.8	69.6	0.0
	s	0.1	0.1	1.6	5.1	3.6	0.5	0.0	0.6	0.5	0.1	0.8	7.0	0.0
Spear (n=1833)	x̄	0.4	0.5	1.8	22.8	0.2	0.1	0.0	1.1	1.7	0.1	2.9	68.3	0.0
	s	0.2	0.3	0.9	11.3	0.3	0.2	0.4	0.7	0.9	0.1	1.9	15.2	0.0

Table 2 Mean and standard deviations for slag inclusions analysed in each iron object. All values normalised and presented in wt%

the initial object documentation, but nothing structural was seen in X-radiography. The identification of the bronze sheet was only possible from sectioning and has implications for modelling the complete object. One possibility is that the studs and bronze strip were positioned around the circumference of the shield rim.

Slag inclusion analysis revealed at least two geographic sources for the iron in the assemblage. Table 2 provides summary data for the slag inclusion compositions aggregated by object. A principal component analysis (PCA) was conducted for the entire set of slag inclusion chemistry obtained for each object. Figure 8 presents a plot of scores projected onto the first two PC axes showing a clear separation of the bar, brooch, grip, and buckle on the left, from the boss, knife and spear on the right. The latter contain higher proportions of Mn and Na relative to Mg, Al, Ca, and Ti. Distinct distributions along PC2 suggest that items represent iron produced in different batches if not at different sites.

Discussion

The integration of sampling into the conservation process ensured a level of guidance and targeted treatment response that protected material and aesthetic values (Figure 9). The preservation of samples, data, and results publication may protect these objects from future sampling when such support may be uncertain. On the other hand, were it not for this collaboration, these objects may have never been sampled and subjected to associated changes without the initial decision of conservation staff to approach archaeomaterials colleagues. Yet change function is not equivalent to damage function (Strlič et al. 2013), and the value gains from sampling are considerable.

The long-term survival of the metallic cores is not guaranteed as corrosion may start again should the objects be exposed to humidity (Liu et al. 2004, Thickett et al. 2008, Thickett 2012, Walker 2020)—the collaboration facilitated access to this potentially at-risk information. Archaeometallurgical results offer meaningful insights into individual object production and the choices and connections maintained by the interred individual and/or the community of which they were a part. The latter is perhaps the most prominent, with slag inclusion analysis

Figure 9 Selected objects after treatment. From top left: Shield umbo, belt buckle, shield studs (one with fill pending), spearhead. Adapted from images provided by Sydney Betancourt, Carolyn Keene, Liu Liu, and Fanxuan Fu

revealing the presence of at least two production systems. Notably, the bladed objects seem to derive from one, while the more decorative elements derive from another. Is this evidence for specialisation among smiths in Early Medieval Britain, individual consumer choices, or the decisions of a village blacksmith? The inclusion chemistry of the shield boss and grip also maintain notably different distributions from one another. The fact that the shield boss is made of phosphoric iron while the grip is ferritic lends support to the possibility that they belong to different primary production systems. Are the boss and grip different because of repair during use or did the shield maker selectively choose iron for different functions? These questions cannot be answered using objects from a single burial, but support ongoing enquiry into early medieval blacksmithing traditions, ironmaking systems, and their relationship to socioeconomic networks. Sampling has captured and preserved the objects' metallographic information—a potentially crucial addition to the limited corpus of analyses of iron from this period.

The project also supported important practical and theoretical learning outcomes. Practising advocacy impacting real-life outcomes showcased the value of conservation knowledge in managing conflicting principles; while metallic core sampling and loss compensation expanded the technical skills typically gained, and improved understanding of corrosion stratigraphy (Figure 4). Of course, treatment decision-making is sometimes informed by discreet sampling at the bench, or students may sample objects for conservation science research (Watkinson 2013). But being instrumental in substantial material removal for an external discipline for students situated as conservation practitioners—responsible primarily for completing an object treatment in a limited time frame—forced particular confrontation with existing notions of ethics and identity. Some entered the consultation hoping their object would not be sampled, prioritising material preservation in the conservation process. However, during discussions with the archaeological scientists, the students identified ways to support sampling decisions to facilitate access to information without abandoning concerns for object integrity. The importance of considering diverse stakeholder needs and the problematisation of minimum intervention is understood in theory (e.g. Villers 2004, Ureche-Trifu 2013). Yet experiences in which traditional disciplinary principles are overtly confronted, as they were in this partnered consultative process, may be needed for this understanding to be truly realised. It is not only practical and communication skills which require active learning, but also assimilation of ethical concepts through nuanced application.

The different and even conflicting techniques, values, and ideas which conservation encompasses has been identified as a primary challenge for training (Sloggett 2022). Sampling may offer unique opportunities in this regard, providing an avenue through which students can authentically engage with the tense multiplicity of the discipline as notions of preservation and destruction are freely debated and examined. One student astutely noted that embedding the sampling process in conservation training was a productive way to exploit the destructive aspect. As well as attesting the value added to their learning journey, this further evidences the ability of the project to facilitate alignment with contemporary theory—rather than absolute preservation, the focus is utility of material, underpinned by a sense that action is justified to make the most of objects in the here and now. For those considering accreditation as a career choice, the project also helped develop proficiency in key areas defined by the Institute of Conservation (ICON) (ICON 2020).

Through this project staff too have begun to explore what best practice collaborative management of archaeological iron might look like at IoA. The integration of research into core teaching and supervision across the two degrees (MSc Conservation for Archaeology and Museums and MSc Archaeological Science: Technology and Materials) provides a sustainable framework which will be used annually to improve practice, including developing a supporting infrastructure for the staff-student collaborative process (Børte et al. 2020). Even in this pilot year there were successes in this regard. The dialogue between students and staff was one of partnership, while students were truly engaged in the research enquiries e.g. one cohort member went on to conduct comparative analysis of strategies for loss compensation of sampled archaeological iron for their MSc2 dissertation. The outcomes of this research will feed back into the project, informing treatment decision-making for subsequent years.

Though beyond the scope of this study, the pertinence of assessing the corrosion/metallic interface and corrosion stratigraphy to inform understanding of the connection between stability and the object microstructure is acknowledged (Watkinson 2013) and work is ongoing to explore how this could be factored into subsequent collaborations. Similarly, though established challenges with conflicts of interest in interdisciplinary collaborative research (e.g. Lobovikov-Katz et al. 2018) were not encountered in the partnership documented here, this topic requires further discussion which will be explored in future work, including impacts and potential for learning outcomes (Chandramohan and Fallows 2009).

Conclusion

This paper illustrates how embedding sampling within the conservation process can reveal and protect temporally diverse object values—uncovering historic processes, maximising contemporary use, and creating potential for these objects to be part of future discourse and discovery. The collaboration afforded protection throughout the sampling process, while research generated significant metallurgical data including evidence for multiple iron production systems, offering a deeper understanding of early medieval ironworking, smithing practices, and their socio-economic implications. The project also enriched student understanding of real-world challenges in conservation. Through consultation, students both advocated for material preservation and scrutinised what minimal intervention *necessary* can justifiably mean to the modern profession, developing understanding of the breadth of object interactions that ethical stewardship can encompass. In this way, the collaboration afforded opportunity for practical teaching aligned with contemporary theoretical understanding of professional identity. Ultimately, it may have caused pause for thought concerning just what it is to be a conservator—something that each new wave of professionals is called to redefine.

The collaborative approach promoted interdisciplinary dialogue between conservation and archaeometallurgy, offering a preliminary model for future research and teaching. The project demonstrates that integrating research into postgraduate conservation training enhances both student learning and professional development. As the framework is refined and expanded, it will contribute to the development of best practices in conservation and collaborative archaeological research, fostering the next generation of conservation professionals capable of navigating the complexities of heritage preservation.

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Materials list

- Acetone, Sigma-Aldrich
- Akapad sponge (neutral pH vulcanised latex material), Preservation Equipment Ltd.
- Araldite 2020, RS Components Ltd.
- Archival card, Preservation Equipment Ltd.
- Cling film (polyethylene)
- Epo-set resin (bisphenol a epoxy resin 2-ethylhexyl glycidyl ether), Metprep
- Ethanol, Sigma-Aldrich
- Frogtape® (acrylic adhesive-backed pressure-sensitive tape), RS online
- Fumed silica (orange indicating), Preservation Equipment Ltd.
- Garryflex
- Hxtal NYL-1, Conservation Resources (UK) Ltd
- IMS, VWR
- Japanese tissue (cellulose fibres), Preservation Equipment Ltd.

— Klucel G (hydroxy propyl cellulose), Conservation Resources UK Ltd.
— Paraloid B-44 (methyl methacrylate/ ethyl acrylate copolymer)
— Paraloid B-48N (methyl methacrylate and butyl acrylate copolymer), Stuart R. Steveson
— Plastazote (closed cell crosslinked polyethylene foam), Preservation Equipment Ltd.
— Microballoons (glass microspheres), Easy Composites Ltd.
— Nital etchant
— Indicating silica gel (amorphous silicon dioxide), Preservation Equipment Ltd.
— RH indicator strip (blotting paper impregnated with cobalt chloride), Preservation Equipment Ltd.
— Stewart box (polyethylene), Watkins and Doncaster
— Tannic acid, BDH
— Tyvek (polyethylene continuous filaments), Preservation Equipment Ltd.
— White fumed alumina, EPAK Electronics
— Xylene, Fisher Scientific