METALS AND METALWORKING
A research framework for archaeometallurgy

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1 The blast furnaces at Stanton, Derbyshire, being demolished in 1976.

2 Maps showing the mineral deposits of the British Isles. a) Iron (excluding bog ores): grey tone = the Carboniferous coalfields, with claystone and blackband sedimentary ironstones; red = the Weald, Cretaceous claystone ironstones; yellow spots = oxide iron ores associated with the SW mineral province, including gossan and oxides after siderite; red spot oxide iron ores associated with epigenetic mineralization on Mesozoic basin margins; stars = sedimentary ooidal ironstones of Mesozoic age; squares = other sedimentary ironstones of Mesozoic–Tertiary age. b) Lead, zinc and silver: areas indicate main lead-zinc orefields. Those in black also produced significant quantities of silver. c) Copper. d) Tin: working of alluvial tin deposits in SW England took place over a wider area than the distribution of the primary mineralization. e) Gold. f) Coal.

3 A rake (an opencast mine following a vein containing lead ore) from which the minerals have been removed, at Dirtlow, Castleton, Derbyshire.

4 Farmhouse with attached smithy (second building from the right) at Dungworth, near Sheffield, Yorkshire.

5 Remains of 18th-century blast furnaces at the World Heritage Site at Blaenavon, Gwent, South Wales.

6 A view of the Sheaf valley, Sheffield in the mid 19th century showing many small workshops with their forge chimneys.

7 A tenement workshop in the Birmingham Jewellery Quarter.

8 Drawing of Dream mine, Wirksworth, Derbyshire showing two shafts, the one to the left with a windlass. After Buckland 1823.

9 The sub-surface of a lead-mining landscape at Gunnerside Gill, North Yorkshire. This engine house is on Sir Francis Level 240ft below the valley (Fig 35). Two Davey hydraulic engines were installed in 1880: one (centre left) worked the pumps (two large vertical pipes) and another (behind camera viewpoint) the winding gear. One cage is suspended just below floor level.

10 A small-scale 17th- and 18th-century mining landscape at Bonsal Moor, Derbyshire. The upcast (spoil) around the mine shafts dominates the view.

11 The Crowns engine house, Botallack mine, Cornwall is set at the foot of a cliff on an outcrop of a rich tin and copper lode. This mine was worked from at least the 16th century.

12 Chingley blast furnace, Kent, under excavation, showing the bellows area in the foreground and the furnace hearth beyond.

13 Plan of Chingley blast furnace with bellows area at the top and the wheel pit to the right, discharging into the culverted tail race.

14 Drawings of common crucible forms dating from Iron Age to the post-medieval periods. 1: Iron Age. 2–3: Roman, 4–6: early medieval, 7: later medieval, 8: post-medieval. The grey tone represents added clay, serving either as lids (2 and 6) or extra outer layers (3 and 7).

15 Base of excavated Iron Age bloomery furnace at Crawcwellt West, Gwynedd. The red-burnt clay shows the walls were originally ~200mm thick. Scale bar 0.5m.

16 Tap slag, showing its characteristic flow-form surface structure.

17 Blast-furnace slags are usually glassy in appearance and can range in colour from blue/green through to grey/brown. They were often re-used as hardcore and so can be found in small pieces far away from furnace sites.

18 Plan of excavated features at the Roman site at Shepton Mallet, Somerset, where both iron smelting (yellow shading) and smithing (red spots) were taking place. Note the partial spatial separation between the two activities.

19 Hoard of complete and fragmentary precious-metal Iron Age torcs from Snettisham, Norfolk.

20 Frequency plot of alloys used to make different types of late-Roman crossbow brooches. The early examples (191A) are mainly leaded bronzes while the latest (192) have only a minority of leaded bronzes but many brasses and other lead-free alloys, many of which were mercury gilded.

21 Section through knife blade showing seven layers in the shear steel. Image width ~1mm.

22 Section through knife blade. The varied texture to the left shows the incorporation of several pieces of scrap metal. Image width ~1.5mm.

23 Sketch, probably from the mid-17th century, showing Little Rowsley lead-smelting mill on the Smelting House Brook that flowed west into the River Derwent, Derbyshire (bottom), and the woodland (top) that provided fuel for the smelter (Chatsworth H304/43).

24 Water-powered stamp mill crushing ore in Germany in the 16th century from Agricola’s De Re Metallica. After Hoover and Hoover 1950.

25 20th-century ore stamps from Zennor, Cornwall. Compare with Figure 24 and note how little has changed in 400 years.


27 Two linear slag tips at Crownddle Beck, Cumbria; the left-hand one is being eroded by the beck. This bloomery site was identified by Davies-Shiel and probably dates to the 17th century.

28 Metal-detectorists collected this later 3rd century copper-alloy waste from the manufacture of Roman-British coinage, and reported it through the Portable Antiquities Scheme.

29 Cabinet containing polished metallurgical samples made between 1863 and 1865 by Henry Clifton Sorby, the pioneer Sheffield metallographer. Now in the collections of the South Yorkshire Industrial History Society.

30 Red-hot wrought iron being rolled at the re-erected rolling mill at Blists Hill, Ironbridge. Traditional metalworking skills are preserved as ‘living history’.

31 Magnetometer survey at Geli Goch, Gwynedd using a 4m-square frame at a sensor height of 320mm. To the right of the furnace is the working pit, with the last run of tap slag still in situ.
32 Left: High-resolution magnetometer survey results for a 4m square containing a furnace at Crawcwell. Right: Calculated map of multiple dipoles (stars mark the centre of each dipole) which closely models the survey, allowing the direction of the calculated dipoles to be used to estimate the date of last firing. Positive contours solid at 100nT, negative contours dashed at 10nT. After Crew 2002.

33 Schematic plan of an Iron Age round house at Billown, 26 Isle of Man, overlaid with areas of enhanced magnetic susceptibility (a), and geochemical survey results for copper (b), showing that metalworking activities were restricted to the NW part of the structure.

34 Iron-smelting furnace 137 at Stanley Grange, Derbyshire after the removal of superficial material and the fill of the slag-tapping pits. Scale bars 1m and 0.3m. After Challis 2002.

35 Gunnerside Gill, North Yorkshire: the surface of a lead dressing floor occupied by a palimpsest of hushes, shafts, levels, ore-dressing floors, and their associated waste tips, water supplies and transport networks.

36 Plot of hammerscale distribution in workshop R at Westhawk Farm, Kent, in relation to other features. Soil samples were collected on a grid and the hammerscale extracted; warmer tones show increased hammerscale concentrations. After Paynter 2007a.

37 Buildings at Jessops Brightside steelworks, Sheffield, set into large-scale metalworking waste (dark soil consisting of ash, crucible waste, cinders and slag). Scale bar 2m.

38 Elemental maps of tin (upper) and copper (lower) in a cross-section of a prehistoric bronze sheet. The warmer colours (yellow and red) indicate high levels of each element. It is easy to see that there are areas of tin enrichment towards the surfaces of the section that also correspond to areas of lower copper concentration. A surface analysis gave a result of 19% tin whereas a bulk analysis of an interior area revealed the correct tin content as 8%.

39 X-radiograph of a post-medieval crucible in section, 32 with the metal-rich slag on the inside surface showing as bright zones, and metal droplets as white spots, especially in the thickness of the base.

40 X-radiograph of a Roman dagger sheath plate made of iron and decorated with tin (which shows as brighter lines). The round rivet heads are also tinned. Both metals are totally mineralized but X-radiography provides a simple and non-destructive method of investigation. Length 105mm.

41 X-radiograph of an early medieval knife with pattern-welding visible in the back of the blade. Length 178mm.

42 Three medieval arrowheads: left: bodkin point, Type 7; centre: compact winged and socketed, Type 16; right: Type 10. Typology after London Museum Beauport Park, East Sussex.

43 Micrograph of pure ferritic iron. Image width 1mm.

44 Micrograph of unhardened steel containing 0.7% carbon. Image width 1mm.

45 Inductively-coupled plasma atomic emission spectrometer.
Agricola's illustration of 16th-century copper smelting in Germany. After Hoover and Hoover 1950.

Coniston copper mines: the site descends from the Mines Royal opencast at Simon's Nick (skyline right of centre), through later adits and spoil tips to the 18th- and 19th-century ore-dressing floors in the foreground.

16th-century crucibles used for melting copper, from the Tower of London. Note the increased size compared with the earlier crucibles in Figure 14.

Two small lead smelting bales beside Fell End mine, Swaledale, Yorkshire. After Murphy and Baldwin 2001.

Reconstruction of a Derbyshire 16th-century lead-smelting bole. In the stone enclosure (G) were placed wood (shankers B and blocks D), with blackwork (part-smelted ore C), beneath ore and small wood (A). The smelted lead flowed by channels (E) to a mould (F). After Kiernan 1989.

Backscattered SEM image of lead-smelting slag from the earlier (16th century) deposits at Combe Martin, Devon. The dendrites are olivine and the bright droplets are sulphides of lead, copper, and zinc in a glassy matrix.

Backscattered SEM image of lead smelting slag from the 19th-century deposits at Combe Martin, Devon. The bright phase is spinel (hercynite), the dark needle-like crystals are corundum (Al₂O₃) and the mid-grey phase is anorthite (CaAl₂Si₂O₈).

Fragment of the lining of a 13th-century cupellation hearth impregnated with lead oxide (also known as a litharge cake) from Thetford, Norfolk.

A bone ash cupel from Cripplegate, London with the silver that was assayed in it still in position. Scale in mm.

Reconstruction of the blacksmith's forge on Site 31 at Hamwic (Saxon Southampton), Hampshire. After Mack et al 2000.

Rockley, Yorkshire. Plan showing the bloomery furnace (A1), bellows house (A2) and water-wheel (A3). The string hearth (B1) for reheating blooms also had bellows (B2) worked by a water-wheel (B3). The purpose of the third wheel-pit (C) is uncertain, being too far from the anvil to be likely to have powered a hammer. The overflow (F) took water from the pond (H) over the dam (G) to the tail-race (E). After Crossley 1990.

Part of the water-wheel in position in the wheel pit at Rockley, Yorkshire.

16th-century gun founding: an illustration from Biringuccio's *Protechnia* showing how castings were bored.

Early-18th-century gun-boring mill at Pippingford, East Sussex. Two of four trolley wheels are shown, with rotted timber rails. The hemispherical object is a chuck to hold a boring-bar, as seen in Fig 80.

Drawing of a French conversion forge showing a finery hearth (left) and water-powered forge hammer and chafery hearth (right). After Diderot (Gillispie 1959). This can be compared with Fig 83.

Chingley finery forge under excavation, showing the dam at the top, water courses on both sides, the finery (lower left) and chafery (lower right). The hammer area is in between, with the anvil base in the centre (under the 3ft scale). In the first phase, it appeared to be driven from a wheel to the left, with fulcrum posts surviving, and in the second from a wheel to the right (in the same race as the chafery) with the base-frame showing. Figure 82 shows the same arrangement of two wheel-races.

The bellows arch of Abraham Darby's furnace at Coalbrookdale, Shropshire.

Reconstruction of the charcoal-fuelled blast furnace at Duddon, Cumbria, built in 1736.

The early-18th-century cementation furnace at Derwentcote, Co Durham with attached working buildings.

The interior of the cone of the cementation furnace at Derwentcote showing internal flues from the firing chamber beneath.

Casting a bell weighing about 5 tons for the San Francisco fire station in 1860 at the Naylor, Vickers and Company works at Millsands in Sheffield. After Barraclough 1976.

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SUMMARY

Metals and metalworking: A research framework for archaeometallurgy

The volume provides a research framework for archaeometallurgy in Britain, including a resource assessment, a research agenda and an outline research strategy. The first section identifies the nature of the resource. The evidence ranges in scale from landscapes and townscape to sites and structures; it includes artefacts and residues from production as well as documentary sources. This section is particularly directed at curators and planners as it also deals with the management and protection of the resource, for which they have responsibility.

The second section, on methods in historical metallurgy, demonstrates that the subject goes beyond the work of the laboratory-based specialist, whose methods of examination and analysis are described. Also essential are the methods of field archaeology, landscape survey, geo-prospection and experimental archaeology, and the skills of metal-smiths and palaeo-environmentalists. The current pattern of development-led archaeology, in particular work on brown-field sites (which may be regarded as contaminated land), threatens the loss of sub-surface archaeological evidence for metal industries; appropriate methodological approaches to investigation, recording and sampling are discussed. The strengths and weaknesses of methods are examined, and areas for further development are outlined.

The third section summarises what is known about metalworking in the past, focusing on selected topics which illustrate either the considerable progress that has recently been made, or the need for further research. The examples include both ferrous and non-ferrous metalworking of all periods. The earliest metallurgy in the British Isles belongs to the Bronze Age and Iron Age. For the Bronze Age the concentration is on metal mining because so much new information has recently come to light. For the Iron Age, the focus is on the introduction of iron as an everyday metal, though copper alloys continued in use. The Roman period saw increasing use of metal and hence metalworking; the two examples given are the iron industry of the Weald, and the widespread adoption of brass as a common copper alloy. In the medieval period the lack of evidence for copper production is highlighted and the use of various copper alloys is discussed. Medieval methods of steel production are considered, as are later steel-making processes. After the medieval period there is a major change of scale, with the industrialisation of many metal industries. Relevant categories of documentary evidence are outlined, emphasising those which complement the archaeological record. An overview is presented of current knowledge of two metal industries important in post-medieval and modern Britain: lead production and the iron and steel industry. Archaeometallurgical studies can show how these industries, and the questions surrounding their development, are linked to changes in British society and the lives of its people.

Finally, the research agenda identifies major gaps in knowledge and suggests how they might best be filled. These comprise multi-period topics relating to methods in fieldwork and scientific examination, and other topics divided by period, from prehistoric to the present day. This section also outlines a strategy for promoting best practice in the discipline.

RÉSUMÉ

Métaux et métallurgie: un cadre de recherche pour l’archéométallurgie.

Ce volume propose un cadre de recherche pour l’archéométallurgie en Grande-Bretagne, présentant dans ce contexte une évaluation des ressources, un agenda de recherche, ainsi qu’un résumé de la stratégie de recherche établie. La première partie répertorie la nature des ressources : celles-ci sont présentées à différentes échelles et varient de paysages et scènes urbaines à des sites et structures archéologiques. Elles incluent également des artefacts et des résidus de production ainsi que des sources documentaires. Cette section est tout particulièrement destinée aux archéologues et historiens locaux ainsi qu’aux principaux entrepreneurs impliqués dans des projets de développement et travaillant pour la commune ou tout autre autorité locale, puisqu’elle est aussi consacrée à la gestion et à la protection de ces ressources, pour lesquelles ils sont responsables.

La deuxième partie concerne les méthodes utilisées en métallurgie historique et montre que le thème abordé va plus loin que le travail d’un spécialiste, uniquement établi dans son laboratoire, dont les techniques d’investigation et d’analyse sont décrites. Les méthodes d’archéologie de terrain, de reconnaissance du paysage, de géo-prospection et d’archéologie expérimentale, ainsi que les compétences des artisans du métal et des paléo-environnementalistes sont tout aussi essentielles. La tendance actuelle de l’archéologie menée dans le cadre de projets de développement, en particulier les travaux sur des sites urbains à l’abandon (qui pourraient être considérés comme des terrains contaminés), menace d’entraîner la perte d’indices archéologiques liés à des industries métallurgiques, qui sont présents dans les sous-couches de surface ; différentes approches méthodologiques adaptées à l’investigation, l’archivage et l’échantillonnage dans ce contexte sont discutées. Les atouts et faiblesses de chaque méthode sont examinés et les domaines permettant de développer plus avant ces problématiques sont exposés.

La troisième partie résume les connaissances que nous avons du travail du métal comme il était réalisé dans le passé, mettant l’accent sur des thèmes bien définis, qui illustrent, soit le progrès considérable qui a été réalisé récemment, soit le besoin pour des recherches plus approfondies. Les exemples choisis comprennent aussi bien le travail du fer que les non ferreux de toutes les époques. La métallurgie la plus ancienne des îles britanniques date de l’âge du bronze et de l’âge du fer. Pour l’âge du bronze, le phase a été mise sur les travaux miniers en raison du nombre important de nouvelles données qui ont récemment été mises au jour. Concernant l’âge du fer, l’attention s’est plus particulièrement tournée vers l’introduction et l’usage du fer dans la vie de tous les jours, alors que les alliages de cuivre étaient encore utilisés. L’époque romaine voit une augmentation de l’utilisation des métaux et par conséquent du travail des métaux ; les deux exemples choisis pour cet ouvrage sont l’industrie du fer du Weald, et l’adoption très répandue du
laiton comme alliage courant de cuivre. Durant le Moyen Age, le manque de preuves liées à la production du cuivre est mis en avant, et l'usage des différents alliages de cuivre est discuté. Les méthodes médiévales de production d'acier sont également expliquées, tout comme les procédés plus récents utilisés en sidérurgie. A la suite du Moyen Age, un changement d'embâle majeur s'est produit, en raison de l'industrialisation de nombreuses usines travaillant le métal. Les catégories pertinentes de sources écrites sont présentées, mettant particulièrement l'emphasis sur celles qui complètent les preuves archéologiques. Une vue d'ensemble de la connaissance actuelle de deux industries du métal qui ont été importantes dans la Grande-Bretagne médiévale et moderne sont présentées : la production du plomb et la sidérurgie. Les études archéométallurgiques peuvent montrer comment ces industries et les questions, qui entourent leur développement, peuvent être liées à des changements au sein de la société britannique et au mode de vie de sa population.

En conclusion, cet agenda de recherche identifie les lacunes majeures de nos connaissances et suggère comment elles pourraient être comblées au mieux. Celles-ci impliquent des thèmes qui comprennent plusieurs époques et qui sont liés à des méthodes de travail de terrain et de recherche scientifique, ainsi que d'autres sujets divisés par époques, allant de la préhistoire à aujourd'hui. Cette section présente aussi succinctement une stratégie permettant la promotion de la meilleure voie à suivre dans cette discipline qui est l'archéométallurgie.

Translated by Aude Mongiatti.

**ZUSAMMENFASSUNG**

**Metall und Metallhandwerk: Ein Rahmenplan zur Forschung in Archäometallurgie**

Der vorliegende Band präsentiert einen Rahmenplan für archäometallurgische Forschung in Großbritannien, bestehend aus einer Bewertung der vorhandenen Datenbasis, einem Forschungsplan, und einer übergreifenden Forschungsstrategie. Der erste Abschnitt beschreibt die Natur der Datenbasis, von spezifischen Landschaften und Stadtanlagen zu individuellen Gebäuden und Strukturen; er umfasst Funde und Produktionsabfälle ebenso wie Textquellen. Dieser Abschnitt richtet sich speziell an Denkmalbeauftragte und Planungsbehörden, da er auch die Verwaltung und Untersuchung der Datenbasis betrifft, für die diese die Verantwortung tragen.


Translated by Thilo Rehren.
Knowledge of the sources, production and uses of metals is a central theme in the development of almost all societies and cultures, so understanding the history of metals and metalworking is a route to the heart of understanding our past. This history, which we call archaeometallurgy, is therefore a significant body of knowledge, and this volume is intended to aid the understanding of the subject and to demonstrate its place in the national research agenda for archaeology.

The need for archaeological research frameworks is widely accepted but the archaeometallurgical content of the emerging national and regional research frameworks (see section 4.5) has been uneven. There is thus a need for a research framework for metal production and use throughout Britain, spanning all regions and all periods, from the origins of metallurgy to the decline of the metal industries in the 20th century (Fig 1). The Historical Metallurgy Society has therefore produced this volume which provides a research assessment and an agenda for future work.

The current pattern of development-led archaeology places particular stress on the need to know more about our metallurgical past. In particular, the development of brown-field sites threatens the loss of important sub-surface evidence for the archaeology of industry. What is generally regarded as contaminated ground often preserves a significant archaeological record, which frequently relates to metal industries. This situation is fuelling an imperative to develop a new methodological approach to the investigation and recording of such sites. If archaeologists, curators, planners and policymakers, often with little previous interest in metallurgy, are aware of the problems involved in securing a satisfactory record of metallurgical processes, then the information provided by structures, residues and artefacts can be effectively captured. This volume has been compiled to assist them.

What qualifies the Historical Metallurgy Society to undertake this work? The Society's membership draws on three areas of expertise and experience, the first two of which are familiar to archaeology. There are academic researchers and other specialist archaeometallurgists, many of them university-based or working within agencies such as English Heritage, but also including independent consultants. The second group are curatorial professionals, including those from museums who are responsible for the artefactual component of the record and those working with field-based agencies such as local authorities, who have responsibility for management and protection of sites. The third area of expertise is perhaps unique to the society, and comprises professional metallurgists.
who have spent their lives working within the metal industries. This group has specialist knowledge of more recent processes, which extends the influence of the society beyond that more usually represented within a specialist archaeological society and provides a continuum between past and present.

The volume has been divided into four parts, each viewing our metallurgical past from a different perspective. The first part deals with the resource. The evidence ranges from landscapes and sites to structures and townscape. It also includes moveable material, artefacts and the debris from production. These resources are recorded, inventoried and audited; they are studied and communicated to the wider community. This section is primarily directed at curators and planners who have responsibility for the management and protection of the resource.

The second part deals with methods in historical metallurgy. It has been included to demonstrate that the subject goes far beyond the work of the laboratory-based specialist, examining and analysing minute samples of metals and metallurgical debris with ever-increasing precision. The repertoire incorporates the skills of field archaeologists, landscape specialists, palaeo-environmentalists, those with geo-prospection skills, metal-smiths and those involved in experimental archaeology. With this range of skills, the tools available for the study of metallurgy are expanding. This section examines the strengths and weaknesses of our methods and flags those areas where further development is needed.

The third part reviews the present state of our knowledge. Given the scope of the subject, this cannot cover everything. The attempt here has been to select not only those subject areas about which we have a good degree of understanding but also those areas which highlight our lack of knowledge and the need for further research.

These three parts can be viewed as a resource assessment, providing an overview of current knowledge and practice. The final part builds on those that have gone before, and provides a research agenda that identifies major gaps in our knowledge and suggests how they might best be filled.