Armourers and their Workshops

The Tools and Techniques of Late Medieval Armour Production

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The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

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Thesis Abstract

This thesis is an interdisciplinary study of medieval armour, with the goal of determining the precise techniques used by medieval armourers in the practice of their craft. The corpus for this research is from the collection of the Royal Armouries, as well as a selection of objects from other museums, with a focus on German and Italian armour between 1400 and 1500.

The thesis makes use of a new methodology by which the armour itself is used as a primary source, in essence a text, using the interpretation of tool marks left on its surfaces. Although metallurgical studies have been undertaken on armour, the marks have not been systematically studied in the past and provide a means by which the techniques of the medieval armourer may be identified.

The thesis also makes use of inventories, artwork, and experimental hammer-work to more accurately understand the workshop environment. Inventories show the variety of tools required in the workshop, as well as what would have been available to an armourer. Artwork showing armourers engaged in their craft is used to interpret some patterns of tool marks as well as identification of certain tools and techniques. The experimental work undertaken was used to recreate particular types of marks and patterns, demonstrating the relation between tools, processes, and the shapes of armour.

The research demonstrates that it is possible, using this method, to reconstruct the ways that armourers worked, something that has been largely conjectural previously. This approach to armour studies has not been attempted before and has allowed for several specific questions to be answered. These include finding differences in working techniques of armourers from different regions, the ability to determine if certain unmarked objects were made by the same armourer, changing methods of construction, and whether a piece is a fake or authentic.

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List of Abbreviations

BNF—Bibliothèque nationale de France, Paris

HHB—*The Household Books of John Howard, Duke of Norfolk, 1462-1471, 1481-1483*, ed. by Anne Crawford (Phoenix Mill: Alan Sutton, 1992)

KAG—Kelvingrove Art Gallery, Glasgow

RA—Royal Armouries, Leeds

TOMAR—Brian R. Price, *Techniques of Medieval Armour Reproduction: The 14th Century* (Boulder: Paladin Press, 2000)

Tower Inv. — Royal Armouries, Leeds, 1913 RAR.13, 'Copies of Inventories and Papers Relating to the Royal Armouries of the Tower of London, etc., etc.'

Chapter I: Introduction, State of Research, and Methodology

1.1. Introduction

Armour represents one of the most recognised and enduring monuments of the Middle Ages, but its fabrication as a craft-product remain obscure. Beginning at the end of the fourteenth century plate armour became much more complete in its coverage and more sophisticated in its design. The art of the armourer reached its apex in the late fifteenth and early sixteenth centuries, with the greatest practitioners working in Germany and Italy. In this period the full suit of armour was perfected, a lasting testament to the armourer which remains fixed in the modern perception of medieval culture.

The working techniques of medieval armourers, and the ways in which they made armour, is the focus of this thesis, making use of a systematic study of the armour to be used as evidence itself. This will allow an analysis of the objects to answer questions regarding the construction of armour, including aspects of working practices, techniques, and types of tools. In addition, related issues of geographic origin, attribution, and the accuracy of artistic convention will be investigated.

There are no medieval written sources describing the making of armour and so an interdisciplinary approach is used throughout with emphasis given to material culture, specifically the surviving armour which serves as the primary corpus, but also using artwork and written sources to supplement the armour. The use of armour as the primary evidence represents a wholly original approach to armour studies and is the most useful for the present topic. This is due in large part to the evidence it provides in the form of tool marks which are in essence a text which may be read.

1.2. State of Research

Writing at the beginning of the twentieth century, Charles ffoulkes began an article on the craft with the statement, ‘Perhaps it may be said as well at the outset both to allay curiosity and to disarm criticism by frankly confessing that very little is definitely known of the methods practiced by the mediæval armourers’.[1] Although much has been learned since then in the field of armour studies, the work of the medieval armourer is a subject that has received comparatively little attention. This is largely due to the focus on the end product, the armour, and not on the methods of production or the producers themselves.

While armour has long been recognised for its military, social, and economic importance this focus has neglected the technical aspects of production as well as workshop organization. Although the work of the armourer has not been completely ignored, what has been done has been cursory or focused on one particular workshop, particularly the Missaglia family of Milan which flourished during the fifteenth century and the Greenwich armouries in England founded in 1511.[2]

Armour has long been a subject for study and a full discussion of all the major works on armour would prove unwieldy, but some should be mentioned both for their contribution to armour studies and for their value, sometimes indirect, to the study of armour making. The critical study of armour began in the 1880s, with *Ancient Helms and Examples of Mail* by C. A. de Cosson and W. Burges. This catalogue recorded an exhibition of medieval and early modern helmets, ‘so as to facilitate a comparative

[1] Charles ffoulkes, ‘The Craft of the Armourer’, *Connoisseur* (1909), pp. 99-104 (p. 99).
[2] See for example J. Gelli and G. Moretti, *Gli Armaroli Milanesi: i Missaglia e la loro Casa* (Milan: [n.pub.], 1903), O. Gamber, ‘Armour Made in the Royal Workshops at Greenwich: Style and Construction’, *Arms and Armours, Scottish Art Review* (1969), pp. 1-13, and Thom Richardson, ‘The Royal Armour Workshops at Greenwich’, in *Henry VIII: Arms and the Man*, ed. by Graeme Rimer, Thom Richardson, and J. D. P. Cooper (Leeds: Trustees of the Royal Armouries, 2009), pp. 148-59.

study of the helmets'.[3] This allowed helmets to be more accurately dated and for restorations and fakes to be identified, as in the case of a helmet with a moustachioed visor placed on a skull of much later date.[4]

In the introduction to his multi-volume *A Record of European Armour and Arms*, still the longest single publication on the subject, Guy Francis Laking claims that his work 'does not pretend to open up a new road to the student of arms and armour'.[5] However, Laking's methodical approach to recording medieval armour and weapons resulted in a very detailed account of the development of personal military hardware and, as with de Cosson's *Ancient Helms*, allowed various pieces to be studied comparatively. Throughout the *Record* the focus is on the development of form and the description of the various types of armour.

One of the most influential English scholars on the subject of medieval armour is Claude Blair, whose works cover nearly the whole spectrum of armour studies. His *European Armour: Circa 1066 to Circa 1700*, first published in 1958, remains the standard text on the subject.[6] In addition, he authored several influential pieces on the Silvered and Engraved Armour of Henry VIII and the Greenwich Armouries, among other subjects.[7]

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[3] Charles Alexander De Cosson and W. Burges, *Ancient Helmets and Examples of Mail: A Catalogue of the Objects* (London: Royal Archaeological Institute, 1881), p. 1.

[4] De Cosson and Burges, *Ancient Helmets*, p. 60. This helmet is now held by the British Museum, registration number 1881,0802.30. Its visor is similar to that of Royal Armouries IV.29, which is mentioned in the catalogue description.

[5] Guy Francis Laking, *A Record of European Armour and Arms Through Seven Centuries*, 5 vols (London: G. Bell and Sons, 1900-22), I, p. vii.

[6] Claude Blair, *European Armour: Circa 1066 to Circa 1700* (London: B.T. Batsford, 1958).

[7] Claude Blair, 'The Emperor Maximillian's Gift of Armour to King Henry VIII and the Silvered and Engraved Armour at the Tower of London', reprinted from *Archaeologia*, 99 (London: Society of Antiquaries, 1965) and C. Blair, 'The Royal Armouries at Greenwich', *Third Congress of the International Association of Museums of Arms and Military History* ([n.p.]: [n.pub.], 1963), pp. 34-43.

Other scholars have done much to catalogue armour holdings in Europe and North America, both public and private. James Mann's work on the armoury at Churburg Castle, a large and well known private holding in northern Italy, reprinted and edited by Mario Scalini, considers not only the objects but also their history as part of a collection and the history of the collection itself.[8] The Wallace Collection, a public museum, has been catalogued in great detail on multiple occasions, first by Laking in 1900, by James Mann in 1945, and by A.V.B. Norman in 1986, and has also had an excellent photographic record of some of the pieces published by Carlo Paggiarino, who has also created similar volumes for the Churburg armoury and the Royal Armouries.[9]

Museum armour exhibitions have also provided valuable works on particular aspects or topics, for instance *Heroic Armor of the Italian Renaissance: Filippo Negroli and his Contemporaries* from the Metropolitan Museum of Art in New York and *Armures des princes d'Europe : Sous l'égide de Mars* from the Musée de l'Armée in Paris.[10] Also of note is Walter Karcheski's and Thom Richardson's study of the armour of the Knights of St John from Rhodes, many pieces of which were studied for this

[8]Oswald Graf Trapp, *The Armoury of the Castle of Churburg*, ed. and trans. by James Gow Mann (London: Methuen, 1929).

[9] Guy Francis Laking, *Catalogue of the European Arms in the Wallace Collection at Hereford House*, 4th ed. (London: HMSO, 1910), James Mann, *Wallace Collection Catalogues: European Arms and Armour*, 2 vols (London: William Clowes, 1962), and A. V. B. Norman, *Wallace Collection Catalogues: European Arms and Armour Supplement* (London: Trustees of the Wallace Collection, 1986). For photographic publications see Carlo Paggiarino, *The Wallace Collection: A Celebration of Arms and Armour at Hereford House* (Milan: Hans Pruner, 2008), Carlo Paggiarino, *The Churburg Armoury: Historic Armour and Arms in the Castle of Churburg* (Milan: Hans Pruner, 2006), and Carlo Paggiarino, *The Royal Armouries: Masterpieces of Medieval and Renaissance Arms and Armour from the National Collection* (Milan: Hans Prunner, 2011).

[10] Stuart W. Pyhrr and José-A. Godoy, *Heroic Armor of the Italian Renaissance: Filippo Negroli and his Contemporaries* (New York: Metropolitan Museum of Art, 1998) and Olivier Renaudeau, Jean-Pierre Reverseau, and Jean-Paul Sage-Frenay, eds., *Sous l'égide de Mars: Armures des princes d'Europe* (Paris: Nicolas Chaudun, 2011).

thesis, which recreates this now-disbursed collection of armour so that it may be interpreted as an assembly as well as individual pieces.[11]

Armour made in Italy during the Middle Ages and Renaissance has been heavily written on, particularly by Lionello G. Boccia, whose *L'Arte dell' Armatura in Italia* remains one of the best works on Italian armourers.[12] Even before him, though, J. Gelli and G. Moretti published a study of the Missaglia family of armourers in their *Gli Armaroli Milanesi: i Missaglia e la loro Casa*.[13]

Ortwin Gamber and Bruno Thomas have both added much to armour scholarship, and the history of armour and armourers in Germany in particular as well as Italy. Thomas wrote heavily on the several aspects of armour and armourers, as well as the modern collections in Germany, Austria, and Italy.[14] Gamber had a similarly broad output, including several works in conjunction with Thomas, broadening the understanding of the development of armour throughout Europe.[15]

Terminology has long been a problem within the study of armour, the result of medieval lack of standardised terminology compounded by variations used by different languages and nationalities, all clouded and corrupted by the passage of time. Some early works, such as George Cameron Stone's *Glossary of the Construction, Decoration and Use of Arms and Armor* attempted to present the types and elements of arms and

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[11] Walter J. Karcheski, Jr., and Thom Richardson, *The Medieval Armour from Rhodes* (Leeds: Royal Armouries, 2000), p. v.
[12] L. G. Boccia and E. T. Coelho, *L'Arte dell' Armatura in Italia* (Milan: Bramante, 1967).
[13] J. Gelli and G. Moretti, *Gli Armaroli Milanesi: i Missaglia e la loro Casa* (Milan: [n.pub.], 1903).
[14] See for example Bruno Thomas, 'Lorenz Colman (Recte Helmschmid), Armourer of Augsburg', *Apollo Annual* (1948), pp. 21-24, and Bruno Thomas, 'Armature e Armi Bianche', *Storia di Brescia*, 3 (1961), 791-815. Thomas' work was collected in *Gesammelte Schriften zur Historischen Waffenkunde*, 2 vols (Graz: Akademische Druck, 1977).
[15] See for example Ortwin Gamber, 'A Funerary Effigy, Grotesque Helmets and the Seusenhofer Workshop', *Apollo* (1988), pp. 105-107, and Ortwin Gamber, 'Kolman Helmschmid, Ferdinand I und das Thun'sche Skizzenbuch', *Jarbuch der Kunsthistorischen Sammlungen in Wien* (1975), pp. 9-38.

armour in a way that would have had a standardising influence through its encyclopaedic presentation, although it does not appear to have ever had that effect.[16]

More ambitious was the *Glossarium Armorum*, published in 1972 with contributions from arms and armour experts from several countries, among them Ortwin Gamber, Claude Blair, Lionello Boccia, and Bruno Thomas. The *Glossarium* was intended to provide a standardised terminology for pieces of armour, across many different languages 'so that by using the index and the illustrations together equivalent terms in these languages can easily be traced'.[17] Despite these potential benefits, the principles of the *Glossarium* were not adopted.

The most thorough works written specifically about the medieval armourer have been Charles ffoulkes' *The Armourer and His Craft* and Brian R. Price's *Techniques of Medieval Armour Reproduction*. ffoulkes' stated purpose was to present 'all the records and references, especially in English documents, which relate to the actual making of armour and the regulations which controlled the Armourer and his Craft'.[18] Though it focuses more on construction details than production techniques, *The Armourer and His Craft* differed from other early encyclopaedic works in its emphasis on methods of assembly rather than simply the evolution of form.

Techniques of Medieval Armour Reproduction is one of the most complete accounts written on the armourer's art. Geared heavily towards technique, it is intended as a manual which discusses the steps of armour-making from design to fabrication. Though not comprehensive, the complexity of the task is well represented. The

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[16] George Cameron Stone, *A Glossary of the Construction, Decoration and Use of Arms and Armor in All Countries and in All Times* (Portland: Southworth Press, 1934; repr. Toronto: Dover, 1999).
[17] Ortwin Gamber, et al, *Glossarium Armorum: Arma Defensiva*, English edition (Graz: Akademische Druck, 1972), p. 5.
[18] Charles ffoulkes, *The Armourer and His Craft: From the XIth to the XVIth Century* (London: Methuen, 1912; repr. Toronto: Dover, 1988), p. ix.

audience of the book is primarily those interested in practicing the craft in the present day, especially those providing armour for the re-enactment community.[19] These armourers typically work alone, and as a result the dynamic of the medieval workshop, with its many artisans and labour structure, is not represented. Techniques for modern production are the focus for their economy and speed, although it discusses the relationship between medieval armour and that produced for the re-enactor.[20]

These are not the only works on the practices of the medieval armourer, though they are the most comprehensive. Others have concentrated on specific elements of the armourer's art in some degree of isolation from others. For example, the importance of tools as another means to understanding how armour was made was recognised early in the twentieth century by Bashford Dean, who declared that they 'give, in a word, no little light upon a field which has been curiously neglected—the ancient manner of making armor'.[21]

Making armour has been the subject of some sections of larger works on the development of armour. In *European Armour* Blair devotes his last chapter to the topic, stating that the armour itself should serve as the basis for understanding how armourers worked, but unfortunately he does not develop this idea. He also highlights one of the important elements of the functioning of the workshop, namely the specialisation of different craftsmen. Workshops are said to have hired decorators to work on their products, though it is not suggested that components such as rivets or buckles could be produced by independent craftsmen which were purchased as required by armourers.[22]

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[19] Brian R. Price, *Techniques of Medieval Armour Reproduction: The 14th Century* (Boulder: Paladin Press, 2000), pp. 37-40.
[20] See for example Price, TOMAR, pp. 207-10.
[21] Bashford Dean, 'A Collection of Armorers' Implements', in Bashford Dean, *Notes on Arms and Armor* (Huntingdon: Ken Trotman, 2007), p. 62 (p. 62).
[22] Blair, *European Armour*, pp. 188-190.

Similarly, Matthias Pfaffenbichler in his short work for the British Museum, *Medieval Craftsmen: Armourers,* devotes his last chapter to the processes of making armour of mail and plate.[23] While Blair's *European Armour* placed armour making in the context of the development of armour through the centuries, Pfaffenbichler placed it in the context of the armourers themselves as a distinct group within medieval society and with their own place in the economy of the period. In addition to being more detailed than Blair in the description of the process of making armour, *Armourers* has a wider coverage of the other aspects of the life and work of the armourer which gives a much better overall impression of medieval armourers than ffoulkes, Price, or Blair. Perhaps the greatest weakness of *Armourers* is its overall brevity.

The bulk of technical study of medieval and Renaissance armour has been limited to metallurgical analysis, relying on photomicrographs to record the crystalline structure of the metal and then drawing conclusions from that data concerning the use of heat during forming, a technique which has been used on plate armour as well as mail.[24] David Starley has contributed a great deal to the understanding of the production of ferrous metals for armour and the decoration of armour by gilding.[25]

The main proponent of this type of analysis has been Alan Williams, who has published extensively on metallographic studies of armour. Some of Williams' conclusions, mostly concerning inclusions and smelting processes, were called into question by Starley who believed that the studies 'would have benefitted from a more

[23] Matthias Pfaffenbichler, *Medieval Craftsmen: Armourers* (London: British Museum Press, 1992), pp.56-70.
[24] Cyril Stanley Smith, 'Methods of Making Chain Mail (14th to 18th Centuries): A Metallographic Note', *Technology and Culture*, 1 (1959), 60-67.
[25] David Eric Starley, 'Medieval Iron and Steel Production: An Assessment of the Changing Technology of European Ferrous Alloy Production through the Analysis of Medieval and Renaissance Armour' (unpublished doctoral thesis, University of Bradford, 1992) and David Starley, 'Only Skin Deep: Residual Surface Coatings on Arms and Armour', in *Make All Sure: The Conservation and Restoration of Arms and Armour*, ed. by Robert Douglas Smith (Leeds: Basiliscoe Press, 2006), pp. 1-5.

objective approach, especially as it appears to have been overly influenced by the conclusions of Williams' more thorough historical and metallographic researches'.[26] In attempting to determine techniques used in creating a particular piece of armour, metallographic examination is useful to a point, but cannot be used to answer many questions, either because the technique did not leave specifically metallographic evidence, or because the evidence was obliterated by other processes including reheating and hammering.

There have been some studies of tool marks on metalwork, such as Mikahil Y. Treister's work on ancient Greek and Roman toreutics, but the focus is almost entirely on decoration and the punches and matrices used, with no discussion of how the armour was actually made, nor any of tool marks.[27] Catherine Mortimer and Martin Stoney developed a methodology for the study of marks left by punches on Anglo-Saxon jewellery, with the aim of identifying when objects were made in the same workshop or by the same tool.[28]

Tool marks on armour have been briefly mentioned before, but there has been no methodology developed for their analysis. In an article on a kettle hat in the British Museum converted into a pot or pail, Jamie Hood describes a series of marks on the object's interior, though as will be seen the interpretation of those marks is only partially accurate.[29]

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[26] Starley, 'Medieval Iron and Steel Production', pp. 61-63.

[27] Mikhail Y. Treister, *Hammering Techniques in Greek and Roman Jewellery and Toreutics*, ed. by James Hargrave (Leiden: Brill, 2001), pp. 35-41, 112-21, 208-10, and 327-333.

[28] Mortimer, Catherine, and Martin Stoney, 'A Methodology for Punchwork Analysis Using Electron Microscopy', in *Archaeological Sciences 1995: Proceedings of a Conference on the Application of Scientific Techniques to the Study of Archaeology*, ed. by Anthony Sinclair, Elizabeth Slater, and Gowlett (Oxford: Oxbow, 1997), pp. 119-22 (p. 119).

[29] Hood, Jamie, 'A Late Fourteenth-Century Transitional Kettle-Hat Found in London', *Arms & Armour*, 9 (2012), 154-80.

Outside the field of armour studies there has been a great deal written about the practical application of metalworking techniques for those interested in both the history and practice of metalwork and jewellery making. Alex W. Bealer's *The Art of Blacksmithing* covers the practice of traditional blacksmithing and includes many skills and tools that were required by the medieval armourer. Oppi Untracht's *Jewellery: Concepts and Technology* does much the same for a large range of techniques for the jeweller. These are only two of a large and vibrant field of publications in the applied arts, and many of their techniques are also applicable to the armourer.[30] As will be shown later in the thesis there are many tools and techniques which are shared amongst these various trades and which have not changed appreciably over the centuries.

One of the consequences of the dearth of knowledge on medieval armour making has been inaccurate information concerning processes. An example is Rosemary Ascherl's assertion that the outer heads of sliding rivets were welded to the exterior plate after assembly, something which could not have been done without destroying the functioning of the joint.[31] She also drew a distinction between the armourer and blacksmith by stating that armourers used files, suggesting blacksmiths did not despite the existence of files found with blacksmithing equipment from a range of periods.[32] Anachronistic assumptions about the state of medieval technology have also led to errors such as the belief that armour was hammered over a die in the intended

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[30] Alex W. Bealer, *The Art of Blacksmithing*, rev. ed. (Edison: Castle Books, 1995), and Oppi Untracht, *Jewellery: Concepts and Technology* (New York: Doubleday, 1985).

[31] Rosemary Ascherl, 'The Technology of Chivalry in Reality and Romance', in *The Study of Chivalry: Resources and Approaches*, ed. by Howell Chickering and Thomas H. Seiler (Kalamazoo: Medieval Institute Publications, 1988), pp. 263-311 (p. 269).

[32] Ascherl, 'The Technology of Chivalry', p. 292. For references to files see Greta Arwidsson and Gösta Berg, *The Mästermyr Find: A Viking Age Tool Chest from Gotland* (Stockholm: Almquist and Wiksell, 1983), pp. 12-13, and W. H. Manning, *Catalogue of the Romano-British Iron Tools, Fittings and Weapons in the British Museum* (London: British Museum Publications, 1985), p. 11.

shape after hammering the plate into a rough shape cold, something more akin to modern die-stamping than the more fluid nature of medieval metalwork.[33]

1.3. Methodology

1.3.1. Research and Approach to the Sources

The most important source for this research is surviving armour, not only because it is more plentiful than the written sources but also because of the unique evidence which is found nowhere else but on its surfaces. Armour has never before been systematically examined and analysed in the manner described in this thesis, and because this research represents a wholly new way of interpreting armour a new methodology of examination had to be developed for the analysis, one which takes into account tool marks as well as the style and function of the piece itself.

The evidence of tool marks and their use in determining the working practices of medieval armourers is a novel approach to armour studies, one which has never been attempted with any sort of systematic approach. Although the lack of research on armour-making has to do in large part with the paucity of written sources, the historian's usual tool, the fact that these marks are part of a working practice has made them much less accessible to even those historians and archaeologists who work with material culture but do not necessarily have practical experience in metalwork.

What is needed is a point of view which takes into account and is familiar with the way in which metal behaves under the hammer, the characteristics of the tools, the effect of heat, and the way plates look when they have been struck. The present author has worked as a blacksmith for several years, working not only in billets but also in plates and sheets, and so is able to bring that practical first-hand experience to the study

[33] Stephen N. Fliegel, *The Making of Armour* (Cleveland: Cleveland Museum of Art, [n.d.]), p. 5.

of armour. This experience makes up an invaluable part of the interdisciplinary approach to this research.

Because these marks have not been systematically studied before, a new set of terms and descriptions has been required to accurately record them.[34] It was vital to be able to handle the pieces instead of relying on published photographs; besides only a relatively few pieces of armour actually being found in print, photographs are most commonly of the exterior, and interior photographs usually do not reveal the detail required. In addition, relying on another's pictures renders it impossible to feel the weight of the piece, the texture of the surface, and the ability to move the piece in the light which can only be done by using one's own hands. Only in this way can many details be detected and the piece be interpreted as a whole.

Recording of the pieces was done in several ways at once. Detailed notes were taken, which included object type, date, place of manufacture, physical description, mark patterns, and measurements. Photographs were taken of the interior and exterior, between fifty and one hundred and twenty per object. Because certain details such as very fine cracks or changes in thickness do not show up in photographs, no matter how many are taken, drawings are also made of each object, both the interior and exterior, as a schematic to illustrate mark patterns and any other details which are of particular importance. These three methods, writing, drawing, and photographing, serve to create the most complete record possible of each object.

Although the bulk of the objects in the corpus are held in one place it was not possible to examine them systematically by type. It was more convenient logistically for the pieces to be grouped by the case in which they are displayed, which are arranged roughly chronologically but could not always be opened in sequence. Therefore there was not any kind of comparative work done at the same time as individual analysis,

[34] These patterns of tool marks will be discussed in detail in Chapter IV.

other than the observations made at the time. Instead, detailed comparative analysis was done after the corpus at the Royal Armouries had been fully examined.

Individual analysis using the collected data was undertaken after the whole medieval collection at Leeds had been studied and recorded. This was undertaken before the comparative analysis so that the full scope of the mark patterns could be assessed and catalogued. The comparative work thus benefited from having the complete picture of each individual item as a starting point, allowing for a more accurate comparison and for more efficient grouping during the process.

Research was not limited to material culture, and a great deal of work was done with textual and artistic sources. Records of armourers' workshops and depictions of armourers at work were used as an important aid in the interpretation of tool marks, as well as helping to elucidate the organisation and contents of a medieval workshop. Texts and images have been linked wherever possible to specific extant examples or identifiable techniques, which has resulted in a reinterpretation of some of the inventories and illuminations which have been previously studied. Although not the primary focus of the thesis they are indispensible for understanding the techniques of the medieval armourer.

Besides answering the primary research questions, it is hoped that this new approach to the study of armour, along with the methodology and techniques developed during the course of this research, will aid future students and scholars. It will add another layer to the information obtainable from armour and provide a means of interpreting that information. This will help others determine how pieces were made, their origin, and be a further aid in recognising fakes.

1.3.2. Description of the Corpus

The limits which have been imposed for this thesis reflect an identifiable and coherent period in the history of the development of armour which is not only convenient for study but also represents one of the greatest flowerings of the armourer's art in Europe. The period in question spans from *c.* 1390 to *c.* 1500, during which time plate armour was perfected. The area of study is primarily Germany and Italy, more specifically the armour producing centres of Nuremberg, Augsburg, Landshut, Innsbruck, Mühlau, Milan, and Brescia.[35] The exact type of armour under investigation is ferrous plate armour, and any form of textiles, leather, mail, and non-ferrous metals will only be included if they are associated with an extant piece of plate armour.

Due to the mobility of armourers, occasional uncertainty as to attribution, and the value of pieces from other areas, objects from the rest of Europe will be considered, in particular England and the Low Countries. Objects from before and after the date range will be considered if they provide clear evidence of the working practices of armourers between 1400 and 1500. There are several pieces, especially from the first decades of the sixteenth century, which have been of particular value as they show clear examples of both change and continuity in technique. Works on medieval armour often focus on the costlier armours of the great masters, which are indeed works of art worthy of attention. However, there is little, if any, difference in the working techniques between pieces of high and low quality, and so this study is able to make full use of a broad spectrum of objects.

The main body of evidence used for this thesis consists of medieval armour held by the Royal Armouries in Leeds. The whole of the medieval collection was studied as

[35] Germany in this context indicates the German-speaking lands of the late Middle Ages, which includes the modern nation of Austria. Although museums will label objects as 'Austrian', especially those from Innsbruck, in this thesis they are considered to be German.

well as several specifically chosen early Renaissance pieces. This assembly gives a good cross-section of the types of armour used during the late Middle Ages, and also shows the full range in quality; there are pieces which would have been worn by the poorest soldiers and pieces owned by kings and emperors. A smaller number of pieces from Kelvingrove Art Gallery in Glasgow and the National Museum of Scotland in Edinburgh were also examined. There are 261 pieces overall in this part of the corpus, consisting of helmets, breastplates, backplates, arm defences, gauntlets, leg defences, and one pair of sabatons. This is supplemented by six tools originally from the Greenwich armoury.

In addition to varying quality of workmanship the quality of conservation varies a great deal from piece to piece. This is due to the disparate places where the pieces resided before coming to the Armouries and the different practices, or lack thereof, used by the owners to preserve the armour. The pieces may have been painted, lacquered, polished, or left to rust on the interior and exterior with a resulting effect on the ease in which tool marks may be observed and analysed.

There are some pieces which have been heavily restored. Restorations done at the Royal Armouries are immediately identifiable on the interior, even when care has been taken to match the exterior surfaces. On some pieces every restoration plate bears the armourer's mark on the interior, a practice not found in the Middle Ages. On others the date of restoration has been engraved onto the plates, including a light-hearted 'Happy Christmas & a happy New Year—H.R. Robinson' on the interior of the backplate III.70.[36]

Restorations do not only take place in a modern museum setting, adding another layer to repairs which are separate from those which are merely restorative. During its working life armour was often subjected to punishing treatment on the field and in

[36] This object is discussed in detail in Chapter V, pp. 203-05.

tournaments, and some repairs and replacements can be identified which are 'original', meaning part of the piece's working life, as opposed to modern restoration.[37] As noted, the life and history of an object does not end with its being no longer used for its original purpose, but it is important to not confuse these period repairs with later alterations.

1.3.3. The Components and Mechanics of Armour

The medieval armourer had a seemingly insurmountable task: encase the human body, with its joints and musculature, in a hard unyielding material with little or no loss of mobility. The solutions adopted to accomplish this represent one of the technical marvels of the age. Medieval armour was light and flexible representing a balance between the defensive capabilities of the armour and the offensive capabilities of the wearer.

The many components of armour have no standardised terminology, but within English scholarship there are generally accepted terms for the various parts of a suit of armour. There are many ambiguous pieces which defy definite categorisation, but even in these cases it is possible to classify them to an extent through comparison to the most similar pieces.

Armour for the head demonstrates perhaps the greatest amount of variety in style. Helmets make up the largest single group of objects for the corpus and the many types are well represented. These types include helms, basinets, great basinets, sallets and bevors, barbutas, close helmets, armets, and kettle hats. Each of these has specific characteristics which make them distinct from one another. Helmets almost always have some sort of medial comb which serves as a strengthening feature, and may be in the form of a crease, a ridge, or a keel; a crease is a simple line at the intersection of two

[37] See for example Figure 178.

convex surfaces, a ridge is essentially a flute or the meeting of two concave surfaces, and a keel is the same as a ridge except that it is flattened at the top. These features, especially medial creases, are found on other types of armour as well.

The torso armour has two main components, the breastplate and backplate, which together make up the cuirass. The breastplate is sometimes divided into an upper main plate and a lower plackart to increase flexibility. The backplate is often divided into an upper plate and a waist plate for the same reason. Below the waist may be attached a fauld in front and culet in back, each composed of wide horizontal bands called lames which cover the body from the waist to the groin. The fauld may be further extended to cover the upper thigh using tassets.

There are several possible pieces of armour for the arm. Over the shoulder may be spaudlers, small defences covering the point of the shoulder and the upper part of the arm, or pauldrons which cover a larger area over the shoulder and wrap around the breast and back. The main arm harness can be divided into three pieces, the upper cannon which covers the arm above the elbow, sometimes called the rerebrace, the couter which covers the elbow, and the lower cannon or vambrace which covers the forearm. The hand is defended by the gauntlet, which may be fingered or mitten depending on the arrangement of the plates over the fingers.

The leg harness is composed of the cuisse over the thigh, the poleyn over the knee, and the greave over the shin. The cuisse may have extension plates at the top and side to increase coverage, while the greave may cover the front of the leg, the outer three quarters, or be fully enclosed. The foot is covered by the sabaton, an iron shoe which protects the top of the foot.

The triumph of the late medieval armourer was not in the variety of defences but in the way they were put together in a working suit. This was achieved through the use of articulations to connect the various large components through flexible joints. The primary element of most articulations is the lame, a narrow strip of metal which provides a pivot for the joints and which fills the gaps which would otherwise open when the body is moved.

In a complete suit of armour there may be dozens of lames. The fauld, articulated backplates, spaudlers and pauldrons, and gauntlets all make use of lames as part of their basic shape. Instead of one large plate the form is broken up into several small ones, attached to each other by internal leathers and rivets, which slide over and under each other to provide movement. The most advanced use of lames is in the couters and poleyns of armour for the limbs. Here the lames are designed to tuck away almost out of sight when the arm or leg is straight, but upon flexing the joint they allow the arc to expand, thereby preventing any gaps in the armour.

The level of flexibility attainable from this system is more than adequate for maintaining mobility. Far from encumbering the knight, many of these pieces actually flex more than the human body is capable.[38] There were some weak areas which were never satisfactorily defended during the late Middle Ages, including the inside elbow and knee and the armpit, and these were often covered in mail. Renaissance armourers were able to cover these areas with very narrow lames called splints, epitomised in the foot combat armour of Henry VIII which leaves only the palms of the hands and bottoms of the feet uncovered.[39] However, this level of coverage becomes an encumbrance when riding a horse and appears mainly on armour for foot combat.

[38] See Figure 1.
[39] Leeds, Royal Armouries, II.6.

1.3.4. Concerning Direction: Up, Down, Left, Right

The overlap of plates is important not only for the functioning of the armour, but also in some cases for dating pieces and seeing the development of different components. When discussing armour it is important to know which side is being described, and the exact definition of words concerning location. The great variety of ways that armour plates were assembled necessitates clarity with regards to the orientation of a plate and its relation to other plates which make up the complete piece. Because of the possible ambiguity of terms, for example inside and outside versus inner and outer, confusion may arise as to whether the left interior or right exterior is being described. Furthermore, does a direction refer to the point to view of the person wearing the armour, or the person facing the wearer? For this reason written description as outlined above has been used in conjunction with photographs and illustrations as much as possible so as to eliminate this ambiguity.[40]

To begin, the point of view of all descriptions is that of the person *wearing* the armour, so that right and left refers to his right and left. Furthermore, all descriptions take for granted that this hypothetical individual is standing straight with his arms at his sides, with his hands facing so thumb is towards the leg and palm is facing backwards. This simplifies the description of gauntlets in particular as it gives a better idea of left and right than if the hands were hanging with the palm towards the leg.

Left and right can refer to which side of the body a piece is worn on, such as left pauldron and right pauldron, but these particular pieces illustrate a possible difficulty, that is, how to describe sides on a piece that is essentially ‘sideways’ when worn. The terms front and back may be used in instances such as this, where there is a clear front and back to the piece.

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[40] See Figures 2-5.

Inner and outer should be seen as related to left and right, not as synonymous with interior and exterior. With greaves, the inner part of the greave is the inner calf, while the outer faces away, so on the left-hand greave the inner part is the right and the outer part the left. Upper and lower are likewise related to top and bottom, so with a gauntlet the cuff is the uppermost plate or the top, while the fingertip lame is the lowest plate or the bottom. Interior and exterior refer only to the surfaces of the plates, the interior being the surface closest to the wearer, the exterior the surface away from the wearer.

When referring to the overlap of plates, they are described usually as overlapping upward or downward. As an example, a fauld overlaps downward since each lame down overlaps the one immediately above it. A pauldron’s lower lames overlap upwards since each lame protecting the upper arm overlaps the one immediately below it. For pieces where the overlap of plates is sideways the exact nature of the overlap will be described in order to avoid confusion.

Chapter II: Written and Iconographic Sources

2.1. Introduction

The greater part of the sources used for this thesis consists of objects, but this body of evidence is not by itself sufficient for understanding the working practices of medieval armourers. Various written and iconographic sources must also be considered to fill in gaps in the material evidence when tool marks are not enough to explain certain techniques, or for understanding the larger context in which armour production took place which is not wholly represented by the finished object. The reverse is also true in that examination of the material sources can be used to explain the meaning of some written or artistic evidence which may otherwise be obscure.

Written sources can be divided into two categories, general sources for metals and metalworking and inventories which are relevant to workshops. The first set of texts are for the most part concerned not with armour but with related subjects that form much of the initial stage of armour-making, production of the iron and steel, as well as some useful information about tools. The inventories deal directly with armour-making since they are a record of the contents of armourers' workshops, though they do not always give a full or clear picture of the space or its contents.

Iconographic evidence consists mainly of manuscript illustrations, but it is also found in a few other forms. These depictions of armourers and other metalworkers engaged in their craft are among the most useful of the non-material culture sources because they show not only tools but processes. The difficulty lies in determining the accuracy of the depiction, but with careful examination and analysis they can be used to illustrate workshop layout, divisions of labour, and metalwork techniques.

The use of these sources may be further enhanced through comparison with surviving tools, where possible. The Royal Armouries holds several original armourers' tools in addition to a large body of later tools which are similar, and tools are also found in other collections. These tools will be given a full technical analysis in Chapter IV.

Not all of this evidence is directly related to armour making, but is no less useful. As will be seen, tools and techniques were in many cases common across all the metalworking trades, and there was very little change in the forms of the tools. Ironworking tools from Roman Britain are very much the same in form as those shown in medieval artwork, or those found in a modern workshop.[41] The use and interpretation of these sources will be explored in this chapter largely in isolation from the material culture, but with comparisons where appropriate. In this way origins, context, and content may be discussed fully before they are directly compared with the surviving armour which is the primary focus of the thesis.

2.2. Treatises on Metalworking

Although there are no medieval treatises written specifically about making armour, there was writing on the subject of metalwork, metallurgy, and iron smelting which make up part of the context within which armourers worked. Information from these texts can then be combined with other sources to help determine how armour was made, in part because the smelting of iron formed one of the first production stages of armour making, and also because many of the techniques were the same for armourers and other tradesmen.

Four particularly significant medieval and Renaissance texts about metals are *De Diversis Artibus* by Theophilus, the anonymous *Von Stahel und Eysen*, *Pirotechnia* by Vannoccio Biringuccio, and *De Re Metallica* by Georgius Agricola. These works date

[41] See for example Roman hammers, anvils, and tongs in the British Museum, in Manning, *Catalogue of the Romano-British Iron Tools,* pp. 2-8.

from between the twelfth and sixteenth centuries, and are aimed at different audiences, yet all are significant because of the interplay and similarity of the metalworking crafts.

De Diversis Artibus was intended for monastic craftsmen working in a variety of media, namely paint, glass, and precious metals.[42] *Von Stahel und Eysen* was written to demonstrate 'a few small technical tricks, which will be quite useful to people who are occupied with metals, and conducive to their further understanding and experience'.[43] In this it resembles *De Diversis Artibus* in being a recipe book, or collection of methods, nowhere near as exhaustive or thorough but nonetheless interesting as it touches on some matters of particular interest to armour-making, the heat-treatment of ferrous metals and gilding.[44]

Both Biringuccio and Agricola wrote for miners, assayers, and smelters interested in extracting and refining ores into useable metals. Biringuccio for example was 'intensely occupied with metallurgy, mineral arts, and the art of war, acquiring briefly and elaborating by his count a large harvest of facts'.[45] *Pirotechnia* is 'the earliest printed work to cover the whole field of metallurgy'.[46] Originally written in Italian, it was translated into French and Latin in the sixteenth and seventeenth centuries, and *De Re Metallica* was published in its original Latin, German, and Italian.[47]

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[42] Dodwell, in Theophilus, *De Diversis Artibus*, pp. x-xi.
[43] Hermann W. Williams, Jr., 'A Sixteenth-Century German Treatise, *Von Stahel Und Eysen*, Translated with Explanitory Notes', in *Technical Studies*, 4 (1935), 64-92 (p. 64).
[44] Hermann W. Williams, '*Von Stahel und Eysen*', pp. 64-69 and 75.
[45] Aldo Mieli, 'Vannoccio Biringuccio ed il Metodo Sperimentale', *Isis*, 2 (1914), 90-99 (p. 93). Translation by the author.
[46] Cyril Stanley Smith, 'The Background of the *Pirotechnia* and its Place in Metallurgical Literature', in Vannoccio Biringuccio, *The Pirotechnia of Vannoccio Biringuccio*, trans. by Cyril Stanley Smith and Martha Teach Gnudi (New York: Basic Books, 1959), pp. x-xix (pp. x-xi).
[47] Agricola, *De Re Metallica*, p. xvi.

There are several surviving manuscripts of *De Diversis Artibus*, the earliest of which dates to the twelfth century.[48] *Von Stahel und Eysen, Pirotechnia* and *De Re Metallica* were published in 1539, 1540 and 1556 respectively and include processes which were practiced during the Middle Ages, a consequence of the longevity of early iron smelting, although they also contain working techniques which were unknown during that period.[49]

An advantage of the disparate periods and audiences of these works is that they illustrate methods for working and ideas about metals in these different times and how they changed or remained constant. The writings of Theophilus would have been familiar to metalworkers in the late Middle Ages, and Biringuccio and Agricola represented a further generation of metalworking craftsmen, part of a continuing and developing industry.[50] At no point does Theophilus mention armour or its production, but since his audience was concerned with adorning abbeys and churches, not kings and knights, this is to be expected.[51] Nevertheless his treatise is important since it lays out methods and tools which would have been known to, and used by, medieval armourers.

De Diversis Artibus differed significantly from earlier *libri secretorum*. According to William Eamon, 'Whereas the earlier works were anonymous, random

[48] Hawthorne and Smith, in Theophilus, *On Divers Arts*, trans. by Hawthorne and Smith, pp. xvii-xviii.
[49] Cyril Stanley Smith, 'The Editions of the *Pirotechnia*', in Vannoccio Biringuccio, *The Pirotechnia of Vannoccio Biringuccio*, trans. by Cyril Stanley Smith and Martha Teach Gnudi (New York: Basic Books, 1959), pp. xix-xxiii (p. xix) and Herbert Clark Hoover, 'Introduction', in Georgius Agricola, *De Re Metallica*, trans. by Herbert Clark Hoover and Lou Henry Hoover (London: The Mining Magazine, 1912; repr. New York: Dover Publications, 1950), pp. v-xvii (p. xvi).
[50] According to Eamon, 'The abundance of technical recipe books from the late Middle Ages strongly suggests that the relationship between the practical and written traditions within the crafts was closer than is generally supposed', and that by the end of the Middle Ages 'writing had become an important method for conveying technical information in the crafts'. William Eamon, *Science and the Secrets of Nature: Books of Secrets in Medieval and Early Modern Culture* (Princeton: Princeton University Press, 1994), pp 86-87.
[51] Hawthorne and Smith, in Theophilus, *On Divers Arts*, trans. by Hawthorne and Smith, p. xxxiv.

compilations based on ancient technology, *De Diversis Artibus* was an original and systematic instructional manual written by an accomplished artisan from his own workshop experience'.[52] Theophilus 'made it my concern to hunt out this technique for your study as I learned it by looking and listening', and his extremely detailed account of working with metals suggests that he was primarily a metalworker himself.[53]

Earlier works on practical subjects were not written by craftsmen and were not as rich in detail. Because much of Theophilus' text was original, the danger of 'informational entropy' caused by repeated copying of others' works was greatly reduced.[54] This can be seen in texts such as *Mappae Clavicula*, a collection of recipes and instructions for a variety of practical applications whose earliest manuscript dates to the tenth century, and 'as it now stands is a compilation of compilations' resulting in inconsistencies and corruptions in the text.[55]

The value and detail of *De Diversis Artibus* was such that it was copied throughout the Middle Ages and into the Renaissance. Perhaps due to the quality and accuracy of much of the material it was not surpassed as a technical treatise until the fifteenth century. According to John G. Hawthorne and Cyril Stanley Smith, there was no 'significant improvement over Theophilus as a source for the arts he describes until the books by Cennini (1437) on painting, Månsson (*ca.* 1520) on glass, and Biringuccio (1540) on almost everything but painting'.[56]

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[52] Eamon, *Science and the Secrets of Nature*, p. 83.
[53] Theophilus, *On Divers Arts: The Foremost Medieval Treatise on Painting, Glassmaking and Metalwork*, trans. by John G. Hawthorne and Cyril Stanley Smith (London: Constable and Company, 1963; repr. New York: Dover Publications, 1979), p. 80.
[54] Theophilus, *On Divers Arts*, trans. by Hawthorne and Smith, pp. xxvii-xxviii.
[55] Cyril Stanley Smith and John G. Hawthorne, 'Mappae Clavicula: A Little Key to the World of Medieval Techniques', *Transactions of the American Philosophical Society*, 64 (1974), 1-128 (p. 15).
[56] Hawthorne and Smith, in Theophilus, *On Divers Arts*, trans. by Hawthorne and Smith, p. xxxi.

The value of their subjects is a matter touched on by all of these authors. To Theophilus, the primary reason for metalwork, indeed art itself, is as an outward expression of religious devotion, and as such he 'gave craftsmanship the highest sanction medieval culture could give: holiness'.[57] In the introduction to his third book he uses David as biblical precedent for material decoration being used to glorify God, 'By pious reflection he had discerned that God delighted in embellishment of this kind, the execution of which He assigned to the power and guidance of the Holy Spirit, and he believed that nothing of this kind could be endeavoured without His inspiration'.[58] By exercising his skill and creating works which depict the Crucifixion and the martyrdoms of the saints, Theophilus believed the artist was able to move those who saw their works to a pious life.[59]

Agricola, on the other hand, saw the works of miners and metalworkers as an essential part to the functioning of society. In the address at the beginning of *De Re Metallica* he says:

> In truth, in all the works of agriculture, as in the other arts, implements are used which are made from metals, or which could not be made without the use of metals; for this reason the metals are of the greatest necessity to man. When an art is so poor that it lacks metals, it is not of much importance, for nothing is made without tools.[60]

This statement raises the status of the miner and metalworker from that of simple labourers to the most important of all craftsmen.

Biringuccio includes a short section on ironworkers and the nature of their craft. He stresses the physical labour that smiths must endure in the course of their work

[57] Eamon, *Science and the Secrets of Nature*, pp.83-84.
[58] Theophilus, *De Diversis Artibus*, trans. by Dodwell, p. 62.
[59] Theophilus, *De Diversis Artibus*, trans. by Dodwell, p. 62-64.
[60] Agricola, *De Re Metallica*, p. xxv.

which leaves them exhausted after a long day of toil.[61] He also draws attention to the division of specialties among ironworkers including smiths who forge anchors, makers of agricultural implements, blade smiths, locksmiths, armourers, and 'many more, so that, in short, there are as many kinds of special masters as are there things that are made or can be made of iron'.[62]

Biringuccio, like Agricola, recognised the importance of ironwork to other crafts, and by extension to society as a whole: 'And surely this art is very necessary to human beings, not only for cultivating the soil, but for an infinite number of activities—indeed, there is no one whom this art does not serve'.[63] Perhaps revealing his own bias gained from working with iron, he claims that the ironsmith could nearly 'take precedence over the goldsmith' due to the necessary skill and knowledge required, though the roughness of many of the practitioners and the baseness of iron, to Biringuccio, detracted from the art.[64]

There is a wide range of tools represented in these texts, from hand tools to large industrial hammers and furnaces. Theophilus gives the best description of the layout of a workshop for craftsmen, though the exact arrangement is better suited to small non-ferrous work with each man seated at a bench. However, the importance of good light is mentioned, the workshop containing 'as many windows as you want and can accommodate'.[65] All the tools necessary for work, and how to make many of them, are listed including the forge and bellows, anvils, specialised anvils known as stakes, hammers, tongs, drawplates, wire swages (*organarium*), files, chisels, and nail

[61] Biringuccio, *Pirotechnia*, pp. 369-370.
[62] Biringuccio, *Pirotechnia*, p. 370.
[63] Biringuccio, *Pirotechnia*, pp. 370-71.
[64] Biringuccio, *Pirotechnia*, pp. 373-74.
[65] Theophilus, *De Diversis Artibus*, trans. by Dodwell, pp. 64-65.

headers.[66] As with armourers these tools must be of a variety of shapes to accommodate different techniques, and so there are hammers 'large, medium, and small, broad on one face and narrow on the other', and 'anvils that are rounded on top, like half an apple, one large, one small, and a third short—these are called stakes'.[67]

The creation of great heat is the most important task for metalwork in these texts, for without heat iron can be neither smelted in the furnace nor worked at the forge. In order to have a sufficient blast of air to feed the fires bellows are required to create a forced draft, and all except *Von Stahel und Eysen* discuss this important machine. Theophilus gives direction for bellows which use the hide of one ram each to power the small goldsmith's forge.[68] Agricola gives in minute detail how bellows and the machinery to operate them should be built, saying that the bellows should be 'composed of two "boards," two bows, and two hides', and that they should be approximately five feet long and two feet wide.[69] This larger bellows arrangement, used in smelting furnaces, was made possible by the use of water power.[70]

Biringuccio included in his work a section describing several ways in which bellows could be operated by means of either human power or water power to work both forges and furnaces, some of which are more practical than others. He plainly states the need for water power in smelting operations, 'Since human forces are weak in large things, one tries to invent devices by employing various levers or the aid of water'.[71] His devices use cams and cranks to open or close the bellows, depending on whether the top or bottom board of the bellows was fixed in place. The use of cams

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[66] Theophilus, *De Diversis Artibus*, trans. by Dodwell, pp. 65-72.
[67] Theophilus, *On Divers Arts*, trans. by Hawthorne and Smith, p. 85.
[68] Theophilus, *De Diversis Artibus*, trans. by Dodwell, p. 66.
[69] Agricola, *De Re Metallica*, p. 362.
[70] Biringuccio, *Pirotechnia*, p. 64.
[71] Biringuccio, *Pirotechnia*, p. 301.

seems to have been the more common approach, shown in other technological works, and is the most mechanically simple and reliable way to provide power to the bellows.[72]

Human powered bellows, which would have been of more use in a blacksmith's or armourer's workshop, were primarily shown to be operated by a rocking horizontal beam worked by a transverse tiller. The bar, attached to the top board of the pair of bellows, raised one bellows while the other was compressed with the aid of a weight. This arrangement is identifiable in many illustrations of forges during the Middle Ages.[73] Variations on this device included placing the horizontal bar on a perpendicular rotating shaft, and another replaced the transverse tiller with a foot pedal 'because the artisan can, if he wishes, work it himself when not striking the iron without the help of anyone else in working his bellows'.[74]

An important feature of these mechanisms is that they are all designed to operate a pair of bellows. One bellows is compressed at a time while the other inflates, creating a steady stream of air into the furnace or forge. Each bellows is single chambered, expelling air when compressed and drawing air in when expanded through a vent in one of the bellows boards.[75] The double-chambered great bellows are a post-medieval technological innovation which remained in general use by smiths until the twentieth century.

These texts demonstrate that medieval metalworkers were highly skilled in their respective trades, and that they could adapt their tooling to meet specific needs. Many

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[72] Agricola, *De Re Metallica*, pp. 371-74.

[73] See for example the armourers in Paris, Bibliothèque nationale de France, MS Latin 7939 A, fol. 156 and the blacksmiths in London, British Library, MS Sloane 3983, fol. 5, Figures 6 and 7.

[74] Biringuccio, *Pirotechnia*, p. 303.

[75] This vent is seen on the bottom boards in two of Biringuccio's illustrations in his chapter on bellows. Vents are required on all types of bellows used in smithing operations as they, in conjunction with valves at the air outlet, allow the air to be drawn through the board, preventing gasses and flame from being drawn into the chamber. See Biringuccio, *Pirotechnia*, pp. 300-02.

of the processes described by Biringuccio and Agricola were the same used to produce iron and steel for armour, and many of the skills and tools they described would have been used by armourers. These sources are able to fill part of the gap left by the lack of any medieval treatises on armour making.

2.3. Inventories

Texts dealing with metallurgy aid in understanding the properties and characteristics of the material which the armourer worked with, but they are less valuable for understanding the specifics of armour manufacture or the environment in which it was undertaken. For this we must turn to other sources which reference the workshop. Inventories are the best written sources for this because they are directly related to a workshop's contents which can be used as a first step in fully reconstructing what a workshop looked like and the tools therein.

A number of inventories survive from the late Middle Ages and early Renaissance, though unfortunately they are scattered and there are many gaps in the record. This is compounded by the fact that, although they are often official documents, the inventory-takers generally gave the bare minimum of information. Any of the multitude of stakes used by the armourer could be reduced to 'stake' or 'bickiron' without any further description. There are also occasionally instances where the number of tools appears insufficient, as though what was described is only a part of the workshop, but there are possible explanations for this and it must not be assumed that the inventory describes with minute detail every item in the workshop.

According to ffoulkes, the 'earliest inventory containing armourers' tools is found in the archives of the city of Lille', which is from 1302 and refers to the effects of Raoul II of Clermont in the Hôtel de Soissons, Paris,[76]

> Une englume et fos a souffler lx s.
>
> Unes tenailes bicournes, i martel et menus instruments
> de forge xiii s. vi d.
>
> Item unes venterieres v s.
>
> Item xxxviii fers faites xii s. viii d.
>
> Item sas a cleus, tenons environs v sommes xxi l. v s.
>
> Item xiii douzaines de fer de Bourgoyne xxii s. vi d.
>
> An anvil and pipe for air lx s.
>
> Item pincers (tongs), bickiron, hammer, and minor instruments
> of the forge xiii s. vi d.
>
> Item bellows v s.
>
> Item xxxviii (pieces) of made iron (rivets?) xii s. viii d.
>
> Item a lock with key holding around five weights xxi l. v s.
>
> Item thirteen dozens of iron from Burgundy xxii s. vi d.

Although short this entry contains many important pieces. The anvil is separate and distinct from the bickiron indicating that it is not a heavy anvil stake, quite similar to a bickiron, and is probably a block anvil.[77] The bickiron itself, an inverted L-shaped tool, served the same function as the horn of the anvil but was a separate instrument set

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[76] ffoulkes, *The Armourer and his Craft*, pp. 24-25. English translation by Ms Sarah Lynch.
[77] Untracht, *Jewelry*, p. 241. The Royal Armouries has a number of 'stump anvils', see for example XVIII.830, Figure 8.

into the anvil stand or a workbench.[78] The *fos a souffler*, conduit of air, is the tuyere or pipe which attaches the bellows to the forge. Since it is listed with the anvil it is likely to be an iron pipe as opposed to ceramic or some other material. The pincers are almost certainly tongs; in some cases 'pincers' refers to small cutters, but this is usually only the case when pincers and tongs are listed together. The hammer and bellows are self-explanatory, and the 'minor instruments of the forge' would have included small tools such as files, punches, chisels, and anything else which did not warrant its own entry.

The supplies consist of the thirty-eight pieces of iron, which are probably rivets, 156 pieces of iron from Burgundy for forging plates to make armour, and a chest with a lock containing an unknown item. The lock is particularly expensive, but the price also would have included the chest as well as whatever the five weights were and so reflect this; what was in the chest can only be speculated upon.

Much more complete than this are indentures found in the *Accounts of the Constable of Dover Castle* dating from 1344 and 1361.[79] These inventories list many things in addition to tools, but are more complete than the entry above and include almost all the necessary equipment of the armourer. The language of the indentures is quite difficult; the first, in Latin, is clearly influenced by Anglo-Norman French, while the second, in French, is influenced by Middle English. This difficulty is made more acute by the use of very technical terminology, but despite these problems they are quite useful. The first entry, dated December 20, 1344, includes an entry for the *Fabrica*,[80]

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[78] Also variously spelled bick, bicorn, bickhorn, and bickern. This stake may be single or double horned. A single horned raising stake from the Greenwich Armoury is held by the Royal Armouries, temporary inventory letter U, see Figure 9.

[79] Albert Way, 'Accounts of the Constables of the Castle of Dovor', *The Archaeological Journal*, 11 (1854), 381-88.

[80] Way, 'Accounts of the Constables of the Castle of Dovor', p. 382. Where editors have chosen an i or a j, their usage has been maintained throughout.

> Item, in FABRICA; ij. maides, ij. bicorn’, iij. martellos magnos, iij. martellos parvos, ij. tenaces magnas, quinque tenaces parvas, ij. instrumenta ad ferrum cindendum, iiij^{or}. instrumenta ferrea ad claves inficiendos, ij. paria flaborum, j. folour de ferro, j. mola de petra versatilis, pro ferro acuendo, et ij. ligamina de ferro pro j. buketto.

> Item, in the FORGE; two anvils, two bickirons, three large hammers, three small hammers, two large tongs, five small tongs, two tools for cutting iron, four tools for making rivets, two pairs of bellows, one fuller of iron, one grindstone for sharpening iron tools, and two iron bands for one bucket.

This inventory includes an important distinction which will be seen in several further entries, the division of tools by size. In this case the hammers are described as *magnos* and *parvos*, which gives no information about their function but does show they are not the same type and probably cannot be used for the same purpose. This may be a difference between heavy sledges and hand hammers, or between hand hammers and even smaller ones for detail-work, but in either case they are distinct.

This entry contains several interesting tools which were probably in every workshop in some form, even if they were not listed in a surviving inventory. The cutters may be shears but are more likely the small nippers found in later inventories. ffoulkes interpreted the next item as some sort of tool to close rivets, while Thom Richardson described them as ‘end cutters’ for trimming rivets.[81] Neither of these interpretations, however, take into account that *inficiendos* in the text is a misspelling and should be read *infaciendos*. From this it is clear that the tools are for making the rivets, or nails, and not closing or cutting them. This would also explain why there are

[81] ffoulkes, *The Armourer and his Craft*, p. 26, and Thom Richardson, ‘Armourers’ Tools in England’, *Arms & Armour*, 9 (2012), 25-39 (p. 25).

four of them; the tool was used to create a head on a piece of rod which had to be the correct size, requiring a different tool for each diameter of rivet.[82]

The pair of bellows was an integral part of the forge; that there are two sets here perhaps indicates that there were two forges or that one was a spare so that work did not have to halt in the event of a punctured bellows. The grindstone was for sharpening and cleaning tool faces, though it could also have been used for grinding plate surfaces. This would have been the same type of tool seen in the Utrecht Psalter of the early ninth century or one in a mid-fourteenth century manuscript of the *Romance of Alexander*.[83] Another small grindstone is listed amongst the gear for siege machinery.[84]

The second indenture from Dover is dated January 26, 1361, and is in several respects much like the preceding one.

> En la FORGE; ij. andefeltes de fer, j. andefelte debruse, j. bikore, iij. slegges, iiij. hameres, vj. paires tanges dount deux grosses, iiij. pensons febles, iij. nailetoules pur clause en icles faire, iij. paire bulghes dount une novell, j. peer moler, ij. fusels de feer aicele, j. paire de wynches as mesme la peer, j. trow de peer pur ewe, j. hurthstaf de feer, j. cottyngyre, j. markyngyre, une cable vels et pourz.

> In the FORGE; ij. iron anvils, j. pointed (horned?) anvil, j. bickiron, iij. sledges, iiij. hammers, vj. pairs of tongs of which two are large, iiij. weak pincers, iij. nail-tools for making the said fastenings, iij. pairs of bellows of

[82] These tools could also have several holes for different sizes. See for example a nail-maker in the *Mendel Hausbuch*, 'Die Mendelschen und Landauerschen Hausbücher', <http://www.nuernberger-hausbuecher .de/index.php?do=page&mo=2> [last accessed 19 September 2012], Mendel I, fol. 19r, Figure 10.

[83] *Utrecht Psalter*, Utrecht, Utrecht University Library, MS 32, fol. 35v, and the *Romance of Alexander*, Oxford, Bodleian Library, MS 264, fol. 113v.

[84] Way, 'Accounts of the Constables of the Castle of Dovor', pp. 382-83.

> which one is new, j. grindstone, ij. iron spindles for it, j. pair of cranks for the aforesaid stone, j. stone trough for water, j. iron hearthstaff, j. cutting iron, j. marking iron, a single cable one inch thick.

Here there are again the anvils, but this time what were two bickirons have been split into two entries. It is by no means certain that these two tools are the exact same as in 1344, but by 1361 there was a pointed anvil and a bickiron. The pointed anvil may be a stake anvil or it may be an anvil with a horn. The hammers are again listed by size more than specific function, and the tongs likewise are noted by size.

The *nailetoules*, described by ffoulkes as tools for closing rivets, are again more likely to be some sort of heading tool to create the initial heads rather than closing.[85] The grindstone has a set of spindles, or axles, and cranks for its operation and repair and a stone trough has replaced the bucket for quenching. Finally, there is an iron rod to tend the fire, a cutting chisel, and a pointed scribing tool for making marks in the metal.

In 1377, on the ascension of Richard II to the throne, a new helmet-maker was appointed whose workshop contained tools both new and old and which were recorded.[86] The list of tools is given thus:[87]

> Willelmo Snell, armatori Regis infra Turrim London' pro diversis instrumentis officii suum tangentis sibi liberandum per literam de privato sigillo datum xxvij Julii, anno regni eiusdem Ricardi Regis supradicti primo et indenturam eiusdem Willelmi de recepto ij anefelds magnos, iij anefelds parvos, j stych parvum cum duobus corners, ij bygornes, j persyingstich, j steryingbigorne, ij paria forcipium cornuta, j molarium parvum, ij paria sufflatoriorum, j furum de

[85] ffoulkes, *The Armourer and his Craft*, pp. 25-26.
[86] Richardson, 'Armourers' Tools in England', p. 27.
[87] Latin edition in Richardson, 'Armourers' Tools in England', p. 39. Translation by the author.

> plumbo, ij toneyrnes, ij fourbyngformes, v stakes de ferro, xij paria tenellorum, vij martella magna, iiij martella parva, j nayltoll.
>
> To William Snell, King's armourer at the Tower of London for diverse instruments regarding his office; releasing to him by a letter of the privy seal dated 27th July, in the first year of the above said King Richard and by indenture of the same William regarding his having recieved ij large anvils, iij small anvils, j small anvil with two horns, ij bickirons, j piercing anvil, j 'sterying' bickiron, ij pairs of horned cutters, j small grindstone, ij pairs of bellows, j form of lead, ij tun irons, ij furbishing forms, v iron stakes, xij pairs of tongs, vij large hammers, iiij small hammers, j nail tool.

Although similar to the preceding two lists, this one contains several items which have not yet been encountered, as well as some new terminology. The small *stych* is a stith, an old term for anvil, and has two horns, making it a small anvil stake. The *persyingstitch* was identified by Richardson as a punch or awl, but is an anvil, a 'piercing stith', most likely pierced with one or more holes used in punching holes in plates.[88] The 'sterying' bickiron is obscure, but may refer to its shape. The 'horned' cutters may refer to bench mounted shears, which had bent ends to their handles to attach them to blocks.[89]

The form of lead is one of the most interesting items listed. A large block of lead could be easily shaped into forms to dome plates, could be used for setting rivets without damaging their exterior heads, and when too marred to be useful could be

[88] Richardson, 'Armourers' Tools in England', p. 28. Anvils of this type may be seen in the *Mendel Hausbuch*, fol. 14r, Figure 11.
[89] See the Royal Armouries' great shears, Figure 12.

melted down and re-formed.[90] Lead could also be used as a backing for decorative embossing.[91] Of the remaining items, the 'tun irons' are most likely synonymous with the *ligamina de ferro* from the 1344 Dover inventory. The identity of the 'furbishing forms' is uncertain; the following entry of five iron stakes makes it unlikely that they are themselves stakes, and may be related to polishing. The final item, the nail tool, is a tool for making the rivets as at Dover.

Little changed in the armourer's workshop between the fourteenth and fifteenth centuries. An inventory of the armoury of the Gonzaga family of Mantua from 1407 records a few tools amongst a very large amount of armour:[92]

> Due Tenalie pro Incidendo ferrum.
>
> Duo Incudines longi forma vnius palli ferri.
>
> Viginti sex libre de smiraglo Integri pisto et non pisto.
>
> 2 pincers for forging iron.
>
> 2 long anvils, in the form of a single iron stake.
>
> 26 pounds of emery, part ground and part not ground.

Missing are the hammers without which the anvils are essentially useless. There is no indication of a forge or any cutting tools, nor any files or other small tools. Any armour making or repair was perhaps carried out in another location, or only the larger items were recorded. An inventory of the same armoury taken in 1542 lists 'An old field

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[90] The armourer's workshop at the Royal Armouries contains such a block. Price also discusses the use of a lead block in TOMAR, pp. 93-94.

[91] Arwidsson and Berg, *The Mästermyr Find*, p. 16.

[92] James G. Mann, 'The Lost Armoury of the Gonzagas', *Archaeological Journal*, 95 (1938), 239-336 (pp. 277 and 281).

trunk containing tools for repairing arms', so it appears that a set of tools was at least kept with the armour to be taken into the field for furbishing work.[93]

Although not inventories *per se*, a letter from the papers of John Paston from *c*. 1468 of what is proper for a man to have in a joust or judicial combat list armourer's tools as necessities. The first part, an 'Abilment for the Justus of the Pees', gives the following:[94]

> And ij dosyn tressis...
>
> And a Armerer with a hamor and pynsons.
>
> And naylys, with a byckorne.

The second relevant part, titled 'The day that the Pelaunt and the defendaunt sall fighte what they shal have w[t] hem in the felde', along with the two gallons of wine, food, and other utensils, is very similar:[95]

> Also, a dosen tresses of armynge poyntis.
>
> Also, an hamyr, and pynsones, and a bicorne.
>
> Also, smale nayles, a dosene.

The arming points were cords used to tie armour onto the underlying garments, a relatively weak and vulnerable component of armour which would need to be replaced frequently. The hammer and tongs, again listed as pincers, are quite expected, as are the

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[93] Mann, 'The Lost Armoury of the Gonzagas', p. 299. The same inventory also includes the following entry, 'E più dui cocodrilli grandi', or two large crocodiles. This is most likely in reference to the personal device of Sigismondo Gonzaga and his motto, *crocodili lachrimae*. See Mann, 'The Lost Armoury of the Gonzagas', pp. 256 and 298-99.

[94] Albert Way, 'Illustrations of Medieval Manners and Costume from Original Documents: Jousts of Peace, Tournaments, and Judicial Combats', *Archaeological Journal* 4 (1847), 226-39 (pp. 228-29) and Francis Douce, 'On the Peaceable Justs, or Tiltings of the Middle Ages', *Archaeologia*, 17 (1814), 290-96 (pp. 292-96). The letter is now known by the title 'Hou a man shalbe armede at his ease whan he shall fight on foote', and is f. 9[r]-9[v] from British Library MS Lansdowne 285, the 'Grete Boke' of Sir John Paston, *c.* 1468. See G. A. Lester, *Sir John Paston's 'Grete Boke': A Descriptive Catalogue, With an Introduction, of British Library MS Lansdowne 285* (Cambridge: D. S. Brewer, 1984), pp. 7 and 84-85.

[95] Way, 'Illustrations of Medieval Manners and Costume', p. 235.

rivets which are also prone to damage. The bickiron is listed alone with no other stakes or anvils, probably because it was small, easy to transport, and quite sufficient for the repairs in the field expected for this type of combat.

Another inventory, this one from 1485, is also brief, seemingly only giving the most important items. The hammer, stake, and tongs are the most basic of the tools used by many metalworkers, but they are not the only ones required for fine armour-making, especially for what is clearly to be a particularly fine harness: [96]

> It'm ij. yerds iij q̃rters of Corse
> of rede Sylke.
> It'm d'yerds d' q̃rters of rede
> velewet.
> It'm iiij grosses of poynts
> It'm vj Armyng nayle.
>
> All splendid and moch more to oon of the Kings herneys.
>
> It'm hamer, j bequerne, j payr of pynsonys, iij pounde of wyre which was sold by Mastr. Wylliam Fox armerer

The silk and velvet could have been for the garments worn with the armour or for covering and lining the armour. It is curious that there are only six rivets recorded and that they are with the textile supplies and not the iron. Possibly this indicates that they are specially prepared rivets, gilt or otherwise decorated and therefore more noteworthy than other rivets. The three pounds of wire may have been thin stock for making the plainer rivets required for assembling armour; it is unlikely that the wire is for mail since there is not much of it. Missing are a great number of tools that would be

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[96] 'An Inventory of Certain Articles Delivered out of the Armory at the Tower; Contained in the Schedule to a Writ of Privy Seal; Anno 33 Henry VI, Preserved among the Records in the Tower', ed. by Samuel Lysons, *Archaeologia* 16 (1812), 123-126 (p. 125).

expected in a workshop, but perhaps the hammer, bickiron, and tongs or pincers were bought from William Fox and added to an existing workshop's array of implements.

Two particularly useful lists of tools come from the foundation of the Greenwich workshop in the early sixteenth century, both from 1511. Although dating from after the end of the fifteenth century they can still be used in the study of earlier workshops because of the relatively stable nature of the tools. These inventories do not list the contents of an established workshop but instead list those things bought for setting up a new one and the prices paid for the various implements. The first concerns the establishments of a glazing, or polishing, mill at Greenwich.[97]

> 11th July, 1511. To John Blewbery, for a mill wheel with stondard, 2 beams, and brasys belonging thereto, and two small wheels to drive the glasys, 40*s*.; for two elm planks for lanterns for the same mill, 5*s*.;...13lbs. of tin at 5*d*. lb.; 28lbs. of white soap for tempering the said mill at 2*d.* lb.; 500 gauntlet nails, 8*d*.; 100 and a half of iron, 4*s*. 8*d*.; three rivetting hammers, 2*s.*; a pair of pynsors, 2*s*. 8*d*.; four crest files, 4*s*.; two great files, 5*s.*; 100 and a half of steel for vambraces and gauntlets, 60*s*.

Here there is the grinding wheel and machinery to drive it, and the soap to maintain the wheel's face and perhaps to lubricate the beams and pinions (lanterns) of the system. Rivets have been purchased ready-made, though the iron and steel appear to have been bought in an unfinished state. The crest files are rounded files to reach into the curvature of flutes and ridges, while the great files are large flat ones for more general work. When compared with the following entry it is apparent that here the pincers are cutters and not tongs.

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[97] J. S. Brewer, J Gairdner, and R. H. Brodie, eds., *Letters and Papers, Foreign and Domestic, of the Reign of Henry VIII : Preserved in the Public Record Office, the British Museum, and Elsewhere in England*, 21 vols (London: Longman, 1862-1910), 1.2, 1496.

The second of these early Greenwich documents is from two months later and gives the tools needed for the main armour workshop itself. The level of detail in this inventory is excellent, and represents nearly everything one would expect to find in a workshop. It does not appear that the 'Armarers of Brussells' brought many, if any, tools with them to England.[98]

> xviii September. Also payde by Owre Commandement to John Blewbery for the new fforge at Greenwiche made for the Armarers of Brussells these peces ensuynge, a vyce xiii s. iv d., a greate bekehorne lx s., a smalle bekehorne, xvi s., a peyre of bellowes, xxx s., a pype stake iii s. iv d., a Creste stake iv s., a vysure stake iv s., a hanging pype stake iv s. iv d., a stake for the hedde pecys, v s., ii curace stakes, x s., iv peyre of Sherys xl s., iii platynge hamers viii s., iii hamers for the hedde pecys v s., a creste hamer for the hedde peces xx d., ii hamers, ii s. viii d., ii greve hamers iii s. iv d., a meek hamer xvi d., ii pleyne hamers ii s., ii platynge hamers ii s., ii chesels wt. an halve viii d., a creste hamer for the curace xii d., ii Rewetinge hamers xvi d., a boos hamer xii d., xi ffylys xi d., a payre of pynsors xviii d., ii payre of tongs xvi d., a harth stake vi d., ii chesels & vi ponchons ii s., a watr. trowgh xviii d., a temperinge barrelle xii d., one Andevyle xx s., vi stokkes to set the Tolys x s., xvi dobles at xvi d every doble xxi s. iv d., xviii quarters of Colys vi s. ix d.

Again there are tools differentiated by size, but in this case there is a greater variety described by function. Hammers and stakes in particular are said to be for the cuirass, helmet, visor, and greaves, and also for laying 'crestes', or flutes. The shapes are not

[98] Charles ffoulkes, *Inventory and Survey of the Armouries of the Tower of London*, 2 vols (London: HMSO, 1916), I, 48-49, and Richardson, 'The Royal Armour Workshops at Greenwich', p. 148.

given but it is likely the cuirass stake was a mushroom stake, the helmet stake was a raising stake, and the crest stake was some sort of chisel-shaped stake.[99] The visor stake may have been a particularly tapered stake to accommodate the long, pointed visors then in vogue. Differences in hammer type would have been in peen size. In addition, several of these tools could have been interchangeable but may have been reserved for specific functions to extend their working life by reducing use and ensuring they were not used for other tasks which may have risked damage.[100]

The vice was a new addition to the armourer's workshop, in use at least by the beginning of the sixteenth century or the very end of the fifteenth.[101] The operation of a vice requires a screw, which was known and in use in the fifteenth century but in a more limited capacity. The hanging pipe stake is rather enigmatic; there is already a pipe stake listed and it is unclear what a 'hanging' pipe stake is, though it is perhaps similar to a regular one save for having a bent face for working curved shapes. There are two quench tanks, one for water and one for tempering, probably owing to the tempering barrel holding something other than water. The most expensive item is the great bickiron at sixty shillings, twice the cost of the pair of bellows and three times the cost of the anvil. This represents the greater skill needed to make this tool and its relative complexity compared to the anvil.

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[99] Again refer to the raising stake in the Royal Armouries, of the same type though not necessarily the same tool.

[100] For example, chiselling should not be carried out over a forming stake owing to the risk of badly marring the working surface of the stake, which would transfer marks onto the armour plate. For this reason modern London-pattern anvils have a 'cutting table' between the horn and the main working face that is unhardened, protecting the chisel from chipping and providing an area which is safe to mar while cutting.

[101] The earliest known use of the word 'vice' for a screw-operated clamping tool comes from an Appraisement of Goods dated January 15, 1500, 'j. hamers (sic), pynsons et unum scalprum, unum vise et diversa files valent in toto iijs.', in *Records of the Borough of Nottingham: Being a Series of Extracts from the Archives of the Corporation of Nottingham*, ed. by William Henry Stevenson and others, 9 vols. (London: Quaritch, 1882-1956), III (1885), 72-73. The earliest known image of a vice comes from a depiction of a locksmith from 1528 in the *Mendel Hausbuch*, Mendel I, fol 143[r].

The greatest variety evident is in the hammers. These are for specific pieces including the cuirass, helmet, and greaves; for particular techniques including fluting, riveting, and embossing; and for more general work. This last includes the plating hammers, which may have been basic cross-peen hammers and are curiously listed twice at different prices, two plain hammers, and a 'meek' hammer. This hammer, unidentified by ffoulkes, is most likely a hammer notable for its small size. Most of these hammers would have been cross-peened, the differences being in overall size, shape of the peen, and head length. Riveting and greave hammers would have had long heads to allow them to reach into armour. The embossing, or 'boos', hammer would have had a small, compact head. The faces of the peened hammers could have had a variety of shapes suitable for forging, doming, and planishing.

The records of Henry, Earl of Northumberland, contain further evidence for the assortment of tools and materials required for an armourer as part of a travelling retinue. Dating from 1513, this particular inventory records the whole equipage for the Earl and his household at the Siege of Thérouanne and is quite detailed.[102]

Emmery & oille for dessing my Lord's harnes.	It'm, iiij lb. of emmery for dressyng of my Lord's harnes. It'm,.....of oyle for dressing of my Lord's harnes.

[102] Francis Grose, ed., 'Equipage of the Right Honourable Henry Earl of Northumberland, at the Siege of Turwin, in France, 5 Henry VIII', in Francis Grose, Thomas Astle, and others, eds., *The Antiquarian Repertory: A Miscellaneous Assemblage of Topography, History, Biography, Customs, and Manners. Intended to Illustrate and Preserve Several Valuable Remains of Old Times*, 4 vols (London: E. Jeffery, 1807-09), IV, 345-73 (pp. 367-68).

Lether bokills & naylles for mendyng my Lord’s harnes.	It’m, a quarter of a hide of garnysshinge lether for my Lord’s harnes It’m CC^{m} white armyng bokylls for mending my Lord’s harnes. It’m, M^{ti} armyng nayles for mending my Lord’s harnes.
Towles conserning the mending of my Lord’s harnes.	It’m, a payre of nyppers, a payre of pynsores, a pomyshe, and ij fylles for mendyng of my Lord’s harnes. It’m, a small sti’the, a hammer, and all ouy^{r} stuffe and tolles belonginge an armorer. It’, viij yerds of white blaunkett for trussing of my Lord’s harnes in.

The emery and oil are for cleaning and preserving the armour against corrosion, and the ‘pomyshe’, or pumice stone, listed with the tools would also have been used for cleaning. Here also we see ‘nippers’ and ‘pincers’, showing a clear difference between the two implements. The ‘sti’the’ was probably a small stake anvil, already seen in the 1377 inventory of William Snell.[103] The ‘other stuff and tools belonging to an armourer’ is in essence the same as the 1302 inventory from Lille, all the small pieces not worth the trouble of recording.

Returning to the Greenwich armoury, there are several interesting entries found in the Tower of London inventories between 1611 and 1688. The first two relevant

[103] ffoulkes, *The Armourer and His Craft*, p. 80.

inventories date from 1611 and 1629. In these there are tools listed in three locations, 'Mr Pickerings woorkehouse', the 'Cutting house', and in the 'Locksmiths Office', all at Greenwich, demonstrating a division of labour between a main shaping area, a rough work area, and probably an area for small, fine work.[104]

None of the stakes are given any function-specific names except for the 'ryffe irons and stakes of iron'. Since there are also 'ryffe' hammers these would appear to be related, probably tools for 'rough' work although they may be of rough quality.[105] Some of the bickirons and hammers are again described by size rather than function, although one of the large hammers is specifically for a water-driven helve hammer. The differentiation between 'forging' and 'hand' hammers is again one of size as well as function. There are also 'Sheeres standerdes', large bench or stump mounted shears, exemplified by the pair in the Royal Armouries from the Greenwich workshop.

The tongs are given specific names in several cases. There is a pair of filing tongs, 'shiver' tongs, and three pairs of gilding tongs. 'Shiver' here most likely has its now more obscure meaning of cutting or fracturing, and the tool is almost certainly what has been called a 'nipper' in other inventories, a small cutter for wire or small plates. The filing tongs are probably a type of hand-vice used to securely hold pieces while filing rather than typical tongs.[106] The gilding tongs were perhaps kept separate from the others due to mercury contamination from the gilding process.

All the spaces have bellows, though only the Workhouse has forges specifically mentioned, including the interesting entry for 'One panne of Iron for fier with fower

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[104] Royal Armouries, Leeds, 1913 RAR.13, 'Copies of Inventories and Papers Relating to the Royal Armouries of the Tower of London, etc., etc.', pp. 55-61. See Appendix A, pp. 275-78.
[105] Another possibility is that they are tools for cutting, perhaps a cut-off stake and a set chisel. 'Ryffe' is also an early form of 'rive', to cut, tear, or pierce.
[106] These tools, called hand vices today, are seen in use in Mendel II fols. 3^{v}, 5^{r} and 12^{r}. See Figure 13.

wheeles', evidently a portable forge for use in the field.[107] The armourers described in Shakespeare's *Henry V* would have used portable forges of this sort for their work before the battle of Agincourt, when

...from the tents
The armourers, accomplishing the knights,
With busy hammers closing rivets up,
Give dreadful note of preparation.[108]

These two 'pans of iron for fire' may both be a type of free-standing forge, while the bellows for the other two spaces were for forges built into the fabric of the building.

There is little in this inventory that has not been seen in some form in the earlier inventories. Two items not encountered before are the 'mould of iron', most likely a hollow iron dishing block, and the 'counter borer' used to counter sink the holes for flush rivet heads.[109] Holes were bevelled on armour plates for flush rivets or as a finish, and this could have been carried out with file, drift punch, or an auger as listed here. Dishing forms could easily be made in wooden stumps or lead and the probably cast-iron version here was most likely a recent innovation.

The next Tower inventory of note is from 1629, and differs from the preceding entry in the arrangement of tools and in some descriptions. There is much less in the Locksmith's Office, not even enough to carry out work. Items are still classed largely by size but now there are 'buckle hammers' in the Cutting House. There are also three grinding stones which were not listed before.

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[107] Tower Inv., p. 60.
[108] *The Norton Shakespeare*, ed. by Stephen Greenblatt (New York: Norton, 1997), *The Life of King Henry V*, IV.0.11-14. ffoulkes believed that the reference to armourers 'accomplishing the knights' indicated that they were riveting the armour shut while the knights were wearing it. It is much more likely that Shakespeare was describing the work of carrying out necessary repairs before the knights donned their armour. See ffoulkes, *The Armourer and His Craft*, p. 33.
[109] Tower Inv., pp. 59-77.

By 1660 almost all the tools had been relocated to the Tower, with no further mention of the Workhouse, Cutting House, or Locksmith's Office. Of those that remained there are some interesting points due to the rather more descriptive names given to the tools. Among them are 'tramping', 'round', and 'welting' stakes; the tramping stake may be a type of planishing stake, while ffoulkes believed the welting stake was used 'for turning over the edges of iron'.[110] It is more likely that they were used in the creation of flutes, which resemble welts. There is also an 'old tew iron', the pipe, or tuyere, for connecting the bellows to the forge. This is the same article as the *fos a souffler* in the 1302 inventory from Lille.

The end of the 1660 inventory gives a grim description of the state of the Greenwich armouries upon which the vicissitudes of time, misuse, and vandalism 'during the time of the late disctraccions' had taken their toll. It also gives a few other details about the operation of the workshops while it was still a centre of production, in particular the glazing mill, and describes tools by size as well as specific function:

> That all the severall Tooles & other utensills for makeing of Armour, formerly remaineing in the Master Armourers workehouse there, & at the Armourers mill, were alsoe within the tyme of thee said distraccions taken & carryed away (saveing two old Trunckes bound about with Iron, which are still remaineing in the said workehouse, one old Glazeing wheele, still at the mill, one other glazeing wheele sold to a Cutler in shoe lane): ...That the great Anvile (called the great Beare) is now in the Custodie of Mr Michaell Banten, locksmith at Whitehall, & the Anville knowne by the name of the little Beare, is in the custody of Thomas Cope, one of his Majesties Armourers; And one Combe stake in the Custody of Henry Keame one other of his Majesties Armourers: And that the said Mill, formerly Employed in

[110] ffoulkes, *The Armourer and His Craft*, p. 35.

> grinding, glazeing & makeing cleane of Armes, is destroyed & converted to other uses...[111]

Many of the earlier tools survived at the Tower as recorded in the inventories of 1676 and 1688, and appear to have been added to. There are few differences of note, though there is further description. In 1676 some of the bickirons have two horns and are likely T-stakes while some of the anvils are noted for having horns.[112] The mould of iron has become an 'Iron hollowing Block', and a hollowing hammer is listed in 1688.[113]

It is important to note how little change there is in these inventories, which span a period of approximately three hundred years. Although they develop in the amount of detail recorded for the most part there is very little difference between the workshop of 1350 and of 1650. Indeed, the similarities go much further than that and this sample only serves to highlight the stability of the smith's trade over time, despite changes in taste and fashion. Hinged tongs, hammers, and other tools found in the Greenwich armouries did not differ greatly from the tools found in the early-medieval Mastermyr tool chest.[114]

Development at the end of the Middle Ages and beginning of the Renaissance included the vice and water-powered glazing mills, and later the double bellows would be replaced by the double-chambered great bellows.[115] Nevertheless, the implements of the armourer remained largely unchanged throughout the Middle Ages. The way in which they were used also seems to have undergone little change as will be seen in the

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111 Tower Inv., p. 91.
112 Tower Inv., p. 99.
113 Tower Inv., pp. 128-29.
114 Arwiddson and Berg, *The Mästermyr Find*, pp.21-25 and 36.
115 Bealer, *The Art of Blacksmithing*, pp. 54-55. This last development marked the final major change in the blacksmith's shop until the nineteenth-century introduction of power hammers and caged blowers.

discussion of artistic representations of armourers and in the later analysis of the marks of those tools on the armour.

The following table summarises the tools found in these inventories in order to further demonstrate the stability of the workshop over time. The two entries from the Paston 'Grete Boke' have been reduced to one as they are essentially identical. The two 1511 entries have been counted as one since they are from the same period of the same workshop. Supplies such as rivets and iron have not been included.

Table 1. Breakdown of tools found in workshop inventories

	1302	1344	1361	1377	1407	1468	1485	1511	1513	1611	1629
Anvil	1	2	3	6				1	1	7	9
Bickiron	1	2	1	3	2	1	1	2		9	4
Hammer	1	6	7	11		1	1	23	1	50	28
Tongs	1	7	6	12	2	1	1	2	1	25	4
Stakes				5				7		32?	1
Files								17	2	1	1
Bellows	1	2	3	2				1		4	3
Forge	1?	1?	1?	1?				1?		2	1
Nail headers		8	3	1							
Quench tank		1	1					2			
Grindstone		1	1	1							3
Chisel			1					2		5	1
Punch								6			
Nippers		2?	4					2	1	1	1
Shears				2						4	7
Vice								1		5	4
Dishing form				1						1	1
Hearth staff			1					1			1

2.4. The Iconography of the Armourer at Work

A key source for the understanding of the work undertaken in an armourer's workshop is the depiction of armour-making in medieval manuscripts and artwork. These illustrate not only the types of tools in use but also the way in which they were used and the layout of the workshop. The value of using images of artists to understand their techniques, as opposed to an interpretation of their products, was recognised by Virginia Egbert in her work on artists depicting themselves, 'Little attention has been paid to the artists' own pictorial conceptions of their profession. This book has been compiled in the belief that it would be valuable to examine mediaeval representations of sculptors, painters, goldsmiths, and wood and ivory carvers actually engaged in their work'.[116]

There are difficulties in using artwork, particularly with regards to the accuracy of the representation. This centres mainly on the artist and his knowledge of the subjects he was painting. There is usually no way to know if these artists were ever in a workshop and they may have been copying other drawings or working by second-hand descriptions. However, the level of detail found in some images and the number of identifiable tools and techniques suggests that many of these artists did have at least good information when painting armourers and may have seen them at work.

The sources for these illustrations are quite varied. One source which is particularly bountiful with images of armourers is the *Mendel Hausbuch*, which records the retired Nuremberg craftsmen who lived at a house established for them by Konrad Mendel in 1388.[117] Begun in 1425, entries were added to the *Hausbuch* until 1791, filling two volumes. Armourers are first shown in 1425, while the last appears in1592. Most images of armourers, though, are found as individual illustrations scattered

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[116] Virginia Wylie Egbert, *The Mediaeval Artist at Work* (Princeton: Princeton University Press, 1967), pp. 20-21.

[117] 'Die Mendelschen und Landauerschen Hausbücher', <http://www.nuernberger-hausbuecher .de/index.php?do=page&mo=2> [last accessed 19 September 2012].

amongst medieval manuscripts and artwork. It is most usual to find armourers in works on subjects of myth, such as Vulcan and Minerva, and other military and craft-based depictions.

There are naturally conventions in the representation of armourers, some of which do not accurately reflect their work but which can be used to identify more accurate depictions. Even with inevitable inaccuracies, as Egbert points out and as particularly relevant to the present subject, 'the realism of these representations of artists can be fairly judged by comparisons of the sculpture, painting, metalwork, and carving that they are depicted in the act of creating with actual pieces of contemporary mediaeval art'.[118] The use of artwork can confirm theoretical construction techniques as well as elucidate otherwise obscure ones.

One typical convention is to show the armourer before a stump, either with a stake or in more simplistic illustrations a block anvil, with a completed helm held on it face up with tongs while he beats it with a hammer. This does not accurately show how armour was made because the completed pieces would not be hammered after assembly due to the risk of damaging joints. Because of the context of these images, often Minerva instructing in the craft or Vulcan forging the arms of Aeneas, it is clear that armour is being produced and not repaired so they are likely to be representative of armour-making in general rather than an exact depiction of a process.

The inaccuracy of this type of depiction is explained by the need to show a complete piece of recognizable armour in order to signal that the subject is in fact an armourer and not some other type of craftsman, sometimes accomplished by displaying finished armour in the background if there is enough room, or on the anvil if there is not, seen with many illustrations of armourers. The first is of Vulcan, from the early

[118] Egbert, *The Mediaeval Artist at Work*, p. 21.

thirteenth century and one of the earliest known images of an armourer at work.[119] The early fourteenth-century *Codex Manesse* includes two men shown as armourers, one of which is very similar to Vulcan.[120] This convention continued to be used through the fifteenth century.[121]

An interesting example of this type of depiction actually comes directly from a piece of armour, a burgonet made in Augsburg by Desiderius Helmschmied and Jörg Sigman for Emperor Charles V between 1550 and 1555.[122] This fantastically embellished helmet contains many scenes, including one on the front left which appears to be Minerva in an armourer's workshop, or possibly a depiction of Venus and Vulcan.[123] In the small, cramped space the armourer is seated before a large anvil, hammering what appears to be a helmet skull which he holds in tongs. To one side is a large brick forge, and behind is a work table covered with tools. Finished elements of armour are scattered about the floor and walls. This piece is self-referential in that it is a depiction of an armour maker made by someone actually engaged in the process of making armour, unique among all the pieces discussed here.

Another common convention shows many men at work at the same anvil and on the same piece, typically a master and two or three apprentices.[124] They may be beating out a formless bar of iron or appear to be engaged in fine shaping. This stance is not reserved for armourers, and is found in illustrations of blacksmiths as well, due no

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[119] Venus and Vulcan, reproduced in ffoulkes, *The Armourer and His Craft*, p. 13, plate IV. See Figure 14.
[120] Heidelberg, Universitätsbibliothek Heidelberg Cod. Pal. germ. 848 fols. 256^{v} and 381^{r}. See Figures 15 and 16. Richardson states that there are no images of armourers from the fourteenth century, but these two in the Codex date between 1300 and 1340. See Richardson, 'Armourers' Tools in England', p. 29.
[121] See for example Paris, Bibliothèque nationale, MS Fr. 598, fol. 13 and London, British Library, Royal 16 G. V, fol. 11, Figures 17 and 18.
[122] Kunsthistorisches Museum, Vienna, HJRK_A_558. Illustrated in Bruno Thomas, *Deutsche Plattnerkunst* (Munich: Bruckmann, 1944), p. 108. See Figure 19.
[123] It is tempting to think that this is a self-portrait of Helmschmied or Sigman at work.
[124] See again Figure 6.

doubt to the use of strikers, extra men with large two-handed hammers, in heavy forging operations.[125] In this context the use of strikers in the armourer's shop is unsurprising; large iron plates had to be beaten to the correct thickness before cutting, an activity made much easier with several men. It is the apparent use of strikers in the shaping process which is rather unexpected.

Despite these inaccuracies artwork contains much information about the function of the workshop and use of tools. Images tend to be one of two types, either they are depictions of the shaping work or they show the finishing work. This leaves out many stages of production but does represent two important ones, and clues to the other processes may also be found.

The first plate armourer in the *Mendel Hausbuch*, from 1425, is seated at the anvil working on what appears to be a finished lower cannon.[126] Also shown are a pair of great shears and three completed pieces of armour. It is interesting that the artist chose to show the armourer with a shear rather than a forge as the forge figures prominently in many of the illustrations of metalworkers of all types in the *Hausbuch*. However, showing the shear may have emphasised that this craftsman worked with plates as opposed to rods or billets.

Indeed, none of the images of armourers in the *Hausbuch* include a forge until folio 155^{r} from 1535. Another interesting omission is stakes, all the armourers in the *Hausbuch* being shown hammering the armour over a plain anvil. This is doubly peculiar since stakes are a common sight in the *Hausbuch* for a whole variety of other trades. This may simply be the artist using the image of 1425 as a guide, but the basic

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[125] See for example an illustration of Jubal and Tubal-Cain in *Speculum Humanae Salvationis*, Vienna, Österreichische Nationalbibliothek, MS s. n. 2612, fol. 25^{v}, *c*. 1330-1340, Figure 20, and Figure 7.

[126] Mendel I, fol. 42^{r}, Figure 21.

structure of an armourer hammering a piece of armour over a block anvil is familiar from other depictions.

Chants royaux sur la conception, from the late fifteenth century, includes an illustration of a busy workshop which shows more than the conventional representation of armour-making as given above.[127] There are five people at work, three at the anvil and two at the forge. A quench tank is built into the pan of the forge and appears too small for very large plates. Air is provided by a pair of bellows, as described in the various inventories, which is operated by a woman standing next to it. A younger woman is working at the forge, tongs showing there is a piece in the fire and a hearth staff in her left hand as she tends the fire, while to her left is a raising stake set into a small stump, the 'bekehorne' set into a 'stokke' as given in the first Greenwich inventory.[128]

In the foreground are three men, presumably the master and two apprentices, working at a large block anvil. The master holds a breastplate with a pair of tongs, the exterior resting on the anvil and red-hot from the forge. In his left hand is a small hammer while the apprentices hold heavy short-handled sledges, or 'grete hamers'. This is evidently meant to represent a rough doming of the plate from the inside over the flat of the anvil, though it seems awkward and unnecessary to have three people involved. Most likely the image is a conflation of beating out iron stock and doming a breastplate from the inside, which would have required only one armourer. The woman at the forge and stake is tending the fire and appears to be engaged in raising.

The tools in the workshop are not unusual but are nonetheless interesting. The raising stake is upset above the tang to provide a steady base in the stump, just as two of

[127] Paris, Bibliotèque nationale de France, *Chants royaux sur la conception*, MS Fr.1537, f44, Figure 22.
[128] See Chapter II, p. 41.

the stakes held by the Royal Armouries, and the tapering working surface is curved downward.[129] This may be an example of the 'hanging pype stake' from the 1511 Greenwich inventory.[130] Above the forge on its hood are a number of loops for tools, including a pair of small nippers, listed as the 'payr of pynsonys' in the 1511 inventory, a centre-punch, a small hammer, and what appears to be a small round file. These are all tools which would be used for more delicate or detailed work and their placement over the forge shows that some of this work, such as hole punching, would have been done hot. Finally, in the quench tank there is a rod sticking out of the water, which by its brown colour can be identified as the handle of a hammer. One method of tightening a loose hammer head is to soak it in water, allowing the wood to swell in the eye of the hammer.

Another particularly useful image for the study of the workshop is the well-known woodcut of Konrad Seusenhofer and Maximilian I by Hans Burgkmair which shows nearly the whole process of making armour.[131] The layout of the shop is quite open; a large forge with a double bellows is set into the right-hand wall, with a basket of coal and a quench tank next to it. Leaning against the forge is a large sledge hammer for beating out sheets. A forging hammer lies on the floor showing that more delicate work was done there than just the heavy work requiring the sledge, such as hot piercing and raising. A block anvil on a large stump sits nearby, its corners mushroomed through use, with a pair of tongs also sitting on the stump. Opposite the anvil is a great shear for cutting out plates set into a low stump. Its seemingly awkward, upward-slanting angle allowed one person to press the whole weight of his body on the shear

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[129]See Figures 9 and 35.
[130] See Chapter II, p. 41.
[131] *Der Weisskunig: Nach den Dictaten und Eigenhändigen Aufzeichnungen Kaiser Maximilians I*, ed. by Marx Treitz-Sauerwein and Alwin Schultz (Vienna: F. Tempsky, 1891), p. 109. The woodcut is also reproduced in ffoulkes, *The Armourer and His Craft*, p. 21. See Figure 23.

while another held the plate. Below a table in the background is a jumble of unfinished pieces, with the flat blank of a cut breastplate clearly identifiable below a shaped helmet skull.

These elements represent all the initial work of the armourer, but it is the wide, cluttered workbench in the foreground where much of the shaping and embellishing would have taken place, as well as any decorating done in the workshop. Three armourers, including Seusenhofer himself, are seated upon stools higher than the level of the bench to allow an adequate posture for work. Into the bench are set a variety of stakes for different purposes, some of which may be identified from the activities of the armourers.

On the left Seusenhofer is shown with a helmet skull; the visor, one cheek piece, and the collar of the gorget are strewn on the bench in front of him. The skull is placed over a stake, perhaps a ‘stake for the headpiece’ or a ‘crest stake’, hiding its face but he is most likely planishing or working the helmet keel. The stake to the right of this has a square, flat head, and to the right of that is a very short wedge-shaped stake. To the right again is a chisel-faced stake for creasing or fluting, the ‘welting stake’. The middle armourer is curling a lame, perhaps for the pauldron to his right, from the interior. To his left is another armourer, probably working the flutes on the cuisse he is holding over a stake which would resemble the fourth to the left. He is using a long, thin cross-peen hammer which resembles Royal Armouries XVIII.98.[132] Near him is a poleyn with the lames attached, presumably for the cuisse, and between the middle and right-hand armourer is a sallet.

On the bench is scattered a wide array of metalworking tools. There are at least four hammers, all of the long cross-peen variety. The most numerous tools are the long, thin files, at least nine being clearly shown. Below the pauldron is what appears to be a

[132] See Figure 24.

graver, its bulbous handle designed to fit in the palm of the hand. The similar-looking tool to the left is more likely a chisel with its striking face mushroomed through use. Although it is difficult to say with certainty, the small, thin objects may be simple punches and drifts, which would have required a punching block or stake which is not shown.

Two other tools deserve mention. One is a narrow strip with two tines at either end, situated directly below the rightmost stake. Price describes this as a 'rivet spacer' used to prevent the rivet shank from expanding during peening, thereby allowing articulating rivets to move freely.[133] The second tool is an unusual three-pronged utensil below Seusenhofer. The tool resembles the spanner of Royal Armouries II.167, a jousting armour for the *Rennzeug*.[134] In the woodcut each of the tines comes to a point, rather than the forked ends of the spanner used to tighten nuts and bolts. This may be due to the limitations in detail inherent to woodcuts, or it may indicate another function for the tool, perhaps a sharpened scribing tool with three points, or an awl for piercing leather straps.

The result of all these tools and all this labour is displayed on the back wall above the flat, cut plates. Leg harnesses, breastplates, and other finished pieces for field and tournament are hung on pegs, perhaps ready to be packed for shipping.[135] However, as relatively complete as this woodcut is, there are some elements missing, and the whole process is not completely represented. All the work shown is being done cold, but there must have been work done hot as the forge was not only for annealing and heat treatment, and there is no indication of finishing or polishing.

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[133] Price, TOMAR, pp. 206-07.

[134] Karen Watts, private correspondence, 2009. See Figure 25.

[135] It is interesting to note that the lance rest and shield are shown on the wrong side, as if the woodcut were a mirror image. The initials H.B. are not reversed.

The representation of finishing work in medieval illustrations is scarcer than images of forging and hammer work. It is almost always depicted as being separate from the shaping area; although the workbench in the Seusenhofer woodcut is liberally covered in short handled files there is no indication of any other tools for polishing. In the fifteenth century the tool used for this was invariably the file and emery stick, attested to in the inventories already discussed and the images detailed below.

From Theophilus we know that there were files with round as well as flat faces.[136] In 1425 a file-maker is shown making a double-cut file in the *Hausbuch*.[137] The size of files could vary greatly as well, from small ones for detail work to very large ones with a loop around the handle and forearm to help brace the file against the work.[138]

The first armourer encountered in the *Hausbuch* is a harness polisher from 1425 at work on a spaudler.[139] The main working surface is a long narrow bench upon which the armour is placed, braced with a board that is held in place with wooden pegs. Extra holes in 7[v] along with a hammer in 101[v] show that the brace board is moveable and probably interchangeable, differently shaped boards being used to support various types and sizes of armour plates. In all but 87[r] there is a second table where pieces which have been finished are placed.[140]

Just as images of hammer men only show one element of the whole process at a time, so too these images of polishers only show the final stage. The tool these armour polishers are shown with is not a file but appears to be a polishing or burnishing rod,

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[136] Theophilus describes files that are 'square, round, half-round, triangular, and flat', as well as 'hollowed' files specially shaped to create a beading effect on wires. Theophilus, *De Diversis Artibus*, trans. by Dodwell, pp. 69 and 72-73.
[137] Mendel I, fol. 41[r], Figure 26.
[138] Mendel II, fol. 3[v], Figure 13.
[139] Mendel I, fol. 7[v], Figure 27.
[140] See Figures 28 and 29. Fol. 87[r] is a much simpler illustration, and the other pieces of armour are shown as if hung on the wall.

thus leaving out the grinding phase. The polishing stick itself is long and curved in the centre, either convex or concave depending on the piece being polished, with a strip of leather or cloth nailed to the curved area.[141] In every illustration there is a bag and a pot to hold the various abrasive compounds used to polish, particularly emery, which is recorded as being purchased for use by an armourer in the Howard household book.[142] By rubbing the emery onto the armour with the buffer the armour was brought to an even, bright surface. The same process could be used to clean armour as well, the purpose of the emery in the inventories of the Gonzaga armoury and the equipage of the Earl of Northumberland.[143]

In every illustration of a polisher in the *Hausbuch* except 17[v], which features a kettle hat, the polishers are working on assembled pieces, two full spaudlers and a frog-mouth helm. This may be artistic licence, a representation of the end product of the polisher's labour and not an accurate representation of his work, as each plate would have been polished before final assembly.

An armour polisher using this method is found in a depiction of Minerva in an armourer's workshop from *c.* 1460.[144] The basics of the representation are the same, but it does offer some additional details. The bench is larger and the polisher straddles it instead of standing beside it. The armour, a complete and decorated cuirass and fauld in this case, is held in place with a pair of iron hooks which have been wedged into the bench. Unlike the other illustrations this shows the polisher in the main workshop itself instead of in another location.

A final image of an armourer's workshop, once again Vulcan forging the arms of Aeneas, by Jan Brueghel and H. Van Balen dates from the early seventeenth century

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141 The nails holding this strip are clearly visible in fol. 7[v] but in none of the others.
142 HHB, II, 379.
143 See Chapter II, pp. 37 and 43-44.
144 Pfaffenbichler, *Armourers*, p. 63. See Figure 30.

but is fascinating in that it shows the entire process of armour-making, either directly or implied, from mining and smelting through forging and polishing, to the finished piece.[145] Although late, the only pieces of equipment shown which would not have been familiar to a fifteenth century armourer are those using a screw, including a vice, and the water-powered polishing wheels, which were in use in the early years of the sixteenth century.[146] Water-powered trip-hammers, forges, block anvils, and stump mounted stakes and shears are all in evidence.

One very interesting feature which occurs in this painting that is found in none of the others is the bench between the trip-hammers and the anvil at which Vulcan himself is seated. On the work surface are two wooden disks, upon which are thick black cakes. Although this is perhaps the most cluttered armourer's workshop of all, there are no tools nearby which seem to be directly related. Alan Williams and Anthony de Reuck described these as 'chipping blocks', or small flattening anvils.[147] However, it is more likely that these are blocks of pitch, the hard but yielding substance used by the embosser to create the sculpted surfaces so in vogue at the time, and which would have seen more limited use in earlier times as well.

Other images of metalworking are worth considering even if they do not depict armour-making. There are many illustrations of blacksmiths, goldsmiths, tinsmiths, and other craftsmen which can shed some light on the tools and techniques of the armourer. An engraving by the Master of Balaam from *c.* 1450 is a good example, showing many

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[145] Worcester, Massachusetts, Higgins Armory Museum, 'Venus at the Forge of Vulcan', 1606-1623, HAM #6166. See Figure 31.

[146] The first image of a harness polisher using a wheel in the *Hausbuch* is from 1523, Mendel I, fol. 138^{r}.

[147] Alan Williams and Anthony de Reuck, *The Royal Armoury at Greenwich, 1515-1649: A History of Technology* (Leeds: Trustees of the Armouries, 1995), p. 55. See Figure 32.

types of metalwork of a very non-military character.[148] The subject is Saint Eligius, patron saint of smiths, and gives a remarkably good image of a workshop.

Eligius himself sits in an episcopal throne before a stump with three stakes: a two-armed stake, a two-horned anvil stake, and a small creasing iron, a stake with a series of small swages. He is raising a vessel over the two-armed stake with a cross-peen hammer with a long head, very similar to armourers' tools of similar function. Although one of the arms of the stake is hidden, what is visible looks remarkably similar, if smaller, to a stake from the Greenwich Armoury in the Royal Armouries collection, which until recently was still in use.[149] Behind him is a large cone mandrel.

On the left is a work table for fine metalwork with bench pins, underneath which are leather pieces to collect every particle of gold or silver which may fall. On the table are many tools, and two people working at it, a man who appears to be preparing a piece for soldering and a woman who is using a tool to press forms into a die, the finished products sitting on the bench next to her. On the wall behind them is a rack of hammers, tongs, pincers, a small shear identical to that used by armourers save its size, gravers, and files. On the left is a youth pulling wire through a draw-plate, and next to him on the floor is a very long set of tweezer-like tongs, probably for use in casting or to tend the fire in the small forge which is well-suited to the comparatively low heat required for precious metals.

Despite the animals, the overall impression of the workshop is orderly with racks of tools and defined work spaces. Armour workshops are frequently depicted as being cluttered and filled with finished or half-finished pieces of armour, nowhere more pronounced than Brueghel's *Venus at the Forge of Vulcan*, but the basic principle of

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[148] Amsterdam, Rijksmuseum, the Master of Balaam, RP-P-OB-963. See Figure 33.
[149] Leeds, Royal Armouries, temporary inventory letter Z. See Figures 34 and 35.

divided work space remains the same. More importantly the tools in use are identical in shape, and in some cases size, to those of the armourer.

Another image of goldsmiths at work, from a manuscript of the Romance of Alexander, shows the men at much the same work as in Eligius' workshop but is from a century earlier, between 1338 and 1344.[150] Although not as detailed it shows the bench pins used in small detail work with the leather piece to catch shavings, tongs, hammers, files, and small forge necessary for their work and similar to those of the armourer. Armourers may have made use of bench pins to support their work when fretting edges or doing other fine file work, but unfortunately Burgkmair's woodcut does not show any on Seusenhofer's workbench. Finally, an illustration from the fourteenth century of Saint Dunstan shows him sitting before a stake hammering a plate. If it were not made clear that the figure was a monk he could just as easily be hammering out a piece of armour, so similar are the tools.[151]

2.5. Conclusion

What conclusions, then, may be drawn from this body of written and artistic evidence in regard to the workshop and practices of the medieval armourer? The documentation is scattered and fragmentary, but overall gives a very good impression of the arrangement of the spaces where armour was made. Although they may often have been the scene of almost frantic industry to meet the demands of princes and patrons they were for all that very ordered. There are clearly divided areas for heavy forging, detail work, cutting, storage, and in some cases polishing. This orderliness of the work space demonstrates the need for efficiency during work; each distinct stage required its own area free from the paraphernalia of other stages.

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150 Oxford, Bodleian Library, MS 264, fol. 164^{v}. See Figure 36.

151 Egbert, *The Mediaeval Artist at Work*, pp. 68-69.

The workshop must have been an extremely loud environment. The constant beat of hammers on hot and cold metal, the ringing of the anvils and stakes, and the blowing of the forge's bellows must have combined into a riotous cacophony. As one fifteenth-century writer put it in his *Complaint against Blacksmiths*, 'Dryue me to deth wyth den of here dyntes. / Swech noys on nyghtes ne herd men neuer: / What knauene cry, and clateryng of knockes!'[152] Biringuccio, when describing the men who worked with iron, noted that 'As you can understand, the unhappy workmen are never able to enjoy any quiet except in the evening when they are exhausted by the laborious and long day that began for them with the first crowing of the cock'.[153]

Besides the detrimental effect this undoubtedly had on the armourers' hearing, there was the other problem of the effect on the neighbours, seen in the *Complaint* but also in a London assize of nuisance from 1377. This complaint concerns a forge 'built of earth and timber', whose chimney was too low causing the coal smoke to foul the plaintiff's property, and what is worse the 'blows of the sledge-hammers (*grossis malleis*) when the great pieces of iron called "Osmond" are being wrought into "brestplates", "quysers", "jambers" and other pieces of armour, shake the storie and earthen party-walls...and spoil the wine and ale in their cellar.'

In their defence the armourers claimed that they were perfectly within their rights to practice their craft in that location and manner, and that 'men of any craft, viz. goldsmiths, smiths, pewterers, goldbeaters, grocers, pelters, marshals and armourers are at liberty to carry on their trade anywhere in the City, adapting their premises as is most

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[152] Nicola Masciandaro, *The Voice of the Hammer: The Meaning of Work in Middle English Literature* (University of Notre Dame Press: Notre Dame, 2007), p. 1.
[153] Biringuccio, *Pirotechnia*, p. 370.

convenient for their work'.[154] Unfortunately there is no resolution to the case. Given the workshop's location on Watling Street, some distance from the Thames, it is unlikely that the hammers were tilt or helve hammers owing to lack of water power and were in fact comparatively small hand-held sledges, capable of producing a great noise but hardly enough to cause the damage claimed by the plaintiffs.

In terms of the division of processes, only the Greenwich inventories are explicit in how labour is divided. That the hammering and polishing stages were usually in some way separate is borne out by specialist polishers and by the artwork which rarely shows the two stages together. The tools found in the inventories and images are almost entirely those for the shaping of iron plates; although the Greenwich texts include water-powered grinding wheels and helve hammers the use of water power is mostly confined to smelting and polishing.

The clamour and fumes, sweat and fire were all necessary. The most sublime works of the armourer's art were made in the same conditions as lower grade armour. Although a wealthy or court armourer's tools may have been of a higher quality or more numerous, the function and types of the tools themselves did not change and the basic assortment of implements could be found in any workshop.

[154] Misc. Roll. FF: 12 May 1374 - 7 May 1378 (nos 600-619), in *London Assize of Nuisance 1301-1431: A calendar* (1973), pp. 154-163 < http://www.british-history.ac.uk/report.aspx?compid=35982> [accessed 4 November 2011].

Chapter III: The Production of Armour

3.1. Introduction

The production of any piece of armour is a complex task regardless of the intended quality of the finished piece. Beyond the skill needed for the individual techniques, creating a practical object from a raw material requires careful thought and planning. What is done to a piece of metal can alter its behaviour during subsequent working, and the efficiency of a task is affected by what was done before. This interrelation becomes a key component in working out the order of construction for individual pieces, where the overlapping of marks shows how several of these steps were performed.

The division into stages, as evidenced by the tool marks and by other physical and written evidence, also clearly demonstrates the need for medieval armourers to plan each piece carefully, or to have an expert knowledge of how every hammer blow will change what comes next, or what must be done before another step may be done. While this may seem obvious given the virtuosity demonstrated by the greatest medieval armourers, it does demonstrate the subtle complexity which was at the heart of their work, a subtlety sometimes lost by the idea of the heat of the forge and inelegance of the hammer and anvil.

When making armour the work is divided into several stages based on the types of techniques used and the way they affect the plate. These broad stages encompass all the fundamental aspects of armour-making, from planning to final assembly. The stages may also be divided into smaller steps which may or may not be carried out depending on the shape, construction, and quality of the finished product. Even if there are fewer individual steps required, such as for a munitions grade sallet with less finishing and decoration, the major stages of production remain. In addition, the exact order of the steps, and even some of the main stages, are not etched in steel and may be carried out according to the armourer's discretion.[155] There are some instances where the order is determined by logical progression, for instance shaping must come before finishing, but this is not always the case. When order is not readily apparent, it is possible to identify which stage came first with some precision using the evidence on the armour.

A thorough understanding of these stages and steps is essential in being able to 'read' a piece of armour. They serve as a basic structure or guide to the technical processes, with which it is possible to show how any piece of armour was constructed. The techniques which have left evidence that is still visible are the most useful, being the easiest to record but also representing the last stages of work. Even those techniques which have not left visible evidence, not through damage and corrosion but because their marks have been obliterated by later work, can be revealing by showing how later steps interacted with earlier ones.

The techniques used during production will also be discussed in greater detail. These techniques must be fully understood both in relation to the stages and more basically how they affect the metal. This will allow for a full description of the processes involved in making armour, placing the techniques within the context of the whole process. More importantly, understanding these techniques is essential in order to 'read' the piece using the tool marks as described in the following chapter. To fully and accurately interpret the tool marks found on armour one must first understand the techniques from which their respective mark patterns come.

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[155] It would appear that piercing and decoration were interchangeable in order, but they still constitute separate phases of work. Decorative piercing such as fretwork is separated from the piercing stage partly due to the greater detail required and also due to the nature of the stage. 'Piercing' refers to punching holes for assembly, breaths, and sights.

3.2. The Raw Materials and their Production

During the Middle Ages the materials which armourers worked with most often were iron and steel. Iron is an element, its ore is common and plentiful in the Earth's crust and its ease of extraction and malleability after smelting has made it one of the defining materials of civilisation, highly prized for its utility as well as for its working properties. It has been used for weapons and armour, as an architectural element, and for tools for all types of craftsmen.[156]

Unlike copper, iron is almost never found in nature in its metallic state and is instead found as an ore, the element chemically bonded with oxygen.[157] These ores are composed of varying percentages of iron and impurities, with magnetite ores having the highest amount of iron at around 65% and hematite ores with slightly less at 50-60%. There are other types of ores with even less which are more difficult to process into usable iron.[158] These include bog ores, a type of limonite that has the appearance of growing quickly by collecting in nodules.[159] This may have given rise to the idea of regenerative ores recorded by Biringuccio in reference to iron from Elba, where so much ore had been mined over time that 'not only the mountains but even two islands like that one should have been levelled', and that some people believed that the ore 'regenerated anew in that soil which has already been mined'.[160]

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[156] W. K. V. Gale, *Iron and Steel* (London: Longmans, 1969), p. 1.
[157] Native, or telluric, iron is very rare, but is found in some places, for example in the American state of Connecticut and most significantly on Disko Island, off Greenland. While the Disko Island iron is workable, these deposits are not pure iron and had no effect on medieval Europe. See Rostoker and Bronson, *Pre-Industrial Iron*, p 41, and Paul T. Craddock, *Early Metal Mining and Production* (Edinburgh: Edinburgh University Press, 1995), pp. 101-03.
[158] Gale, *Iron and Steel*, p. 2.
[159] Rostoker and Bronson, *Pre-Industrial Iron*, p. 42.
[160] Biringuccio, *Pirotechnia*, pp. 61-62. Black lead in Britain is said to regenerate by Pliny the Elder, and Strabo states that stone regenerates on Elba and Rhodes. See J. F. Healy, 'Pliny on Mineralogy and Metals', in Roger French and Frank Greenaway, eds., *Science in the Early Roman Empire: Pliny the Elder, his Sources and Influence* (London: Croom Helm, 1986), pp. 111-46 (p. 116).

Like any metal, iron has certain working properties which a smith must take into account and these dictate the stresses which a piece can withstand, both during forming and in use after fabrication. One of the most important properties of iron is its ability to be worked at high temperatures, the high ductility of the material allowing it to be formed into many shapes. Iron can also be worked cold to a lesser degree, and can be easily forge welded to join pieces together. Due to its grain structure and the tendency for slag inclusions from the smelting process it is also prone to delaminating along the grain boundaries if forged at too low a temperature. Brittleness and toughness are two other factors which affect how the material is worked, brittleness indicating that the material breaks easily, and toughness that the material has the ability to deform without damage.[161]

When carbon is added to the pure iron the element becomes the alloy known as steel. Steel and iron behave differently under working conditions and have different properties concerning their strength and their ability to be heat treated. While iron cannot be hardened appreciably, an exception being high-manganese 'steely iron', the carbon content of steel allows it to be hardened and tempered in a process known as heat treatment.[162] This may either be a collective, two stage process where hot steel is hardened by rapid cooling then tempered by slow reheating, or it may be single-stage 'slack quenching', where the hot steel is immersed repeatedly in a quenchant, allowing the residual heat to temper while at the same time hardening.

Heat treatment makes the steel hard, useful for keeping an edge and resisting impact, but also greatly increases its toughness. Under the hammer the high carbon content of steel also makes it brittle in comparison to wrought iron and susceptible to cracking while being forged if not hammered at the correct temperature. Poorly

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[161] Rostoker and Bronson, *Pre-Industrial Iron*, p. 2.
[162] Leslie Aitchison, *A History of Metals*, 2 vols (London: MacDonald & Evans, 1960), I, 115.

tempered steel is also prone to cracking during and after cooling, known as cold shunting, either spontaneously or through repeated bending.

Before these metals can be worked they must first be smelted, the process of reduction which removes the oxygen from the ore. Oxygen and iron react easily, most commonly seen as rust, and in smelting the oxygen is removed by chemically bonding with carbon, which is also the fuel for the fire in the form of charcoal. In the furnace, ‘the carbon unites with the oxygen and goes off in the form of a gas, leaving the iron behind’.[163]

By the beginning of the fourteenth century ferrous metals had been known and worked for thousands of years, but in that time little had changed in mining and smelting technology.[164] Small furnaces were still used to reduce the ore into a mass which was relatively free of impurities, the sponge or bloom, which could then be worked into useable iron.[165] What was known of the smelting process was gained only by experimentation and observation in what has been called a ‘triumph of empiricism’.[166]

During the early part of the Middle Ages and before, small hearths were used in conjunction with manually driven bellows to provide the environment necessary for reduction. Temperatures created by this system never rose high enough to melt the iron, resulting in a lump of spongy iron which was removed from the furnace and hammered into a piece of wrought iron. This type of smelting is known as the direct process, a one-stage operation with a resultant product that can be heated and forged, or solid state reduction, since the ore does not melt in the furnace.[167]

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[163] Gale, *Iron and Steel*, p. 3.
[164] Aitchison, *A History of Metals*, I, 111.
[165] Aitchison, *A History of Metals*, I, 100.
[166] Rostoker and Bronson, *Pre-Industrial Iron*, p. ix.
[167] Craddock, *Early Metal Mining and Production*, pp. 241-46.

In the fourteenth century the combination of water power with larger smelting furnaces created the blast furnace, which differs from the earlier types of furnaces by melting the ore inside the reducing chamber.[168] Water power had first been harnessed for use in ironworking during the thirteenth century, for example in 1273 at S. Salvatore, in Siena, Italy.[169] Water-driven bellows are larger and can deliver a more powerful blast of air for as long as the wheel is driven, a great advantage over human-powered bellows.

Agricola's instruction in *De Re Metallica* on iron produced by the blast furnace begins with a description of the shape and size of the hearth, and how it was to be charged by the master who 'first throws charcoal into the crucible, and sprinkles over it an iron shovel-ful of crushed iron ore and unslaked lime'. The furnace was thus filled in layers, and the process of smelting could take eight to twelve hours.[170] The master was responsible for the level of ore and fuel, for tapping slag, and for controlling the flow of water which powered the bellows of the furnace, the result of his labours being that 'iron is melted out and a mass weighing two or three *centumpondia* may be made, providing the iron ore was rich'.[171]

As the iron travels down through the chamber it absorbs a great deal of carbon from the charcoal fuel, more than earlier furnaces due to the blast furnace's larger incandescent zone. This reduces the melting point of the iron from 1500°C to 1150°C. The molten iron is tapped from the furnace bottom and cast into ingots.[172] This cast

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[168] D. W. Crossley, 'Medieval Iron Smelting', in *Medieval Industry*, ed. by D. W. Crossley, CBA Research Report, 40 (London: Council for British Archaeology, 1981), 29-41 (p. 29).
[169] Maria Elena Cortese, 'Medieval Ironworking on Mount Amiata (Siena, Italy): Economy, Society, Technology', in *Prehistoric and Medieval Direct Iron Smelting in Scandinavia and Europe: Aspects of Technology and Society*, ed. by Lars Christian Nørbach (Aarhus: Aarhus University Press, 2003), pp. 55-59 (p. 56).
[170] Agricola, *De Re Metallica*, pp. 420-21.
[171] Agricola, *De Re Metallica*, p. 421.
[172] Aitchison, *A History of Metals*, II, 342-43.

iron can then be re-melted to burn off the carbon and create wrought iron, or combined with already produced wrought iron for making steel.[173] This two stage method of iron production is known as the indirect process owing to the intermediate cast iron stage which cannot be forged by a smith due to the high carbon content and requires further treatment to create a useable product.

Whether smelted in a one or two stage process, the resulting bloom of iron must be extracted from the furnace or finery and beaten with hammers.[174] According to Agricola it is first put on the floor where it is worked with hand hammers before being moved, still hot, to the trip hammer, a large hammer whose shaft is raised by cams and then allowed to fall onto the anvil below.[175] Beginning in the thirteenth century water powered tilt hammers were increasingly being used for this purpose. As a result of the water driven bellows and hammers used in the medieval iron industry it was important to locate suitable sites for the mill.[176]

Working the bloom with hand sledges and the heavy trip hammer serves several functions. First, at high temperatures the bloom is welded into a single unit and can be welded with other blooms to create larger pieces of iron. Second, during the welding process residual slags are forced out of the iron. Third, the grain structure of the iron is formed and elongated, with the remaining slags being extruded between the grain boundaries producing a more homogenous structure, though still quite heterogeneous by today's standards.

After processing the iron by hammering it is cut, again using the trip hammer and a set chisel. After cutting, 'These pieces, after they have been re-heated in the

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[173] Crossley, 'Medieval Iron Smelting', p. 39, and R. F. Tylecote, *A History of Metallurgy* (London: The Metals Society, 1976), p. 65.
[174] It is from this hammering that the term 'wrought iron' is derived.
[175] Agricola, *De Re Metallica*, pp. 421-23. This hammer is also sometimes called a tilt or helve hammer.
[176] Aitchison, *A History of Metals*, II, 310.

blacksmith's forge and again placed on the anvil, are shaped by the smith into square bars or into ploughshares or tyres, but mainly into bars'.[177] The iron in bar form would have been easier to transport than larger masses of iron and could be shaped to standard sizes for the market.

Iron produced using the indirect method of smelting is made using, for the first stage, either a high bloomery, a 1444 reference to fining pig iron providing the earliest reference in Germany, or a blast furnace for the production of cast iron, and for the second stage a fining hearth which decarburized the cast iron through 'exposing it to hot oxidizing conditions in a charcoal fired hearth'.[178] The capability of melting the ore is one of the main distinctions of the blast furnace which differentiates it from earlier smelting furnaces which could only create solid blooms, though the high bloomery, as an intermediate development, was able to produce both solid blooms and cast iron.[179]

As the cast iron melts in the furnace it collects near the bottom of the hearth. The resulting mass, called a 'loup', was stirred and re-melted in the furnace until it could 'no longer be melted under the tuyère blast which indicates that the carbon has been entirely removed'. The loup was therefore essentially the same as the bloom from a bloomery.[180] Working the loup would then continue in the same way as working the bloom in the direct process.

Iron may be alloyed with carbon to create steel and cast iron. Steel is much stronger than iron and may be heat treated, while cast iron during the Middle Ages was a step in the process of iron and steel production resulting from the use of the blast furnace. Carbon is added to the iron either during or after smelting, less than 2% being

[177] Agricola, *De Re Metallica*, p. 423.
[178] Starley, 'Medieval Iron and Steel Production', pp. 31-32 and 35.
[179] Starley, 'Medieval Iron and Steel Production', p. 33 and H. F. Cleere, 'The Classification of Early Iron-Smelting Furnaces', *Antiquaries Journal*, 52 (1972), 8-23 (pp. 8-9).
[180] Starley, 'Medieval Iron and Steel Production', pp. 31-32.

required for steel.[181] According to Paul Craddock, 'To produce steel which regularly contains a controlled amount of carbon has been one of the principal aims of the smith for over three thousand years'.[182] Experimentation led to advances in steelmaking techniques, which were the product of empirical observation since the role, indeed the existence, of carbon would not be understood until the late eighteenth century.[183]

Biringuccio's description of the nature of steel includes an accurate account of the visible changes in the crystalline structure of steel which has been heated and rapidly cooled. To Biringuccio, after iron had been changed into steel it seemed 'almost to have been removed from its original nature', though he understood that they were still in the same group of metals and therefore treated them together.[184] Agricola's instructions for steel production are much like those in *Pirotechnia*.[185]

David Starley identifies four methods of creating steel during the Middle Ages and early Renaissance:

1. Primary carburisation of iron within the bloomery furnace.
2. Secondary carburisation of iron, from either bloomery or finery.
3. Partial fining of cast iron.
4. The Brescian process.[186]

Primary carburisation involves the production of steel within the bloomery, as part of the larger mass of iron. The amount of the bloom with enough carbon to have become steel must be removed from the rest and forged similarly to iron.[187]

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[181] Craddock, *Early Metal Mining and Production*, p. 236.
[182] Craddock, *Early Metal Mining and Production*, p. 252.
[183] Cyril Stanley Smith, 'The Discovery of Carbon in Steel', *Technology and Culture*, 5 (1964), 149-75 (pp. 167-73).
[184] Biringuccio, *Pirotechnia*, p. 67.
[185] Cyril Stanley Smith, in Biringuccio, *Pirotechnia*, p. 68, n. 1.
[186] Starley, 'Medieval Iron and Steel Production', p. 41.
[187] Starley, 'Medieval Iron and Steel Production', p. 42.

Secondary carburisation involves the case carburisation, or case hardening, of a piece of iron.[188] In this process carbon diffuses into the iron's surface, creating a layer of steel over an iron core. This may be a final treatment, or several pieces of case hardened iron may be forge welded together, allowing further diffusion of carbon and creating a more homogenous steel.

In his description of files needed by the craftsman, Theophilus makes a distinction between solid steel files and files that are made 'so that they are stronger in the middle, of soft iron inside but outside covered with steel'.[189] He describes case hardening these soft iron files,

> When they have been incised with the hammer, or chisel, or with a knife, smear them with old hog's lard, bind them round with strips cut from goat-skin, and tie them up with flaxen thread. Afterwards cover each one separately with kneaded clay leaving the handles bare. When they are dry, put them in a fire and blow vigorously until the skin is burnt. Then remove them quickly from the clay, quench them evenly in the water, withdraw them and dry them at the fire.[190]

The lard and skin provided the carbon which, when encased in the clay and heated in the forge, migrated into the iron to create the steel layer. Keeping the handles uncovered insured that they remained soft and malleable, reducing the chance of breakage during use. While medieval knife blades could be produced by forge welding thin strips of iron and steel together, Theophilus' text suggests that case hardening was the preferred method for file making, perhaps because it would have been easier to cut the teeth into the softer iron.

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188 Starley, 'Medieval Iron and Steel Production', pp. 43-44.
189 Theophilus, *De Diversis Artibus*, trans. by Dodwell, p. 72.
190 Theophilus, *De Diversis Artibus*, trans. by Dodwell, p. 73.

Partial fining is essentially the same as the fining of cast iron to produce wrought iron, with the difference that the loup is removed before all the carbon is removed. The Brescian process, by which solid wrought iron is mixed with melted cast iron so that it absorbs the carbon, is first mentioned in Biringuccio's *Pirotechnia* and was not used during the Middle Ages.[191]

3.3. Types of Workshops

There are two primary types of workshop which were found in the Middle Ages and Renaissance, the free and court workshop. The main differences between these types are economic, in terms of patronage and supply of material. Both types were found all over Europe and although the relationship of an armourer to the state may not have necessarily changed how the armour was actually made, it did have an impact on the way he conducted business.

A court workshop was attached to a particular ruler, which directly affected the armourers' pay, output, and sourcing of material. Seusenhofer's workshop at Innsbruck under Maximilian I, Henry VIII's Greenwich workshop, and the armoury of the Gonzaga family are all examples of this type of arrangement.[192] There were variations in how these armourers worked and their exact relationship to their princely patron, but all were free from the regulatory influence of the guild system.

According to Mann, 'the Lords of Mantua maintained their own armourers, whom they usually imported from the headquarters of the craft in Milan. One also learns...that the armourers in their service were allowed to execute orders for outsiders, especially for the neighbouring House of Este, Lords of Ferrara'.[193] In 1498 their

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[191] Starley, 'Medieval Iron and Steel Production', p. 44.
[192] Williams and de Reuck, *The Royal Armoury at Greenwich*, pp. 22 and 27-28 and Mann, 'Lost Armoury of the Gonzagas', p. 241.
[193] Mann, 'Lost Armoury of the Gonzagas', p. 241.

armourer was a member of the Missaglia family, one Bernardino, who despite his connections was imprisoned for failing to deliver an armour for the king of France on time.[194] England's Henry VIII also imported armourers, beginning with Italian and Flemish workmen in 1511 as court armourers, and the Almains in 1515.[195] Both Henry and Maximilian salaried their armourers, and supplies were purchased for them.[196]

Some armourers also maintained strong connections to royal patrons, but more through favour than as employees. The Helmschmied family of armourers of Augsburg were strongly associated with the Holy Roman Emperors, starting with Lorenz Helmschmied who was made court armourer to Maximilian I in 1491, before the establishment of the Innsbruck workshop.[197] His son, Kolman, was also attached to the Emperor.[198] In 1523 the Gonzaga's agent in Augsburg 'complained that he could not obtain delivery of a suit from Colman, as the latter had been called away to work for the emperor'.[199]

The free workshop may or may not be part of a guild system. Although the guilds imposed regulations and restrictions on armourers, they were not directly attached to any court and therefore in a way more free to conduct business with an array of patrons. They were, however, largely responsible for finding their own iron, steel, fuel, and other raw materials and tools needed to carry out their work. There is great variation in how these workshops conducted their business from city to city depending on the existence of a guild and how they were regulated.

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[194] Mann, 'Lost Armoury of the Gonzagas', p. 242.
[195] Williams and de Reuck, *The Royal Armoury at Greenwich*, pp. 27-28.
[196] Thom Richardson, 'The Royal Armour Workshops at Greenwich', pp. 148-50 and Williams and de Reuck, *The Royal Armoury at Greenwich*, p. 22.
[197] ffoulkes, *The Armourer and His Craft*, p. 133.
[198] The family name was Colman, hence Lorenz Colman and Coloman, or Kolman, Colman. These different names for the two men occasionally cause confusion but it is more common now to use their moniker 'Helmschmied'.
[199] Mann, 'Lost Armoury of the Gonzagas', p. 243.

One of the more restrictive guilds was that of Nuremberg, which from the middle of the fourteenth century severely limited the number of journeymen and apprentices an armourer could have, two and one respectively in contrast to Augsburg whose guild was less restrictive and allowed larger workshops. In addition, Nuremberg armourers tended to specialise only in specific parts of armour, since they were 'examined and licensed to practice only component by component...at yearly intervals'.[200] While Nuremberg was a centre for lower-quality munitions armour, Augsburg armourers specialised in high-quality armour for rich patrons.

Both these cities worked quite differently from their Italian counterparts. Milan, which had no guilds until the sixteenth century, was the centre of the industry until the end of the Middle Ages. The highly developed business acumen of the Missaglia family of Milan made them one of the most successful medieval armour-making families, independent of guild or court control. Indeed, several princes found themselves heavily indebted to the Missaglia, which the family used to their advantage.[201] Large workshops and partnerships with other armourers facilitated a thriving armour-making centre in northern Italy which exported its wares across Europe.

3.4. Division of Labour and Types of Work

Labour was certainly divided in medieval workshops, as part of the apprenticeship system and also the nature of medieval industry. Tasks within the workshop would be divided by skill-level and specialty, while tasks requiring skills or tools not found in the workshop would be done by outside craftsmen. In other cases several workshops would

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[200] Williams and de Reuck, *The Royal Armoury at Greenwich*, p. 20.
[201] Williams and de Reuck, *The Royal Armoury at Greenwich*, p. 19.

be involved in creating a single harness, often the case in Italy where work was frequently 'subcontracted'.[202]

One element which points to a clear division is the number of different marks found on homogenous suits of armour such as the 'Avant' armour in the Kelvingrove collection, Glasgow. There are fifty-one marks on this armour, including four different members of the Corio family, Giovannni, Ambrogio, Bellino, and Dionisio, as well as Giovanni da Garavalle, each making a different part of the armour. The Avant armour is not unique in this respect. Another harness, dating to *c.* 1451 and now in the Hofjagd- und Rüstkammer, Vienna, has six marks belonging to several armourers, including two of the Missaglia, Tomasso and Antonio, and Antonio Seroni.[203]

Not all these armourers worked in the same workshop. Garavalle was contracted to make legharnesses for the Corios for two years, a common arrangement for Italian armourers, and Seroni had a shop separate from the Missaglias.[204] The advantage here is speed, the whole of the armour being worked on more or less simultaneously rather than piece by piece by fewer armourers.[205]

The household books of the Howard family, a late medieval English source, give entries for several armourers doing many day-to-day tasks. Interestingly, despite John Howard's growing importance during the period recorded in the accounts, there is only one reference to an armourer personally attached to him. In 1462 there is a payment of twenty pence 'to my lordys own armorere ffor hys costys be the wey'.[206] In 1453 the

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[202] Williams and de Reuck, *The Royal Armoury at Greenwich*, pp. 19-20 and Pfaffenbichler, *Armourers*, p. 19.
[203] Williams, *The Knight and the Blast Furnace*, pp. 80 and 96.
[204] Emilio Motta, 'Armaiuoli milanesi nel periodo Visconteo-Sforzesco', *Archivio Storico Lombardo*, 41 (1914), 187-232 (p. 201) and Williams, *The Knight and the Blast Furnace*, p. 96.
[205] Tobias Capwell, *The Real Fighting Stuff: Arms and Armour at Glasgow Museums* (Glasgow: Glasgow City Council (Museums), 2007) pp. 26-27.
[206] *The Household Books of John Howard, Duke of Norfolk, 1462-1471, 1481-1483,* ed. by Anne Crawford, 2 vols (Phoenix Mill: Alan Sutton, 1992), I, 150.

'armerer of Jebyswysche' and his men were paid for a week's work at Howard's home, though there is no indication what the work was, and the armourer himself appears to have been hired in for the occasion.[207] Near the end of the accounts a large number of buckles and rivets are recorded, either for a household armourer or for supply to an armourer.[208]

The majority of references to armourers in the accounts are to furbishers, armourers tasked with the cleaning and maintenance of harness elements. In 1463 Robin, an armourer from Ipswich, was paid three shillings 'ffor xij dayis werke in fforbeshynge'.[209] There are also records for possible specialist cleaning, such as the 20 pence paid for cleaning of a velvet harness, and 15 shillings to a mail-maker for, among other things, cleaning mail.[210] The entries are not limited to payments for services, but also give materials which were bought for basic upkeep, including olive oil and emery.[211] The implication from these entries is that the armour was brought to local armourers wherever Howard was at the time, and then repairs were carried out there.

An interesting, and rather different, aspect of the work undertaken by armourers as recorded in the Howard accounts is not to do with making or upkeep, but with carriage. A 'harneys barrelle' and its lock were bought in 1463, and various other containers are listed for holding armour.[212] More importantly, armour was clearly brought to armourers for the purpose of packing, for instance when Howard paid 'an armerer for dressynge the harneys into a pype, and a hoggeshed, and a barell'.[213] It is possible that in addition to simply putting the harness into the containers the armourer

[207] HHB, I, 219.
[208] HHB, II, 385.
[209] HHB, I, 226.
[210] HHB, I, 293 and 538.
[211] HHB, I, 413, and II, 379.
[212] HHB, I, 217.
[213] HHB, I, 401.

also oiled it to preserve it during shipment, and armourers may have been considered uniquely qualified to pack armour in such a way as to prevent damage during transport. The barrels themselves were sometimes supplied by the armourers as well, as in 1467.[214]

3.5. Planning

In the workshop the first stage in producing armour would have consisted mainly of planning. This may be simple or very detailed, and includes not only the decisions regarding the physical appearance size of the finished object but also the supplies which will be required to make it. If made for a specific individual this will require consultation and measurements in much the same way as bespoke tailors work today. It is also perhaps the most difficult stage to document because it comes before physical work has begun and therefore has no distinctive marks or other material evidence. The traces of this stage are found in documentary rather than material sources, including bills and correspondence.

Specific orders for armour for individuals are perhaps the most revealing when there is surviving documentation between armourer and patron in the form of letters or bills. An excellent example is found in a letter from1473 from Martin Rondelle, an armourer, to John Paston, who had dealings with Rondelle previously as indicated by the opening of the letter which pertains to a dispute between the two which resulted in Rondelle's not delivering certain pieces due to non-payment. The second part of the letter refers to a new order for armour,

> ..Moreover, I have heard that you would like to have a full armour. As I recently took your measurements when you were in this town of Bruges, you know that I still have them for all pieces. For this reason, if you would like

[214] HHB, I, 416.

> me to make it for you, I will do it willingly and all the elements that you would like made. With regard to the price, I shall ensure that you shall be satisfied with me. So, when you know what pieces you would like to have and the style and the day you would like to receive them through someone with whom I can deal in your name and who will pay me a deposit, I will work so well that, God willing, you will praise me.[215]

There are several interesting points in this letter, particularly with regards to measurement and appearance. Rondelle himself took Paston's measurements some time previous to writing the letter and was able to use them for making the armour. Measurement is extremely important for the fit and functioning of armour, and Rondelle stressed that the measurements were recent because old measurements would not provide as good a fit due to changes in weight or muscle tone.[216] The 'style' of the armour, *la faisson* [sic] in the original document, refers to how Paston wished the armour to appear in terms of design and decoration, be it in a German, Italian, or English style.[217]

There are other references to measurements, which include several different methods of taking them. The best way for an armourer to get measurements was to see the patron in person, as in the case of Rondelle and Paston. This allowed more than simple measuring, though, which could quite easily be done by an agent of the armourer. In 1466 Francesco Missaglia visited Louis XI of France for the purpose of studying the king. During his stay, 'many times the King had caused him to go into his room by day

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[215] Translated by Karen Watts, in Karen Watts, 'The Arts of Combat', in *Gothic: Art for England 1400-1547*, ed. by Richard Marks and Paul Williamson (London: V&A Publications, 2003), pp. 192-208 (p. 192), from J. D. Gairdner, ed., *The Paston Letters, A.D. 1422-1509*, 6 vols (London: Chatto and Windus, 1904), III, 95-96.
[216] The effect of a patron's changing shape on his armour is most dramatically displayed in the surviving armours of England's Henry VIII, as he became progressively heavier.
[217] Watts, 'The Arts of Combat', p. 192.

and by night, even when he was going to bed, so that he might study his person and know his desires, and in what way his armour should be constructed so that it might not hurt him in any way, as his body was very delicate'.[218] The advantage of this method was that the armourer could not only take all the measurements he needed but would also be able to observe the bearing and carriage of the patron which would have an impact on the shape of the armour.

If the armourer could not see the patron, although a third party could be used, sending a mock-up was also an option. In 1386 Louis, Duke of Touraine and son of King Charles V of France, purchased three ells of Rheims linen to make a doublet, which was 'sent to Germany as a model for a pair of plates to be forged for his person'.[219] Because of the close-fitting nature of a doublet it could be used to determine not only size but also the curvature of the breast, back, and shoulders, allowing a better fit than from measurements alone.

At the opposite end of the spectrum only general sizes would have been required for munitions armour. Fit could be adjusted with straps or by moving internal leathers, a simple process for an armourer, or by changing the tightness of arming points. These low quality armours could not fit the wearer as well as the high quality armours, but since they were rarely full harnesses requiring the more complex interaction between plates and body this would not have been as much of an obstacle.

The specific style of the armour would also be determined before work began. A passage in Baldesar Castiglione's *The Book of the Courtier* is indicative of the range of

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[218] Laking, *Record*, I, p. l. As Laking points out, this particular encounter is somewhat unusual and reflects royal patronage, but even on a shorter meeting an armourer could assess the physique and characteristics of a patron.

[219] 'A Guill. Gallande, marchant de toilles, demourant á Paris pour 3 aulnes de toilles de Reins...pour faire un patron á un petit pourpoint pour Mds. le duc de Thouraine, pour envoier en Allemaigne, pour faire et forger unes plates d'acier pour son corps'. *Compte royal de Guillaume Brunel*, fol. 25[v], quoted in Victor Gay, *Glossaire Archéologique du Moyen Age et de la Renaissance* (Paris: Société bibliographique, 1887), p. 24, and Laking, *Record*, I, xlviii.

choices a patron would have as regards the final product, 'Let it suffice that just as a good soldier knows how to tell the smith what shape, style, and quality his armor must have, and yet is not able to teach him to make it, nor how to hammer or temper it...'[220] By the time Castiglione was writing it was possible for patrons to choose their armour from pattern books such as the one made *c*.1554 by Filippo Orsoni, an Italian artist working in sixteenth-century Mantua, but this does not appear to have been the practice during the fifteenth century.[221]

The earliest known pattern book, the *Thun Sketchbook*, 'was probably some kind of pictorial record of the work of the armourer Lorenz Helmschmid', as well as his son Coloman, and is from the first half of the sixteenth century.[222] According to Alexander von Reitzenstein the style of the *Sketchbook* was a result of the close association of the Helmschmied and Burgkmair families, and suggests that the designs were made before the armour.[223] Tragically the *Thun Sketchbook* was destroyed by the Allied bombing of Dresden in 1945, but parts of it were photographed before it was burned and there are several extant pieces which can be matched to drawings in the *Sketchbook*, so there is no doubt that it was used.[224]

Another example of a pattern book, which is perhaps more typical, is the *Stuttgart Codex* of Jörg Sorg, dating between 1548 and 1563.[225] This manuscript

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[220] Baldesar Castiglione, *The Book of the Courtier*, ed. by Daniel Javitch (New York: Norton, 2002), p. 31.
[221] James G. Mann, 'The Lost Armoury of the Gonzagas', *Archaeological Journal*, 95 (1938), 239-336 (pp. 264-73), and Pfaffenbichler, *Armourers*, p. 6. Orsoni's book is held by the Victoria and Albert Museum, London, E.2031-1929.
[222] Pfaffenbichler, *Armourers*, pp. 5-6, and Ortwin Gamber, 'Kolman Helmschmid, Ferdinand I. und das Thun'sche Skizzenbuch', *Jahrbuch der Kunsthistorischen Sammlungen in Wien*, 71 (1975), 9-38 (pp. 10-18).
[223] Alexander von Reitzenstein, 'Die Plattner von Augsburg', *Augusta* (1955), pp. 265-72 (pp. 265-66).
[224] Ortwin Gamber, 'Kolman Helmschmid, Ferdinand I und das Thun'sche Skizzenbuch', pp. 24 and 29, and Karen Watts, personal communication, 2010.
[225] Williams and de Reuck, *The Royal Armoury at Greenwich*, p. 21.

records the work of ten different master armourers, including the name of the patron each armour was made for.[226] This is similar to the *Almain Armourers Album* of Jacob Halder, recording armour made at the Greenwich workshop for the Elizabethan court.[227] Albrecht Dürer was also a designer of armour and its decoration.[228] While it is possible that a patron could have used these records as a guide for choosing their armour, it is likely that in most instances armourer and patron would discuss and come to an agreement on style in the manner of a modern tailor, as indicated in Rondelle's letter and *The Book of the Courtier*.

3.6. Procurement

It is unlikely that all the resources necessary to create any piece of armour were bought at the time of order. The workshop would have needed to keep a supply of metal and other requisites on hand to deal with a steady flow of work, with a stock that was continually replenished as the need arose. A particularly large order may have provided reason for a large amount of material to be bought for that specific purpose. The nature of procurement would also vary depending on the type of workshop, whether an armourer was working independently or as part of a guild, or an armourer attached to a specific patron as in the case of court armourers.

Iron was the most important raw material in the armourer's workshop and it was available from many different sources. If the armourer was wealthy enough he could produce his own iron; in 1492 Antonio Missaglia held a lease on an iron mine and had the ore smelted and brought to his workshop in finished billets. Alternately the iron

[226] Charlotte Becher, Ortwin Gamber, and Walter Irtenkauf, *Das Stuttgarter Harisch-Musterbuch, 1548-1563* (Vienna: Anton Schroll, 1980), pp. 26-45.
[227] *An Almain Armourer's Album: Selections from an original MS. In Victoria and Albert Museum, South Kensington*, ed. by Viscount Dillon (London: W. Griggs, 1905), p. 2.
[228] Heinrich Müller, *Albrecht Dürer: Waffen und Rüstungen* (Mainz: von Zabern, 2002), pp. 70-74.

could be brought by the patron or the armourer could recycle old armour plates.[229] The active trade in iron meant that the majority of armourers were able to buy the raw material in an assortment of shapes to suit their requirements, including bars, plates, and roughly shaped blooms known as osmonds.[230]

Rivets were a key element in the production of armour, and an exceptionally large number of them could be required for a whole suit.[231] What is more, because of the variety of functions rivets had, they came in many different forms and sizes. This is illustrated by an entry in the Howard Household book,

Item, for ij.c. off armyngnayle of on sorte	ij.d.
Item, for iij.c of armyngnayle of a nother sorte	iiij.d. ob.
Item, for iij.c. of armyingnayle of a nother sorte	xij.d.[232]

Unfortunately, though not uncharacteristically, there is no indication of what the differences were between these rivets. It is interesting that for three hundred of the second type four pence was paid, yet for the same amount of the third twelve pence was paid. This could be due to size, one being significantly larger than the other, though rivet sizes do not seem to vary a great deal. More likely it was due to the third type having a special type of head, perhaps engraved or gilt as was likely the case with the six rivets from the 1485 inventory given in Chapter II.[233]

There is generally not enough difference in the majority of rivets to be identified as being meant for specific elements of a harness, though they are sometimes listed as such in bills and inventories. In 1466 twenty thousand ‘Bregander nayle’, or rivets for

[229] Henrietta M. Larson, ‘The Armor Business in the Middle Ages’, *The Bulletin of the Business Historical Society* (1940), pp. 49-64 (p. 59).
[230] W. R. Childs, ‘England’s Iron Trade in the Fifteenth Century’, *Economic History Review*, 34 (1981), 25-47 (p. 42).
[231] See Chapter III, pp. 105-07 for a full discussion of rivets.
[232] HHB, II, 385.
[233] See p. 39.

brigandines, purchased for 11s. 8d. by John Howard, and in 1514 five hundred 'gauntlet nailes' were bought for 8 pence.[234] The 1407 inventory of the Gonzaga armoury includes entries for gilt rivets, 'rivets of latten for helmets', small rivets, 'black rivets for vambraces', and other rivets for visors, gauntlets, and vambraces.[235] This demonstrates a difference in material, decoration, finish, and size for these specialised rivets, though telling less about specifics including exact size, shape, or if they were intended for plate-to-plate or plate-to-leather attachments.

Fuel was required for the forge to heat the metal for shaping, annealing, and heat treatment. In the Howard accounts coal is referenced several times, with no differentiation between coal and charcoal. In some cases, however, there is a special kind of coal listed as being specifically for smithing, 'The same vj. day of Jenever, Thomas Seynclow delyverd to the smyth of Thoryngton strete, ij. chaldre of smyth cole: my Lord and he is agreed of the prise'.[236]

3.7. Preparatory Work

Because armourers would not usually buy or have to hand sheets of exactly the right size and thickness they would often be compelled to beat out the required plates from iron stock. This is advantageous for the armourer despite the extra work required since the exact thickness could be achieved at the armourer's discretion. By hammering his own sheets he was able to vary the thickness of the plate to provide more protection for specific areas of the body or to take into account certain construction elements.

This could be done by forging thick plates down, welding many smaller bars together and forging into plates, or on a more basic level forging blooms or 'osmonds'

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[234] HHB, I, 342. ffoulkes incorrectly places this purchase in 1465, see ffoulkes, *The Armourer and His Craft*, p. 29. For the gauntlet nails, see Chapter II, p. 40.
[235] Mann, 'The Lost Armoury of the Gonzagas', p. 280-83.
[236] HHB, II, 339.

into useable pieces of metal which could then be formed into plates. The latter seems to have been the case in the 1377 dispute over the noise and smoke of the workshop on Watling Street in London, when the workmen were forging ‘great pieces of iron’, referred to as osmonds.[237] Although the record implies that the work was directly from the osmond to finished product, it is unlikely that the scribe responsible was familiar with armour making. The most important element of the complaint, the great hammers, show that the armourers were engaged in the heavy forge work of beating out plates and not more refined shaping which required lighter hammers.

The next element of the preparatory work would have been cutting out the sheets of iron and steel to the appropriate shapes. These cut pieces are shown in the background of Burgkmair’s woodcut of Seusenhofer’s workshop, underneath the bench against the back wall.[238] A breastplate is clearly visible along with some other less easily identifiable pieces, though they appear to be another breastplate and perhaps a helmet.[239]

Cutting plates to shape is achieved through the use of bench shears or chisels. The shear’s pivot makes complex cutting difficult, especially tight and inside curves which are nearly impossible and which require other tools.[240] Nonetheless, they are useful for cutting basic shapes or large circles, such as a helmet blank, or for cutting large plates to manageable sizes. These huge shears were set into stumps and arranged either so that the blades were either horizontal or pointed up at an angle. Perhaps to prevent injury to the hand, some of these great shears had a crooked end to the back of

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[237] Misc. Roll. FF: 12 May 1374 - 7 May 1378 (nos 600-619), in *London Assize of Nuisance 1301-1431: A calendar* (1973), pp. 154-163 < http://www.british-history.ac.uk/report.aspx ?compid =35982> [accessed 4 November 2011].
[238] *Der Weisskunig*, p. 109. This woodcut is fully analysed in Chapter II, pp. 55-57.
[239] See Figure 37.
[240] The modern ‘Beverly’ shear is throatless, lacking this pivot point, and as such is able to cut a wider array of shapes with a longer cut. See Price, TOMAR, pp. 75-77.

the working handle which prevented it from crushing the hands when the jaws were shut.

It is difficult to find evidence of the use of these shears on the armour even though they appear in inventories, artwork, and in collections of armourer's tools. Although the cut itself could be quite clean, the ends of each cut would be rough, and the exact shape would need to be filed prior to forming.[241] The interior of the right side arm-opening roll on III.4572 may show evidence of the shear; it is very rough, and the edge has notches which would be consistent with the length of a single cut.[242] This is along a curve, and the plate would have been removed, turned slightly, and cut again to achieve a rough curvature through several small, straight cuts.

The other common way to cut metal is with a hammer and chisel. This method has several advantages, including the ability to cut out tight curves and, most importantly, the ability to pierce the sheet which is impossible for a shear.[243] Thus sights, breaths, and other openings may be made, both by chiselling and punching. The edges of chiselling can sometimes be seen at the corners of openings, when the very edge of the chisel scored the surface and was not or could not be subsequently cleaned up.

Although cutouts were done after the plate was hammered into its final form it was more economical and efficient to begin work with a plate of the correct shape to reduce waste. Extra metal left around the edges would still need to be formed with the whole creating more work and wasting valuable time and material. The plate would

[241] Plates were cut using the great shear from the Greenwich royal workshop, Royal Armouries temporary inventory letter H, and the cut achieved was very clean. The roughness is a result of the difficulty in cutting small, exact shapes with this type of shear. See Figure 38.
[242] See Figure 39.
[243] A painting of Venus at Vulcan's forge by Frans Floris, *c*. 1560, shows a hot sheet being pierced with a set chisel. Frans Floris, *Venus at Vulcan's Forge*, Staatliche Museen, Berlin. See Figure 40.

have been marked to provide a guide for cutting, using a ‘marking-iron’ or scribe to score the metal.

Preparation is otherwise difficult to quantify owing to the highly individual nature of the work. Certain parts of this stage were important but were part of basic workshop practice, such as making sure the tools were in good order, annealing the metal prior to cold working, and gathering materials for work. These are not explicitly recorded in any form and were doubtless different depending on the armourer and what he deemed necessary in any given situation.

3.8. Shaping and hammer work

Much of the work of the armourer was taken up by hammering the plates in order to shape them and add certain elements of design which are integral to the plates themselves. Indeed, the hammering phase of armour making was the most common motif used to represent the trade in artwork, rather than any other aspect; in that regard they were similar to other smiths such as blacksmiths and farriers. The hammering phase was extremely diverse in terms of tools, methods, and goals. Many ends could be served during this stage besides the creation of the basic shape; fluting, creasing, and rolling could also be done which served an aesthetic as well as functional purpose.

The two basic shaping techniques used by the armourer to create volume are raising, which Price has called ‘the cornerstone technique’, and doming.[244] Raising is used to create a curve or volume in a flat surface in such a way as to not thin the metal by stretching. Instead, the metal is compressed over a stake with the hammer peen striking the exterior of the plate just above where it makes contact with the stake.

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[244] Price, TOMAR, p. 213.

Raising may be either synclastic where the curvature is in one direction, or anticlastic where the planes curve in two directions.[245]

An armourer is depicted raising a helmet skull in the fifteenth-century manuscript *De Mulieribus Claris*.[246] According to ffoulkes, 'The helm-smith is working on a bascinet which he holds with pincers, but he is using the toe of the hammer and not the face, which hardly seems a likely operation'.[247] In fact, the artist has depicted the armourer using the narrower peen of the hammer to direct a more focused blow to the plate, forming only the small section struck at a time and maintaining control over the emerging shape of the helmet.

Raising is still widely used by metal smiths for the creation of vessels because very deep forms may be accomplished without any need for joining, and as such it is suitable for forming armour components such as helmet skulls and elbow couters.[248] However, although the technique allows a great deal of control over final shape and does not introduce a joint, it requires skill to accomplish, while piecing together smaller plates can be done with less skill and does not require such large plates as raising.

The functional opposite of raising is doming, also called dishing or sinking, even though the goal of each technique is the same. Doming is accomplished from the inside of the piece, stretching the metal instead of compressing, and can be performed in two ways. A doming stump, no more than a large wooden stump or block set on the floor of the shop with a depression carved into it, is used in conjunction with a round, dome-

[245] Tim McCreight, *The Complete Metalsmith: An Illustrated Handbook* (Worcester: Davis Publications, 1991), p. 62. As synclastic raising is the most common method used it is referred to simply as 'raising'. See Figure 41.
[246] MS British Library, Royal MS, 16 G. V, fol. 11. See Figure 42.
[247] ffoulkes, *The Armourer and His Craft*, p. 23.
[248] McCreight, *The Complete Metalsmith*, p. 60.

faced hammer.[249] When the metal is struck it sinks into the depression and the armourer, choosing where to strike the metal in relation to the edge of the depression and how he moves the metal over it, can control the shape the plate takes. Another possibility utilises the flat face of the anvil and a domed hammer. The plate is held on the anvil and struck just above where it contacts the anvil. This continues, turning the plate but striking the same part of the anvil with every blow, until the required depth is achieved.[250]

While not difficult, doming has the major disadvantage of stretching the metal. In order to create a three-dimensional form by working the *interior* of a plate it must be pushed outward, gradually thinning the piece at the centre which tears if the process is carried too far. Like raising, doming can be done hot or cold, heat making the material move much easier but also increasing the risk of overstretching and tearing the metal. If dishing is done over a flat surface and the metal is struck where it contacts the anvil the plate will be forged, thinning it without increasing the depth. It is also less suited to the complex shapes which armour often takes because the forming operation is less precise than raising. Despite these disadvantages it is still a useful technique as it can be used to add a small amount of curve to otherwise flat plates, as well as straight sided cones and cylinders.

The final hammer work technique which was used by armourers for creating primary shapes is curling. This process was used to create the basic shape for perhaps more plates than any other, introducing curvature instead of volume as with doming and raising. The upper and lower cannons of arm defences and the plates of cuisses were made using this method, and the lames which gave articulations flexibility. More

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[249] This is the ‘hollowing hammer’ referred to in the Royal Armouries Tower inventory. See Chapter II, p. 48.

[250] See Figure 43.

complex shapes could also be formed, most significantly the compound curves of greaves which do have depth but which are made through an advanced curling technique.

Usually the major shaping would be followed by planishing, a technique more closely associated with finishing as it does not shape the plate at all but only cleans the rough outer surface. However, like raising, fluting, and creasing it requires the use of a hammer and stake and so is hammer work. Planishing is the means by which the exterior surface is smoothed and hammer marks from forming removed by a series of close hammer blows with a flat-faced hammer. The intention is to create a clean, faceted surface which is free of dings and lumps which can then be filed or ground to the final finish.[251]

Planishing is not necessary, and a piece may be left rough, or it may be minimally planished. It is typically done with a flat faced hammer over a rounded stake that matches as closely as possible the curve of the area being planished. If the curvature of the piece changes the shape of the stake under the plate must be changed, either moving to another area on an irregularly curved mushroom stake or switching to a ball stake with a different diameter. For concave surfaces a domed hammer is needed to planish the surface without deformation. As with techniques such as raising and creasing, the plate is moved below the hammer, with the hammer striking over the same part of the stake.

Because planishing is done over large areas of a piece and is meant to smooth the surface, it obliterates many marks which may have been on the interior or exterior surfaces. However, the marks from the planishing may remain, and some areas such as flutes cannot be planished as it would be difficult to reach the surface with a planishing hammer without damaging it.

[251] Price, TOMAR, pp. 178-79.

After the basic shape of the piece has been achieved, and before any finishing or decorative work, elements such as flutes, creases, and rolls would be added to the plates where required. Although often highly decorative in themselves, like planishing they are integral to the hammer work phase and are formed using the same tools. Because they are formed after the main shaping phase their marks overlay the marks from raising, dishing, curling, and planishing, and it is also possible to determine what flutes were laid in what order based on the overlap of marks.

Creases are the point where two curved surfaces meet at a slight angle, making the surface flush on either side of the crease. Flutes are also the point where two curves meet, but where a crease is two convex curves, a flute is two concave curves, making the flute a raised feature of the plate. Both may be made in a similar fashion, by hammering the plate on the exterior over a creasing stake, first on one side and then the other. This effectively creates a flute, but in the case of a crease the resulting concavity is hammered out on the interior over a flat surface. Flutes may also be set by using a blunt chisel on the interior first, then planishing over a stake on the exterior.[252]

Edge finishes usually take the form of rolls, folds, or embossing, with rolls being the most common. Folds, where the edge of the plate is simply folded over, usually to the interior, and hammered flat are uncommon, perhaps due to their aesthetic inelegance and weakness relative to the roll. Embossing may take the form of a recessed border, sometimes to hold an applied decorative band, or may simulate a roll.

Rolls may be of any size, may be even in diameter or tapered, and may be round or boxed. Further elaboration is found in decorative roping. They may be done to the inside or outside, depending on style and function, and they may be either hollow or contain a wire. The primary function of the roll is to provide strength, necessary for the thin edge of a plate, and they are also used to avoid cutting edges such as at inner elbows

[252] Price, TOMAR, 184-89.

and the bottoms of great helms. Whether rolled to the inside or outside, the edge of the plate must be carefully worked over with the hammer, which may be done over a stake to begin and then eased over by carefully working the edge over into a U-shape, and from there closing it.

Hammer work does not only make use of the hammer, but also of the forge. Most of these techniques can be accomplished either hot or cold, with the exception of planishing which must be done cold, but in either case heat is an indispensible part of armour making. When the piece is heated in the forge and brought to the anvil or stake it is easier to form and there is less stress put on the structure of the metal. If the forming is done cold then the metal will tend to work-harden, becoming brittle from repeated hammering, and must be annealed through heating to become soft again.

While this is certainly not the only time the forge is used during the process, it is the most uncertain and contested use. There is disagreement on how much the forge was used and what techniques were done hot, largely revolving around the depiction of armourers and how they are holding pieces of armour, whether with a hand or with tongs. Blair states that 'the actual shaping of the plates the metal seems to have been worked cold', and Pfaffenbichler uses Burgkmair's woodcut of Seusenhofer and armourers in the *Mendel Hausbuch* as evidence to support this, 'In both of these the armourers are shown working the metal held in their bare hands, and therefore it must be cold'.[253] Price also agrees that much of the work was done cold, but believes that some was done hot, saying 'It is likely that in cases where extensive raising was required, medieval armourers worked their pieces hot. But for detail work or pieces that did not require as much rough shaping, cold work would have been preferred because the work is easier to handle and more precision is thus available'.[254] He goes on to point out that

[253] Blair, *European Armour*, p. 189 and Pfaffenbichler, *Armourers*, p. 62.
[254] Price, TOMAR, p. 224.

artists may not have understood techniques, 'but this seems unlikely since the tools are reproduced with such accuracy'.[255]

While there is a level of accuracy which can be identified in artwork, demonstrated in Chapter II, seeing a tool and being familiar with its shape is not the same as being familiar with its use. The level to which armour was worked hot or cold has been partially determined by Williams though metallographic examination, 'distortion of the grains indicates cold-working, while elongations of slag inclusions indicates hot forging'.[256] Unfortunately this only gives an impression of the fraction of the armour looked at under the microscope, and gives no real indication of which specific techniques were done hot and which were done cold. There are certainly several medieval illustrations of armourers holding plates with tongs, but these do not provide enough information to definitively say how much the forge was used.

3.9. Finishing

The finish of a piece can refer to any treatment, or even lack of treatment, that an object received as its final surface. This may be anything from a 'black' surface, which is not truly black in colour but only the rough surface left from the hammer, to a highly polished 'white' surface which is burnished to mirror brightness. Treatments carried out on the surface to affect its appearance, such as blueing or applying textiles, are purely decorative as they are additive as opposed to finishing techniques which remove material. In general, the more finished a piece is the longer and more laborious the processes to complete it owing to the hardness of the material which must be ground with abrasives.

[255] Price, TOMAR, p. 225.
[256] Williams and de Reuck, *The Royal Armoury at Greenwich*, p. 17.

The simplest way to finish a piece was to not finish it at all, an option for low-quality armour produced in large quantities for common soldiers. This finish would be taken to the planishing stage but rarely any further, even the planishing being cursory and only smoothing out the worst ridges. Some very simple filing could also be carried out. IV.13 is an excellent example of a 'black' sallet with its rough surface which is so lightly planished that the raising marks can still be seen.[257]

Not all pieces which have been left at the planishing stage can be classed as 'black', such as the mid-sixteenth-century Lion Armour.[258] Several elements have the faceted surface associated with planishing, yet they are smooth and were blued and gilt with great care. With that decoration and the superb embossing which has made the Lion Armour famous, it can hardly be called rough from the hammer.

The majority of armour, even those pieces of lower quality, was finished to a higher degree in some way than planishing. Finishing has the aesthetic effect of creating an attractive appearance but also has the practical aspect of being easier to clean because there is less roughness for corrosion to take hold in. These steps are abrasive in nature regardless of the tool used. The amount of filing, sanding, and buffing depends on the level of brightness desired in the final product.

Files were well-known by the Middle Ages and Theophilus describes several different types important to metalworkers, as well as different methods of manufacturing: 'When these have been beaten to the required size, they are levelled off with a straightedge and then are incised with a hammer which is sharp on each side. Others are also incised with the chisel...'[259] The files of a metalworker generally have finer teeth than files or rasps used on other materials such as wood, because large teeth

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[257] See Figure 44.
[258] Leeds, Royal Armouries, II.89, see Figure 45.
[259] Manning, *Catalogue of the Romano-British Iron Tools*, p. 11, and Theophilus, *De Diversis Artibus*, trans. by Dodwell, p. 72.

are not as efficient at cutting smoothly into metal.[260] Files were available to the medieval armourer in a wide range of shapes, including flat, square, triangular, and rounded, which were normally incised on all sides making full use of the space available.[261]

The teeth of a file are essentially small chisels that cut away metal as they bite into it. Rough files are typically used first because the larger teeth leave deep marks on the surface; these are followed by successively finer files which reduce the roughness of each preceding pass. Files with flat faces are used for convex curves, and files with rounded faces were used for concave curves. One of the problems with files is that they sometimes cannot reach particular areas, due to their shape or the shape of the armour plate, requiring a large number of files for the workshop so that if one cannot be used another of the appropriate shape is available.

Filing with even the finest files can only take the process so far, and so progressively finer mediums must be used in order to achieve a truly polished surface. Fine stones, including whetstones and the 'pomyshe' stone recorded in the *Equippage* of the Earl of Northumberland, served to smooth the grooves left by the files.[262] The stones would be rubbed across the surface in a circular motion, further diminishing the rougher marks. Finally, grit-based abrasives such as emery were used to bring the surface to a bright, clear polish. This final stage, either done with hand-held burnishing rods or water-driven wheels, was frequently illustrated, especially in the *Mendel Hausbuch* as discussed in Chapter II.[263]

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[260] Manning, *Catalogue of the Romano-British Iron Tools*, p. 11.
[261] Theophilus, *De Diversis Artibus*, trans. by Dodwell, pp. 72-73.
[262] Grosse, *Antiquarian Repertory*, p. 368.
[263] See Chapter II, pp. 58-59.

3.10. Piercing

Holes in armour plates serve three main functions: they allow plates to be attached to one another or to straps and linings with rivets, they are used for catches and pins to hold armour elements together when being worn, and they are used on helmets for sight, ventilation, and for the attachment of crests. Piercing can be done before or after finishing, though it would be better to do it before since the surface could be marred during piercing. There is not a single component which does not require holes for its construction and function, and proper placement is essential for armour elements to interact correctly with each other and with the body.

The simplest way to create a hole is with a punch and a hammer; the punch is placed on the exterior and then struck through the plate. The plate must be supported from underneath so that it does not deform around the punched area. On modern anvils the pritchel hole serves this purpose, though a special anvil with holes for different sized punches could be used, as already seen in the *Mendel Hausbuch* in use by a belt maker and a nail smith.[264]

In addition to punching the hole may also be drifted, which is a process by which holes are made regular in size and shape. Drifting is done with a tool called a drift, similar to a punch except that the middle has parallel sides, with a size and shape the same as the desired hole, and tapered ends to prevent it from becoming lodged in the plate. A hole is gradually drifted to a larger size, or another shape such as a square or rectangle. A rectangle or irregular shaped hole, such as a keyhole, may also be shaped with small files, although in some cases the ends of the opening would be pierced with a punch, the outline of the opening scored, and then cut with a chisel. This technique is clearly shown on a helmet in the Wallace Collection, A30, which has slots on one side

[264] Mendel I, fols. 14^{r} and 19^{r}, again see Figures 10 and 11.

of the visor and pairs of holes with the scored lines on the other which were not completed.[265]

A further stage is counter sinking, where the edge of the hole on the exterior is bevelled. This can be accomplished with a round file or conical drift, but the Tower inventories also reference a ‘counter-borer’, most likely a hand-held auger with a specialised spoon bit used to cut in the bevel.[266] When a rivet is peened on the exterior over this bevel it fills the space and the excess is filed off to create a flush rivet. Counter-sinking is also one of the first stages in creating screw holes as the bevel gives the thread or cutter a surface to bite into to start the tapping.

Piercing must be done after all shaping is complete and before heat treatment. Any further shaping would distort the hole and could lead to a possible tear, the many holes weakening the plate, and heat treatment would leave the plate far too hard and brittle for the plates to be punched. The metal must be as soft as possible, which means it should be done hot; although the plate could be pierced when fully annealed, the controlled deformation needed for drifting requires the malleability of hot iron or steel.

3.11. Decoration

Some armours made inexpensively for poor knights or common soldiers bore no decoration whatsoever, but this was not the norm. Even low-quality armour often had some form of decoration, however crudely executed, and the finest and most expensive armour served largely as a canvas upon which the decorator worked from a large pallet of techniques to enhance the aesthetic value of the armour as well as serve as a conspicuous indicator of the wealth of the patron.

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[265] London, Wallace Collection, partial armour attributed to Kolman Helmschmied, A30. See Figure 46.
[266] Tower Inv., p. 59.

There are many ways to decorate armour, which can be divided into methods which are additive and methods that are reductive. A third category overlaps with hammer work and consists of embossing. Additive methods are any that are achieved through applying something to the plate, such as copper alloy or gilt borders, paint, or textiles. Reductive methods are achieved through the removal of material, usually in the form of engraving or punch work. Many of these could have been done by the armourer in his workshop, but some pieces were enhanced by specialist decorators, either as a stage in overall construction or to put a new finish on an already-existing piece of armour.[267]

Applied borders could be very costly. The product of goldsmiths, they are in many instances highly intricate, with fretwork and moulding similar to the tracery found in medieval stained glass windows. Alternatively, relatively simple copper-alloy bands with some manner of decoration could be applied, as with the sallet IV.424 which has a band that is swaged and punched with a complex pattern, or the basinet IV.470 which has an applied border which has been engraved.[268]

Although these bands could simply be riveted on, as is the case for the two objects above, they could also be applied into a recessed border which required more time, planning, and coordination between armourer and decorator. This recessed border, exposed on AL.23 107 as it has lost its applied decoration, causes the band to lay flush, or closer to flush, with the main surface of the plate.[269] Thus, it must be decided upon beforehand and cannot be added at the last moment, at least not without great difficulty.

More common are those methods which are reductive. Most of this type of decoration is fairly simple, being rather linear or repetitive in nature, but it also includes

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[267] Pfaffenbichler, *Armourers*, pp. 37-45.
[268] See Figures 47 and 48.
[269] See Figure 49.

very intricate engraving and etching, pierced fretwork, and sculpted carving. Engraving and etching often have similar results though they are carried out in very different ways. For engraving a specialised tool called a graver, a tiny shaped chisel, cuts material away from the surface. Engraving is often used to define borders or accentuate features, and in this capacity it is fairly simple. More advanced engraving becomes an art in its own right, and is limited only by the skill of the engraver and the space allowed by the plate.

Etching is achieved not with a tool but with acid which eats away at the surface, and is a technique which 'first appeared on late-fifteenth-century armour...appearing in print for the first time in *Von Stahel und Eysen*'.[270] In order to create the desired pattern, and prevent the whole piece from dissolving, the plate is coated with a resist such as wax which is scored with a stylus, causing the acid to only affect that part which has been exposed.[271] Vinegar was probably the most popular etchant used; *Von Stahel und Eysen* recommends mixing lime charcoal, vitriol, sal ammoniac, and vinegar as an etchant and using 'red lead tempered with linseed oil' as a resist.[272]

Etching can be very intricate but has its drawbacks compared to engraving. The ends of lines generally have a blunt termination rather than a tapering point and differences in depth are not possible. Henry VIII's tonlet armour shows the range of quality possible with etching, from very fine to extremely crude, including mistakes. A close examination of the lines shows the sweep at the end of the stylus strokes which is one of the indicators of this type of decoration.[273]

Punch work is a very simple way to decorate, and like engraving is frequently seen as an embellishment to a border, or to demarcate the line between sections such as the waist of a backplate. Files are used to incise decoration into the plates, especially on

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[270] Eamon, *Science and the Secrets of Nature*, p. 119.
[271] Untracht, *Jewellery*, pp. 321-23.
[272] Hermann W. Williams, '*Von Stahel und Eysen*', pp. 71-72.
[273] See Figure 50.

edges, and to create a roped effect on rolls. Much of this decoration is basic notching, but it can be used in conjunction with piercing to create very intricate fretwork and decorative finials. In some cases the notches may have been made with a chisel, but teeth marks within the notch are an indicator that a file was used.

Some of the most fantastic, and fantastical, decoration found on armour was achieved through embossing. Although embossing is in fact a hammer work technique, and is certainly used for basic shaping such as making the steps of sallet visors, it finds its fullest development as a decorative technique, adding not to the defensive quality of the armour but to its aesthetic value. Embossing flourished at the end of the era when armour was worn, finding only limited use in the fifteenth century. Besides the aforementioned practical uses of embossing, it could also be used to raise up decorative roping, distinct from flutes, and bosses over wrist and ankle bones.

3.12. Heat Treatment

One of the last stages to affect the metal itself is the heat treatment phase, the combined process of hardening steel through rapid cooling followed by partial softening through tempering. There are also processes related to heat treatment including case hardening and annealing, a process by which metal is softened through heating and slow cooling. Work hardening, where the steel is hardened by hammering cold, does not appear to have been used at all during the Middle Ages.[274] The purpose of any kind of heat treatment is to alter the working characteristics of a metal through the use of heat. Although non-ferrous metals may also be hardened, the hardness and toughness of heat-treated steel made it the superior material for arms and armour.

[274] Alan Williams, 'To What Extent Can Forgeries be Detected by Metallurgical Analysis? A Study on Some Helmets', *Institut suisse d'armes anciennes*, 3-4 (1979), 61-78 (p. 63).

During heat treatment the crystalline structure of a piece of steel is altered, thereby changing its working properties. Hardening is achieved by quenching the hot steel in water or some other quenchant, at a temperature where it has lost its magnetic properties, about 800°C, to be fully hardened.[275] With experience the proper temperature can be judged by eye from the colour of the metal. During hardening, the arrangement of ferrite and carbon in the steel changes resulting in pearlite, bainite, or martensite depending on the speed of cooling and amount of carbon.[276]

The result is a very hard but very brittle material which must be softened, or tempered, to increase toughness. Tempering may be done by re-heating the steel slowly at a low heat, altering the martensite structure of the steel.[277] It may also be done by interrupting the quench or cooling it more slowly, known as slack quenching. Instead of cooling the piece all at once it is taken out of the quenchant several times before cooling completely, allowing the residual heat to relax the stresses. According to Williams, slack quenching techniques 'nowadays are avoided but seem to have been regularly practiced in the Middle Ages' due to the difficulty in successfully tempering steel.[278]

Theophilus gives a brief but accurate description of the process when instructing on hardening files: 'you place their tip in the fire, and, as soon as it gets red hot, it is withdrawn and quenched in water'.[279] His direction for hardening chisels is likewise concise, but the following description for preparing a quenchant for tools used in cutting stone and glass is more detailed, recommending the urine of a goat which has been

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[275] Craddock, *Early Metal Mining and Production*, p. 237 and Bealer, *The Art of Blacksmithing*, p. 152.
[276] Williams, *The Knight and the Blast Furnace*, p. 17.
[277] Craddock, *Early Metal Mining and Production*, p. 237.
[278] Williams, *The Knight and the Blast Furnace*, pp. 17-18. Slack quenching is still practiced by modern blacksmiths and the term 'slack tub' survives for the smith's quench tank.
[279] Theophilus, *De Diversis Artibus*, trans. by Dodwell, p. 73.

starved for three days and then fed on ferns and water.[280] As an alternative, 'Tools are also given a harder tempering in the urine of a small, red-headed boy than in ordinary water'.[281] Cyril Stanley Smith notes that 'It has been common to scoff at the old recipes for quenching baths ... but there may be justification for them'.[282] The properties of a quenching medium can be changed to affect cooling rates, and regulating what the goat ate would have changed the content of its urine and how quickly it cooled the metal.[283]

Von Stahel und Eysen contains several different methods of hardening, tempering, and annealing iron and steel. The recipes for quenchants focus on different ingredients to mix to achieve varying results, and like Theophilus' may seem strange today. For example, mustard and vinegar, boiled human hair, or a mixture of radish juice, celery juice, and resin are all recommended for hardening steel.[284]

Regardless of the efficacy of these directions, there is one direction which was no doubt as important then as it is now, 'It is very advantageous, too, in tempering, to have everything you want to temper all clean and well polished up in advance'.[285] When drawing a temper it is necessary to have a clean, bright surface so that the colour

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[280] Theophilus, *De Diversis Artibus*, trans. by Dodwell, pp. 73-74. The hardening effect of a goat's bodily fluids may have its origins in Isidore of Seville, as given by Eugenius of Toledo, 'Praedurus adamans ferrum non suscipit omne;/ hircino tactus sanguine mollis erit'. 'The very strong adamant does not accept any iron; It will be soft having been touched by the he-goat's blood'. 'Adamans' did not refer to steel but to a gemstone, and the blood was used to soften, not harden, but still had an effect upon the nature of the thing being immersed. Eugenius of Toldeo, 'De Adamante' (carmen 62), in *Eugenii Toletani Opera Omnia*, ed. by Paulo Farmhouse Alberto, Corpus Christianorum Series Latina CXIV (Turnhout: Brepols, 2005), p. 262. Translation by Mark Tizzoni. See also Mark Lewis Tizzoni, 'The Poems of Dracontius in their Vandalic and Visigothic Contexts' (unpublished PhD thesis, University of Leeds, 2012), p. 247.

[281] Theophilus, *De Diversis Artibus*, trans. by Dodwell, pp. 72-74. The term 'tempering' is sometimes used to mean hardening or the whole of heat treatment, and must be interpreted through context.

[282] Cyril Stanley Smith, in Biringuccio, *Pirotechnia*, p. 371, n. 2.

[283] In the same manner, the urine from a human may have different effects on the cooling rate of hot steel. Hair colour is unlikely to play any part.

[284] Hermann W. Williams, '*Von Stahel und Eysen*', pp. 65-69.

[285] Hermann W. Williams, '*Von Stahel und Eysen*', p. 67.

of the metal may be observed. During tempering a thin layer of oxidation is created which changes from yellow to blue, and it is this visual signal that the smith uses to judge when the proper hardness has been achieved.[286]

3.13. Assembly, Strapping, and Lining

The final stage in the creation of a piece of armour is its assembly, not only of the several component parts but also the addition of the straps and linings which are necessary for it to be functional. Assembly consists almost entirely of riveting, as does strapping and to a certain extent lining, though leather and textiles also used ties and sewing as joining methods.

By far the most common method of assembly used by medieval armourers was riveting. Riveting is a cold mechanical join which requires no heat to achieve. Rivets are used to join plate to plate, leather to plate, and other elements such as buckles to plates. Plain rivets hold pieces together without any articulation, or attach leathers to plates, and are the most common type. They can also be articulated, either simply allowing the plates to rotate, or rotate and expand through the use of sliding rivets. The exterior head can be a simple dome, it can be made invisible as a flush rivet, or it can be made decorative through the use of incised lines or applied caps.

Plain rivets are often hammered, or peened, on the interior, the exterior presenting a clean dome which must be created before use much the same as the head of a nail. The rivet head is placed on a lead block or an anvil with a recess to preserve its shape while being worked. Simple rivets may also be made using a short piece of rod, with a small amount extending from the hole on each side, which is hammered on the interior and exterior to swell the rivet heads and hold the plates together.

[286] Bealer, *The Art of Blacksmithing*, pp. 150-52.

For a flush rivet the hole must be specially prepared by countersinking, which bevels the edge of the hole so that when the rivet is peened from the outside it will swell to fill the bevelled area. When the rivet head is finished flush with the surface of the outer plate there remains enough of the head to hold the two together. Flush rivets are useful in areas where a domed head may interrupt the movement of other articulated plates, and also reduce the number of surfaces upon which an opponent’s weapon may catch. The jousting helm of Nicholas Hawberk, held in the Royal Armouries, uses flush rivets to hold all the plates together to prevent a lance catching the helmet and possibly throwing it off or causing serious neck injury.[287]

Rivet heads may also be highly decorated and become a prominent feature of the piece. On two sallets on display in the Royal Armouries the rivets which would have attached the linings to the interiors have large external heads which are decorated with embossed lines.[288] Similarly, the Brocas helm has large copper alloy caps over the rivet heads, quite different from the flush rivets of the earlier Hawberk helm.[289] Rivets may also be decorated by cutting in patterns of radiating lines with a file or chisel before the rivet is used on the armour. A soft backing such as lead would be used to protect the decorated head from deformation during peening.

Some rivets are not meant to hold the plates rigidly, but must allow them to articulate, either by a simple pivot around an axis or by allowing expansion through use of a slot. For a pivoting articulation to have a smooth joint the hole and rivet shank must be of the same diameter, perhaps using a special tool like the one postulated by Price, or else through very careful peening of the rivet.[290] Making the hole larger than

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[287] Leeds, RA, Helm, AL.30.1. See Figure 51.
[288] Leeds, RA, Sallet, IV.410 and Leeds, RA, Sallet, IV.427. See Figure 52.
[289] Leeds, RA, Helm, IV.411. See Figure 53.
[290] Price, TOMAR, pp. 206-07.

the rivet can allow for a larger range of movement in the articulation, but the less precise fit of the plates also increases the risk of gapping.[291]

A more efficient means to create an articulation with a wide range of movement is the sliding rivet. These allow two plates to not only pivot but also slide past each other, greatly increasing mobility. Sliding rivets are essentially the same as other types of rivets with two exceptions, one being the slot shaped hole on the interior plate and the other being the interior rivet head. On the exterior the head appears the same as other rivets, but due to the internal slot the inner head's surface area must be expanded in some way to prevent it from tearing out. This can be done using a washer between the plate and the rivet head, or the head could be flattened using a larger amount of material resulting in a correspondingly wider head.[292]

Rivets are also used to attach straps and other internal leathers. These leathers serve three main functions, to secure the armour to the wearer through the use of buckles or points, to prevent the armour plates from gapping, and for the attachment of the linings. Leathers must be secured using rivets with wide heads or washers so that the rivet head does not tear through.[293] Linings are sewn onto the edges of internal leathers, and can be removed by cutting the thread, and replaced by using the same holes for reattachment.

3.14. Conclusion

The journey from unrefined ore to completed piece of armour is a long and complicated one, as demonstrated by this discussion of the necessary stages. Even crude pieces required the skills of many people specialising in many different capacities. Making

[291] Price, TOMAR, p. 244.
[292] Leeds, RA, Pauldron, III.1305. See Figure 54.
[293] Leeds, RA, Pauldron, III.1196 B. See Figure 55.

functioning armour also required that the armourer have some of the skills of the blacksmith, the goldsmith, and the sculptor to mould plates of iron and steel to properly interact with each other and with the body they were made to cover.

Armourers were not unique in this respect; the great cathedrals required masons, carpenters, blacksmiths, and glaziers. Though in no way the same in terms of scope or majesty, armour required smelters, armourers, polishers, decorators, rivet makers, and leatherworkers. This level of cooperation was necessary, particularly given the level of demand to equip the knights and soldiers for the princes of Europe. Armour was also an end unto itself, ensuring a continuing market among the European elite.

Just as armour making must not be thought of as the work of a lone individual in a workshop, it must also not be thought of only in terms of hammering plates. That phase does not begin until the work of the smelter is complete, and there is much more to be done after shaping. It is therefore more accurate to view the armour-making process as the complex interrelation of techniques, all used in conjunction with one another resulting in the finished object. In a time before microscopes or thermometers this was augmented by a keen eye to judge colour when working, which could only be learned through experimentation and skill. Due to the heterogeneous nature of medieval steels the ability to judge quality was essential, but heat treatment could still be prevented by poor materials. The medieval armourer was much more than just a tradesman, he was an artisan whose experience allowed him to balance all these factors to produce highly complex and prized objects.

Chapter IV: Tools and their Marks

4.1. Introduction

The tools which were used in the armourer's workshop represented both a continuing tradition of basic tools common to the metalworking trades and several specialised ones which were used for very specific purposes and which may only be found in use by certain craftsmen. The primary difference between the working practices of armourers and blacksmiths is that the latter mainly works with bars of iron while the former works with plates and sheets. In this the armourer resembles the coppersmith and the silversmith and many of the tools are similar. However, due to the much heavier work required to shape plates of iron and steel, as opposed to the softer copper or silver, the tools tend to be much more robust to stand up to heavy use and provide efficient working of the plates.

These tools and their uses have been introduced in the preceding two chapters, so it is now time to turn to their marks and their interpretation. The exact shapes of the tools and the marks resulting from their use on armour plates is the text which must be read in order to understand how armour was made. The marks and the patterns in which they are found can be linked to the techniques already discussed, and by so doing the exact processes, the order in which they were carried out, and other information about technique can be derived.

The tools themselves will form the first part of this chapter, together with a detailed examination of their shapes and the marks they leave behind. A more detailed discussion of the techniques will follow this, which when joined with the mark types will demonstrate how mark patterns and techniques are related. A practical exercise in the form of experimental plate work, undertaken by the author, will be used to demonstrate the relation of tool, technique, and mark. It will also show the value of experience with the way in which metal behaves under the hammer.

The result of this will be a complete diagnostic tool which may be used to determine how any piece of armour which retains the necessary tool marks was constructed. This methodology will be used in successive chapters in the examination of extant objects and groups of objects to further expand on and demonstrate this approach to armour studies.

4.2. The Tools and their Marks

The tools used by the armourer were extremely varied in type and purpose, and they will here be given a technical examination before their use on armour is detailed further in the following chapters. Although there are a seemingly endless variety of tools used by armourers, there are relatively few basic shapes found amongst those tools. Their specific arrangement and size would have had a significant impact on the manner in which they were used and formed ferrous plates. There are other tools which were essential as well, including the forge, bellows, tools for tending the forge, and tongs, but the tools which are most interesting for the present purpose are those which were used in the actual shaping of the plates, primarily hammers, stakes, and anvils.

As has been seen in the inventories cited in Chapter II, especially those from Greenwich, tools could be highly specialised and reserved for specific uses. Despite this, a stake used for a helmet crest is not necessarily different from one used to make a flute in a breastplate, and one used to raise a couter could also be used to raise a helmet visor. The specialisation was partially due to a tool being well-suited for a given task, not because that tool could only be used for one purpose. In addition, as already stated on page 42, reserving tools for particular uses could extend working life and reduce the risk of damage.

Working faces generally fall in one of several broad categories: flat, domed, spherical, cylindrical, or chiselled. Flat faces are typical of anvils and hammers used for planishing. Domed faces have a slight curvature and are typical for hammer faces and some stakes. Spherical faces are found on ball stakes and ball-peen hammers. Cylindrical faces are found on cross-peen hammers, the horns of anvils, bickirons, and a variety of stakes. Chiselled working faces are any which have such an edge, though it need not be sharp. Some small cross-peen hammers may be said to have a chiselled peen, and many stakes used for creasing and fluting have this type of working surface. There are other shapes and many variations on these shapes, dictated by the specific purpose of the tool, but these five shapes form the basis from which most others are derived.

It is useful to group tools by their most basic function: cutting tools, striking tools, and bottom dies. Cutting tools include shears and chisels, but can also include gravers and files which also work by cutting into the metal, demonstrating the variety in type and function which can be found in these broad categories. Striking tools are most often hammers and mallets, usually consisting of an iron head and wooden handle though mallets entirely of wood could be used for some operations. Dies are anything over which the object is worked, in particular anvils and stakes, which act as a base to support the object as it is being shaped.

Hammers, the most important and recognizable tools of the armourer, are used to move metal to achieve the final shape of armour plates. The hammer is capable of very subtle work, especially in the hands of a competent artisan, and metalworkers make full use of the various face shapes and the ways they deform plates. There are two main ways in which the metal is directed by the hammer peen, determined by shape. When the metal is struck by a ball-peen hammer on an anvil it is forged, that is formed through compression, and the material displaced between the top and bottom dies moves outward in all directions because of the sphere of the peen. If the peen is cylindrical, as with a cross peen hammer, the metal is moved only in two directions, perpendicular to the long edge of the peen.[294]

Armour-making adds another level to this hammer work. While blacksmiths most often forge the metal directly between dies, the armourer usually strikes the material where it is above the bottom die in order to *prevent* forging and the resultant thinning of the material. By hammering above where the metal contacts the stake and forcing it down, the metal is compressed or stretched in the desired manner to shape the plate.

All of the tools used by the armourer left marks, and the techniques produced distinctive patterns which can be identified on the armour. The marks of the cross-peen hammer and the ball-peen or round-faced hammer are by far the most common. The marks of the planishing hammer are more uncommon due to being made exclusively on the exterior which was typically also filed or ground. That stage is more readily identified by the marks of the stake rather than the hammer.

Cross-peen hammers leave marks which are longer than they are wide, though they are not always clearly defined around their edges. Some have narrow peens with a cylindrical section, some are broader but still domed and rectangular, while some have very narrow, almost chisel-like peens. This variety means that their marks can range from shallow and broad to clear and narrow. The basic way in which the metal is

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[294] The usual shape of narrow-peened hammers in the Middle Ages and before was the cross-peen. Slash and straight-peen hammers move the metal in the same manner but the peen is oriented differently with regards to the handle, diagonally and parallel respectively.

moved, though, remains unchanged. There are instances where a long mark may be from a chisel with a very blunt edge rather than a hammer, as the two can be similar, and tool type must be determined based on context.

Rounded hammers can be ball-peen or be hammers with a domed face. In either case the mark left is round, usually with no sharp edges or corners. These marks are at least as common as oblong marks, and are mostly, though not exclusively, associated with round armour shapes such as breastplates. Because there are usually no defined edges, overlapping of marks can very easily obscure their shape and size, though this same effect also demonstrates the use of a round hammer.

One of the difficulties in identifying the marks of a rounded hammer is that they can very often be confused with the marks left by a rounded stake. A distinguishing feature of the hammer versus the stake is that marks made with a ball-peen hammer tend to be deeper and more well-defined since the peen is likely to be of a smaller diameter and the force of the striking die tends to create a more defined mark. This is not true of hammers with gently domed faces which would not make such deep marks and which would have been used on more gently domed pieces because of the face's greater radius. It is usually necessary to take the context of the marks into consideration, including the type of armour, its quality, and the other features which may interrupt the round marks, to make a certain determination regarding tool type.

Planishing would usually have called for flat faced hammers, and here the shape of the face, whether circular or square, is much less important than its flatness, which allows the hammer to create a smoothly faceted surface on the exterior of plates, instead of the divots or pockmarks that a domed face would create. The mark left by planishing is only a flat facet, making it impossible to identify any other characteristic of the tool. In addition, planishing was usually only a prelude to polishing, and so the marks left by the hammer itself are almost invariably lost. Where pieces have been left at this stage with no further polishing the marks are difficult to determine and as a result it is usually the smoothness on the exterior, the result of planishing and polishing, and the smoothness on the interior, the result of the stake, which are indicative of the technique.

Planishing works best when the curvature of the stake exactly matches the curvature of the area of the plate being worked, and for this reason stakes which are not perfect hemispheres but are instead mushroom-shaped are today preferred for this operation.[295] Because of the irregular curvature of the surface a single stake may be used where many spherical stakes would have been required. The need for the stake to match the curvature, and the closeness of the hammer blows during planishing, results in a very smooth interior surface that can usually be differentiated from marks made by a ball-peen hammer, even though both often have little pattern and are usually rounded.

Although the marks from the planishing stake are the ones most commonly encountered they are by no means the only ones. Light planishing may not have been enough to obscure earlier marks, and its lack could leave any stake marks intact. Because plates can be worked on both the interior and the exterior the difficulty lies in distinguishing stake marks from those left by hammers or other tools.

Context is often helpful in these cases. For example, oblong tool marks in a simply curled form are from a hammer, not a stake, since the piece was most likely hammered on the interior; a stake would not leave the same sort of marks and is less likely to have been used. Marks in a deep form which has not been planished are more probable to be stake marks since hammer work on deep forms is normally carried out on the exterior.

A particularly good example of the types of stake marks which can be found on the interiors of unplanished or semi-planished pieces is Royal Armouries IV.499, a late

[295] Untracht, *Jewellery*, p. 254.

fifteenth-century German sallet.[296] The interior is heavily marred by three distinct bands of marks: those in the top of the skull, a wide band around the middle circumference of the skull, and a lower band on the lower skull and tail. The upper and lower patterns are primarily round although closely overlapped, very deep in the skull and shallower on the tail. The depth of the upper marks would seem to indicate internal doming, possible with a long-headed hammer, but the marks *overlap* the middle band at its upper edge, showing that they were made later as part of a heavy planishing stage.

The middle band is remarkable not only for its roughness, much rougher than is commonly seen, but also for the clarity of the stake marks which in this case have a square or rectangular shape. These are partly obscured by a very light planishing mark layer, much lighter than the one above, which does not remove the entirety of the larger square marks. These suggest that a square-headed stake was used for raising, and that the armourer was hitting the metal exceptionally hard to leave such well-defined marks, which is borne out in the unusually heavy planishing pattern at the top of the skull.

Unfortunately, IV.499 presents an almost unique opportunity to identify a stake face of a shape other than round. Stake types, either general or specific, typically cannot be determined using the tool-mark evidence because they left very little marking and what they did leave conveys little about the stake as a whole. It is impossible to determine anything about the raising stake used by the IV.499 armourer other than a part of it having had a squared face. That a wide variety of stakes were used is shown in inventories and artwork, but the information that is more readily available pertains more to hammers and the overall pattern of work left by them and the stakes.

Although little can be determined about stakes from the tool mark evidence, there are enough surviving examples and depictions to form an idea of their types. The

[296] See Figure 56. For a complete description of this object and its marks, see Chapter V, pp. 177-80.

lower half of stakes usually had some sort of step below which was a square tang which would be set into a bench or block. This step could have been made with a forge-welded collar, or by swelling the step by forging. The stakes shown in Burgkmair's woodcut are of the latter type, as are the two stakes from the Greenwich armoury now in Leeds. This step prevented the stake from being driven into and splitting the base it was set in.[297]

The working ends of stakes come in three basic types, two projection, one projection, and upright.[298] Stakes with two projections are sometimes called T-stakes, and double-horned bickirons fall in this category. Those with one projection include basic bickirons and raising stakes. Upright stakes include ball, mushroom, and creasing stakes, which may have an offset shaft to reach into deeper forms.[299]

The Royal Armouries has a fine example of a two projection stake, temporary inventory letter Z, with its two small faces possibly used for planishing, and it likely dates to the sixteenth century and the royal Greenwich workshop.[300] This very form of stake is still in use today, under the name of a 'saucepan belly stake' because of its modern function of planishing the sides of rounded pots.[301] A two-projection stake of this same type is shown in the *c.* 1450 woodcut of St Eligius discussed in Chapter II.[302]

The shaft is upset, or forged back on itself to swell it, with a square tennon to fit in a block. The upper end was split, a horizontal bar was placed in the split, and the two were forge welded together. The thickness created by the three layers was turned into a square, flat work surface while the ends of the bar were turned up and slightly domed to

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[297] Modern stakes lack this step and have a tapering, wedge-like tang. This is suitable for steel stake plates and facilitates their removal from the plate.
[298] Untracht, *Jewellery*, p. 242.
[299] See Figure 57.
[300] See Figures 58 and 59.
[301] R. H. Warn and J. G. Horner, *The Sheet Metal Worker's Instructor* (London: C. Lockwood, 1906), p. 204.
[302] See pp. 60-62.

form the main work surfaces. The two ends allow for two slightly different shapes, increasing its usefulness.

The Armouries' raising stake already mentioned is likewise a perfect example of a one projection stake.[303] This precise shape is sometimes known as a side stake today.[304] It has been a part of the working collection of the Royal Armouries most likely since the days of the Greenwich workshop and was still in use by an armourer until *c*. 2010, when the workshop in the Leeds museum was closed. It is the armourer's stake *par excellence*, useful for not just raising but also many other functions, and was the most-used stake during the experimental plate work done for this thesis.[305]

The stake has an octagonal shaft ending with a swelled base and a wide square tennon. The upper part of the shaft also swells to a flat-topped working face with three straight edges. The projecting horn is round and slightly tapered, and the nose is cut at an angle. The base was formed by upsetting, where the hot iron was forged back into itself, causing the swelling. The horn was also clearly forged, shown by a small depression in the centre of the end, formed when the hotter exterior forged more easily than the cooler interior.[306] The working faces may have a steel plate welded on, but without testing this is difficult to say with certainty.

The horn and flat face of this stake make it perfect for nearly all of the shaping operations of the armourer. Raising, curling, doming, fluting, and edge finishes can all be performed, and a ball stake for planishing and a tool for piercing holes are the only other essential stakes needed. It is likely that the 'byckorne' listed amongst the armourer's tools in the Paston letters was just such a stake.[307]

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[303] See Figures 60 and 61.
[304] Warn and Horner, *The Sheet Metal Worker's Instructor*, p. 204.
[305] See Figures 62 and 63.
[306] See Figure 64.
[307] See Chapter II, p. 38.

Upright stakes such as a creasing or fluting stake are shown on Seusenhofer's workbench in the Burgkmair woodcut.[308] There are none of this kind of stake in the Armouries' collection, but the 'Creste stake' in the 1511 Greenwich inventory was almost certainly of this type, as was the 'vysure stake' because it needed to fit into a fairly narrow space.

Besides stakes the armourer made great use of anvils for several stages of the work. Anvils are distinct from stakes in that they have a large flat work-surface, which a stake usually does not, and the majority of the work is done over the central mass, while stakes usually have protruding arms upon which the work is done, or small shaped heads which lack the mass of an anvil. The mass of the anvil is central to its design, since it increases the effectiveness of the hammer blows through absorption of energy and the rebound this allows for the hammer. Other now-familiar features of the anvil, in particular the horn, were known at the time but were typically separate tools.[309]

The disadvantage of anvils is their size which requires a great deal of material, time, and effort to construct. Because of this, probably most particularly the material requirement, early anvils were very small and block shaped with a tang on the bottom to drive into a wooden base. These 'stump anvils' are the common ancestor of both large anvils and slender stakes. The tennon and small working surface was retained on stakes, while the block form and central mass was retained on anvils. Both would grow in size and complexity over time, although small 'stake anvils' would continue in use, combining the tennon of the stake and shape of the anvil.

The Armouries has a fine stake anvil, struck three times with WP in a heart, which probably belonged to William Pickering, the master of the Greenwich workshop

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[308] See Figure 65.

[309] A small horned anvil is illustrated in Bashford Dean, 'An Armourer's Workshop', in Bashford Dean, *Notes on Arms and Armour* (Huntingdon: Ken Trotman, 2007), pp. 109-111 (p. 111).

from 1608-18.[310] It has a curved rectangular face and a short, blocky body which flares out on two sides to create the rectangular upper shape. At the bottom is a square tennon to set the anvil in a stump or a bench.

Although this small anvil is not as versatile as the raising stake it would still be a very useful tool in the workshop. The curved face would be well suited to anticlastic curling on smaller plates, as well as forging and shaping other small areas. Because of its size it is not suited to large plates such as breastplates or helmet skull, but armour is made up of much more than these large pieces.

Based on artistic evidence, block anvils of great size appear to have been the most common type in armourers' and blacksmiths' workshops during the fifteenth century. They grew in size over the course of this period, but there was little change in shape. Horns were occasionally included, such as a 1490s depiction of Vulcan and an early fifteenth-century fresco at Castello Buonconsiglio in Trento, Italy, showing a smith at work.[311] Block anvils have the advantage of a broad working surface as opposed to a narrow one, convenient for doming plates.

A subset of tools, called anvil tools, is related to the anvil though they are in essence stakes. These anvil tools are largely known as 'hardy tools' today because they are usually set into the hardy hole on modern anvils. These include cut-offs and bick irons, which can be seen in some illustrations set into the stump upon which the anvil is set, but could also be used alongside stakes.

Armourers also made heavy use of chisels for cutting, shaping, and decorating. Chisels may be sharp or blunt, and have a long or short edge, but there is little

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[310] RA inventory entry and Richardson, 'The Royal Armour Workshops at Greenwich', p. 153. See Figures 66 and 67.

[311] Vulcan, Êchecs amoreux (Paris, Bibliothèque nationale, MS French 143, fol. 148), c. 1496-1498, and Detail from the February fresco at Castello Buonconsiglio, Trento, Italy, *c.* 1405-1410. See Figures 68 and 69.

difference otherwise. Cutting could also be done with a shear or smaller cutters, as listed in several of the inventories.[312] The Royal Armouries great shears, originally from the Greenwich workshop were until recently in use, although they were lost for a time after the closure of the Armouries' Leeds workshop.[313] They were found by Pierre Gaite in 2012, having been lying unnoticed in the workshop's coal bin. They are meant to be set into a wooden block and are well-designed.[314]

The shears are made of two sections, pivoted on a modern nut and bolt. The upper blade has a short horizontal arm with a vertical shaft, the upper end of which is extended about three centimetres above the arm, and the lower end is tapered to be set into the block, and it appears to still have wood fragments adhering to it. The lower jaw has a long handle and the end is bent 90°. When closed fully the handle contacts the short extension on the arm below, preventing the blades from crossing. The cut from the shears, as demonstrated by their use in the experimental plate work, is very clean and produces a straight, square cut, not the bevelled edge suggested by Hood in relation to the cuts on the converted kettle hat.[315]

4.3. The Marks and Their Patterns

As useful as the marks can be in determining the types of tools used, their greatest value is as evidence for the techniques and processes used by the armourer with those tools. Here is demonstrated how the marks can be used to read the armour, the patterns and combinations of marks all together showing how each piece was made. Of course, as has been seen above, planishing presents a problem but only to a degree; planishing marks are useful and valuable in and of themselves, and not every piece has been

[312] See for example the 'payr of pynsonys' in the 1485 inventory, p. 39.
[313] Richardson, 'Armourers' Tools in England', p. 30.
[314] See Figure 70.
[315] Hood, 'A Late Fourteenth-Century Transitional Kettle-Hat', p. 157.

planished. The other difficulties in this task are corrosion, which can obliterate the marks very easily, and modern coatings applied by conservators to prevent corrosion which can hide or obscure the marks. Despite these obstacles armour surfaces offer a wealth of information which is often very well preserved, even after centuries of use, abuse, neglect, and restoration.

It is not enough to simply link patterns to specific techniques because there are many possible combinations which may or may not produce the same shape. Therefore, the context of the pattern within the armour must be used in conjunction with the mark type and pattern to deduce the technique. For example, concentric patterns may be seen in both raising and doming, and the overlap of tool marks and corrosion of the surface may hide all but the faint outline of the pattern itself, which is usually visible even when the details have been rusted away. Type of piece, a helmet instead of a breastplate, would indicate that raising was the technique, and the concentric pattern on the interior would confirm this. Further information, such as whether the helmet was planished or the means by which the medial crease was created and when it was laid, can be further gleaned from the tool marks if they are present.

This last also highlights another value of the mark patterns, their use in demonstrating the order of construction either through one set of marks overlaying another, or a feature cutting though an existing mark pattern. Thus it is possible to demonstrate the order in which flutes were laid, whether a helmet skull was planished before the medial keel was created, as well as other details about the order in which techniques were used to create the object.

There are two primary patterns which the tool marks form, concentric and linear. These two broad groupings of patterns are created by several techniques, but their ubiquity demonstrates how the armourers tended to favour particular ways of doing things since it can be seen with what type of hammer they were made and if they were hammered on the interior or exterior. The mark patterns also show how the armour plate itself was moved under the hammer, another clue concerning technique.

Concentric patterns are created when the armour plate is moved in a circular motion while the hammer strikes over the stake, with raising being one of the best and clearest examples of concentric patterns. After making a full 360° turn the plate is repositioned and another row laid, making concentric circles of marks.[316] In the case of raising, the oblong hammer paired with a usually horn-shaped stake produced oblong marks on the interior so most raising, when it has not been obliterated by planishing, can be described as a concentric pattern of oblong marks, with the width of the mark being a variable which depends on the exact shape of the tool faces. IV.580, an early sixteenth-century brow reinforce for a close helmet or armet, very clearly demonstrates these marks, and also that it is possible to locate the exact centre of the plate as it was worked, which is slightly forward of the centre of the plate itself.[317]

Linear patterns tend to be in rows as well, but with the major difference that they were made by hammering in a straight line then stopping, going back to the start point, and laying the next row above or below. Thus the motion of the plate is side-to-side, not circular, resulting in a linear pattern.[318] This particular pattern is most commonly found in curved pieces such as lames, upper and lower cannons for the arms, and all the plates of the leg harness except the main poleyn plate.

Linear patterns are also associated with long features such as flutes, creases, and ridges where they are the result of creating these forms. When this is the case they are said to be running parallel with the flute or other feature, and they can be inside, on the

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[316] See Figure 71.
[317] See Figures 72 and 73.
[318] See Figures 74 and 75.

edge of, or spaced from it as long as they are running along it and can be associated with it. Another pattern possible along these features is for the oblong marks to be at an angle or perpendicular to the path of the feature. These are grouped separately from parallel marks because even though they follow a linear path the differing orientation of the plate in relation to the tools can have various effects on the shape of the plate.

There are several types of mark patterns which do not fall neatly into these two main categories. The largest is planishing mark patterns, which would best be described as no pattern. According to Untracht, 'When properly supported, the undersurface of the work becomes smooth and bright' during planishing.[319] Even though the piece is moved in a similar way during both planishing and raising, planishing does not create a definable concentric pattern due to the extremely close and overlapping hammer blows and the possibility of going over the same area more than once. Indeed, the point of planishing is to remove the ridges which the raising or doming process could create, making the smoothest surface possible with the hammer before moving on to polishing.

4.4. Experimental Plate Work

It is possible to demonstrate the relationship between technique and shape by using the techniques to replicate the mark patterns found on armour. This part of the research was carried out after the primary research on the Royal Armouries collection was completed so that the original marks would be fully recorded. The work was done in its entirety by myself, using skills I had developed as a practicing blacksmith and metalworker, in two stages, first in my own blacksmithing shop and then at the Royal Armouries using tools from their workshop including some from the Greenwich armoury. This experimentation allowed me to replicate some of the shapes and marks found on

[319] Untracht, *Jewellery*, p. 254.

medieval armour to confirm theories regarding technique in areas where there was uncertainty.

The tests involved using brass sheets, due to their availability, ability to be easily worked at room temperature, and softness compared to steel which makes the marks deeper and easier to see.[320] A large number of tools were used; those in my own shop included a ball-peen hammer, a chisel-point rock hammer, a reproduction of a medieval hammer, an anvil, a lead block, and a ball stake. At the Armouries the tools included a selection of cross and ball peen hammers, a planishing hammer, chisels, an anvil, lead block, raising and ball stakes, and shears.

The particular techniques being tested were raising, doming and curling over a flat surface, their relationship to planishing, and fluting. Curling included striking the interior and exterior to create both cylindrical and anticlastic shapes. Planishing was done on one half of a raised form and one half of a domed form so that the marks could be compared in various stages of completion. The findings explain problems in mark patterns on several pieces, especially the linear patterns on greaves, and also recreate the marks found on breastplates and most gutter-shaped pieces. Doming, planishing, and basic curling were tested in both locations, and so only the anticlastic curling will be discussed in detail from my own workshop, as the results were the same for the other tests.

The tests at the Royal Armouries benefitted from being done twice, one set of plates being done for the thesis and the second set being done at the request of the Conservation Department to provide them with examples of plate working.[321] Because of this all the main tests were done twice, while doming, planishing, and plain curling from the interior were done three times overall.

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[320] See Figure 76.
[321] See Figure 77.

The first plate at the Armouries was cut using the Greenwich great shears on three corners and a chisel on the remaining corner to create a circle for raising. The shear required a number of straight cuts resulting in a roughly curved line. The cuts themselves were clean with very little burring. The chisel resulted in a rather ragged edge which followed the curve of the circle much more closely and only required a file to dress the edge.[322] The rest of the plates were cut with a modern guillotine shear.

Raising was the first test done at the Armouries, using the Greenwich raising stake and a cross peen hammer, which despite being modern rather resembles hammers in period illustrations. The plate was twenty centimetres in diameter and 1.5 millimetres thick. A simple dome was raised, working in concentric courses and annealing with a torch at the end of each pass. The resulting vessel had clear ridges showing where each successive pass began, though the tool marks on the interior were not especially clear. There was some round internal marking from where the plate was driven onto the stake, and oblong marks on the exterior from the hammer which had corresponding bumps on the interior which were initially brought out through planishing.[323]

This plate was then further worked on one half. Some low areas were slightly domed with a ball peen hammer into a depression on a lead block, and especially high areas were worked down over a ball stake. This only constituted minor corrections of shape to aid in planishing, which was done over the same ball stake. Planishing itself was done with a planishing hammer and resulted in a very smooth, polished-looking exterior with small facets, and a very smooth interior, in keeping with Untracht’s description.[324]

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[322] See Figures 78-81.
[323] See Figures 82-87.
[324] Untracht, *Jewellery*, p. 254. See Figures 88 and 89.

Planishing had the effect of making tool marks clearer at first before completion of the technique completely obliterated them. Exterior marks from planishing mirror those on the interior in that they are very closely spaced, showing no shape to the individual marks due to very close overlapping, and have no real pattern. These exterior patterns were almost always ground away, though planishing could be left as a final finishing technique.

Doming was the second test, using a plate of the same dimensions. This was initially done over the anvil, but the second plate was done over the flat section on the raising stake. Working from the edge towards the centre with a ball peen doming hammer, a rather shallower dome was created. This shallowness was intentional, to avoid over-stretching the plate and because the round marks resulting from the technique are associated with shallower forms such as breastplates.[325]

As can be seen in the photographs of the plate as it is shaped over several consecutive passes, the marks from the peen of the hammer are round and somewhat spaced, but despite the consistent concentric path of the hammer there is only a very faint definable concentric pattern to the marks. The exterior was rough with dimples from the hammer blows. The subsequent planishing on one half of the dome, like that on the raising, had no real pattern.[326] The most important factor separating the two types is spacing; planishing results in much closer, shallower marks which consequently almost totally obscure their shape.

These two techniques represent two functionally opposite methods of creating a similar shape; while raising works through compression to make the form, doming works by stretching. Raising begins at the centre and works towards the edge, as opposed to the edge working towards the centre as was the case with doming. There is

[325] See Figures 90-92.
[326] See Figures 93-95.

also greater control of the shape possible with raising, though this does not mean that fine work cannot be done with doming. The kettle-hat of Charles I in the Tower of London consists of two domed halves joined at the centre, an excellent example of the technique.[327] If it had been done from a single piece, though, it would have been raised.

The next test involved creating a simple curled form, both by striking the interior and the exterior. This was carried further by using three different hammers for the interior work, each with a different radius. The first test was done over the horn of the raising stake, and resulted in very little marking on the interior, though there were some spaced round marks where the hammer had struck.[328] The tests done on the interior resulted in marks of a significantly more medieval character.

The work was done in straight linear courses, starting at the edge and working up. The curling was completed much more quickly than was the case when done from the exterior, with more control of the final shape. This is a contrast with raising and doming, where the external technique results in greater control. A narrow peen was used first, followed by a medium-sized peen, and finally a broad peen. The shape of the narrow and medium peen marks reflect the shape of the peen, being narrow, oblong marks quite like medieval marks. The broad peen marks appear much more spaced but are similar in width to those made by the medium peen. This is a result of only a small portion on the peen coming in contact with the plate during curling.[329]

The marks are clearly defined for the first two internal working tests, and this also suggests that no planishing was required on pieces formed in this manner. Indeed, the exteriors of the plates are not heavily marked on the exterior, as opposed to the doming test which was marked on the exterior. The existence of clear, long, narrow

[327] London, RA, II.90.
[328] See Figures 96 and 97.
[329] See Figures 98-101.

marks in curled plates indicates that planishing was not preferred for those pieces in many instances.

This method most easily creates a simple gutter form, usually enough for lames, but more shaping is often required for armour plates, and so a test was done to determine the possibility of creating a curved, anticlastic form with an entirely linear pattern made up of narrow or oblong marks. This was done especially to replicate the mark patterns found in several greaves, which are highly sculpted around the calf and ankle but in many instances have only oblong or narrow marks running parallel with the main axis of the greave. This is at odds with the expected patterns, which would consist of perpendicularly concentric oblong marks from a raising operation or round marks from doming the area over the calf.

The sheet used for this test, carried out in my own workshop, was thinner than the previous ones due to availability of material. This made clean shaping more difficult but not impossible as long as care was taken to not strike the sheet with too much force. The hammer used was a hammer I made based on Royal Armouries XVIII.98, which itself bears a strong resemblance to the hammer wielded by one of the armourers in Burgkmair's woodcut of Seusenhofer's workshop. The 1511 bill of payment for armour-making tools includes a reference to 'greve hamers', though no greave stakes and there is no indication what the hammers looked like.[330] Given the marks found in greaves, they were probably much like XVIII.98 but slightly larger, with a long slightly curved head to reach into the curve of the plate and a long, thin peen.

A number of striking surfaces were used, including an anvil, ball stake, and a large lead block with a depression formed into it.[331] Work initially began on the anvil,

[330] ffoulkes, *The Armourer and His Craft*, p. 27. See Chapter II, p. 41.

[331] The lead block is the same as the 'furum de plumbo' in the William Snell indenture, in Richardson, 'Armourers' Tools in England', p. 39.

with some shaping and curling achieved. It became apparent that it would be easier to create the convexities and concavities by hammering over curved surfaces, and so the lead block was used to create the outwardly curved portions on either end and the ball stake was used the create the inward curve in the centre. The sculpted nature of the original greaves suggests that some sort of formed surface such as a cow-tongue stake may also have been used.

Several passes were required to achieve the desired result, but the test was successful in the end. The final shape of the plate is a compound curve in all three dimensions, and most importantly the only mark pattern found on the interior is linear with short narrow marks from the small hammer peen.[332] This confirms the evidence of the marks in the original pieces in that the only hammer required is cross peen. Because of the thinness of the test plate the exterior surface is quite dimpled which would be reduced or eliminated by using steel.

The final test piece, again done at the Royal Armouries, includes three flutes in a spray over a plate, each formed using a different method. This made possible a comparison of three different mark types for similarly-shaped features.[333] The first flute was embossed on the interior over a lead block using a very small cross peen hammer. The resulting flute was rounded on the exterior, and so the plate was laid over an upright stake with a sharp corner to planish. A planishing hammer was used at first, but it was found that a cross peen hammer was more effective at finishing the flute. The stake left small oblong marks which are at an angle to the direction of the flute, but which do not extend beyond it. These overlay but do not entirely obliterate the short oblong marks which were left by the embossing hammer.

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[332] See Figures 102-04.
[333] See Figures 105-12.

The second flute was also made by embossing, but this time it was laid with a hammer and chisel over a lead block. Although similar in principle to hammer-embossing, this technique resulted in a different set of marks. The chisel itself left long, narrow marks within the flute, while the exterior was nearly a perfect flute, the result of the narrower chisel and more focused blow. It was planished in the same manner over the same stake, but the small diagonal marks were much less pronounced and the narrow chisel marks remained.

The third flute was formed only on the exterior, raised as opposed to embossed. The plate was laid over the upright stake and the medium cross peen hammer was used to strike just below where plate met stake, which was then repeated on the other side. Hammering was done on alternating sides until the flute was finished. The marks left were quite different, being mainly oblong marks parallel with the flute, but with little overall marking.

The second plate done for Conservation was worked slightly differently on the raised flute, with the plate also hammered over the nose of the raising stake, which makes clearer that this method of fluting is identical to raising as the relation of stake, hammer, and plate is the same. The upright stake allows the orientation of the plate to be more perpendicular to the nose of the stake, but the horn of the raising stake necessitates a different orientation, and also requires that the further side of the flute be hammered and not the nearer. The resulting marks were similar to those from embossing, with very prominent oblong marks diagonal to the flute, showing two distinct mark patterns for the same overall technique.

These tests demonstrate the value of experimental work in this field, which as shown can confirm hypotheses as to the formation of certain mark patterns, and by extension the methods of construction. Skilled metalworkers today have the ability to reproduce the shapes of armour, but often use modern techniques including welding, raising greaves from the exterior, and other time-saving methods which do not result in the same interiors as medieval pieces.[334] The ability to reproduce the shape and accompanying mark pattern, though, can be used as a diagnostic tool for research, and the findings from these tests will be used in identifying techniques in the following chapters.[335]

4.5. Other Marks Found on Armour

Most of the marks found on armour are directly related to its manufacture, but there are other sets of marks which are found on some pieces. These include assembly marks, makers' and city view stamps, and mar marks. Assembly marks and makers' stamps both were used to convey certain information, and while the assembly marks were used as part of the construction process neither of them are directly related to the techniques of production.[336] Mar marks were created as a direct result of creating the objects on which they are found, but are purely accidental. Although they had no direct impact on how a piece was made they are interesting in how they show the state of the tools in the armourer's workshop.

Assembly marks had nothing to do with the actual shaping of the plates, but were used by armourers to indicate various attributes of individual armour plates to aid in their assembly.[337] They are common and come in an array of forms, but their precise meaning is not always clear. The difficulty is compounded by later repairs,

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[334] Price, TOMAR, pp. 471-72 and Marc Rengarth, 'A Treatise on the Historical Development, Defensive Consequences and Method of Construction of the Leg Defences Used During the Middle Ages in Western Europe', *Hammer,* 30 (1989), 33-51 (p. 45).
[335] See Figure 113.
[336] These 'stamps' are usually called makers' marks or armourers' marks, but to avoid confusion with construction marks from making armour they will be referred to as stamps.
[337] These marks will exclusively be referred to as 'assembly marks' and not 'construction marks', also to avoid confusion.

modifications, and restorations but even so they are useful as an indicator of a small part of the process: reminding the armourer which plates belonged together, sometimes in what order, because when not yet assembled it can be very difficult to determine what goes where due to the similarity of lames.

The most common assembly mark is the notch, cut into the edge of a plate with a chisel or file, which is seen on both the interior and exterior of a piece. The second type of mark is the punched dot or dimple, usually round from a blunt punch but also occasionally triangular, perhaps from the corner of a chisel. There are some other anomalous mark types, described below, but nearly all the assembly marks encountered are of these two types. Some modern marks are made of shallow scratches which are the result of restoration work.

Assembly marks were useful to the armourer in several ways. They indicated in what order plates were to be riveted together and they also were used to differentiate left and right components, such as with arm harnesses, and to indicate a piece belonged to a particular suit or set of pieces. AL.90, a polder mitten for the joust from *c*. 1500, is an example of assembly marks which are most likely to denote a side, single notches clearly visible on the inside narrow edges of the lames, couter, and upper cannon, on the exterior of the plates. The two exceptions are the lower cannon and the lame connecting couter to upper cannon; possible explanations for their absence show how even assembly marks can be used to illustrate the history of an object.

The lack of a notch on the lower cannon is logical given that this is a piece of specialised jousting armour and is further evidence of their use to denote left and right; the right-hand lower cannon would have been a completely different shape from the left, and so no differentiating mark was required. This is not necessarily so on the other plates, so why was there no notch on the upper lame? The plate matches with all the other pieces, so rather than being the result of a modern restoration it could have been a mistake or oversight on the part of the armourer or, more likely given that this is a piece of jousting armour, it may be indicative of working-life replacement.

Some assembly marks seem to indicate that two separable objects belong together, as in the case of the left pauldron on the Avant armour and its reinforcing plate, which is held on with a simple staple and pin. The main plate of the pauldron has three notches on the rear edge, as does the rear edge of the two upper lames and the reinforcing plate. In contrast, the right pauldron has no clear assembly marks.

It is not only separable objects which are so marked but also plates which are affixed permanently to one another. A particularly interesting example is the fifteenth-century sallet IV.499, which has a pivoting visor. To each side of the point of the tail and at each side of the medial crease on the visor, filed into the bottom edge, are three notches.[338] This interesting pattern, two sets of three on each component, is neither decorative nor does it denote a side, but is only to show that these pieces belong together for the purposes of assembly. The very smooth, rounded edges of the notches suggest that they were created before the finishing stages. The armourer may have used them to make sure the polisher or assembler knew that the two plates belonged together, or even to mark that they were intended for a particular patron. It is impossible to know whether this helmet was originally made together with a full suit which also had these marks.

There are many other examples of this type of assembly mark. III.1282, an Italian breastplate from *c.* 1470 has six notches on the lower edge of the plackart and each fauld lame and six filed into the neck roll of the upper plate, and on the plackart and fauld a sequential series of punched dots which, given that the lower set are visible on the exterior and were made after the plates were finished, suggest that they are later

[338] See Figure 114.

marks from working life or later restorations. The notches are not sequential, hardly an issue with the very different parts of a breastplate but giving no indication of order for the fauld, and only show that they all belong to the same object. Similarly, the fauld of III.96, a heavy late fifteenth-century breastplate for the *gestech* form of the joust, has three notches on each of its three lames. Finally, the bevor to II.168 has a series of six notches on the gorget plate and the chin-piece, the notches on the gorget plate arranged in two sets of three to either side of the central cusp, similar to IV.499.[339]

A more common use of these marks is to mark order of assembly, often for only a small portion of a piece. III.732, a pauldron also for the *gestech* form of the joust and from the same period as III.96, has sequential notches on four of its five lames, the lack of a notch on the top lame perhaps denoting the start of the sequence, or zero. On AL.23 224, a cuisse and poleyn, the lames are marked from one to four, starting with the bottom-most lame and working up.

A particularly interesting example of the use of assembly marks is found on II.6, one of the foot combat armours of Henry VIII.[340] The narrow splints covering the backs of the knees are covered in all the possible assembly marks: the edges are notched, there are punched dimples, and there are several scratched marks. Their placement is irregular; the numbering is not sequential and skips plates on the right leg, and neither the notches nor the punched dots are consistent. These irregularities stem largely from the unique history of this particular armour, which was left in an unfinished state until it was finally assembled after the sixteenth century.[341] The rivets currently in place are newer even then that, making analysis of the marks problematic. The scratches are certainly modern, from the late nineteenth or early twentieth century, but the notches

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[339] Leeds, RA, II.168 B.

[340] See Figure 115.

[341] Rimer, *Henry VIII: Arms and the Man*, p. 116.

and dimples may be sixteenth- or seventeenth-century. They do not correspond with each other, and there is no reason that both would have been required by the original armourer.

It is most probable that the notches are related to the original manufacture. They are the most sequential and most numerous, and their placement is more in keeping with the likely sequence of construction. There is nothing substantial to indicate that the dimples are earlier or later than the notches except that the notches are more in keeping with usual armourer's practice. In addition the dimples are large, surprisingly deep, and widely and unevenly spaced. In this they are not in keeping with the character of the notches, and are more likely from the period when the armour was first assembled. They are certainly earlier than the scratched numerals.

While the leg harness of II.6 is an excellent example of the major difficulties encountered with assembly marks, its history makes it a somewhat exceptional piece. However, it should be noted that assembly marks are by no means universal and many pieces of armour have no evidence whatsoever of their use. What, then, is their particular value and why are there so many pieces without them? Assembly marks are not so much directions to the armourer as they are mnemonics, simply reminding the armourer what plates belonged together, and in some instances in what order.

Their use can be taken as a means of transmitting information to another individual who was also involved in a given object's creation. Their lack can be taken to mean that the armourer did not feel it necessary to have the reminder, or that they were created in a way that has been lost. Shallow dimples can be lost through corrosion, and other hypothetical marks such as shallow scratches or marks made with lead would have been removed during polishing. In some rare cases the marks may simply be hidden, such as by an internal leather or by being cut into the overlapping edge. Such is the case on III.828, a fifteenth-century cuisse and poleyn which has two notches cut into the lower edge and three notches cut into the upper edge of the poleyn. The Avant armour also has notches cut into the edges of the poleyn which are nearly invisible.[342]

The next types of mark found on armour which are not a result of manufacture are the various stamps added as a signature or to denote origin or acceptability by a guild. Makers' stamps serve many functions, particularly as the signature of a single armourer and the approval stamp of cities where armourers worked, especially Augsburg and Nuremburg. In most cases the name attached to the mark has been lost, or is only hypothesised.

An early attempt to collect and publish the various armourers' marks was made by the Baron de Cosson in his, ultimately unpublished, *Dictionary of Armourers and Weaponmakers*.[343] His index would have made possible not only the easy referencing of marks for identification, but also cross-referencing marks to look for similarities and possible relationships between marks.

The personal stamps of armourers have been very useful in the attribution of armour, for example a previously unattributed backplate which bears the stamp of Jorg Treytz, covered by a shoulder strap until discovered by Dr Karen Watts.[344] The famous armour of Archduke Sigismund of Tyrol made by Lorenz Helmschmied was not attributed until the 1940s when his stamp was found on the sallet.[345] A previously unattributed stamp was able to be identified as belonging to Hans Blarer the Younger by Pierre Terjanian, using the records of the city of Basel. The stamp on a sallet in the

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[342] See Figure 116.
[343] This is the de Cosson Index, now held by the Royal Armouries, Leeds.
[344] Leeds, RA, III.1284, personal communication with Karen Watts, 2010.
[345] Bruno Thomas, 'Lorenz Colman (Recte Helmschmid), Armourer of Augsburg', in Bruno Thomas, *Gesammelte Schriften zur Historischen Waffenkunde*, 2 vols (Graz: Akademische Druck, 1977), I, 611-16 (p. 615).

Metropolitan Museum of Art, New York, has a stamp closely mirroring the arms used by the Blarer family and which may be ascribed to the proper place and time.[346] Not all discoveries of stamps lead to identification, however. The author discovered a previously unknown stamp on a great helm in the Royal Armouries which belonged to an armourer who is as yet unidentified, though probably English.[347]

City stamps were the mark of a particular guild, and could indicate that the piece had passed inspection and was made in that city. In Nuremberg, all the armour made 'had to be approved for quality and stamped by the Guild before sale, with the mark of the arms of Nuremberg after 1499', and likewise the Augsburg guild had a panel of four view masters.[348]

As important as makers' and city stamps are in the study of armour, it must be remembered that the majority of pieces of armour do not have any at all. This is true of pieces from the lowest quality armour for foot soldiers to the highest quality armour made for kings and emperors. Those pieces at the higher end of the scale demonstrate how the stamps differ from artists' signatures. While a piece of art without a signature will be of much less value and prestige than one with a signature, a piece of armour of even the highest grade does not require a stamp.[349] Armourers at court workshops did not need to mark their work because of its prestige, and an assumption that if, for example, Maximilian I wore a piece of armour, it was the work of Konrad Seusenhofer. Today we can identify these pieces though provenance or style, and pieces which cannot be definitely attributed to any particular armourer are not diminished in value or quality.

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[346] Pierre Terjanian, 'Armour Made in Basel: A Fifteenth-Century Sallet Attributed to Hans Blarer the Younger', *Metropolitan Museum Journal*, 36 (2001), 155-59 (pp. 155-57).
[347] Leeds, RA, AL.30 2. See Figure 117.
[348] Williams and de Reuck, *The Royal Armoury at Greenwich*, p. 20.
[349] Karen Watts, private communication, 2010

The final type of marks found on armour is mar marks, which are uncommon, much more so than assembly marks and stamps. These marks were created when a tool face, either stake or hammer, had a deep scratch or nick in it. Mar marks have not been examined by scholars, indeed their existence is only alluded to in modern metalworking books through the injunction to keep tool faces smooth to avoid them. As stated by Untracht, 'If a working surface becomes nicked, this defect will be imparted to any metal placed over that position and struck with a hammer'.[350] The same holds true with hammer faces. These marks occur very infrequently, but offer an otherwise unattainable glimpse at the condition of the tools of the armourer at the exact moment of an object's creation.

There are very few objects with these marks, most likely because the medieval armourers kept their tools in good enough condition to prevent them. This is evident from the piece with smooth enough tool marks to see that the tool faces were clean, but one object, the left pauldron of the Avant armour, actually has evidence of cleaning the tool face. In a series of marks on the main plate, which are deeper than the surrounding marks owing to the hammer being tilted and the edge digging into the plate, there are three lines in each mark which are the result of a file being used on the hammer face.[351] These filed scratches were not fully polished away and as a result left a 'ghost' in relief on the plate.

The Avant armour, in fact, is notable for its large number of mar marks. In addition to the ones just described, there are marks in the arms, couter reinforce, and further marks on both pauldrons. These marks are all of the more typical small round or oblong shape, which appear to have been mostly on hammers but some may have been from stakes. The lames of each pauldron both have the same small round bump, in the

[350] Untracht, *Jewellery*, pp. 242-43.
[351] See Figure 118.

same location in each mark, showing that it was the exact same hammer that made each lame.[352]

There were three other objects found to have mar marks during the course of study. The first was the Lyle basinet, which has a few long raised marks inside the visor, from the stake over which it was planished. The second was a backplate, III.2446 A, which has a number of L-shaped marks over one shoulder. Finally, the Pembridge helm in the National Museum of Scotland in Edinburgh has long mar marks on the interior of the cap plate, from a fairly large nick on the face of the planishing stake.[353]

4.6. Screws and bolts

One final detail of construction of many on these pieces of armour is their screws and bolts.[354] There has been comparatively little study of early screws, particularly those used on armour, and the methods used to create them are poorly understood. However, by close examination of the few medieval pieces from the Royal Armouries which do have screws, along with the scanty evidence available for medieval screw-making, some of these questions may be answered.

There are three ways a screw or bolt may be used on a piece of armour. It may be used with threads which are formed directly on the plate, it may be used in conjunction with a threaded plate which has been riveted or brazed onto the armour, or it may pass all the way through the plate and be secured with a nut. The use of these bolts is to either rigidly affix elements such as a lance rest or auxiliary pieces for the joust, to hold pieces of armour together or close them, or to act as pivots, without doubt

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[352] See Figure 119.
[353] See Figure 120.
[354] Screws are any fastener which hold plates together directly by the use of their threads and threads on the plate. Bolts pass through the plates without engaging any threads and are secured by a separate nut.

the least common use. Due to the difficulty of manufacture, the time needed to repair them, and the difficulty of repairing them in the field when compared to straps and rivets, bolts are more commonly found on armours of higher quality meant for the tournament, though some field armour also made use of them.

All of the pieces using screws are from the late fifteenth and early sixteenth centuries, and armour may be one of the earliest widespread uses of screws and bolts in Europe.[355] Their use is rather evenly distributed among helmets and breastplates in various roles, with one arm defence, AL.90, and of the ten objects with screws and bolts the full range of uses is well represented. Some objects, such as the great basinet from II.7 and a number of other great basinets and helms have holes through which bolts passed but were not included in this group since they only have simple holes with no threads.

The use of bolts as pivots is in a way unusual, since the action of raising and lowering the visor could work the nut loose and cause eventual loss. Three of the helmets have this arrangement, IV.12, IV.13, and IV.502. The last is a jousting helmet and so would not have seen extended use on campaign, but the other two are for field use and of low quality. It is possible, though only conjectural, that these are later working-life modifications, but the holes on the skull of IV.12 are square to accept the head of the bolt. This prevented the whole bolt from rotating with the visor, perhaps as a solution to the problem of the nut loosening. The holes on IV.13 are round, and the bolts are modern, so the arrangement is possibly not original.[356]

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[355] C. F. C. Beeson, *English Church Clocks* (London: Phillimore, 1971), p. 27, quoted in Randall C. Brooks, 'Origins, Usage and Production of Screws: An Historical Perspective', *History and Technology*, 8 (1990), 51-76 (p. 55).
[356] RA inventory entry. The sallet had this arrangement in the nineteenth century, as shown in de Cosson's *Helmets and Mail*, pp. 180-83.

Holding pieces together in a more rigid arrangement is much more common. In this case bolts may be used, but screws are also a possibility, either threading into an attached plate or into the actual armour plate. For both these methods there is ample evidence. IV.502 contains, in addition to its pivot bolts, four other screws which fasten the sides of the bevor to the skull and close the shoulders.[357] At the sides the screws pass through the bevor and into lobes brazed onto the skull plate. These lobes are irregular in shape and may be repairs or additions, but are in any case thickened in order to provide more purchase for the threads. At the shoulders small pieces have been riveted to the interior on the skull plate to serve the same function, thickening that area where the screw passes.

Similarly on III.96, a heavy jousting breastplate, a number of holes are pierced for the attachment of several components, including the plackart, the shield, the helm, the lance rest, and the lance brace.[358] As such the whole of the piece is heavily perforated, although some of the holes were later filled. For the shield, lance brace, and most of the lance rest holes large thread plates have been riveted to the inside to correspond with the external holes. In the centre for the helm and just above the lance rest plate there are holes which are threaded with no internal plate. Significantly, not all the central holes are actually threaded, though neither have they been closed. The untapped holes on the breastplate may represent where screws could be put in the future if the breastplate was used with a different helm requiring a different arrangement.

It is likely that in some cases the plates were pierced and then threaded as needed, as with III.96, though it would have been unusual for a piece of field armour where efficiency of design was more essential. Pieces with separate threaded plates or lugs which were riveted on would also have allowed threading to be carried out without

[357] See Figures 121 and 122.
[358] See Figures 123 and 124.

directly impacting the plate. This would possibly be more efficient and present less risk of damaging the armour as it is only a small piece that need be worked at a time. The holes on III.96 also have threading on the breastplate itself, which would have been done after the already tapped plate was attached.

This is related to the question of manufacture of screws in the Middle Ages, and on this point there has been very little scholarship. Heron of Alexandria created cutting tools for both the male and female components of screws, and Randall C. Brooks claims that this same process was in use throughout the Middle Ages, though there is little, if any, direct evidence.[359] Aubrey Burstall claims that taps and dies were in use during the fourteenth century but unfortunately gives no supporting evidence.[360] There is a screw-lathe illustrated as early as 1483 in *Das Mittlealterliche Hausbuch*, but this is not a tap and appears to be meant only for making wooden screw presses.[361]

An alternative method for making screws would be to file them by hand individually. The threads could have been marked in the same way given by Heron, with a guide tracing the path of the thread. The thread would then be cut by hand with files, gravers, or chisels.[362] However, this also meant that while screws could be similar, they were never exactly the same due to variations in filing, and also that they were extremely labour-intensive compared to other fasteners.

While the creation of the screw or bolt, no matter the method, is fairly straightforward it is the threaded hole in plate or nut which presents a particular problem. Without a tap there is no efficient way to create the threads; neither gravers nor files can reach into the hole. The holes on the armour plates which have no

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[359] Brooks, ‘Origin, Usage and Production of Screws’, pp. 52-53.
[360] Aubrey F. Burstall, *A History of Mechanical Engineering* (London: Faber and Faber, 1963), p. 155.
[361] Brooks, ‘Origin, Usage and Production of Screws’, p. 63.
[362] Stephen V. Grancsay and Cyril Stanley Smith, *Made of Iron* (Houston: University of St Thomas Art Department, 1966), p. 134.

accompanying thread plates offer a solution that takes advantage of the plastic nature of ferrous metals.

The breastplate from II.1, a late fifteenth-century German piece, has a plackart which is attached by means of a screw, just as with III.96 although II.1 is a piece of field armour. There is a single hole in the centre of the plackart and two holes on the breastplate, allowing for a certain amount of adjustment. The two breastplate holes are threaded with no internal plate, and the interior of the holes is very ragged.[363] In this case it is not a matter of the armourer not cleaning the interior but actually making use of them, formed when metal was displaced during punching. This created a slightly thicker area around the screw holes without resorting to leaving that area of the plate thick during forging. The thickness is especially important when considering the wide threads of the screw. Even on III.96, itself a very thick plate, there are burrs around the screw holes.

It was not only punching that caused this increase of thickness, and indeed it is this thickening which points most at the method of tapping; these holes were most likely tapped by the screws and bolts themselves. The screws were not self-tapping as we understand them today, but rather it was a combination of the helix of the screw, bevelled edges, and heat that allowed the holes to be threaded. There is precedence for this type of thread-making found in nineteenth-century screw threading plates. These plates consisted of a series of holes of graduating size which were threaded. The blank was inserted into the largest hole and the plate twisted around, and then each smaller hole in succession. ‘The forming action by a screw plate was to squeeze the metal blank into the threaded form...The addition of more rows of holes permitted a more gradual forcing of the shape into successively deeper threads’.[364] The action of the

[363] See Figure 125.
[364] Brooks, ‘Origin, Usage and Production of Screws’, p. 61.

screw plate was thus more akin to a wire-drawing plate than a modern screw die. The same process would be done in reverse to create the plates, and so a set of taps and dies unique to the workshop would be created.

The 1611 and 1629 inventories of the Tower mention a ‘counter borer’, which was likely used for bevelling the edges of holes for flush rivets, but could also be used to prepare holes for tapping.[365] The lance rest for III.69, a fifteenth-century German breastplate, has two threaded holes and three holes which are countersunk but not threaded, showing the preparatory step.[366] The underside is clean on all the holes, since the rest’s base must fit the breastplate firmly and the plate it is made from is quite thick enough already.

This counter-sinking would have given the screw a starting point, making the tapping slightly easier, and also helping to align the screw. The last step of the tapping process would have benefitted from the plate being heated to make deforming the plate easier. The screw or bolt was put in the hole and turned, driving into the plate and creating the threads not by cutting away material, but by displacing it. That displaced material makes up part of the burr seen on III.96 and II.1. The threads of the hole would be an exact match to the screw or tap which created them, making replacements difficult if the originals were lost or unavailable.

4.7. Conclusion

Most studies of armour have focused on its outward appearance and changes in shape, but it should now be apparent that the interior of armour is just as varied and complex. These marks which were left by the tools are as much a part of the armour as the

[365] Tower Inv., pp. 59 and 76.
[366] See Figure 126.

decoration on the exterior, and one of the most important pieces of evidence for the manufacture of armour.

When discussing the marks on the converted kettle hat mentioned in the introduction, Hood describes some identifiable patterns:

> ...the thinning of the metal close to the apex corresponds with the process of deeply drawing out the metal in order to create the short comb. This same raising process is already evident on the inside of the skull where square-shaped hammer marks run in concentric circles. The hammer marks on the inside of the helmet are not matched on the relatively smooth exterior and this suggests that the outer surface was polished smooth...[367]

However, as has been demonstrated above the thinning of the metal was not from raising but from embossing, which pushed the comb out and thinned it, not raising which compresses. The concentric marks are not hammer marks but were made by a stake, from raising but made clearer through planishing which smoothed the exterior surface. Hood further states that 'The one-piece construction of the helmet and the deep drawing of the metal to create the short, crisp comb denote the hand of an armourer of considerable skill', but the techniques of raising and fluting were essential for all armourers to know.[368] It was the skill with which the techniques were carried out that signifies the work of a master.

Although metallographic examination and related techniques may be used to determine some aspects of how an armour was made, each tool mark is the direct result of a single hammer blow by an armourer centuries ago. Those marks taken together may be analysed to read a piece of armour to better understand the actual working practice of the armourer for a greater amount of the process.

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[367] Hood, 'A Late Fourteenth-Century Transitional Kettle-Hat', p. 158.
[368] Hood, 'A Late Fourteenth-Century Transitional Kettle-Hat', p. 171.

Although the marks themselves are not immensely varied in shape, being largely either round or oblong, their precise shape paired with their size, pattern, and context within the armour may be used to accurately identify the exact technique used in making each piece. Overlap of marks from one feature to the next shows order of construction. Some of the assumptions about the ways in which armour was made have been found to be inaccurate.

The experimental plate work was especially helpful in this regard as it resulted in confirmation linking mark patterns and techniques. Greave mark patterns were demonstrated to come from internal curling rather than raising, planishing was differentiated from both raising and doming, and the marks from several different fluting methods were identified, providing a basis for further study and identification.

Chapter V: Case Studies

5.1. Introduction

The previous chapter identified the mark types, the kinds of tools that created them, and the patterns they are found in, the text which is to be read on armour. The focus of this chapter, however, is on techniques, the interrelation of techniques, and the ways in which they may be identified on multiple objects. Several objects will be examined in detail to demonstrate the wide range of marks found and, most importantly, identifying method of manufacture using the mark evidence, the practical application of the methodology developed for this thesis.

The first section will consist of short case studies where each object will be analysed individually based on its own merits. Much may be learned from looking at the objects in this manner because each one, no matter the techniques used or the armourer responsible, is slightly different. The comparative case studies will form the second part of the chapter, where the mark patterns and construction details on multiple pieces may be seen together. This will show where technique has been different or similar, through which it will be shown that groups of objects may be assessed using the thesis' methodology demonstrating how armourers and regions of manufacture may be identified by the types of marks found within features from different techniques.

Although hundreds of individual objects were studied in the course of this research, only a relative few were selected for inclusion in this chapter. Those which do appear here were chosen either because they are a particularly good example of a specific technique or mark pattern, or because there is something unique or especially enlightening about the object. The rest of the objects have been used to support the findings from those which will be detailed here.[369]

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[369] For a list of all objects examined, see Appendix E, pp. 513-26.

Each individual case study will begin with a short inventory-type entry for the piece giving a physical description. This must be done in order to explain how the various plates are attached to each other, how they are secured to the rest of the armour, and how they are shaped to the body. It is also critical to understand not only how a piece was shaped but *why* it was made a certain way, or the significance of certain features related to function. The inventory description will be followed by the constructional analysis of the interior tool marks on the armour, concerning their type, the related technique, and how they demonstrate how the armour was shaped.

For reasons of analysis the pieces have been grouped based on very broad defence types.[370] Helmets, of which there are more than any other single type, are the first, and are made up of close helmets and armets, great basinets, basinets, sallets, and helms. Armour for the torso, breastplates and backplates which together form the cuirass, form the second group. Armour for the limbs, including the shoulders and extremities, are the third group.

Although the objects in this chapter span a period of approximately one hundred and sixty years, they are not arranged in chronological order. While the form of armour certainly developed during that time, there has been no difference found in the construction techniques of late medieval and early Renaissance armourers. Since the techniques found remained quite stable, it is more useful to arrange them by defence type.

Attribution to a place, such as Germany or Italy, is for the most part taken from the objects' inventories, with some exceptions. Assigning a piece an origin is often a stylistic exercise, based on shape or other factors. Types of decoration are often

[370] Bevors, covering the neck and chin, are classed as head defences, although the Royal Armouries inconsistently places them in class III and IV, body armour and head armour respectively. Shoulder armour, as well as armour for the extremities, is included with limbs.

strongly associated with certain localities. This is aided by the makers' and city stamps which are found on several pieces, which helps refine the stylistic criteria. If an attribution is found to be incorrect it will be explained. 'Germany' means the late-medieval German lands, not the modern nation, and so includes several pieces which the Royal Armouries has labelled 'Austrian'.

Assembly marks and makers’ stamps will not be indicated in every instance, unless they are of particular interest or are of an unusual character, since the precise meaning of assembly marks is not always clear. Likewise damage will only be mentioned if it is of particular interest or importance to the construction or history of the piece. The name, provenance, and date for each object is derived mostly from its inventory record in the museum in which it is found, largely the Royal Armouries but also the Kelvingrove Art Gallery, and the National Museum of Scotland.

5.2. Head Defences

The objects included here were created using many techniques, but first among these was raising. It was the main process used to form the overall shape of each piece, and it remains visible even after planishing, another regular part of helmet-making. Fluting is also a common feature on these pieces, and various types of embossing. Some of these objects have been studied closely, and yet their precise methods of manufacture have not been fully analysed until now.

IV.580 Skull reinforce

Italian, *c*. 1510

Figures 127-30

This reinforcing plate for an armet or close helmet, though small, has a very clear pattern of marks on the interior which may be used as an initial demonstration of how to read a piece of armour. It is rounded with a medial keel and a short extension at the front over the face with an inward fold. At either side of the keel at the top are large circular cutouts. It is pierced at the top with a keyhole slot and at the sides for the pivots and further attaching rivets. The back edges have notched decoration, and the top of the keel has an incised double herringbone pattern.

The interior is heavily marked with clear marks and a definite pattern. The primary pattern is made up of small oblong marks in a very clear concentric arrangement, with the centre being obvious at about the midpoint of the medial keel. At the rear left corner there is a separate set of marks of the same shape and character, but at a 45° angle from the edge. Overlaying the marks at the centre are long, narrow marks running parallel and diagonally to the medial keel, both inside it and to the sides.

The concentric marks are certainly from raising, made clearer and more defined by light planishing. The unusual direction of the marks at the rear left corner was likely a result of the armourer correcting an imperfect initial shaping by curling from the interior. The marks in the keel are from raising it on the exterior, and long thin marks near the centre show that it was also chisel embossed.

Although it is only a single, rather simple plate, this skull reinforce is useful because it is possible to see the exact axis around which it was turned during raising. This is shown to be not in the exact centre of the plate, where it would have been assumed. Usually it appears that raised pieces were indeed started at the centre, but it was not always the case.

IV.22 Armet - the 'Horned Helmet'

German, Innsbruck, 1512-14

Figures 131-34

Perhaps one of the most iconic pieces in the Royal Armouries, even providing its logo, the Horned Helmet of Henry VIII is noted for its grotesque face-mask and dramatically curled horns. All that remains of a now-lost armour made by Konrad Seusenhofer and presented to Henry by Maximilian I, the helmet has undergone several alterations in its lifetime and the provenance of many of its components has been called into question.[371] Examination of the plates has allowed for a more concrete interpretation of the origins of the piece.

The helmet is composed of four plates: a skull, two cheek pieces, and a full mask-like visor. Added to this are two large plates worked to resemble the horns of a ram, and scissor-type spectacles made in two pieces. The skull is round, with an arched opening over the face and a short, broad tail at the rear with cutouts at the sides for the cheek-piece hinges and which terminates in a channel for the collar flange. The surface of the skull has a checkerboard pattern of raised and sunken rectangles, the sunken ones having holes for decorative panels.[372] There is also a row of holes along the centreline, possibly for a crest.[373]

[371] Alan Borg, 'The Ram's Horn Helmet', *The Journal of the Arms and Armour Society*, 8 (1974-76), 127-37 (p. 134).
[372] Claude Blair, 'The Emperor Maximillian's Gift of Armour to King Henry VIII and the Silvered and Engraved Armour at the Tower of London', reprinted from *Archaeologia*, 99 (London: Society of Antiquaries, 1965), pp. 17-18.
[373] Borg, 'The Ram's Horn Helmet', p. 129.

The cheek pieces are hinged at the sides rather than at the top as is usual for an armet, and once fastened under the chin though the exact method is lost. The lower edge is formed into a channel for the collar. They have a series of brass-capped rivets for a lining and are pierced over the ears. The front edges have small applied hinges for the attachment of a lost alternative face-defence. The ear piercings are decorated with etched rosettes, the hinges with dragons' heads, and the front and upper edges with a hatched pattern.

The mask is elaborately embossed in the image of a male face with piercing on the nose, mouth, brow, and eyes, and is heavily etched to show lines and beard stubble. It is attached to the exterior of the skull by a small hinge on the upper edge, and is overlapped by the cheek pieces except for the upper corners which overlap the cheeks by means of a slot cut into the visor. The upper edge has a recessed border which once held a decorative band.

The horns and spectacles are a source of considerable controversy and it is not clear whether or not the helmet came furnished with them when presented to Henry. It is known that they were in place fairly early, since it is listed in inventories with them at least since 1547.[374] The horns are very well made, realistically imitating ram horns, but are inserted through rough slots in the sides of the skull and riveted in a very crude manner. The spectacles are brass and are pivoted at the centre of the bridge. The edges are decorated with fine hatchwork and incised lines. They are attached to the mask with modern screws passing through the bottoms of the rims and holes pierced below the eyes. Like the horns they may not be original to the helmet, though it is a difficult point to prove.[375]

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[374] Claude Blair, 'Comments on Dr. Borg's "Horned Helmet"', *The Journal of the Arms and Armour Society*, 8 (1974-76), 138-85 (p. 140).

[375] Blair, 'Comments on Dr. Borg's "Horned Helmet"', p. 173.

The interior of the skull is covered in small, round, closely set marks indicative of planishing. These marks are in several areas overlaid by long, narrow marks which were created by the embossing of the sunken panels in a similar manner to fluting. The cheek pieces have little shape and consequently little marking. Significantly, however, there is heavy marking in the channel on the lower edge, both on the skull and on the cheeks. These are long, thin marks which run parallel with the channel, created by curling and embossing on the interior with a small hammer, and are identical on all three plates. This demonstrates that, whatever the provenance of the other components, the skull and cheeks were made by the same hand.

The interior of the mask is heavily marked from embossing, primarily with small round and small oblong marks from the chasing hammers and small stakes which would have been used to create the complex shapes of the human face. The dew drop under the nose would have been particularly difficult, requiring a long rounded punch to reach inside the nose and work the drop out from the interior, supported on the exterior by pitch or lead. Other features such as the lips and jowls would also have been worked from the interior over a soft but resistant backing. The nose is deep enough that it would have been raised out of the centre of the plate before embossing was used to refine it. This is also likely the process used on the shallower but still sharply domed chin. Because of the depth of both the nose and chin, simple dishing or embossing would have caused the metal to tear during forming.

Although there are similar marks on the interior of the mask as on the other plates, there is no place where a feature-to-feature comparison can be made. However, Williams performed metallurgical analyses on the plates of IV.22 and found that the microstructure of the cheeks 'closely resembles that of the mask'.[376] This supports the

[376] A. R. Williams, 'A Technical Note on Some of the Armour of King Henry VIII and his Contemporaries', *Archaeologia*, 106 (1979), 157-65 (p. 161).

theory that the four main components of the helmet were made in the same workshop, since it has been demonstrated that the cheeks and skull were made by the same hand, and the mask and cheeks are similar metallurgically.

Although it has long been assumed that the main plates of the helmet were made in the same workshop, the findings here conclusively show that this was the case. It is also an example of the metallurgical study and tool mark analysis being used side by side to arrive at a conclusion regarding the manufacture of the object.

IV.29 Close helmet - the 'Moustached Masked Helmet'

German, *c*. 1520

Figures 135-43

This close helmet is one of the finest examples of metalwork in the Royal Armouries collection. It was made for the tourney and, like the previous helmet, features a removable visor resembling a human face but on this piece with a large handlebar moustache projecting from under a large and crooked nose.[377] It was incorrectly labelled a ‘tilting bourguinot’ by Jules Labarte who used it to illustrate the use of ‘the chaser, the engraver’ in sixteenth-century armour making.[378] The methods used on this object beautifully demonstrate just how much a ferrous plate can be shaped, and the effects of that shaping upon the material.

There are four plates composing the helmet, a skull, chin-piece, tourney visor, and parade visor. The skull is large and round with a low, heavily roped medial keel

[377] There is a remarkably similar visor in the Museum of the Polish Military, Warsaw, which based on external construction details may be attributed to the same armourer as made IV.29. This is a possible area of further study, to determine if they were in fact made in the same workshop using the tool-mark evidence.

[378] Jules Labarte, *Handbook of the Arts of the Middle Ages and Renaissance, as Applied to the Decoration of Furniture, Arms, Jewels, &c. &c.*, trans. by Bury Palliser (London: John Murray, 1855), p. 364.

and with rows of low, parallel flutes covering the surface to either side. The lower edge is formed into a roped channel for the gorget flange. The front has a shallow cutout over the face, and to either side a deeper cutout forming a short, broad tail at the rear. Around the face opening and above the collar are flush rivets for a lining and there are several pairs of holes at the rear of the skull, perhaps for a crest. At the lower right corner is an interesting spring catch; the spring pulls the post for the chin-piece inwards, as opposed to pushing it out. The post is raised by turning a wing-nut on a screw riveted to the spring. Above the face opening is a more conventional spring catch, with a simple square post which holds the tourney visor closed.

The chin-piece is pivoted to the skull at the temples on rivets with wide, flat outer heads. It shaped to the chin and appears to be rather exaggerated in size.[379] The bottom of the chin is flush with the bottom of the collar channel which fits over that of the skull. The upper edge is nearly horizontal, with the pivots at the rear corners, and then curves down around the face, rising to a blunt cusp at the centre. The upper edge is also recessed to fit the tourney visor, and in this recess and around the neck are flush rivets for a lining. At the right-hand side is a restored spring-catch with a button for the parade visor.

The tourney visor is made from a relatively thin sheet of metal. Pivot arms extend from the rear to the same pivots as the chin-piece, and the lower edge is round to fit the face-opening. The whole of the visor is pierced with wide lozenge shaped holes, with two long cutouts for sights. The centre has a strong medial crease.

The parade visor is the most interesting and unusual component of the helmet. It is attached with hinge pivots using the same rivets as the chin-piece and tourney visor. The hinges are riveted to the arms' interior and are completely covered. There are two

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[379] The original owner is unknown, but the helmet's moustache and crooked nose seem to be a caricature, perhaps of the original owner.

long, narrow sights above a sharp projecting beak below which is a caricature of a human face with a large crooked nose, subtly puffed cheeks, and a full, twisted handlebar moustache. There are ventilation holes pierced on each cheek, two under the nose, a slit for the mouth, and a hole at the right for the spring catch.

There is little marking in the skull owing to the low flutes which have overlaid the forming passes, though the areas between the flutes are lightly faceted on the interior from planishing. The flute channels themselves are straight and deep, with little marking other than some light, long parallel and diagonal marks, and the comb is clean with no marks along it. Corrosion makes interpretation difficult, but they appear to be consistent with embossing from the interior. The collar is likewise clean, probably due to its width; the larger radius of the turn, compared to IV.22, may have allowed the edge to be more easily shaped. Forming marks may then have been obliterated by roping the collar from the exterior with a blunted chisel. The point of the chin-piece is lightly marked with faceting from planishing. The medial crease of the chin has a corresponding channel on the interior from embossing but it has no other marking.

The tourney visor is practically free from marks on the interior, though this is mainly because so much has been removed to form the lattice. On the exterior there are some nicks on the corners of the cutouts, probably from the file that was used to clean the edges. On some, however, especially on the left side, there are thin cuts which do not quite align with the corners. These marks are from the chisel that was used to cut out the lattice, accidentally cutting outside the intended outline. Filing the edges clean enlarged the cutouts, causing this scoring to be misaligned with the final edge.

The virtuosity of the armourer is most clearly shown in the parade visor. Forming the long moustache out of the same plate as the rest of the visor would have required great skill, careful planning, and flawless execution. The visor must have been raised; with the depth of the visor, and especially the nose, dishing would easily have torn the metal. In addition, the plate is quite thick throughout, especially evident at the cheeks, observed through the ventilation holes. The plate would be cut to the rough shape of the visor, long extensions at either side with a much wider centre, and raised into a rough dome. The areas around the moustache would then be compressed inwards, especially at the sides, creating a smaller bulge separated from the rest of the visor by a narrow neck. The area between the moustache and the nose, between nose and prow, and above the prow could then be raised, completing the basic form of the visor, though in a very bulbous and inelegant shape.

Drawing out the moustache would have been the most difficult part of the operation. At this stage it was two appendages protruding out from the front of the visor to either side. The moustache was forged, drawn out over the anvil, hot as with the raising. Rotating it around the axis of the moustache, the armourer would carefully hammer the hollow tube. This is very difficult because kinks or divots are extremely difficult to mend in a tube. This process would have lengthened and thinned the extensions, and the ends were probably forge-welded solid. The ends are hollow from the centre to six centimetres in on each side, but the extremities needed to be solid to aid in forming the spherical terminals. These were probably formed by shouldering the ends over the edge of the anvil and made round by forging. The area between the nose and the top of the moustache was also cleaned, and is a uniform concave radius, from both a stake and filing.

With the basic shape of the moustache finished, the roping could be very carefully worked in with a blunt chisel over the front. The roping does not continue to the rear of the moustache, since it would be too difficult to reach with any tool. Before roping, the whole moustache would have been heated and gently curved back towards the face, and then the ends turned up.

The extreme compression which was required to form the moustache is evident from the stress cracks which have formed at its centre where it joins with the rest of the visor. These cracks follow the contour of the visor and taper toward the join, then continue along the moustache for about two centimetres, mainly on the back. They do not twist or turn in any direction other than the curve worked into the plate, showing that the metal was compressed evenly, if just beyond the working stresses the material allowed. Since these cracks are neither large nor gaping it is unlikely that they were evident during or after manufacture, but rather formed slowly afterwards due to internal stresses and, after the initial crack formed in the surface, through corrosion. A much larger crack on the right side was exacerbated by damage, probably the result of a fall, which also bent that side of the moustache further back and damaged the tip enough to require a brazed repair.

The nose is also an intriguing feature of the visor due to its form and its construction. In addition to being large and hooked it is crooked, as if modelled on a broken nose. Taking into consideration the care, skill, and precision which went into the rest of the helmet, it is unlikely that the armourer made an error in this regard. It is tempting to think that the visor is based on a real person, perhaps a caricature of the owner with an exaggerated but recognizable nose. While the main bulk of it was formed in the initial phase of raising, which also formed the ends of the moustache, the final shaping was carefully hammered and embossed. Most revealing is a deep depression on the interior at the tip which was created by driving a blunt chisel into the nose, at an angle to begin the crooked shape, which would have been backed up on the exterior with a firm material such as pitch. This created definition for the tip, and also a point of reference for the final finishing and setting the medial crease. The nostrils were created through embossing from the exterior and probably working on the interior as well.

Working over a sharp stake, and perhaps also with a chisel, the lower edges of the sights and the mouth could be formed, and the slits on both features cut out. The cheeks are slightly puffed as if from exertion, and this could easily have been domed from the interior. The hinge leaves could then be attached with flush rivets to the interior of the rear extensions, and the exterior filed and ground to its final finish, and the small amount of engraving done around the moustache and flutes.

Because this piece is unusual, the type of forming used on it is not likely to be found on many pieces of armour. Nevertheless, it shows just how far steel can be shaped and moulded, its level of plasticity, and the skill of a master armourer. A similar helmet is in a collection in Poland, and a comparison of the two pieces may link them, making them two pieces by a currently unknown armourer.[380]

II.6 Close helmet of Henry VIII

English, Greenwich, 1520

Figures 144-47

One of the well-known foot combat armours of Henry VIII from the royal workshop at Greenwich, II.6 is remarkable in the extent of its coverage and protection. It was intended for Henry's use at the Field of Cloth of Gold but was not completed in time and was left in the workshop, black from the hammer, and was not assembled until the eighteenth century.[381] Although it now appears to be a completed armour, it is in fact

[380] Warsaw, Museum of the Polish Military, unknown inventory number.
[381] Rimer, *Henry VIII: Arms and the Man*, p. 116. For the Field of Cloth of Gold, see Sydney Anglo, *Spectacle, Pageantry, and Early Tudor Policy* (Oxford: Clarendon Press, 1969), pp.

unfinished. The close helmet, and indeed the whole armour, is plain-looking because it lacks what would no doubt have been intricate etched and gilt decoration. It consists of three plates, a skull, a chin-piece, and a visor, all pivoting on the same rivets at the temples.

The skull is rounded and closely fits to the head and neck. The front is cut away for the face opening with a further shallow cutaway for the sights. The lower edge has an inwardly turned flange to fit over the gorget collar, not a channel as often found on other contemporary helmets, in order to maintain a flush surface at the neck.[382] The top has a tall, narrow medial keel. Around the base of the skull and over the face opening are holes for the lining rivets, the holes over the face being empty. At either side on the neck is a pierced pin for a spring catch which engages with a hole and hook on the chin-piece to hold it closed.

The chin-piece overlaps the skull and has a large curved face opening rising up to the pivots. Around the neck are rivets for a lining, and around the face opening are holes for lining rivets. On the right side are two modern rivets and an empty hole for the missing visor catch. The front has a medial crease and the lower edge is also flanged for the gorget collar. The flange is unusual, as the lower edge is typically a larger collar, as is the case with IV.22 and IV.29, but here allows a smooth transition on the neck.

The visor is large, with a single long raised sight with a blunt projecting prow and a heavily pierced front. The front is creased and rises to a medial keel to fit over the skull. The rear edges taper to the pivots. The lower edge of the sight is folded inward as a reinforce, and the ventilation holes form an open lattice.

124-69 and Joycelyne G. Russell, *The Field of Cloth of Gold: Men and Manners in 1520* (London: Routledge, 1969).

[382] See for example IV.22 and IV.29 in this chapter, pp. 151-54 and 154-59.

The construction marks on the interior of the helmet are mostly the same as would have been found if it had been completed; the only differences would have been some additional marks as a by-product of decoration and probably quite small. As they now stand, the skull and chin-piece both have small round marks on the interior from fairly cursory planishing. On the exterior the chin-piece is slightly dimpled on the right side, the result of planishing facets which had not been fully ground away. The collar around the neck on both plates has oblong marks perpendicular to the lower edge from curling on the interior with a medium cross peen hammer, as demonstrated in the previous chapter.[383]

The small fold on the lower sight has very small oblong marks perpendicular to the edge which are the result of hammering the fold flush with the inner surface of the visor after the sight had been cut. The fold was initially formed by embossing a furrow in the raised prow of the sight with a blunted chisel and the sight cut out of the area behind it.[384] Of particular interest is the heavy file marking along the medial keel of the skull and visor. This area would have been rougher from the hammer since it seems that the keels were at least partially worked after the main planishing. This area may also have been more difficult to reach with file or grindstone, as with under the chin, resulting in rougher passes before the surface could be blended into a smooth and even finish.[385]

The unique history of this piece makes it an interesting example of something which was left unfinished but then completed later. The heavy grinding marks in particular are unusual, as these are usually not seen even on munitions armour. Since low quality armour was never meant to be polished it was often left simply planished,

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[383] See Chapter IV, p. 129.

[384] This process may be seen half-completed on the great basinet IV.2, see pp. 166-68.

[385] See also IV.499, pp. 177-80.

and the current finish of II.6 is highly unusual, being a rough grind with no further work done to the surface, which otherwise would have been completely smoothed.

II.7 Great basinet from Henry VIII's tonlet armour

Italian, Milan, *c.* 1520

Figures 148-53

The great basinet from one of the foot combat armours of Henry VIII is an interesting piece for its unique history and unusual modifications. It bears the makers' stamps of the Missaglia family, one of the most prominent armour making families of the Middle Ages, and dates to the very beginning of the sixteenth century, but by 1520 it had been modified to become part of the foot armour used by Henry at the Field of Cloth of Gold in place of the armour which had been originally made for the tournament, II.6.[386] It is quite unusual for a piece of armour to undergo heavy modifications during its working lifetime. It also speaks to the armourer's state of mind when assembling this armour that he chose an imported helmet and cobbled much of the rest of the armour together due to the time constraint placed on him. The helmet is very large, 43.8 centimetres in height, and heavy, in common with other great basinets, and consists of three main plates, the skull, the visor, and a bevor.

The skull is large and rounded with a squared face opening. The plate is fitted to the neck and flares out over the shoulders and back. The top has a pronounced medial ridge, and around the base of the skull and the face opening are rivets for a lining. There are also holes for attachment to the backplate and holes for the crest. At the temples are leaves for the hinge pivots.

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[386] A new armour had to be hurriedly assembled due to a rule change. See Rimer, *Henry VIII: Arms and the Man*, p. 124.

The visor is very large and thick, of a rounded bellows form.[387] Hinges for the pivots are riveted to the interior and are covered by the tapered ends of the visor. The upper edge has an applied reinforce riveted to the exterior. A single square hole is pierced on the right for the missing spring catch. There is a light medial crease. Between each horizontal flute the visor is heavily pierced with five rows of square, round, and triangular holes to allow sufficient vision and ventilation for foot combat. Riveted to the interior of the visor are four reinforcing strips which have been pierced with round holes to restrict the size of the openings, one of the modifications required for the Field of Cloth of Gold.[388]

The bevor is pivoted at the front edge of the skull and is only lightly shaped to the chin. The lower part flares over the shoulders and breast and the upper edge has a wide recessed border to fit the visor. Two pairs of large holes are pierced at the lower corners for attachment to the breastplate and the neck and upper edge are pierced for lining rivets. There are also two square holes for a missing spring catch on the right side.

A close analysis of the tool marks revealed several interesting points of construction, especially on the skull and the visor. The skull is heavily worked on the interior, especially at the top, mostly with round or slightly oblong marks although their shape is mostly obscured through close overlapping. The pattern is roughly concentric, and appears to be from raising, overlaid by planishing.

There is also a very pronounced pattern surrounding the medial ridge: to each side is a band of short oblong marks perpendicular to the ridge, with a width of three rows of these marks. On the edge of the ridge are short narrow marks running parallel

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[387] It was not possible to measure thickness as there was no access to digital callipers, so most measurements are based on visual estimation.
[388] Rimer, *Henry VIII: Arms and the Man*, p. 124.

with it, and on the interior are more spaced narrow marks at an oblique angle. The ridge appears to have been formed after the skull was shaped, since the marks on the sides overlap the raising and planishing marks. Because it is so tall the ridge no doubt required a great deal of hammer work to raise out of the plate, with a resultantly rough area to each side.

The side marks were a result of working the plate from the interior over a flat surface to bring the top of the skull back to being flush with the rest. The orientation of the marks shows that it was rotated over the anvil while it was worked from front to back (or vice versa), and the three rows of marks show it was rotated slightly to the side of each row. The result of all this turning of the plate was to restore the curvature of the skull by doming over the anvil. Furthermore, the slightly flattened outline of the marks indicates a light planishing pass, perhaps the same one done over the rest of the skull. The oblique marks in the ridge itself are from a stake, probably an upright one to reach into the fairly deep flute, and the clean channel at the centre may be the result of chisel embossing, as demonstrated by the experimental plate work on page 130.

The marks on the lower part of the skull are primarily long and narrow, in spaced vertical rows from the light curling of the extension. These marks do not appear on the lower part of the bevor, and in fact the marks on the bevor are of a completely different character, being more in line with careful planishing. There are none of the small oblong marks found on the backplate, and the two were probably made by different armourers.

The visor presents some interesting features along with two clear levels of work, first the original shaping and then the applied reinforcing strips which were added later. The actual interior surface of the visor is rough and dimpled but with no clear pattern. Where visible, the areas forming the horizontal flutes have some parallel oblong marks and oblique narrow marks quite similar to those in the medial ridge of the basinet skull, suggesting the same technique was used in their creation, probably chisel embossing followed by planishing over a stake though much of the surface is obscured by the reinforcing strips. There are some other small marks which cannot be definitely attributed to the original armourer as they may have been made when the reinforcing strips were added.

The reinforcing strips are long, wide, thick bands which have been riveted over the original, fairly wide ventilation holes and sights. The plates have been swaged to fit closely to the inside of the helmet. After the plates were fitted they were pierced with round holes. These are not all of even diameter, nor are they evenly spaced or level, though they appear to be intended to mimic the original round holes which form the second lowest row of breaths. They were then riveted between the sets of original holes, and punching these rivet holes split the visor in several places. Because of the irregular size and placement of the breaths on the inner bands, the edges of the original openings overlapped some of them. The armourer used a round file to cut away the material of the original visor to preserve the roundness of the new holes. In some cases he even went too far, cutting into the reinforcing strip as well as the visor creating an ovoid hole.

In preparation for the tournament the whole armour was elaborately etched and gilt with symbols of England and the Tudor monarchy. Most of the gilding has been lost though some remains. Because of the limited time the decorators had the quality of the etching is uneven and degrades, and there are several mistakes. This is most visible on the tonlet but appears on the great basinet as well. On the border around the lower edge the background is not hatched at the back right side, and on the visor the etcher accidentally began a foliage pattern, which is on all the other plates, between the breaths on the left side, then carried on with the scale pattern which is on the rest of the visor.

Overall, this great basinet is not only a very good example of a particular class of helmet, it is also useful for its clear, defined tool marks which may be linked to particular techniques. This is doubly important because it is a marked piece, and may serve as one of the key pieces in recording the tool marks representative of the Missaglia workshop. Its working-life alterations are also illuminating in that they show an armourer being creative, doing his best with very limited time.

IV.2 Great Basinet - the 'Blind Basinet'

West European, possibly English, *c*. 1510

Figures 154-57

Known as the Blind Basinet due to its curious unfinished visor, this great basinet is very large and composed of a skull, bevor, and visor attached in an atypical manner for this type of helmet. The skull itself has the large rounded shape typical for a great basinet, with a pronounced medial keel and a lower section which flares over the back and shoulders. The bevor is likewise mostly regular, slightly shaped at the chin, with holes for the attaching bolts, and a recessed upper edge to fit the visor. The terminals have been extended so that the bevor pivots at the same points as the visor, much like a close helmet. The visor is superficially shaped like a jousting helm's visor, with a high prow and ventilation holes pierced only on one side. Its terminals have also been modified, presumably at the same time as the bevor, to simple bolt pivots. It may have at one point had the more usual hinged pivots but there is no direct evidence of this.

The Blind Basinet presents several problems, particularly with regards to the odd visor. As suggested by its moniker there are no sights cut above the prow. The ventilation holes are pierced on the wrong side for use as a jousting helm, and in any case the visor is constructed of far too thin plate to withstand the impact of a lance. The internal tool marks allow a partial interpretation of this helmet's history which cannot otherwise be made by use of the historical record.

The visor's many oddities are at the centre of this mystery, specifically the lack of sights and the ventilation holes. The marks on the interior of the skull and bevor are rather large and overlapping with no definite pattern, and the smoothness of the interior indicates rather careful planishing. Significantly, there is no separate marking along the skull's medial keel due to careful raising. On the interior of the visor there are none of the large planishing marks, though it does appear to have been planished. The medial keel at the top, which fits over that on the skull, has small oblong marks which are perpendicular to the keel on either side and parallel within it, quite similar to II.7 though not as pronounced. This shows that at least two armourers using two different techniques were involved in the production of this helmet.[389]

The lack of sights offers a valuable look at a technique in a half-finished state. The prow is raised from the surface of the plate and a furrow has been worked down behind the prow with a rounded chisel. Next, the armourer would have cut away the rectangle of metal where the sights ought to be with a sharp chisel, above the prow and at the bottom of the furrow. The folded lip thus created on the prow would have reinforced it.

The ventilation holes are very poorly made in addition to being on the wrong side, and it has been suggested that they were intended to fill the role of the missing sights.[390] They are of uneven size, being the result of a simple conical punch with no

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[389] For a further discussion of this object, see Chapter VI, pp. 262-63.

[390] See for instance Charles ffoulkes, *Inventory and Survey of the Armouries of the Tower of London*, 2 vols (London: HMSO, 1916), I, 170.

subsequent drifting to a uniform diameter, and are badly marred on the sides. This is the result of the punch becoming lodged in the plate and being jerked from side to side to free it. Indeed, the poor workmanship of the holes compared to the otherwise carefully made plate and their placement on the wrong side of the helmet to properly simulate a helm indicates that they were not made by a proper armourer at all, but perhaps by a blacksmith or farrier. In addition to these points, the lowest holes are blocked by the upper edge of the bevor when the visor is closed, showing that the actual function of the holes was not considered in relation to the other plates.

Taken all together, it appears that the visor was shaped and brought to the stage where it was ready for the main piercings, the ventilation holes, and sights but then left incomplete for some unknown reason. This may have been at a later date than the fabrication of the skull and bevor or contemporary with them. Sometime later the breaths were pierced for display purposes only, and it has been an interesting curiosity in the collection of the Royal Armouries since then.[391]

This helmet provides an excellent example of multiple plates that were made by two different hands. The differences are very clear between the visor and the skull, and show that two different techniques may be used to create an identical external feature. The incomplete state of the helmet also provides a rare look at a technique in a half-completed state, the folded lip and uncut sight of the visor. This technique can be seen completed on the close helmet of Henry VIII's foot combat armour II.6, which uses the same process to form a raised prow with a reinforced lower lip. On that piece the lower edge of the lip has been hammered flush with the interior of the visor, leaving very small narrow marks from the hammer peen.[392]

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[391] ffoulkes, *Inventory and Survey*, p. 171.
[392] See Figures 157 and 147.

IV.470 Basinet - the 'Lyle basinet'

Italian, *c*. 1380-1400

Figures 158-67

This is the famous Lyle Basinet, named for the man who donated the helmet to the Royal Armouries.[393] It consists of a large, deep skull, a broad conical 'pig-faced' visor, and a mail aventail. The shape, fit, and decoration of this helmet is excellent. It is the only basinet whose visor and skull certainly belong together, due to the matching decorative borders, and it retains its original mail aventail, making it one of the finest extant basinets in the world.

The skull is very large, twenty centimetres in height, the lower edge nearly reaching the shoulders and the top drawn into a long, rear-facing point which is pierced. The back is very slightly curved, and the front has a large, arched face opening. A medial crease extends over the top of the skull but does not reach the edges. At the temples are hinge pivots, attached by large brass-capped rivets. Over the face opening is a copper-alloy strip decorated with engraved wiggle-work, attached with iron rivets which have leather traces from the lining band. Around the skull are closely set brass-capped iron vervelles for the aventail.

The visor is broad with a pointed, conical snout and short pivot arms. The ends of the arms are folded back, affixed with a single rivet, and cut with three knuckles for the pivots. The edges have an applied brass border, missing at the extensions, decorated with the same wiggle-work as above the face opening, degrading in quality of work as it progresses. The sights are boxed below, and form a smooth surface over the brow, causing the sights to 'look' up. There is a small boxed area on the bottom of the snout, cut with a slit to form a mouth. The right side of the snout is heavily perforated with

[393] RA inventory entry.

large ventilation holes, and there is a diamond pattern of five holes on the left side. The snout only has a medial crease.

The exterior is carefully polished and in good condition, save for several sword cuts, and the interior is heavily marked with no corrosion, only some oxidation. In the skull the marks are from planishing; large, shallow, and overlapping, with a roughly round shape and no real pattern. These are overlaid by small, narrow marks along the medial crease, running parallel and about 1.3 centimetres to either side of it, from embossing and planishing the crease. The lining holes are cleanly punched and have no burr on the interior. The vervelles are of iron, pierced for the cord and each with a shaped brass strip soldered over top. When the aventail is in place no iron is visible, leading to the belief that they are of solid brass.[394]

The visor is likewise heavily marked, but with greater variety. The marks appear to be mainly from planishing, being very similar to the marks in the skull. Although the visor and skull have been linked due to their shared decoration, this demonstrates that they are linked by construction methods. In the snout the marks are roughly concentric but on the rest of the visor there is no discernible pattern, probably due to the edges of the plate being more curled than domed and so requiring no circular movement of the visor during planishing. Also within the snout are several long marks from a marred tool face. Along the medial crease are deep, narrow, spaced marks, different in character from those in the skull due to the greater difficulty of creasing the snout, probably made with a chisel and a stake.

On the sides there are long, narrow marks which follow the crease near the edges from a small hammer peen. The boxed area over the eyes has several very small, narrow marks roughly parallel with the sights. These marks appear to be almost accidental, as though left by the edge of a stake while working. However, the sharp

[394] See for example the RA inventory entry.

edges of these marks may have been created during planishing, and the marks that remain are only the deepest parts of the original marks which were not forged away. If this is the case, then these small marks are the remains of the pre-planishing raising which formed the sights. Finally, the ventilation holes have small, even burrs on the interior, a result of punching and drifting, and perhaps some cleanup with a round file.

Although the aventail is not plate it is remarkable for several reasons. First, it is original to the basinet.[395] It is also of very high quality, with small riveted links forming a very smooth mesh. The outer edge and the edge around the face are made of copper-alloy rings. Included in these, on the face edge, are three maker's links of excellent quality. Each is stamped with the word 'Magister' and all are identical. These links have apparently not been observed before, as they are not recorded in any of the publications which include the Lyle basinet, and in the Armouries inventory the helmet is listed as being free of maker's stamps.

The Lyle basinet presents exceptionally fine hammer work with a number of interesting details in its construction and decoration. Because its interior is so well-preserved the marks are exactly as they were several centuries ago. The marks along the creases and areas of embossing are especially clear and valuable.

IV.497 Basinet

Italian, Milan, *c*. 1380-90

Figures 168-70

The skull of a basinet, missing its visor and aventail, this piece has a similar shape to the Lyle basinet but the internal marking is quite different. The sides extend nearly to the shoulders and the top is drawn into an acute point, making the helmet very tall and deep. The face opening is arched with back-sloping sides. Like the Lyle the top third

[395] RA inventory entry.

has a medial crease, but the lower front and rear are not creased. The edge is heavily perforated with small countersunk holes for the lining, and above this is a row of larger holes, except over the face opening, for the missing vervelles. Below the lining holes over the face are three brass rivets for a missing border. Some of the vervelle and lining holes are filled with flush rivets for a later lining band. The skull is also pierced at the temples with large holes for the visor pivots.

The exterior of the helmet skull is oxidised but otherwise in good condition. The only marks are from sword blows, especially over the front medial crease, a stark reminder that this object was constructed to ward off violent death for its wearer. The pivot holes are burred on the interior and exterior, possibly from reaming them to a larger size. The interior is smooth but with shallow marks, roughly round and overlapping with a very vague concentric pattern, a result of raising and slightly uneven planishing which was then finished by grinding the exterior. In a few places the marks become smaller and closer together which shows where the armourer took closer blows, perhaps to smooth out a particularly rough area of the raised skull. There is no evidence of a weld and the whole skull appears to have been raised from a single large sheet.

The marks from the planishing stage are the most important element of this basinet, because the different size marks and regions are so clear. They are certainly from a spherical planishing stake and are one of the few instances where the effect of the armourer going over an area with more care than over others may be seen.

II.168 A Sallet

Italian, possibly Brescia, *c*. 1460

Figures 171-73

This sallet has a very interesting pattern of marks on the interior, and is a perfect specimen from a number of helmets with the same pattern. It is small, finely shaped, and is composed of a skull and a visor. The skull is round with a graceful transition to a short, upswept, bluntly pointed tail. The face opening is square, the top has a narrow medial keel, and the bottom edge has a boxed outward roll. There is a row of lining rivets, flush under the visor, and rivets below these for a chin-strap. The visor is tall with a single heavily boxed sight and a strong prow. The visor's upper edge is broadly scalloped, the lower edge has a boxed outward roll, and the front has a medial crease which broadens to a keel at the top. There is no visor catch, the visor instead being held in place by wrapping around the bottom edge of the skull just past the widest point, gripping the skull through its own spring tension.

The interior of the skull is marked over the whole surface with shallow overlapping marks in a concentric pattern, rougher in the upper skull than on the skirt and tail as a result of raising and a somewhat rough planishing pass.[396] On the tail there is a wide band of small narrow marks on either side of the medial crease which does not continue past the curve into the back of the skull, and which appears to have been made by a small cross peen hammer curling and flaring the tail. The bottom half of the visor, which is the only visible part, has rather widely spaced, short, narrow marks arranged perpendicularly to the bottom edge from interior curling. The inner lip of the lower sight is dimpled with very small, roughly round marks from finishing the flat shelf of the prow, likely with a small stake and hammer that could fit into such a confined space.

[396] See IV.499, pp. 177-80.

The clarity of the marks make this helmet valuable for identification of technique, and the bold pattern of marks on the tail in particular are interesting for their placement. They are similar in purpose to the marks along the keel of II.7, as a refining technique, and again very well-represented on this sallet.

IV.13 Sallet

German, possibly Nuremberg, *c*. 1490

Figures 174-78

A 'black' sallet like IV.12, nearly the whole process of armour-making is in evidence on the surfaces of this sallet. Left much rougher from the hammer than any other object in the corpus, it is heavily marked on both the interior and exterior. The only lightly smoothed exterior gives a particularly good view of some forming marks which are usually obliterated by finishing or corrosion. On the exterior there are marks from both raising and planishing, as well as some repairs which are certainly contemporary. It also has a rare lining still attached which obscures some of the interior but provides valuable insight into the construction of the textile element which was integral to all helmets, though now mostly lost.

The piece is composed of a skull and a visor which is pierced with a long, single sight. There is no clear delineation between the skull and the tail, which is long and comes to a point, and the sides flare out slightly. The top is rounded with no medial ridge. The front has a medial crease and a large cutout for the face, and the rear has a pronounced medial ridge. The bottom edge has a very rough inward fold, which has been worn away in places. The visor is pivoted at the temples with nuts and bolts. The pivot extensions are wide and upswept, and the upper edge rises to a cusp. The rear edges have round cutouts, and the front is strongly creased and comes to a point. The sight has a small boxed inward turn on the lower edge. On the lower right corner is a large hole for a spring catch on the skull, which is opened with a button. Around the edges of both pieces and around the visor sight are pairs of small holes for a fabric covering.

The exterior raising marks are most clear on the sides of the skull and tail. They follow concentric courses which are roughly parallel with the edge of the plate but slope up on the sides. On the upper portion of the skull the marks are round and follow less of a recognizable pattern, a clear indication of planishing. In addition to the divots left by the tool marks the surface is wavy and rough, particularly on the sides, further evidence that the sides were planished very little. On the interior the surface also has a concentrically wavy surface which matches the raising marks on the exterior. This surface is overlaid with a series of small round marks, which are more well-defined on the sides of the tail, the result of the light planishing.

The marks on the visor are similar to those on the skull, but there is less mark definition on the exterior, while those on the interior are clearer. They are oblong and closely set, running roughly vertical though angling out towards the ends, from interior curling with a broad-faced hammer. Unlike the skull, there are no small round marks and no apparent faceting from a planishing pass.

The medial creases of both skull and visor are heavily marked and not as cleanly finished as on more carefully constructed helmets. The skull front interior is completely hidden by the lining, but most of the back is exposed. There is a group of small, narrow, oblong marks running parallel with the crease and extending about an inch from it on either side. There are a few marks on the exterior which correspond, but these were clearly worked on the interior with a narrow peen hammer to adjust the curve of the tail, and not as a primary shaping technique.

The skull shows a surprising amount of damage caused not by battle or corrosion but by careless fabrication. This manifests in two ways, by cracks from improper forming and by cracks and delaminations from improper heat treatment or low-quality metal. The cracks start at the edge and are perpendicular to it, mostly over the face opening but also on the sides. Although they may not have become visible until well after the helmet was constructed, the stresses that caused them were created at construction.

During raising the circumference of the rim of the vessel becomes smaller and the metal is compressed. There is a tendency for the edge to become wavy and uneven as the edge bends to maintain its overall length, since even at high temperature it is difficult to compress ferrous metals. These undulations, which were apparent during the experimental plate work, must be carefully worked back down, but doing this carelessly will cause the metal to fold.[397] Over-aggressive raising to make the work go faster will also cause these undulations to become much worse, making edge cracking even more likely. It is significant that the visor has no such cracks, due to being curled and not raised, showing that they were caused by forces unique to the skull. The helmet does have one certain working-life repair: a crack on the left side has been reinforced with a small patch on the interior which has been recycled from another armour plate, the small cusp clearly visible.

The skull has several patches where the plate appears to have delaminated, particularly on the top, and several cracks caused by stress on the top and sides. The delaminations are most likely from the earliest stage of production, where the iron sheet was formed from smaller billets forge welded together, poor welds leading to eventual separations on the plate. Likewise, the extreme working of the plate would have caused further separations along grain boundaries. If the carbon content were high enough, not

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[397] See Figure 84.

annealing the plate or over-hardening would explain the smaller stress cracks. Some of the larger holes have been repaired with patches and brazing, which may be working-life though it is less certain than the edge repair. Again, none of these are in evidence on the visor, due to the gentler forming processes used.

When placed against the likes of the Horned Helmet or some of the other princely armours found not only in the Royal Armouries but in any armour collection, IV.13 may seem rather humble. As demonstrated above, though, it is in fact one of the more revealing objects of them all, in terms of construction. Evidence of all the major armour-making techniques are still visible on the surfaces, a rare quality, and as such this sallet ranks as one of the most useful pieces in the thesis.

IV.499 Sallet

German, *c.* 1480

Figures 179-82

This piece is composed of a skull and a pivoting visor, with a remarkable pattern of marks on the interior which are clearer than usually found on armour. The skull is deep with flaring sides and a long, acutely pointed tail. The front has a square face opening, the lower edge has a small outward roll, and the top has a wide, low medial keel with deeply chased lines bordering it. Below the clear demarcation between skull and skirt there is a row of rivets for a lining, now filled by modern rivets which are flush above the brow. At the rear and point of the tail are two sets of empty holes and the keel is pierced with two holes for a crest. At the lower right corner is a modern replacement spring catch with a button.

The visor is narrow, with long arms extending up to the temples with round terminals, decorated with complex washers in the shape of three flowers of decreasing size which may be brazed into a solid unit. The pivot rivets are pyramidal. The sides have sharp cusps which are decorated with three punched holes. The upper edge in front is boxed inward to form the lower sight, the centre is strongly creased, and the lower edge is rolled outward. The lower right corner is pierced for the visor catch.

The interior of the sallet is very heavily marked in what may be an idiosyncratic way. Particularly in the skull there are three distinct bands of marks, all with different shapes, depths, and patterns. At the top, comprising the bowl-shaped part of the skull, the primary marks are round and close-set in a faintly concentric pattern which seems to overlay but not quite obliterate an earlier phase of work. The small marks are from planishing, the rougher pattern from raising which has retained some of the concentric ridges normally planished away. Between this band and the next there is a small area of very small round marks which appear to be from a small round faced hammer used to ‘bump out’ the curve of the skull, which was probably not quite rounded enough.

The second primary band covers the sides of the skull to the lining rivets. This band is extraordinarily rough, with large square marks with clearly defined edges. These no longer have a clear pattern and seem to be from the edge or corner of a stake, probably the remains of a very heavy, rough raising pass. The third band covers the skirt and the tail from the lining rivets to the edge, and is the smoothest. The marks are small, round, and overlapping with no underlying rough pattern, clearly from a normal planishing.

The three distinct mark areas correspond very precisely with the three primary shapes of the skull: the skull, the relatively straight sides, and the outwardly curved and flaring skirt and tail. The armourer may have used the same stake for the upper skull and tail, the roughness of the former being from raising which did not affect the latter, or from more careful planishing on the tail.

While having three bands of marks is unusual, the skulls and tails of sallets do often have distinct mark patterns with the skulls being much rougher, for example Royal Armouries IV.424. This is probably due to consideration of a further stage in construction, that of grinding and polishing. The very rough interior of IV.499 shows that it was probably heavily ground to the current smooth exterior, but more would have been required on the skull because of the more careful planishing of the skirt and tail. The reason for this can be found in the shapes of the components. The skull is primarily convex, easily reached by file or grinding wheel as shown in the Mendel Hausbuch.[398] The more concave surfaces of the lower half would have been much more difficult to reach, especially if the polisher did not have a stone or file with the proper radius, and as a result were more carefully planished which reduced the need for grinding. This may have had a side effect in thinning the skull more than the tail, but by leaving the centre of the plate thicker than the edges when being beaten out this would have been avoided. Alternatively, the difference in thickness may not have been seen as enough to warrant concern.

The interior of the visor is comparable to the tail in having small overlapping round marks. The medial crease of the visor has little or no separate marking on the interior except for a smooth channel from a chisel, which is different from the skull crease and keel which has some narrow parallel marks. The visor and skull also share some assembly marks of interesting character. The skull and visor both have two punched dots on the interior, on the left front edge for the skull and on the right side for the visor. In addition, both have six deeply scored nicks on the bottom edge in two groups of three, on either side of the central point. These marks are not visible from the exterior, and appear to have been cut with a file as there is no displacement of metal.

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[398] Mendel I, fol. 138^{r}.

They are much more carefully done on the tail than on the visor, the visor marks being not so well spaced and showing signs that the file skipped out of the notch by accident.

Because of its marks this sallet provides some of the clearest indicators of tool shapes and processes of all the helmets studied. It is especially notable for the distinct horizontal bands of marks in the skull, a division of patterns which is rarely encountered. It is one of the most striking examples of the different levels of planishing which are often found on sallets, and it is an example of just how rough a piece may be and still have a finely shaped, smooth exterior.

IV.2056 Sallet

Western Europe, mid-fifteenth century

Figures 183-84

This small helmet, which does not quite conform to the classic lines of a German-style sallet, is somewhat unusual. In fact, if not for the truncated tail at the rear it would be a skull cap. Although its heavily corroded state makes analysis difficult, it may be classed as an unfinished piece, showing a half-completed technique on the medial ridge.

The skull is rounded, and the rear has a sharply angled, round tail whose bottom edge rises up. Its sides do not flare, the lower edge is mostly straight, and the skull is short enough that there is no need for a face opening. A row of rivets circles the skull, and the top has a rough medial ridge.

It is evident that the helmet is of low quality, but it is also incomplete. The poorly worked medial ridge is bordered by faint depressions on either side, which is a result of working the flute on the exterior over a stake with a cross peen hammer. That valley could then be worked from the interior to raise it up and create the smooth transition and arc of the complete feature. The unfinished state of this helmet suggests that it was possibly a rush job, or that it was made by an apprentice or other less-skilled worker. The latter seems more likely given the crude shape and poor workmanship.

Like IV.2 this sallet provides a rare glimpse of a technique which has not been brought to completion. Although the two pieces could hardly be less similar in quality or provenance, those objects which were never finished show an intermediate step which is nearly always lost through later work or planishing.

IV.537 War hat

Possibly Flemish, *c.* 1460

Figures 185-90

This is a very large kettle hat of disputed authenticity. It is entered in the Royal Armouries inventory as a 'European, 20th century fake of a Flemish piece of about 1460'.[399] It was purchased for the Armouries by H. Russell Robinson as a genuine medieval object, but every expert since has denounced it as a fake, and it has not been displayed for that reason.[400] Its great size and modern finish have been given as evidence against it, but the construction marks on the interior indicate that the piece is in fact genuine.

It is nearly round, with a very blunt point and faint medial crease at the rear of the brim. The brim itself is flared outward, more on the lower half than the upper, and tapers towards the temples. The edge is outwardly rolled but hammered flush to create an inwardly-turned lip. At the temple it meets the skull at a sharp point. The skull is large and bulbous, tapering in towards the temples. A medial keel rises out of the top of the skull, and there is a single row of lining rivets just below where skull and brim meet.

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[399] RA inventory entry.

[400] Karen Watts, personal communication, 2012.

The interior is heavily marked with four distinct bands of marks. Around the outer circumference of the brim the marks are small and very closely spaced, the overlapping nature obscuring their shape. The inner circumference of the brim has similarly close marks, but they are slightly larger and rougher and have a clearer oblong shape, arranged in concentric courses. The lower part of the skull has very rough marks, clearly from raising, which are oblong and concentric. The upper half of the skull, partly obscured by corrosion and a thick coating of an old lacquer, is smoother and appears to have been more carefully planished. The keel is completely clear of any definite marks, probably carefully raised from the exterior.

Although the edge has been rolled to the outside, that roll was then hammered in so that the exterior surface is perfectly flush, but without flattening the roll to a fold. This created a welt on the interior which gives the illusion that the edge was rolled inward even though there is a line from the plate edge on the exterior. This had the effect of making the edge much stronger than it would have been if merely folded, and removed the projecting roll which was a potential ledge for a weapon to catch on. This same edge treatment is found on a sallet in the Royal Armouries, IV.429, though the edge on IV.537 is more cleanly executed.

The rivets and finish are without doubt modern. The rivets hold unusual washers and modern leather remnants on the interior. They are flush on the exterior and the surface perfectly matches, to the point where some of them are difficult to see, showing that the surface finish was achieved after the rivets were added. There is a fleur-des-lys maker’s stamp at the rear which is poorly struck and may or may not be original, though it does match a very similar helmet once belonging to Jakob von Hefner-Altenek, sold at auction in 1904 and now at Hever Castle.[401] Although this

[401] RA inventory entry and *Kunstsammlungen des Verewigten Herrn Geheimrats Dr. Jakob von Hefner-Altenek, des ehemaligen Direktors des Bayerischen Nationalmuseums und*

helmet is exceptionally large, there are similar helmets in the Deutsches Historisches Museum, called *eisenhut*, which share the same basic shape save for a slightly deeper brim with a sight cut in, making them related to both sallets and kettle hats.[402]

The best indicator that this is an original piece is the tool marks. They bear a striking resemblance to IV.499 with its bands of rough and smooth marks, in particular the very rough area around the skull with cleaner areas in the upper skull and lower portions. Of the modern plates encountered in the Armouries' collection, some of which were stamped restorations and some of which were forgeries, none of them actually replicated the mark patterns of a medieval or Renaissance piece.[403]

A metallurgical analysis by Williams concluded that the iron is highly heterogeneous and is medieval in origin.[404] Although it is possible a faker could have made the helmet from a piece of medieval iron it is much less likely that their working practices would have copied the tool marks of an original so precisely. It is therefore most likely that this piece is indeed original, perhaps for a particularly large individual.

IV.537 provides one of the best examples of how the marks may be used to determine authenticity. This is in fact a piece of superb craftsmanship, but it has suffered from being held in doubt. This analysis shows that doubt was unjustified. It is also another rare example of a particular mark pattern, the horizontal bands also found in IV.499, showing that the sallet is not a fluke nor is it entirely idiosyncratic of the armourer that made it. The clarity of the marks make this helmet valuable as the techniques are easily identifiable.

Generalkonservators der Bayerischen Alterumer, ed. by Hugo Helbing (Munich: Hugo Helbing, 1904), pp. 9-10.

[402] Deutsches Historisches Museum, Berlin, W 613 and W 623.

[403] For example, the 'Gothic' pair of legs III.2561 and III.2562 has two original plates, one with a maker's stamp, but the rest of the plates are spurious and have uncharacteristic marks.

[404] RA inventory entry.

IV.411 Jousting helm - the 'Brocas helm'

German, Innsbruck, *c*. 1480

Figures 191-96

Known as the Brocas helm, this is a jousting helm of very large proportions, both tall and wide, and extremely heavy at 10.2 kilograms owing both to its size and the thickness of the plates, especially at the front. It is of frog-mouth form, intended for the joust of peace, and was rigidly attached to the breast and back by means of heavy charnels. The Brocas helm also shows some of the violence of even the joust of peace, with corrosion highlighting scratches on the front from impacts with the lance coronel.

The helm is formed of three main pieces. On top is a shallowly domed skull with both medial and transverse creases. It is overlapped by flanges on the front plate and itself overlaps the upper edge of the rear plate. It is fixed to both with large, domed rivets with brass caps attached with a lead solder. The exposed front edge forms the upper sight, and slightly back from the edge on the interior is a narrow reinforcing plate, riveted to the interior using the same rivets that attach the front plate. At the top and along the rear edge are four pairs of holes for attaching a crest.

The front plate is very thick, three millimetres at the shoulder, and flares dramatically towards the top to form a thick lip, and the very edge is turned inward to reinforce the lower sight. The rear ends of this rise out to overlap the cap plate. The front has a strong medial crease. The lower edge of the plate flares over the shoulders and breast, widening in the centre. Below where the upper part and flange join is a row of domed rivets for a lining, which do not appear to have been capped.

The rear plate is thinner than the front due to its not being a target during the joust. It does not flare quite as much as the front plate, and is overlapped by it, attached with a row of brass-capped rivets. The top is sharply boxed, creating a smooth line with the cap plate and the join of the plates at the sides. The upper edge has a V-shaped cutout, hidden by the rear edge of the skull plate. There is also a medial crease, which splits at the centre and becomes two creases arching towards the shoulders. The lower part flares over the shoulders and back, and has domed lining rivets as with the front. At either side are two sets of four holes in a square for the lining, and a large hole at the rear. Over the shoulders, attached to back and front, are staples for the attachment of the pauldrons.

There are two heavy charnels for attachment to the cuirass, one each at the front and rear. The front consists of a heavy plate with two rows of six rectangular holes for the staples on the breastplate. At the rear the charnel consists of two straps with three cylindrical bars of decreasing diameter. Above these is a hinge pin which affixes the assembly to a hinge on the rear plate, and also a short, broad tongue for the strap which was attached to the backplate and was threaded through the charnel bars.

There is also a simple square buckle riveted to the exterior of the rear plate, above the charnel and to the right. These are found on other jousting helms of the period, but is unusual in being on the right-hand side. It is more common to find this buckle on the left, where it serves as an anchor point for the shield.[405] Possibly it represents a different strap arrangement, or the strap was meant to wrap further around the neck to reach the buckle.

The interior of the helm is corroded but still heavily marked. The massive front plate has long, thin vertical marks consistent with curling and flaring the plate from the interior with a cross peen hammer, probably over a heavy bickiron. The backplate has matching marks over most of its interior surface. The boxed section at the top of the rear plate has oblong marks that run perpendicular to the main axis of the helm. This

[405] Olivier Renaudeau, Musée de l'Armée, personal correspondence, 2011.

plate was most likely curled and the boxed section was then raised to shape and planished, resulting in these transverse marks.

The skull plate is more complex in its marking despite its relatively shallow profile and simple form. The medial and transverse creases create four large facets, with a small diamond facet at the very top which joins the four creases. On the two front facets there are oblong marks running at a 45° angle to the front crease, forming a chevron pointing forward. The two rear facets have marks which run parallel with the transverse crease along the whole rear. Because the dome is shallow, and the plate very thick, the skull may have been domed rather than raised. The linear pattern of the oblong marks indicates a sort of hybrid process between doming and curling, where the curling was done in quarters to form the volume.

It would be difficult to overstate the size of the Brocas helm, and it does seem initially to be a very complex piece of armour. Looking at the interior, though, shows that in truth it is not. The plates were mainly curled, with little else required, and the cap plate is shallow enough that it did not require much shaping in comparison to other helmets. It is a fine piece demonstrating how a simple, rather quick technique was adapted to create a very subtle form.

IV.502 Tilting helmet

German, possibly Augsburg, *c*. 1490

Figures 197-204

This is a tilting helmet of very complex form and is attributed to Kolman Helmschmied.[406] This helmet was included in the Thun Sketchbook, and may have belonged to Maximilian I.[407] It is composed of six pieces, a skull with an attached back

[406] RA inventory entry.

[407] RA inventory entry.

gorget and a skull reinforce, a bevor with an attached front gorget, and a visor. The fit of the plates and the construction is superb, and the helmet also shows evidence of alteration at some point during its working life.

The skull is large and round, closely fitted to the head and neck, with a wide medial keel pierced with two holes for a crest. The sides are cut away to form a large face opening, at either side of which are threaded lugs, somewhat crudely brazed on, for fastening the bevor. There are several piercings on the skull, including shaped starbursts over the ears, additional holes for the crest or lining, and the whole edge around the face opening and neck has modern flush rivets attaching a lining band. The lining band obscures the lower edge, which is perforated with small, closely set holes from the helmet's original configuration.

Riveted to the bottom of the skull is the back gorget plate, shaped to the neck and back and flaring over the shoulders. The lower edge has wide, shallow rounded cutouts. There is a medial ridge and three holes at the bottom for attachment to the backplate. Riveted to the shoulders on the interior are threaded lugs for the bolts attaching the front gorget plate. The skull reinforce is round and deep, with blunt terminals and a squared-off central cusp, attached at the temples using the pivot bolts only.[408] The lower edge over the face has an outward boxed roll to form the upper sight. The medial crease and keel are shaped to fit over the skull.

The bevor is shaped to the neck and chin before flaring out to closely fit the sparrow beak of the visor. The upper edge, which has a deep notch for the missing lifting peg, follows the transverse crease of the visor and arcs up to round corners which fit over the pivot bolts. The sides have holes for bolts which screw into the lugs on the skull. The right side has six long vertical slots for the breaths. Rectangular flanges

[408] Empty holes on the reinforce do not correspond with any holes on other components of the helmet.

have been riveted on the interior on either side to secure the lower edge of the visor when closed, to prevent the visor from collapsing in if struck by a lance. The lower edge has a lining band, which covers a row of small perforations as with the skull plate. The front gorget plate overlaps the bevor and the rear gorget, with holes at the shoulders for the bolts. The plate is large and square with a medial crease and an elaborately pierced and fretted decoration at the bottom centre edge. Above this are two crudely punched holes, and at either side are rows of three vertical holes, larger and more finely made.

The visor is very narrow with long arms fitting over the pivot bolts and a sharply pointed beak with medial and transverse creases. The upper right is pierced with round ventilation holes, and there is a hole for a missing lifting peg. The beak shape was created by rolling the plate into a cone and riveting the lower edge. The upper edge has a boxed outward roll forming the lower sight.

The interior of the helmet is not heavily marked, as a result of careful planishing, but there are still some marks visible. The skull in particular has a concentric pattern of large, shallow planishing marks and long narrow marks within the medial keel from raising it, similar in manner to raising a flute but with space left between to create the flattened top. The skull reinforce has round marks of a different character than the skull, more likely from internal doming given their depth and clarity, as well as narrow marks along the keel which appear to be from hammer embossing.

The visor is hardly marked at all, again from careful planishing, save for some short, narrow marks parallel with the creases from hammer embossing, and some faint curling marks on the pivot arms. The bevor has short oblong marks running both vertically and horizontally from curling its complex shape. The front gorget plate is smooth on the interior, but the rear gorget plate is covered in faint marks, mainly long and broad from curling, and some remaining marks from hammer embossing the medial ridge.

The helmet is interesting, as it shows many signs of being heavily modified and repaired during its working life. The small holes along the bottom edge of the bevor and skull indicate either a different lining attachment or may have been for a mail drape. The edge on the bevor intersects some of these small holes showing that it was trimmed to fit the gorget plates which were added later. There are many holes filled with false or flush rivets, and some which are empty but with no clear function. Some of these holes are very crude in comparison with others on the helmet, particularly on the gorget plates. The visor has a repaired right pivot and a rectangular hole for a catch, but there is no catch or spring for it to engage. However, two holes now filled on the bevor may have been for the spring post and button. The lugs for the bevor bolts are uneven and the seams ragged, suggesting repairs.

The decoration is of uneven quality and does not match the overall quality of the helmet, and some of it may have been added later. Over the medial keel is an engraved trellis pattern with double-punched dots between the lines, and each side of the keel is bordered by lines with the same stippled pattern. In the area of the skull which is covered by the skull reinforce the trellis pattern becomes careless and was obviously very quickly hacked onto the surface, using possibly a short chisel to cut in the hatch instead of a double punch. Around the outer edges of the gorget plates is a hatched border of very poor quality, and the hatching simply was not done in patches on the back. This border was most likely a later addition as it does not match the skull in style or quality, and further indicates that the upper part of the helmet was completed before the gorget plates were added.

This helmet is notable for its superb workmanship, though a very close investigation uncovers some irregularity and roughness in a few of the details. This is a common feature of even the finest armours, especially ones such as this which have seen much use and been modified. The marks found on this helmet may be compared with other pieces attributed to Kolman Helmschmied, which may reveal if it is in fact the work of that master.

IV.600 Great helm - the 'Royal Armouries helm'

English, mid-fourteenth century

Figures 205-08

The Royal Armouries great helm is an excellent example of a helm for war, and one of three ‘English’ great helms, along with the Pembridge helm in the National Museum of Scotland in Edinburgh and the helm of Edward the Black Prince in Canterbury Cathedral. It is identical in construction to the Pembridge helm and so similar in details and form that it was initially thought to be a well-made fake.[409] The helm is surprisingly light for its large size, only 2.49 kilograms due to its thin plates, and is well constructed.

The helm is composed of three plates, a domed cap and two barrel hoops. The plates overlap downward and are all riveted together using very small dome-headed rivets which are simply bent over on the inside instead of being peened. The inner ends of the rivets are pointed like a modern nail, and the term for rivets at the time was indeed ‘arming nail’.[410]

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[409] Derek Spalding, ‘An Unrecorded English Helm of *c.* 1370’, *The Journal of the Arms and Armour Society*, 9 (1977-79), 6-9 (p. 6) and K. N. Watts, ‘Samuel Pratt and Armour Faking’, in *Why Fakes Matter: Essays on Problems of Authenticity*, ed. by Mark Jones (London: British Museum Press, 1992), pp. 100-107 (p. 104).

[410] See for example the 1485 inventory quoted in Chapter II, p. 39.

The cap is teardrop shaped with the blunt point facing the front. The top has a medial crease and a large ragged hole from its previous use as a funerary achievement, while the lower edge is very slightly flared to fit the flange on the middle hoop. There are three pairs of holes, at the front and sides, and loss at the rear has most likely obliterated a fourth pair. The lower edge has a very slight flare to fit with the middle hoop.

The middle plate is conical and the upper edge is slightly flanged inward to fit the cap. At front and back of the edge are small double cusps. The plate is conical, with a greater slope at the front than the rear, with a strong crease in the front and a light one in back. The plate thickens very slightly at these creases. The bottom edge over the face is flanged outward to form the upper sights, cut away in the centre to make room for the nasal. Above the sights is a row of lining rivets. At each side the plate is pierced with four pairs of holes, two horizontal and two vertical in a square pattern. At the front and rear are pairs of holes, all for the attachment of a crest.

The bottom hoop is straight-sided, creased like the middle and also teardrop shaped. The lower edge drops to points in the front and back and is rolled inward over a wire to strengthen the edge. The upper edge is flared outward in front to form the lower sights, and a long extension in the centre forms the nasal. This is thicker than the rest of the plate and attached to the middle plate with a single flush rivet. The thickening was achieved either by leaving that part of the plate thick whilst beating it out or by forge welding.[411] There are six pairs of vertical holes around the plate below the line of rivets, which also serve as lining rivets, for the crest. The right side over the face is heavily perforated with ventilation holes. At either side of the front point is a cross-shaped charnel hole.

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[411] Price, TOMAR, p. 375.

There is no marking on the interior of the helm from construction, mainly due to the corrosion though the marking would not have been heavy originally. The cap could have been either domed or raised, but either way could have been easily planished smooth, and the lower two hoops would have been easily curled. The sides of the middle plate are very slightly domed, and the bottom plate also has very subtle contours, the result of skilful curling from the interior.

The most significant technique used during manufacture was forge welding. Each hoop has a forge welded seam so that there are no vertical rows of rivets joining two plates to create a tube, as with several other contemporary helms.[412] Welding must have been difficult and done with great speed and skill, because the thinness of the plates meant that the loss of heat from forge to stake, and then further heat loss as it bled into the stake, would have quickly dropped the temperature of the plates below the critical level required for welding. On the lower hoop it was done so well and with such skill that there is no evidence for it by way of a visible seam, but on the middle hoop there is a very slight, linear change in thickness on the right side, vertical from top to bottom. This is the result of the two layers of iron being overlapped and hammered together, but not so much that they were forged to the thickness of one plate.

It has been suggested that the seam is located at the back, but its location at the right side is significant for two reasons.[413] First, it locates the weakest point of the plate away from the most likely direction of impact from a lance or other weapon, the same reason the ventilation holes are pierced only on the right side. Secondly, it suggests that the armourer intentionally moved the seam away from the back medial crease. This indicates order of construction for the hoop, and probably for the lower one as well

[412] See for example the Bolzano helm, inventory number 869, National Museum of Castel Sant'Angelo, Rome, and the Prankh helm, inventory number HJRK B 74, Kunsthistorisches Museum, Vienna.
[413] Price, TOMAR, p. 369.

since it is likely that the seam is in the same location. While the armourer could have welded the hoop and then created the teardrop shape and worked the medial creases, the location of the weld could have been easily lost, but its location shows that it was put there deliberately. Additionally, if the seam were too close to the crease it could have split open if the weld had not been done perfectly. Instead, the plate was shaped with the ends free, which allowed the armourer to crease the plates and adjust the fit, probably to the lower hoop, and then weld the seam. The slight flanges at the upper edges of the hoops could easily have been made after welding.

This helm's very clean shaping and excellent use of forge welding combine with its other characteristics to make it a very practical piece of armour. Although it looks heavy it is not, and the range of vision it provides is suitable for its purpose of use in a mounted charge. It is, in fact, exactly suited for this use, and although it may be seen as rather ungainly the piece is a purely functional piece of armour.

A.1905.489 Helm - the 'Pembridge helm'

England, mid-fourteenth century

Figures 209-12

The Pembridge Helm, held by the National Museum of Scotland in Edinburgh, is one of the best known helmets of this type and bears a striking similarity to the Royal Armouries helm, IV.600.[414] It is composed of three plates: a domed, teardrop-shaped crown plate, a large tapering middle hoop overlapping the crown, and a mostly straight-sided lower or side hoop overlapping the middle. The two hoops, like IV.600, have been welded into tubes and so there are only two riveted seams. It is surprisingly light and very well formed, and is also in exceptionally good condition.

[414] These two pieces will be discussed in direct comparison later in this chapter, pp. 236-39.

The crown plate has a medial crease and comes to a blunt point in front. The lower edge is flared outwards very slightly to meet the skull hoop. There are four pairs of holes for attaching a crest, at front, back, and at the sides. It has no central hole from its previous use as a funerary achievement.

The skull hoop is large and has very slightly curved sides and also has a teardrop shape with a medial crease at front and back. It has an inward flange at the upper edge to meet the crown plate and the front and back have two small rounded lobes as decoration. The front of the lower edge is flared outward to form the upper sight with a cutout to allow the nasal to pass. There are four pairs of holes on each side in the form of a square, two pairs at the back, and one pair at the front for attaching the crest. Above the sights is a row of six rivets for the lining.

The lower hoop has a strong prow and crease at the front, with a slight crease at the back. The upper edge is slightly flanged to meet the skull hoop and the lower edge is rolled inwardly over a wire which is visible through a damaged area at the front. The lower edge drops to a point at front and back. The upper front is turned outward to form the lower sight and a long projection forms the nasal which is riveted to the skull with a single flush rivet. The front is heavily perforated on both sides with breaths and charnel holes at the bottom. The rear has two holes for a strap, and around the upper edge are vertical pairs of holes for further attaching the crest.

The interior of the Pembridge helm is much cleaner than IV.600, and the exterior also shows much less corrosion. The rivets are all sharp nails which have been bent over, and some retain diamond-shaped washers from holding a lining leather. Most significantly there are clear tool marks on the interior of all the plates. The crown plate is the most heavily marked, being the most shaped overall, and shows concentric ridges from raising overlaid by round planishing marks. The planishing stake had an oblong nick in it, and there are many raised mar marks on the interior as a result. The medial crease is slightly rough but with no definable marks. The hoops both are characterised by wide oblong marks which are all perpendicular to the edges. These are from curling the plates from the interior with a broad cross peen hammer prior to welding and are neither deep nor clearly defined.

The welding seam appears to be on the right side as with IV.600, though the roughness which has not been corroded away makes certain identification difficult. The skull does thicken at the front and back, and the lower hoop thickens at the back. That it occurs at all these points suggests that these are not the welds, and because they are at the back and there is no detectable thickening at the front of the lower hoop these areas are more likely to be associated with the creases. The front prow meets at an acute angle and so required much more work than the other three creases which consequently thinned the area in front to blend with the rest of the plate. The other creases were not worked as much and retained their thickness.

This helm is the twin to IV.600, with which it will be directly compared below, but its clean interior allow for a fuller analysis of the construction techniques used for the entire object. These, much like the Brocas helm, show relatively simple curling which has nonetheless resulted in very subtle shaping; the sides of the helm are not perfectly straight and the pieces are perfectly fitted to each other.

VI.48 Tilting chanfron

German, late fifteenth century

Figures 213-19

This final piece of armour for the head is not for a man's head at all, but rather for a horse. The focus for this study has been on armour for humans, but the opportunity to examine any piece of armour in an unpolished state is invaluable and as such warrants inclusion. This is a tilting chanfron for the *Scharfrennen*, large and rather heavy with no openings for the eyes, leaving the horse blind to prevent it from swerving during the joust. Significantly, this piece has been left black from the hammer, a state rarely encountered with armour.[415]

The chanfron is shaped to fit the head of the horse closely. There are cut outs in front of the ears with outwardly rolled edges, and the lower end flares slightly with a rolled edge. There are no plates to cover the ears. There are large domes over the eyes providing extra protection, and there is a large, pronounced medial ridge on the lower two thirds. All around the edge are pairs of holes for a lining, and there is a hole between the eye bosses for an escutcheon. This chanfron would most likely have been covered by the caparison, which explains why it was left unfinished.[416]

Being rough from the hammer, both the interior and exterior are covered in tool marks. It is useful to note the relationship between the marks on one side and the corresponding marks on the other, which give an indication of which side the hammer was used on which is often more difficult on pieces which have been ground on one side. In this case most of the marking indicates working from the interior. The area over the snout has large, well-defined oblong marks parallel with the medial crease on the interior from curling this area, while on the exterior the surface is rather smooth with only light faceting. The top of the ridge is domed, and has narrower marks in a concentric pattern around the apex, possibly from light raising. The domes over the eyes also have a concentric pattern, probably ridges from raising, while the external

[415] In this case, the 'black' describes both the chanfron's being straight from the hammer and its colour, which is now a deep black.

[416] See an illustration of one of these chanfrons in use, in Theobald Senefelder and Clemens Senefelder, *Turnier Buch Herzogs Wilhelm des Vierten von Bayern von 1510 bis 1545* (Munich: [n.p.], 1817), plate 6.

facets are from planishing. The brow area has round markings on the interior and exterior from light planishing as this area has very little shaping, only some slight curling which could have been easily achieved over a ball-stake.

Like the few other pieces which are black from the hammer, VI.48 allows for valuable comparison between internal and external marks. Because this piece would have been covered with a caparison there was no need to fully polish it, leaving the tool marks intact. The faceting shows that it was planished to an extent, but not so much as to remove all the tool marks.

5.3. Torso Defences

The cuirass, or defence for the breast and back, is quite different from the helmet in its methods of fabrication. Raising is not frequently encountered, and doming from the interior and planishing appear to be the most common techniques. Curling is the second most common shaping technique, found mainly on the lames of the fauld protecting the lower torso and hips, but also on some backplates made from articulated lames. Fluting and embossing is more common than on helmets, especially on German pieces.

III.96 Breastplate

German, Innsbruck, *c*. 1485

Figures 220-24

This is a large and very heavy breastplate, weighing 8.3 kilograms, for the joust of peace and shows evidence of much use and modification over its working life. The marks in the piece are unusually deep, which show the use of several tools and layers of work. It is composed of an upper plate with a bifurcated reinforce, a plackart, and a fauld of three lames now missing the lower pieces, probably a pair of heavy tassets.

There are large modern metal straps at the sides and shoulders for attachment to the backplate.

The breastplate is slightly rounded, but with a large boxed area below the right breast for attaching the queue, or lance brace. The neck and arm openings have outwardly boxed rolls. It is very heavily perforated with holes, mostly threaded, for the helm charnel, lance rest, shield, and queue. Behind the holes for the lance rest, shield, and queue are large plates to provide more threading for the bolt, and all the threaded holes are heavily burred on the interior from having the threads reamed. At the bottom centre are holes for the bolt attaching the plackart. Riveted to the straight bottom edge is a large inverted V-shaped plate with holes for a lining which kept the fauld from striking the legs.[417]

The plackart is square and inelegant, asymmetrical because of the boxed section of the upper breast and crudely shaped at the upper edge. At the top are two holes for attaching bolts, though there is now only one bolt. The bottom edge has a short flange for the fauld. The fauld plates have cusped upper edges, and the lower edge of the bottom lame has a shallow cutout at the groin. There are holes for an internal leather, slots for sliding rivets at the bottom, and the ends of all the lames have empty holes as a result of damaged or incorrect riveting.

The interior of the breastplate is not corroded, only lightly oxidised, and because of the heaviness of the plates the marks are both deep and clear if somewhat haphazard. The types and shapes of the marks is unusually varied, including broad, narrow, and round marks on most of the plates. The ones on the upper plate are a mix of roughly oblong and round marks. Because there is not much shaping of the plate, and many of the marks are very small and well-defined, they are hammer marks from working the

[417] RA inventory entry.

breastplate’s interior. There is no layer of closely set round marks which would indicate careful planishing.

There is almost no marking on the reinforce, which is hardly shaped at all, but interestingly the plackart is also very lightly marked. Although there is some slight roughness to the interior and a few angled, very narrow marks which may not be from manufacture, there is nothing like the roughness of the upper plate and fauld. While this may be from the plackart being a replacement, it is clear it was made specifically for this breastplate, perhaps by another armourer in the same workshop.

The fauld, like the upper plate, is very heavily marked. What is remarkable about these marks, however, is that it is possible to see the exact shape of the hammer peen that made them. The marks are long and perpendicular to the lower edge, and some were struck with the hammer slightly rotated, causing the corner of the peen to dig into the plate and leave a squared end to the mark. From these it is possible to measure the approximate size of the cylinder of the peen, which was about 3mm in diameter. This effect is also seen on the test pieces done at the Royal Armouries.[418]

Another interesting mark which appears on III.96 is the centre-punch. The tell-tale dimple appears in several places on the main plate, both in the interior and exterior. On the interior there is one at the centre of the neck opening edge and two by the shield thread plate. On the exterior there are two below the holes for the shield and two next to holes for the helm charnel. They are definitely not damage sustained during jousting, being round and having the same spacing as the holes they are near, though offset. This shows that the holes were punched both from the interior and exterior, with no clear difference that would indicate why the armourer chose one over the other.

This much-used breastplate's internal marking is, as shown above, very distinctive. The clear hammer strikes make this a fine example of internal doming, and

[418] See Figure 103.

the use of heavy internal plates for the screws are good examples to compare with other similar pieces of armour. The thickness of the main plate required the very heavy working, and allowed the marks to be preserved.

III.1281 Breastplate

German or Italian, *c*. 1470

Figures 225-28

This piece is of rather low quality and less refined workmanship, perhaps for use by a sergeant or poor knight, but since the end of its working life it has had an interesting history. Originally in the armoury of the von Trapps at Schloss Churburg, the breastplate was bought by William Randolph Hearst and was housed in St Donat's Castle, Wales. From there it was purchased by the Royal Armouries in 1952.[419] At some point between fabrication and its final home the plackart and upper breast were united from two separate armours, something which was never noticed before and which probably occurred during or before its time at Churburg.[420] The evidence for the two components being from different armourers may be found in the marks.

The piece consists of an upper breast, a plackart, and a fauld of three lames. The upper breast has deep cutouts for the neck and arms, with moderately boxed outward rolls. The lower edge is concave and pierced for a connecting rivet at the centre and internal leathers at the sides, with which it is joined to the plackart. The plackart is bulbous and rises to a truncated point, with a crude finial. The bottom edge is flanged for the fauld. Both upper plates are fluted. The fauld has no flutes or creases and is of very plain construction. An internal leather at the centre prevented overextension.

[419] RA inventory entry.

[420] Something similar may have happened with the Avant armour, which lost its original helmet and now is displayed with a barbuta.

The main interior surface of the two upper plates is fairly smooth, but covered in faint, indistinct marks from planishing. The flute channels on the upper breast are deep and wide with short narrow marks from a small cross peen hammer. Although they were planished over an upright stake, the parallel marks from the hammer remain, especially where a missed blow struck outside the line of the flute. Interestingly, the marks in the plackart flutes are quite different, characterised by narrow marks at an angle with no parallel marking, a pattern associated with using a raising stake. This shows that the breastplate and fauld were worked with two different techniques by two different armourers, though it is impossible to say if the two plates were made in the same workshop or were joined at a later date from two different breastplates. The latter is more likely, as there is a second central rivet hole on the upper breast which appears torn, probably when the original plackart was removed.

The fauld plates are covered in widely spaced crescent-shaped nicks with no pattern, which appear to be from the corner of a tool. The depth and clarity of these marks is surprising given the little shaping that was required for the plates. Since they are on all three plates they are not accidental later damage and are certainly from initial shaping. The most probable explanation is that they are from the corner of the hammer which was used in shaping the plates, which was done from the inside over a flat surface, and the marks were created when the armourer, using an incorrect striking angle and too much force, drove the corner into the plate.

The identification of the work of two armourers on this breastplate is a perfect example of the use of the methodology developed for this thesis. In this case it is not a question of authenticity, but showing that a piece of armour which had been thought to be homogenous is in fact a composite of two different armours. It was unexpected in a piece such as this which has a fairly clear provenance which did not suggest any particular chance of alteration.

E.1939.65.e.3 Upper cuirass of the Avant armour

Italian, Milan, *c*. 1440

Figures 229-31

The upper cuirass of the Avant armour was made by Giovanni Corio, having two of his stamps, and has an interesting pattern of marks on the interior which highlight the very different construction methods between the breast and back. It is rounded and quite heavy, consisting of a breast and backplate attached to each other by solid hinges. The breast is made from a single large plate while the back is formed from four wide lames.

The breastplate has large openings for the arms and neck, all of which have wide, flattened outside rolls. On the left side is a single large hinge and on the right is a strap to close with the backplate. There is also a slot on the right which engages a rivet on the backplate to prevent shifting. Straps are riveted at the shoulders. Over the right breast are four large staples to attach a lance rest with a pin, and under the neck roll is an applied stop-rib. A large strap is riveted at the centre of the rib to suspend the lower cuirass.

The backplate is shaped slightly to the spine and also has large openings for the arm and a shallow one for the neck, with large rounded rolls. The lames overlap downwards and are attached by rivets at the sides and centre. The lower three lames rise to points in the centre. There is another large strap to suspend the lower cuirass and buckles at the shoulders and sides.

The front rolls and stop-rib are all decorated with fine punch-work. The front neck roll has ‘IHS’ included in the decoration, and the arm rolls have ‘AVANT’, from which the armour takes its name. The armour is also known for its excellent makers' stamps. Over each shoulder on the breast is a crowned I and at the centre, covered by the strap, is a ZA, both attributed to Giovanni Corio.[421] The upper and lower lames of the backplate are stamped with ZA with a crowned I on either side.

The interior of the piece is heavily marked, but more so on the breast than the back owing to the very different construction of the two halves. The breast is heavily and evenly marked with closely spaced, rather small round marks in no discernible pattern, from skilful doming and planishing. The lames of the backplate, however, are much less marked since they were largely curled and, perhaps, planished. The lower edge of the breast has six assembly marks, as do the lower edges of the backplate lames.

The very clear marking of the breastplate on this piece is a good example of its construction techniques, and just as with stamped pieces already seen the particular marks made here by Giovanni may be used in identifying other pieces by him. This cuirass is also interesting because of the contrast between the breast and back. Although this may be simply explained by the different procedures needed for the two, it should be noted that there are other breastplates and backplates that have similar marking patterns on the upper and lower parts, showing that Giovannni Corio approached the two elements with quite different methods.

III.70 Backplate

German, late fifteenth century

Figure 232-37

This is a well-formed, heavily decorated backplate of Gothic form, heavily fluted and possessing a very curious treatment to the main plate at the neck. The whole piece is

[421] Capwell, *The Real Fighting Stuff*, p. 27.

composed of nine plates, the main plate with a neck plate and two waist lames (one a modern restoration), a waist plate, and a culet of four lames.

The main plate is butterfly-shaped, with a heavily scalloped lower edge and an oddly sculpted neck opening. It appears to be an outline of a design which would have been further engraved, but it is not known what it originally represented. It is off centre and very deep, and includes a piercing. There are assembly marks on its upper edge, which is off centre. The opening this creates is filled on the interior with a large, asymmetric neck plate which matches the rest of the plates in colour and marking. Since this plate is original and there is no evidence of mistakes, the unusual design must be interpreted as being intentional.

The waist lames overlap upwards and themselves overlap the waist plate. The lames are scalloped and fluted to match the main plate. The waist plate itself is pointed at the top and has a wide flange below, with deep cutouts at the sides. Very faint remains of engraved decoration can be seen over the kidneys. The culet overlaps downward, the lames having scalloped upper edges with cusping over the flutes, and a bottom lame that widens to a point at the lower centre.

The interior of the plates are rough with tool marks, primarily on the main surfaces. The marks are shallow, rough, and ill-defined for the most part, though they become clearer in some areas such as the flange of the waist plate and the culet lames. The marks on culet and flange are identical, probably made with the same cross peen hammer, curling the lames and flaring the flange. Culet and fauld lames do not normally exhibit such rough interiors, so these plates were probably worked in a way different from usual, perhaps a difference in hot and cold working.

The flute channels are very clear, broad, and deep. On the exterior the flutes are blunt but not rounded at the apex, but on the interior they have a much larger radius, with the occasional misplaced strike, suggesting very careful hammer embossing. These were then set over a stake with a rather rounded nose and carefully planished on the exterior to sharpen them, resulting in the few very narrow marks within the channels.

The treatment of the cut out decoration on this backplate is unusual and interesting, but it is the flutes which make this piece so interesting. The very clear channels with their mark patterns and the way in which they taper show very clearly how they were made, in a manner very different from II.168 D. The patterns from the shaping of the plates are also distinctive, which may allow future attribution if a similar pattern is identified.

II.168 D Backplate

German, *c*. 1480

Figures 238-44

This piece has been attributed to Jorg Treytz of Innsbruck by the Royal Armouries based on stylistic evidence.[422] It is of Gothic form, sharply waisted and consisting of eight articulated plates. The main backplate has a small neck plate riveted to the inside forming a shallow neck opening and has deep openings for the arms with boxed outward rolls. The main plate overlaps a narrow chevron-shaped lame, which itself overlaps the waistplate. The three plates are attached by rivets at the sides and an internal leather in the centre. The lower fauld lames are modern restorations. Except for the neck plate which is plain all the pieces are decorated with flutes and scalloping to the edges.

The interior is surprisingly rough, especially along the fluting. The whole interior surfaces of the four original plates are covered with roughly round marks of

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[422] RA inventory entry. For a piece known to be made by Treytz, see III.1284, pp. 207-08.

irregular size and pattern. The neck plate has long narrow vertical marks from curling in addition to these rough marks, and the waist plate has some very faint, broad vertical marks, also from curling but with a much larger hammer. The extreme roughness and irregularity of the marks indicate that they were not the product of careful, measured hammer blows.

The other striking pattern is found in the fluting and embossing. These are extremely rough on the interior, with long and short narrow marks within and to the sides of the features. The marks in the flutes are so rough and deep that they actually obscure the flute channels, and were clearly embossed from the interior with a narrow cross-peen hammer, and further worked over a raising stake. The inner flutes, which are the roughest, actually appear to have been corrected, as shown by the way the marks extend even further out of the flute at the centre. The curve was likely deemed incorrect, so the half-formed flute was hammered back down and re-set, which also suggests that these inside flutes were made first.

Some of the marks are very long, longer than would be expected from a narrow hammer peen, possibly indicating the use of a chisel as well. The pattern of the marks does seem to be consistent with very quick hammer blows. If two tools were in fact used, the general course of the flute would have been roughed in with the chisel and the rest of the flute embossed with the hammer, followed by final clean-up.

The distinctive nature of these marks, which not only show just how the flutes were made but also provide evidence for fixing a mistaken curvature, will eventually be essential in identifying more objects by the same armourer. Comparison with known Treytz pieces will confirm or disprove the attribution. The piece also bears a similarity to III.1325, discussed below, which may result in a reattribution to an anonymous armourer

III.1284 Backplate

German, Innsbruck, *c*. 1480

Figures 245-47

This piece is a well-made backplate by Jorg Treytz in the Gothic style, graceful in line and not over-complicated.[423] Composed of five plates, the upper two are large and consist of an upper back and waist plate. The back is butterfly-shaped and sculpted to the backbone and over the shoulder blades, with deep cut outs for the neck and arms. The arm edges are rolled outwards and the neck edge has a raised border with stippled decoration. This plate overlaps the waist and his attached by rivets at the sides and an internal leather at the centre. The waist is broad and rises to a point at the top, with a narrow flange at the bottom. The line at the top of the flange has stipple decoration. The three-lame culet is attached with rivets at the sides and a central internal leather. The plates are sharply cusped at the centre and the bottom plate drops to a point.

The interior is heavily marked on all surfaces. The upper plate is completely covered in round overlapping marks with no clear pattern which appear to be from dorming overlaid by planishing. The embossed border at the neck is heavily marked with long thin marks from a chisel used to emboss the border. The waist plate is much rougher, with larger, heavy marks which are oblong and vertical from curling the plate. There was less shaping required for the waist than the upper back, and so the lower plate did not require as much hammer work. There are a few long cuts into the surface which appear to be accidental and may not date to the original construction. The lower flange is marked similarly to the upper plate with small round marks, probably from planishing after the flange was flared. The culet lames appear to have two layers of marking, a rough curling like the waist overlaid by a rough planishing like the upper plate. The lower edge of the bottom lame is embossed to simulate a roll, and the

[423] RA inventory entry.

interior of this feature is marked the same as the raised border at the neck, with long narrow marks from a chisel.

Unlike II.168 D, this piece bears the stamp of Treytz, and so the marks may be more certainly linked with a particular workshop. The two will be compared directly later in this chapter, but III.1284 will be able to form the base of future study of Treytz pieces, much like II.7 will serve as the starting point for more research into the marks of the Missaglias.

III.1325 Backplate

German, Augsburg, late fifteenth century

Figures 248-52

This backplate is Gothic in form with sprays of flutes over all the plates, which have remarkably rough interiors. There is a large upper backplate with a small neck plate, a waist plate, and a culet of three lames. The upper plate has embossed borders to simulate rolls, flutes, and embossing on the upper and lower edges. It overlaps the small, plain neck plate and the waist plate which is rigidly fixed with three rivets. The culet is attached with rivets at the sides, with no internal leathers, though the current arrangement may not be original.

The interior is marked over the whole surface, evenly but not heavily. The marks are all distinct and not obscured by rust, but are neither deep nor sharply defined except at the flutes and embossing where they are much heavier. On the upper back the marks are circular in the centre and oblong at the lower sides. These may simply be forming marks and not planishing, representing the curvature of the sides and doming over the backbone. The waist is covered mainly in oblong vertical marks, except at the top centre where they are round, matching the upper plate in mark distribution based on shape. The culet lames are all covered in irregular round marks, with none of the usual oblong curling marks. While this could indicate a different method of forming the plates, it is more likely to be planishing. Although they overlap, they do not follow any sort of linear pattern which would be expected for shaping operations.

The flute channels are for the most part poorly defined, except for the spray of flutes over the centre of the culet. The other flutes have heavily marked channels, all of which were embossed on the interior with a small hammer and possibly planished on the exterior, but not enough to eliminate the hammer marks. The centre culet flutes were made in a different way, probably because they are straight and not curved as with the others. These were embossed with a rounded chisel from the interior, and then laid over a stake and sharpened from the exterior, creating the light marks to the sides of the channels but retaining their round shape. It appears that the same chisel was used for all three lames.

Although there are no particularly distinctive shaping marks in this piece, the fluting and embossing marks are very much so, in a similar manner to II.168 D. There is a difference in the way the embossed decoration at the small of the back is accomplished on the two pieces, as well as the embossing at the neck. Both pieces were purchased from the Hearst collection.[424]

5.4. Limb Defences

Defences for the limbs include a greater variety of objects, but there are some overall similarities. Although there are several components to encase the shoulders, arms, hands, legs, and feet, curling is by far the most common technique, followed by fluting for the decoration. There is some possibility for raising in some parts, for instance

[424] II.168 D was originally from Churburg, but I am not currently aware whether III.1325 was also held in that armoury. See the RA inventory entry for each piece.

elbow couters and knee poleyns, but the vast majority of plates were only curled, with most of them also having a medial crease and possibly some fluted decoration.

II.3 Right and left cuisses and greaves

German, *c*. 1475-85

Figures 253-58

A pair of cuisses and greaves, there are several restoration plates on both cuisses, mainly the upper extension plates on the left leg. Each is a mirror of the other and each is constructed of fourteen plates, an upper extension with four extension lames, a main cuisse plate, two side plates, a poleyn with four lames, and a demi-greave. The three quarter greaves are each formed from a single piece. The very clear marks which exist on the plates are excellent for examining the forming techniques for a Gothic leg harness, but also demonstrate the potential fragility of the evidence on the right leg.

The cuisses and greaves are finely sculpted to fit the leg and all the plates fit very well. The tops of the cuisse and extension lames are sharply cusped, the upper edge of the cuisse is embossed to simulate a roll, and the upper extension rises towards the hip. The side plate has a single upper extension which is articulated by a long sliding rivet. The poleyn is articulated with two lames above and beneath and has a large curved wing. The demi-greave has a rounded lower edge and a slot for the greave's turning pin. All the front plates have a medial crease and there is some decorative fluting and embossing on the cuisse, upper extension, and poleyn. The greaves are very finely sculpted and are three-quarter, leaving the leg bare where it would make contact with the horse. There are straps and buckles at the sides and empty holes on the upper front which suggest modifications in how the greave was attached to the rest of the leg harness. The side of the plate has a medial crease.

The interiors of the plates are covered in very clear overlapping oblong marks which are even and regular from curling. There are long, narrow marks which follow the decorative fluting in rough, ill-defined channels, probably as a result of hammer embossing. The greaves are also covered in long vertical marks, but they are narrower and slightly less regular than the marks on the cuisses, becoming more closely set near the long vertical edges, particularly fine examples of anticlastic curling from the interior.

Another interesting feature of these is the difference in character of the marks in each leg. While the interior of the left leg is only very lightly corroded at worst and oxidised at best, the right leg is corroded over more of its surface. Although the corrosion does not appear severe it is enough to almost totally obliterate the marks on the plates which it is presumed were identical to the left. In the centuries since the pieces were made, particularly after their working life, they were either packed or displayed in some way which allowed moisture better access to the right leg causing more damage. This shows that only a small amount of rust is required to remove otherwise valuable marks from the interior, just as polishing can remove marks and decoration from the exterior.

II.167 Tilting sockets

German, late fifteenth century

Figures 259-61

This pair of tilting sockets for the *Rennzeug* form of the joust protected the rider's legs from collision with his opponent's.[425] They are very large and gutter-shaped, tapering to and cupping around the knee, with large semi-circular fans on the outer side and a narrow, straight flange on the inner side. Both are decoratively fluted and heavily

[425] See for example Figure 219, which shows a pair in use.

pierced around the edge for a lining, and each has a reinforcing plate on the interior under the smaller flange.

The interiors of the plates are covered in very faint planishing marks, with some heavier curling marks at the upper outside corners. The most marking, however, is along the flutes, which range from lightly to heavily marked. The sunburst pattern of fluting along the top is the least marked, and was clearly very carefully worked to taper towards the knee, likely by raising from the exterior. The fluting above this pattern is somewhat more heavily marked, with some narrow marks running parallel.

It is the fluting along the knee that is most interesting, particularly on the right socket. For the most part the flutes are moderately marked, but over the right knee the flute channels are roughly hammer embossed and are also heavily scored with short narrow marks perpendicular to the flutes. That the same marks do not occur elsewhere could mean that a lesser-experienced armourer did this particular section, or it may be a simple mistake by the same one who did the rest of the fluting. This variety of marking on the flutes of the two pieces is unusual, but they are another example of apparently differing techniques, or attempts at a technique, being used to reach the same outcome.

II.168 G & H Pair of cuisses and poleyns

Italian, Milan, *c*. 1450-60

Figures 262-67

The leg harness of II.168, the right is II.168 G and the left is II.168 H. These pieces are another excellent example of the use of curling to make complex objects, this time Italian instead of German. Both are very well formed and are mirrors of each other in most respects. They are each composed of eight plates, a main cuisse with a single upper extension and a side extension, and a poleyn with one lame above, two below, and a long demi-greave for the attachment of the greave.

The cuisse is sculpted to the thigh and has a straight upper edge with a boxed outward roll. The lozenge-shaped upper extension is attached by two rivets, and also has a boxed outward roll. The two plates share a medial crease. The side extension is attached by two external hinges and follows the contour of the top edge of the upper extension. At the centre of the plate is a vertical crease. The poleyn lames are plain, and the poleyn itself is domed with a strong medial crease. On the outside is a very large embossed teardrop-shaped wing.

The marks on the interior of both plates are very similar to each other, by the same hand. They consist almost entirely of deep, well-defined large curling marks from internal curling. Along the inner edges of the articulation the marks are somewhat more closely spaced due to refining the fit of the plates. There is very little identifiable marking along the creases, as the marks have cleanly blended with the curling marks to each side. Only the poleyn wings have noticeably different marks along the embossed borders, which are diagonal to the fluting and from a hammer.

In all, these objects represent another example of how well curling may be used to create well-shaped defences, as has also been shown with other pieces such as IV.411 and II.3. The very clear marking along the poleyn wings' embossing is especially useful, as it provides clear evidence of the use of a hammer on the interior.

II.168 I & J Right and left greaves

Italian, Milan, *c*. 1440

Figures 268-73

This is a pair of greaves for the leg harness of II.168, I is the right and J is the left. They are fully enclosed, consisting of a front plate which overlaps a rear plate, and both are closely sculpted to the calf muscles. The front plate has a medial crease, as does the lower two thirds of the rear plate. The two pieces are joined by two internal hinges and are closed with two straps and buckles which pass through slots to the outside. The bottom of the front plate has an arched opening for the foot with a very fine outward turn, above which is a row of small holes for the attachment of a mail sabaton. Every few holes are filled with a rivet for an internal lining leather. The rear plate has a triangular opening for the heel and spur, also with a small outward turn, and the top as a vertical staple to pass the lower leg harness strap through.

The marks on the interior of both greaves are a mix of small narrow vertical marks and small round marks. The round marks are concentrated on those areas which are most convex on the exterior, particularly over the calf and the ankle. The long marks fill in the other areas which are mainly concave such as the shin. The whole surface may have originally been covered in long marks, as the round marks appear to be from planishing, not internal doming, and would therefore have obliterated the original oblong forming marks. The medial creases have very short oblong marks which indicate they were formed from the exterior over a stake.

The marks found in greaves are quite interesting, since they do not appear in the form which would be expected, that is, from raising. The round marks here are somewhat unusual, though similar to those found in the leg harness of II.6. The existence of the curling marks shows that a large section of the greaves were curled, and the other round marks indicate planishing and probably doming for refining.

E.1939.65.e.10 and 11 Left and right greaves of the Avant armour

Italian, Milan, *c*. 1440

Figures 274-77

These are the greaves from the Avant armour, fully-enclosed with a front and backplate, and they retain their original mail sabatons although the toe plate has been lost. They are struck with the maker's stamp of Giovanni da Garavalle, as are the cuisses and poleyns of the same armour. They are of excellent quality, and retain the curling marks from their construction.

The greaves are very well shaped to the lower leg with highly sculpted, complex curves. The front plate is embossed over the ankle bones, has a medial crease, and a small outward roll over the foot opening. The rear plate has rolls at the upper and lower edge and a medial crease. Closure is made by a strap and buckle at the ankle and a post and hole near the top. A simple post is riveted to the front to engage the hole in the demi-greave, with a staple at the back for the strap. The area just below the roll at the foot on the front plate is heavily perforated for the mail sabaton.

The interior of the greaves is characterised by closely overlapping oblong marks from curling. This pattern is constant throughout the piece, except for some very faint narrower oblong marks running parallel with the medial creases. The greaves appear to have been worked from the interior, curling with a broad cross-peen hammer. This pattern of marks is consistent with other findings and supports the position that greaves were formed in this manner.

III.828 Cuisse

Flemish or Italian, fifteenth century

Figures 278-83

A cuisse and poleyn for the left leg, the quality of workmanship is very poor, enough to qualify as what Laking termed a 'sixth-rate original', and as a result has a stiff and inefficient articulation at the knee and hip.[426] The piece consists of a main cuisse plate with two upper extensions and one lower, and a poleyn with one upper lame. There is also a lower lame and demi-greave which are modern restorations, and evidence of working-life replacements.

The main plate tapers towards the knee and has a medial crease, a spray of flutes on the left hand side, and is boxed on the outer edge with a crease. There is also a raised and embossed border and the upper edge is lightly raised to simulate a roll, and there are holes for straps and leathers. The first extension plate is narrow and has a raised edge. The top extension in much wider, has a spray of flutes to the left of the medial crease, and has an inwardly folded edge. The lower extension is long and has several jagged wedge-shaped cut outs in an uneven pattern. The upper lame has an inelegant triangular cusp at the centre. The poleyn is deeply domed with a large, heavily embossed and scalloped wing. The crease in the centre is lopsided to the effect that the right appears to be a medial crease, but the left a medial ridge.

The interior has several sets of forming marks, which also indicate a working-life restoration. The marks on the upper extension plate do not at all match those on the lower plates, and are in fact almost absent. This, coupled with the different patina and

[426] 'Indeed, we will go as far as to say that certain fabrications, made not to deceive but to stand as faithful copies of some fine models, are at times preferable to sixth-rate originals'. Laking is somewhat unfair in this assessment, for even the crudest pieces of armour may have some interesting details, and they were, as R. L. Scott once put it, 'the real fighting stuff'. See Laking, *Record*, V, 148 and Capwell, *The Real Fighting Stuff*, p. 5.

character of corrosion indicate that this plate was a later addition made by a different armourer. The other plates have heavy oblong curling marks, mainly vertical but some also angled. The creases and flutes are somewhat rough, with narrow parallel marks and a deep channel which suggests chisel embossing and finishing over an upright stake. The marks are heavier on the poleyn wing, and are consistent with embossing with a hammer. There are interesting construction marks on the top and bottom edges of the poleyn, two on the bottom and three on the top, which probably indicated orientation. If there were corresponding marks on the upper lame they are lost or hidden.[427]

Although the marks are not any different from those found on many other pieces of armour, what this particular piece lacks is finesse. Not taking into account the poor quality of the embellishment and decoration, the curvature of the plates and the placement of the articulation rivets is not sufficient to allow freedom of movement. A more competent armourer may have been able to take the same plates and create a useable defence through better manipulation of the iron.

III.1348 Pair of sabatons

Italian, Milan, *c*. 1450

Figures 284-88

A pair of sabatons, each made up of seven plates, a toe plate, four lames, an ankle plate, and a heel plate. All the plates have a medial crease and the upper edge of the ankle plate has an outward fold. The toe is bluntly pointed and all the plates overlap from the ankle to toe, leaving the toe the uppermost plate. The heel is affixed with an internal hinge and is closed by a strap and buckle. Another strap passes under the instep, with a cutout on the ankle and first lame making the bottom of the strap flush with the bottom

[427] There are three scratches on the interior, but they are probably later.

edge of the plates, preventing wear. A three-point strap, riveted to the sides and point of the toe plate and of which traces remain in one sabaton, enclose the toe of the shoe.

The interiors of all the plates have narrow oblong marks from simple curling. The area over the heel does not have any round marks, and if no dishing was used is an example of very skilled work over the anvil's horn. The edges of the toe plate do have some round marks, probably from bending in the edge. The curling marks are also not all parallel on the toe plates. On one side they are parallel with the medial keel, but on the other they are at an angle. The left and right side of the plate are not identical, the outer half being a little longer than the inner half, and as a result the armourer treated each side of the plate slightly differently in order to create a smooth shape with uneven lengths.

These sabatons demonstrate just how much flexibility armour provided the wearer, as they articulate much further than the human foot can bend. This remarkable feat is achieved with a number of lames in a system which would evolve into the intricate defences for the inner knee and elbow found on II.6 and II.7.

III.1116 Couter

German or Italian, *c*. 1500-10

Figures 289-290

This is a shell couter, one of the valuable, unfinished pieces which retain hammer marks on the exterior. It is rectangular in form with a round dome over the elbow and a pucker over the inner elbow, with a flange above and below. There are rivets and empty holes for straps and internal leathers for attaching the missing upper and lower cannons.

The interior of the couter is very badly corroded, completely obscuring all the tool marks, but the exterior is unusual in having many tool marks over its whole surface, rough from the hammer unlike the majority of surviving armour which has a smooth, polished exterior. The bulge over the elbow has long vertical marks and round marks, showing two levels of construction. The first was most likely curling, creating the basic shape of the couter wrapping around the elbow. This was followed by doming of the elbow, and probably light planishing. The vertical orientation of the oblong marks over the bulge rules out raising, and the round marks result in a mostly smooth, faceted surface with no discernable pattern.

The upper and lower flanges of the couter are covered in the vertical marks which are much clearer than those on the bulge, the result of the curling and the flaring at the pucker. Although the curling would have been done from the interior, the hammer marks would have been transferred to the exterior and made more prominent through the light planishing. The edges of the couter have a recessed border, which has some small narrow parallel marks, but even here the faint outline of the vertical marks can be seen showing that the border, like the elbow bulge, was formed after the initial curling.

This is one of the few pieces in the corpus which is black from the hammer, and like IV.13 it has many marks which would not have been seen if it had been brightly polished. These pieces are especially valuable for these unique patterns.

AL.23 107 Couter

German, *c*. 1480

Figures 291-94

This shell couter, in the style of Lorenz Helmschmied, is of the highest quality and superb craftsmanship, and is in a good state of preservation although the applied copper-alloy borders have been lost.[428] It is puckered over the inner elbow and at the rear is rolled into a long, tapering point. The whole surface is covered in fluted and engraved decoration. There is a single large hole in the centre, probably for a missing brass bushing, for the attachment to an arming jacket, and there are small holes along the outer edges for the applied border, some with remains of brass rivets. There are two small repairs, probably working life, at the rear edge.

The interior is rather heavily marked, although the marks are not deep. The marks on most of the surface are consistent with flaring and curling and are not unusual for a shell couter. The flute channels are deep and clean, with only a very few narrow marks parallel with them. The marks indicate that the roughly horizontal marks which border the elbow cone were laid first, followed by the sprays of flutes on the sides. These side flutes are excellent examples of the most skilled and subtle armour-making because of the shape of the channels. On the exterior the flutes appear to widen closer to the edge, and on the interior the flute channels do indeed widen slightly, but with no change in the marks.

Brazing was used on the point of the cone where it is fully enclosed, the tube made by curling and overlapping the edges. Looking at the interior, the inner edge is curled more tightly that the overlapping edge to ensure a close fit. The seam was then brazed and the point filed and finished, the spelter filling any void that may have existed at the tip. Another piece in the Armouries' collection, III.864, has a couter constructed in a similar manner though in that case the seam was riveted and then brazed, a combination which seems unnecessary as the brazing alone would have held the plate edges together.[429] In addition to the interesting construction techniques used for this

[428] Karen Watts, personal communication, 2009.
[429] For a further examination of alternative ways to create deep forms, see Chapter VI, pp. 245-46.

couter, the expert use of embossing to create the flutes may prove useful in further study to determine if this was the work of the master Lorenz Helmschmied.

III.1216 Left pauldron and vambrace

German, *c*. 1480-90

Figures 295-97

This is a left arm harness of Gothic form, with a restored main pauldron and upper lames and a matching restored right arm harness. The restored pauldron has a very large wing behind with two upper lames, and three original lames below attaching to the upper cannon. The couter is a floating shell couter, and the lower cannon is also of shell form with an outwardly turned edge at the wrist. The plates are decorated with fluting and some scalloping on the upper cannon lames, and they retain their marks, some of which indicate the composite nature of the elements.

The marks within the plates are mostly long and oblong, and are most evident on the lower cannon. Similar marks from curling and flaring are found on the couter. The marks on the upper cannon and its lames are less well-defined, and the creasing marks are much different. On the upper cannon there are deep, clear, long thin marks to either side of the crease which are rather curious. They resemble chisel marks but there is no reason for there to have been any chisel embossing so far from a simple crease. On the lower cannon the crease has a few marks along its length. Although the two cannons match stylistically and have the same pattern of flutes, the interior marks are different enough to indicate that the lower cannon is likely a working-life replacement. The matching decoration indicates the two pieces were probably not cobbled together from separate armours, though there has been re-strapping, especially on the lower cannon where there are empty holes from an earlier configuration.

The couter's flutes are somewhat rough, with long marks parallel to the flutes and clean channels, possibly from chisel embossing and further planishing. The flutes on the cannons, however, are quite broad and very clean on the interior, indicating chisel embossing. This may be due to another armourer making the couter, or that the couter and cannons, though stylistically similar, were joined from separate armours at some point in the past, unsurprising given this piece's long history of restoration and display.[430]

AL.90 Left vambrace

Flemish, *c*. 1500

Figures 298-302

For the left arm, this is a large, heavy vambrace specifically designed for use in the joust, protecting the bridle arm but providing little mobility. The couter presents another method of creating a cone, through welding, and the cannons are also interesting for their specific construction techniques. There are nine pieces, an upper cannon, a couter with one upper and two lower lames, a lower cannon with an integrated gauntlet, two finger lames, and a retaining hook for the reins. A bolt-on elbow reinforcement is missing.

The upper cannon wraps three quarters of the way around the upper arm and has a large cut out at the front for ease of movement. The upper and lower edges have wide outward folds, and there are several lengthwise creases to create a geometric appearance. There are four pairs of brass bushings at the top for points, formed from a flanged copper alloy tube soldered onto a copper alloy ring. The couter is deeply pointed with a small puckered wing on the left side which is pierced with an added threaded lug for a reinforce. The lower cannon is large and formed from a single piece

[430] RA inventory entry.

wrapped in a tube and riveted closed, with a shaped end over the metacarpal of the hand. In the centre of the lower cannon is a threaded bolt, possibly for a shield attachment. Articulated to the end of the gauntlet are two heavy finger lames which do not allow a great deal of movement, but the end lame retains a thick padding, and the rest of the edges have rivets for a lining. Riveted to the interior of the gauntlet is an iron hook to catch the reins if they are dropped.

This large vambrace has some interesting construction features. The lower cannon may have been riveted and forge welded, but it is difficult to say with certainty. The couter, however, is an example of the use of forge welding to form a cone, the seam visible on the exterior as a fine crack and the overlap clear on the interior. Forge welding does not seem to have been a common method to create cones, and indeed the various methods using seams, including riveting and brazing, do not appear with any frequency until the very end of the fifteenth century. The growing use of methods besides raising may be related to attempts to find faster techniques, or it may be as a result of the smaller, more acute cones then popular, such as elbow couters and helmet visors. Still, raising remained the most common method to create any vessel due to the strength of having no seam.

The upper cannon shows evidence of a failed heat treatment, or perhaps poorly handled hot working. In one area of the plate the surface appears to be crumbling, as opposed to the fine spidering seen from the stress of over hardening. This crumbling is seen in high-carbon steels which have been worked at the wrong temperature or have been heated to a white heat, which destroys the structure of the steel. Although the plate may have been worked hot, it is very likely that the plate was unevenly heated during the hardening process, and the crumbling area, which is localised on the lower left side, shows the point of the plate that was in the hottest part of the fire.

E.1939.65.e.6 Left arm harness and couter reinforce of the Avant armour

Italian, Milan, *c.* 1440

Figures 303-08

This is the left arm harness of the Avant armour, consisting of an upper cannon, a couter with one upper and two lower lames, and a lower cannon of two plates. It is very well-shaped and the vambrace is attached to the couter with sliding rivets allowing easier rotation of the lower arm. The couter wing is quite small, and the piece is supplemented by a large reinforcing couter forged from a single piece. Both pieces bear the stamp of Dionisio Corio, DB surmounted by a cross twice on each piece.[431]

The upper cannon wraps three-quarters around the upper arm with an outwardly rolled upper edge and cutouts at the inner elbow. Directly below the roll is a row of rivets for an internal leather. The plate is overlapped by the upper couter lame. The couter itself is well-shaped, a cone with gently curved sides coming to a point, with a small lobed wing embossed over the inner elbow. The first lower lame is a normal lame and articulates with the second lower lame, which overlaps the lower cannon and is affixes with three long sliding rivets. The plates of the lower cannon have a subtle tulip shape, narrowing to the wrist which has a small outward roll. The smaller plate is attached to the main plate with two external hinges and closed with a strap and buckle.

The reinforcing couter is made from a single large piece of metal and resembles a shell couter, with a large cone over the elbow, a flared top and bottom, and an embossed extension over the inner elbow. In this case the features are exaggerated owing to its need to fit over the arm harness and provide greater protection than a typical couter. It fits the inner couter very closely and is secured only with a staple and pin on the small couter wing. The edges are mostly plain, except for the upper front edge which has a small inward roll.

[431] Capwell, *The Real Fighting Stuff*, p. 27.

The interior of the upper cannon has long oblong marks from curling, with narrower ones from curling and doming the area of the articulation, which is very well-executed. The marks on the lames match those on the upper cannon, while the couter has small round marks from planishing. The lower cannon plates also match the upper cannon. The upper cannon has a very clear set of mar marks, small raised bumps, oblong in shape and at 45° to the long axis of the hammer mark. Although the marks on the lower cannon match those on the upper, they do not have this mar. The right exterior of the couter has cracking which appears to be from over-heating the metal as was the case with AL.90. The couter and lames have single assembly marks, but the cannons do not. The fit of the reinforce is so close that the stress has broken the wing off; it is now held on with a riveted repair plate.

The couter reinforce has several different mark patterns owing to its much more complex shape. The upper and lower flanges have faint oblong marks from flaring and curling, while the cone over the elbow has faint raising marks which have been partially planished away. There are also divots at the point from the edge of the stake. Near the bottom is a faint line from a flute which was started and hammered out, with small oblong marks running parallel.

E.1939.65.e.4 Left pauldron and reinforce of the Avant armour

Italian, Milan, *c*. 1440

Figures 309-13

This is the left pauldron of the Avant armour, composed of a main plate and two upper lames and has a small reinforcing plate which is held in place with a single post and pin. The main plate is large and rounded, shaped around the upper arm, and has a medial crease and a raised flute on the rear wing to mimic the shoulder blade. The lower edge of the area over the arm is rolled to the outside with rivets for straps at front and rear. At the side is a pair of holes, perhaps for another strap. At the front is a post with a slot for the reinforce and the upper rear edge has an applied stop-rib. The lames are articulated by rivets at front and back with no internal leathers. The upper lame is pierced for attaching points and the upper edge has a roll to the outside. The reinforcing plate fits closely over the pauldron in front with a shaped area over the upper arm, a flat roll to the outside at the top, and a diagonal flute across the front. There is only one hole, in the centre for the post on the main pauldron.

The stop-rib is decorated, including the words 'AVE DN̄E', the roll on the upper lame has geometric decoration, and the roll on the reinforce has the words 'AVE MARIA'. Both plates have a B and crowned BE maker's marks, and the reinforce has an I in addition, the stamps of Bellino and Giovanni Corio.[432] The exteriors are smooth with little corrosion, but the interiors are heavily marked. In the pauldron are oblong curling marks which are fairly distinct. The flute has oblong marks at an angle within the flute, and the crease has very small, overlapping oblong marks at an angle to either side. The reinforce is more lightly marked, with curling marks below the flute and planishing marks above. The flute itself is hardly marked at all but is of a different shape than the flute on the main plate, being straighter and more pronounced.

The pauldron has an extra set of marks which are quite interesting. On the two lames are small, round, raised dots in the centre of some of the hammer-marks and on the lower lame there are some long, narrow raised bumps. An even more curious mark is found on the rear interior of the main plate, where there is a series of deep oblong marks which are slightly different in character from those around them. These deep marks have three diagonal raised lines in each. These are all from marred tool faces, transferring the mark from face to plate as seen with the visor of the Lyle basinet.

[432] Capwell, *The Real Fighting Stuff*, p. 27.

Although the damage to the tools could be from anything, the line on the upper lame appears to be from a sharp tool such as a chisel while the dots are from a pointed tool like a punch. The three lines in the main plate are more interesting, and may be the ghost of file marks. If the stake or hammer was ground with a file and not smoothed enough to remove all the marks of the rough file it could have easily transferred those marks to the plate.

E.1939.65.e.5 Right pauldron of the Avant armour

Italian, Milan, *c*. 1440

Figures 314-15

This is the right pauldron of the Avant armour, and in keeping with Italian practice of the time is of a different shape than the left. It is composed of four plates, a central lame with a single lower lame and two upper lames, and an applied stop rib. It is different in overall shape and construction than the left pauldron, although it is from the same workshop.

The main plate is shaped to the arm on the lower half and has extensions on the upper part which go over the breast and back. The upper edge has a flat bar riveted to it as a stop-rib. The lower plate overlaps the main, articulated with three internal leathers and a single sliding rivet at the rear, and is also shaped to the arm with an extension at the rear over the shoulder blade. The back has a small flute, there are straps for the arm, the lower edge is rolled outward, and there is an empty hole, perhaps for a missing reinforcing plate. The upper lames overlap downward with the main plate and are narrow. The upper lame has holes for the attaching points and a flat, outward roll.

The marks on the interior are close but fairly well-defined, consisting almost entirely of oblong marks from curling from the interior. There is a set of marks on the lower top lame which is perpendicular and appears to be accidental. Most significantly, there is a set of mar marks on this lame which exactly matches marks on the left pauldron, the single raised dot in the curling marks. This shows that the exact same hammer was used to create both lames, and that even if the mark had been noticed, it was not corrected between making the two plates. This piece will be further compared with the other pauldron, and the rest of the Avant armour, in the following section.

III.1918 Mitten gauntlet

Possibly Flemish, *c*. 1510

Figures 316-21

This is a heavily modified and restored gauntlet. Although now a short mitten gauntlet for the left hand it was originally a much larger defence, possibly a manifer or other piece similar to AL.90. The three finger plates and the thumb lames are modern. These modifications demonstrate just how removed an object can become from its original form and purpose.

The main plate of the gauntlet is a narrow tube which flares only slightly from the wrist over the hand and forearm. There is a medial crease and several flush rivets for the glove. The overlapping edges are not flush, and in fact the plate has been reduced considerably in diameter. On the interior a line is visible just back from the seam's edge which shows that the seam was originally formed to be flush on the outside, consistent with jousting armour, but this was hammered out and the tube narrowed. All the marks in the tube are fairly wide oblong curling marks. The finger lames do not allow the hand to close, and although the left hand does not require much mobility in the joust, it must still be capable of grasping the reins, indicating that all the finger lames are modern additions. The narrowing of the original tube may or may not be contemporary with that modification, but as the gauntlet would allow for very little movement of the hand it is probable that the whole piece was cut down at the same time.

A piece of armour may go through many changes in its working life and beyond, as typified by this object. The initial modifications narrowing and shortening the plate may be from the sixteenth century, but the finger lames show how much more may be done to a piece to make it look 'complete', even though those changes also render it completely useless as a piece of armour.

5.5. Comparative Analyses

Now we will turn from individual analysis to comparative analysis. The several pieces given above are each useful in their own right for demonstrating how technique and mark patterns may be found on armour, but the objects may be used comparatively to show even more about the processes, workshops, and armourers that made them. This mainly consists of examining pairs, objects which are known to belong together, but is not limited to this. Some similar or associated objects may also be readily compared, as with the Avant armour and the two fourteenth-century great helms.

III.1698 and III.1699 Pair of spaudlers

German, *c.* 1510

Figures 322-23

A small set of spaudlers from early sixteenth-century Germany, III.1698 and III.1699 are heavily fluted and have little internal marking, save for a small set of oblong marks on the bottommost lame. They were made most likely with a small cross-peen hammer, but they are curious, as they have no apparent bearing on the shape of the pieces. There is no curling in the direction that the marks would suggest, and yet they occur on both bottom lames, indicating some purpose.

When the spaudlers are laid side-by-side the marks are on the left-hand side, and the patterns are the same in shape, type, and direction, showing that the lames for left and right were made in the same manner, probably with no regard which arm the lame was meant for, and then they were randomly chosen for each side during assembly. For elements such as this, where there is absolutely no difference in the shape of the armour on the left and right side of the body, this sort of identical working was probably common. It would have been easier to make two identical plates than to make two pieces which were mirror-images of each other.

A possible explanation for this interesting pattern is that the originally intended shape was changed. Changes in design can sometimes be seen, such as on the backplate II.168 D and the arm harness of II.3, where original patterns or placement of flutes was altered. Armour plates could be recycled, but the marks on the spaudlers are too deliberate for any kind of random assemblage, also ruling out accidental marking, which may explain one plate but not both in the same manner.

II.3 Pair of Gauntlets

German, *c*. 1475-85

Figures 324-28

This is a pair of gauntlets, the right one original with restored finger-plates, while the left gauntlet appears to be a well-made modern copy. The RA inventory entry for the gauntlets describes them both as ‘doubtful’, but the differences in detail and quality support the argument that it is only the left which is doubtful. They are composed of thirty plates each, a long pointed cuff plate, a wrist plate with an upper and lower lame, a metacarpal plate, a long knuckle plate, four fingers composed of three lames and two knuckle gadlings each, and a thumb attached by a hinge with two further lames and a knuckle gadling. All the plates are heavily decorated with fluting, embossing, and fretwork.

The marks on the interior of the right gauntlet are composed entirely of small, oblong curling marks. There do not appear to be any marks along the flute channels, though corrosion may obscure them. The channels do clearly intersect the curling marks, showing a definite order of construction.

Although the two gauntlets are nearly identical, there are several small details which indicate that it is the left gauntlet that is modern. There are several empty holes on the right gauntlet, common on medieval armour due to construction mistakes or repairs, but the left gauntlet has none. The left's fretting and file-work is much more meticulous and even, but some details have been missed out such as the small notch at the base of the right's thumb plate. The pitting on the exterior of the two matches but this can easily be achieved artificially.

Perhaps most telling is a comparison of the articulations. The right gauntlet makes use of plain and sliding articulation rivets which provide a wide range of movement. The left gauntlet has no sliding rivets and consequently has very poor articulation at the wrist, barely allowing any movement at all. This makes the right gauntlet a useful and practical defence, while the left looks correct in a static display but would not allow for the motions required to wield a weapon.

II.168 D, III.1284, and III.1325

Figures 329-33

These three backplates, which are all German from the late fifteenth century, are at the centre of a case of misattribution. This is an excellent example of how the tool marks may be used to assess attribution, and also how they may be used to reassign an object. The controversy centres on II.168 D, which has been listed as probably being a product of Jörg Treytz, the armourer from Innsbruck. III.1284 is without doubt a product of the Treytz workshop, as it bears his stamp. III.1325, which has an unattributed maker's stamp and the Augsburg city stamp, was an unexpected addition which provided a solution to the problem of II.168 D.

II.168 D has been identified based only upon stylistic considerations.[433] The interiors of that piece and III.1284 were compared to determine if there were any significant similarities. While II.168 D is fluted over its surface, III.1284 has a plain surface with raised borders at the edges. Both do have quite irregular, heavily marked interiors, the result of working over an anvil with a round, dome faced hammer.

The flute channels and areas of embossing on II.168 D are exceptionally rough; long, thin marks both inside and to the sides of the features on the interior, both parallel and at a slight angle, from a narrow hammer peen. The embossed edges of III.1284 are by comparison cleaner with less marking.

It is here that III.1325 becomes relevant. From the hand of an unknown armourer who used a sallet-shaped stamp, it is much closer to II.168 D in stylistic terms of overall shape and construction, though the style of decoration is somewhat different.[434] Although the interiors do not immediately look the same, there is a

[433] RA inventory entry.

[434] It is unfortunate that II.168 D has lost its lower lames, but the upper portions are more than enough to draw conclusions.

differing level of corrosion on each which obscures what appear to be matching, rough surfaces.

Most importantly, the marks along the flutes match, indicating an identical working process on each backplate. They were made with a hammer, embossing on the interior, in a somewhat haphazard way. The marks are both parallel and oblique, in the channel and just outside of it. This is very unusual for German pieces, as will be further explored in the next chapter, and appear to be the work of the same hand. The inner flutes on II.168 D also show signs of being corrected, now having less curve to match the outer flutes. However, III.1325 has inner flutes which have a tighter curve than the outer ones, in the manner the other backplate would have had. Although the embossed sections at the small of the back have different mark patterns, they are not the same shape and so this is to be expected.

The constructional evidence of the marks and the overall style of the objects are enough to alienate II.168 D from the known Treytz piece, III.1284, but more significantly it is enough to reassign it to another armourer. This would make II.168 D an Augsburg piece, and the idiosyncratic method of flute embossing this unknown armourer had may allow other pieces to be attributed to him upon further examination. Although all three of these backplates have been in the Royal Armouries collection for some time, it has not been until now that the evidence on their interiors has been recognised, nor its importance realised.

E.1939.65.e - the Avant Armour

Italian, Milan, *c*. 1440

Figures 334-47

The Avant armour, being a mostly homogenous armour with pieces from known armourers, provides a good opportunity to examine pieces made by different armourers working together, some of whom made more than one component. The upper cuirass was made by Giovanni Corio, the lower cuirass and fauld by Ambrogio Corio, the pauldrons by Bellino Corio, the arm harnesses by Dionisio Corio, and the leg harnesses by Giovanni da Garavalle, who was working under contract for Giovanni Corio.[435] The armour is quite remarkable, but the interiors of the pieces have not previously been studied in detail.

The upper and lower parts of the cuirass were made by two different armourers, and so they are worth comparing, especially the upper breast and plackart. Normally these two plates would be similar in mark pattern owing to their similar shape, but under the hammers of Giovanni and Ambrogio, brothers working in the same workshop, the marks are quite different. The upper breastplate's marks are clear, well-defined, and appear to be from a combination of doming from the interior and light planishing. The plackart, however, is almost completely smooth showing that Ambrogio planished much more carefully and closely than Giovanni.[436]

The upper and lower backplates are constructed in different manners, lames on one and a single plate on the other, and so are not directly comparable. The lames of the backplate, though, are similar to the lames of the fauld, which are lightly marked in approximately the same manner as the backplate lames, though the fauld is perhaps slightly rougher in appearance.

[435] Capwell, *The Real Fighting Stuff*, p. 27.
[436] See Figure 334.

The pauldrons are not mirror images of each other, normal for Italian armour of this period, but share similar shapes and are primarily curled. The mark patterns in all the plates are composed of oblong, overlapping marks made by a cross-peen hammer. Most significantly, it is clear that they were all shaped with the *same* hammer, due to a small raised dot, the result of a mark in the hammer face. While such marks are occasionally encountered, these pieces are the only time in the course of research that multiple plates on multiple objects could be linked by the same mar mark.[437] Bellino either did not notice or did not mind, though it is interesting that both his pauldrons and the arm harnesses are replete with mar marks. The creases and flutes are also similar, all with oblique, short oblong marks, especially visible on the left pauldron. That pauldron's reinforce also has some oblique marks in the flute, but they have been almost entirely planished away.[438]

The arms are both finely made, and although they are mainly curled like the pauldrons they exhibit slightly different mark patterns. The primary curling marks on the upper and lower cannons are shorter and rounder than those on the pauldrons, though still slightly oblong. There is a mar mark pattern on the left upper cannon which is not repeated on the right; either the hammer was dressed or replaced, or the right upper cannon was made first and then the hammer damaged. The marks on each cannon are very similar and could have been made with the same hammer. The couters and couter reinforce were all raised, and the marks in the cones of the three plates all match. All were carefully planished and have round, well-defined marks in an irregular pattern. The curling on the wings of the reinforce may have been done with the same

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[437] For other mar marks, see Chapter IV, pp. 138-39.
[438] See Figures 335 and 336.

hammer and the cannons and couter lames, but it appears to have been planished somewhat as well.[439]

The leg harnesses are quite different from most of the preceding pieces. Like Ambrogio's lower cuirass, the cuisse plates are lightly marked, mostly with faint oblong or irregular marks, and may have been planished. The poleyn lames and the demi-greaves have more consistent oblong marks from curling, but are much simpler in shape, without the very subtle curvature of the cuisse. The greaves have small oblong marks, likely from a different hammer with a slightly smaller peen, all running the length of the greave. The creases all have some light marking with short, oblique marks, but are not as rough as Bellino's.[440]

The Avant shows many different tools and techniques being used by many armourers, but all were working together to produce this one armour, and even with the very different working styles of Giovanni and Ambrogio, the cuirass matches beautifully, and the pauldrons of Bellino and the arms of Dionisio likewise fit together both functionally and in terms of craftsmanship. Da Garavalle's legs, showing a mix of the working practices of Ambrogio on the cuisses and Dionisio on the greaves, nevertheless constructed a very elegant pair of leg defences.

Royal Armouries IV.600 and the Pembridge Helm

English, mid-fourteenth century

Figures 348-533

These two great helms, one in the Royal Armouries, Leeds, and the other in the National Museum of Scotland, Edinburgh, have been the subject of much speculation

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[439] See Figures 337-42.

[440] See Figures 343 and 345.

since the Royal Armouries helm first came to light in the early 1970s.[441] Both are helms for use in war, dating to the mid-fourteenth century, both lack a maker's stamp, and they are almost identical in appearance save for some hole placement, the Pembridge being pierced with breaths on both sides, a fact which has been noted in the past.[442] However, the number of similarities between the two has not been fully discussed, nor has its full importance been realised.

The Pembridge helm once hung over the tomb of Sir Richard Pembridge in Hereford Cathedral, whose dean presented it to Samuel Rush Meyrick. It passed then to the collection of Nöel Paton, finally being bought by the Royal Scottish Museum, now the National Museum of Scotland, along with the rest of the Paton collection.[443] The Armouries helm has a much less prestigious history. Unknown until 1974, it was put up for sale by Sotheby's but was considered a fake, probably, as Karen Watts points out, because at the time there was a tendency to regard anything unexpected or unusual as the work of the infamous team of Samuel Pratt and Thomas Grimshaw. The helm was purchased by the Armouries in 1976, and is now recognised as genuine.[444]

Working down from the top, the similarities are striking, far beyond the immediately obvious physical likeness. The lower edge of the cap plate on both is very slightly flared to fit the flange of the middle hoop. Corrosion has, unfortunately,

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[441] See Figure 348.

[442] For example, see the RA inventory entry and Derek Spalding, 'An Unrecorded English Helm of c. 1370', *The Journal of the Arms and Armour Society*, 9 (1977-79), 6-9 (p. 8). The Pembridge is also missing two holes on the front for the crest and one at the back for the strap which affixed the helm to the body armour which are found on IV.600, while the Armouries helm has a hole in the cap from a spike associated with its use as a funerary achievement. However, a different crest explains the different front holes, and the one missing hole on the back did not prevent a strap from being attached with the two other holes.

[443] Guy Francis Laking, 'The Nöel Paton Collection of Arms and Armour, Now in the Royal Scottish Museum-II', *The Burlington Magazine for Connoisseurs*, 17 (1910), 198-202 (p. 202.)

[444] RA inventory entry and K. N. Watts, 'Samuel Pratt and Armour Faking', in *Why Fakes Matter: Essays on Problems of Authenticity*, ed. by Mark Jones (London: British Museum Press, 1992), pp. 100-107 (p. 104).

obscured the tool marks on the Armouries helm so it is impossible to see if the mar marks on the Pembridge are also on its twin.[445] The middle hoop on both have small double cusps at front and back in the same manner on the upper edge, a tiny decorative detail which would probably have been hidden by the crest. Both pieces thicken at the front and back, and both were welded at the right side.

The lower hoop on both also thickens at the back, and any additional thickness at the front has been lost through working the plates. The nasals of both are affixed to the middle hoop with a single flush rivet, and have two round cusps on either side and two bordering lines chased into the edges, a detail almost entirely hidden by corrosion on IV.600.[446] The lower edges of both are turned inward over a wire, exposed on the Pembridge helm, and this roll provides the final piece of evidence for their shared origin. The points of the rolls at front and back are slightly dimpled and have a small hole, from the armourer cutting out a small wedge at the points to make finishing the rolls cleaner. To prevent a crack from forming the point of the wedge was punched or filed round.[447]

As seen with the cuirass of the Avant armour above, just because two pieces were made in the same workshop does not mean that they were made by the same armourer. It is clear from these details just described, however, that the two helms were not only made in the same workshop, but were made by the same armourer. This unknown armourer was clearly very skilled, demonstrated by the extreme care taken with the details of the two pieces and the very fine shaping which make them two of the finest medieval helms extant. This is the first time that the close relationship between the two objects has been proven beyond the stylistic similarities, and demonstrates that

[445] See Chapter IV, p. 139. Further scientific investigation of IV.600 may reveal the existence of the marks.
[446] See Figure 351.
[447] See Figures 352 and 353.

the work of an armourer may be identified without any personal stamps. The other English great helm, that of the Black Prince, may also be examined to determine if there are any constructional similarities.

5.6. Conclusion

The objects studied in this chapter have covered the whole spectrum of the armourer's art, from basic raising and doming to complex anticlastic curling, embossing, and decorative enhancements. Although there are some spectacular examples and unusual features on some, the techniques are those which are found on many pieces of armour, including those which have been studied but not explicitly detailed here.

The most common technique for specific elements of armour have been identified. Doming is by far the technique used most on breastplates, and raising is most common on helmets. Curling, whether synclastic or anticlastic, is most common on curved plates such as lames and the plates of leg harnesses and arm harnesses. This does not mean they were the only possibilities, only that they were used more than any other for these elements.

The greatest and most important differences are largely found in the precise pattern of the marks, the result of tools with unique shapes and sizes used for similar techniques. Tool size and precise shape had an effect on the mark created, as did the closeness and care with which the work was done. Some of these differences have significance beyond simply what technique formed them, as will be discussed in the following chapter.

The ways in which armourers worked was diverse even in the same workshop, as shown by the Avant's cuirass. Perhaps the most important thing shown in that example is that just because the marks are not the same, it does not mean that pieces came from different workshops. Armourers, being artisans and not machines, left their own individual signature with every hammer blow.

However, the marks and construction techniques are most helpful when they are the same, for it is in those instances where particular armourers may be identified, and thus those signature marks may be used to identify armour by the same maker. The marks in the pauldrons of the Avant would signal that they were made by the same man, even if they did not have the stamp of Bellino Corio. The construction details have also proven that the Pembridge helm and IV.600 were the work of the same armourer, not just the same workshop. Conversely, the mark patterns have shown that II.168 D was *not* made by Treytz, but was made by another armourer.

The marks found on the plates also link plates of the same object which have been contested, best shown with the various components of the Horned Helmet, and they provide evidence for previously unknown methods of construction, such as in the case of greaves. They have also aided in determining authenticity, both to identify fakes and genuine articles believed to be fakes. As a diagnostic tool, they have proven invaluable for these examinations, both individually and comparatively. The final chapter will compare the tool marks and techniques in even greater detail.

Chapter VI: Analysis of Techniques

6.1. Introduction

In the previous chapter single pieces were examined individually in order to determine what they, on their own merits, could show regarding the details of particular techniques and mark patterns. Some objects were then examined in groups to compare the marks, which resulted in an identification of particular styles of individual armourers and workshops. It is possible to carry this application of the methodology further, beyond the determination of how a piece was made, to *where* it was made.

The tool marks in pieces of armour vary as much as the object themselves, even when there are similarities in style and form. There are in features, such as flutes, a great variety of internal construction marks which do not repeat from one object to another; a series of marks on one piece may not be found on another piece with a nearly identical feature, and that piece may in fact have a completely different pattern of marks. The reason for and significance of these differences is linked to construction technique, the methods of each individual armourer being a product of their own training which was in turn influenced by local and regional techniques and traditions.

This chapter will compare pieces of armour made in certain ways and pieces which have similar features. Many pieces will be considered in groups according to the various elements and patterns such as shape, feature, or tool marks, because particular features or patterns may be found on many different elements of armour which protect different parts of the body.

There are three primary shaping technique which have been identified, raising, doming, and curling, and these will be considered first. As planishing has been found to often be a precursor to later stages, it will then be considered. Particular features, such as edge rolls and flutes, will be examined last.

The following table will give an idea of the breakdown of objects used when conducting the examinations for this chapter. Because some pairs in the Royal Armouries are accessioned under one number and some as two, simply using the inventory numbers would result in a lower number of objects.

Table 2. Breakdown of objects used in comparative analysis.

	German	Italian	Other	**Total**
Helmets	12	20	8	40
Torso armour	15	3	4	22
Limb armour	26	33	13	72
Total	53	55	26	**134**

6.2. Raising

Raising represents a fairly violent change from smooth plane to three-dimensional shape, and as such tends to leave traces even after planishing and polishing have obliterated all traces on the exterior. Often it is evident only by a faint pattern of concentric ridges within the object, the exact borders of the marks obscured and smoothed away by planishing, made necessary in most cases by the heavy hammering required by raising. In other cases there are more defined marks than simple ridges, creating a concentric mark pattern around the interior of the object.

The objects selected for this comparison were all helmets, since they are the most likely to have identifiable raising marks. Other deep forms, such as couters, would also have been raised, but their interiors tend to be obscured by lames. Helmets, on the other hand, have easily accessible interiors and are often very heavily marked. The set consists of twenty head defences, one being a horse's chanfron, covering a broad spectrum of types, ten from Italy and ten from Germany.[448]

Of the types of evidence for raising, the most common is concentric ridges. The spacing and the clearly outlined path of the hammer shown by these ridges is unique to raising and is not produced by any other technique. The very close hammer strikes of planishing and the smoothing nature of the technique preclude it from being the source of these ridges, and although doming is worked concentrically it also does not produce this pattern. The experimental plate work demonstrated the clear ridges found in a raised object, which also had few clear tool marks on the interior.[449] The cap plate of the Pembridge helm is a good example of this type of interior, which is easily identifiable and shows the three levels of raising used to form just this small plate.[450]

The difference between helmets with ridges and those without lies in planishing; internally smooth helmets had more planishing and less grinding, and internally rough helmets had less planishing and more grinding. The larger, more defined ridges most likely represent the least planishing, though not necessarily a lack of it. As the piece is refined and planished the ridges remain while the marks' edges are made clearer, until both they and the ridges are smoothed away. IV.532, an Italian kettle hat from *c*. 1470, shows this effect, with some deep, clear long marks from raising which were particularly rough and which were not entirely planished away although the ridges have been removed.[451]

Helmets with identifiable oblong marks in a concentric pattern are found in normally raised pieces that were moderately planished, which removed some of the high areas on the interior and brought out the marks. Blending of overlapping marks makes

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[448] See Appendix B, Tables 3 and 4, pp. 278-79.
[449] The formation and character of these ridges is discussed in detail in Chapter IV, p. 122.
[450] See Figure 354.
[451] See Figure 355.

identification difficult on some pieces, but there are pieces which do have identifiable raising marks. IV.13 is a very fine example since the actual hammer marks are still visible on the exterior and there is a definite change from the mostly raised to mostly planished parts of the helmet, though the latter part is mostly covered by the lining on the interior. There are large oblong marks on the interior, overlaid by clear round marks from light planishing. The chanfron VI.48 has concentric patterns in the dome over each eye, while the exterior is smooth and faceted, and the sallet IV.424 has a concentric pattern in the skull while the tail has been more fully planished.[452]

The final type of marks are those which are very clearly defined and from raising, which need not be part of a full pattern of marks around the object and may be isolated. This includes the aforementioned IV.532, and the fifteenth-century German sallet IV.12 which has a short band of small oblong raising marks on the side of the skull.[453] Some objects do have full patterns with very clear marks, such as the skull reinforce IV.580, the sallet IV.499, and the war hat IV.537.[454] The last two have clear patterns of raising marks alongside more fully planished areas, showing the progression from one pattern to the other.

Ridges with no clear marking is by far the most common type of pattern found in helmet skulls, followed by pieces with marked concentric patterns and pieces with highly defined marks being less common. The combination of these mark types demonstrates a difference in later stages, not the raising itself. The differences which do occur, such as the lesser marks on the tails of sallets, do have reasons which are particular to the type of armour.[455] They occur in sallets, a tilting helmet, a chanfron, armets, basinets, and kettle hats. This strongly indicates that there was no difference in

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[452] See Figures 356-60.
[453] See Figures 355 and 361.
[454] See Figures 129, 180, and 189.
[455] For a discussion of the lesser marks on sallet tails, see IV.499, Chapter V, pp. 177-80.

raising technique by helmet type when shaping. In terms of geography, German helmets tend to have the clearer marks and concentric patterns, while Italian helmets tend to have fairly smooth concentric ridges. This indicates that the German armourers were planishing their armour to a lesser extent than the Italians, probably making more use of grinding to achieve a finish, or leaving them rough from the hammer. The ridges in the Italian pieces have been largely planished leaving little independent marking, the last stage before they are completely removed.

6.3. Alternatives to raising

The task of medieval armourers was not an easy one. Forming ferrous plates to fit the body was difficult, not only in terms of basic metalwork but engineering as well. Experimentation was constant, to find new ways to better protect the wearer, and some solutions were more successful than others. For example, when the basic form and articulation for the arm and leg defences was perfected in the late fourteenth century, it remained the dominant form of articulation until the abandonment of armour.

One area which saw continual experimentation was the creation of a deep vessel. Raising was certainly the most common method for doing so, allowing excellent control of the final shape and giving strength to the piece by having no joint. The disadvantages, though, of requiring a single large plate, the need for planishing, and the greater skill required to raise a deep object meant that alternatives were sought, with varying degrees of success. All of the conical pieces from the fourteenth century in the corpus, mostly basinets but also the couter III.1714, were raised. Several fifteenth- and sixteenth-century objects, however, were formed in a variety of ways.

What seems to have been the preferred alternative was to curl a plate into a conical shape and close the resulting seam. AL.23 107, the fifteenth-century couter already described in Chapter V was formed in this way, and brazed closed.[456] III.864, an early sixteenth-century German arm harness for the joust, is likewise curled and brazed, but the seam is also riveted shut with two flush rivets, perhaps to hold it closed while heating to braze. IV.502, a late fifteenth-century German helmet also for the joust, has a visor which is simply curled and riveted, with no brazing which would have made the join much stronger. Two other pieces of jousting armour, AL.90 and III.1808 B, both arm defences and probably Flemish from the beginning of the sixteenth century, have their couters curled in the same manner as AL.23 107 and III.864, but the seams are forge welded, with no brazing or riveting of any kind.[457]

Although the difficulty of raising may have been a factor in finding ways around it, no assumption should be made about the quality of the objects themselves or the skill of the armourers who made them. AL.23 107 and IV.502 were possibly made by Lorenz and Kolman Helmschmied, and the other pieces are not of low quality.[458] That all but one are for jousting is interesting given the greater protection added to pieces of armour not meant for use in war. The potential vulnerability of the seamed pieces may have relegated them to the tournament. The greatest advantage these methods have over raising is speed, since the main depth can be formed quickly and then refined to the desired shape.

6.4. Doming

The place where doming is most clearly seen is on breastplates, which can be demonstrated not only though marks but through iconography which shows breastplates being formed from the interior.[459] Doming has the difficulty of sometimes resembling

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456 See Chapter IV, pp. 219-21, and Figure 362.
457 See Figures 363-67.
458 RA inventory entries.
459 See for example Figure 368.

planishing since the marks are both from contact with a domed surface, a stake for planishing and a hammer for doming, and it often has little identifiable pattern, despite being done in a concentric manner. If it was done over a dishing stump or other similarly hollow form it could leave very little trace because there was no bottom die backing up the piece.

Because of these difficulties there is a comparatively small selection of objects for study whose marks are more likely to be from doming than planishing. There were only twelve pieces which had marks which were deemed to be from doming, and even these are likely overlaid by planishing.[460] However, even in this small sample there is a good deal of variation of the internal marks which demonstrate some interesting ways to practice what is in essence the same technique.

Nearly all of the objects have an irregular series of marks. While the process of doming would have followed a roughly concentric pattern in the same way as raising, there was much more room for both error and small deviations in pattern, as demonstrated by the test doming plate done at the Royal Armouries.[461] The lack of a clear pattern may in some cases be exacerbated by planishing which has blended in with the doming.

Doming does not leave any ridge in the way raising does, and none of the objects have any, though it is possible that some later, very deep breastplates such as the peascod were raised. In the Middle Ages, though, doming appears to have been the preferred technique for these shallower forms. It is also worth noting that even pieces by known virtuosos, such as III.1284, made by Jorg Treytz, have irregular tool marks

[460] See Appendix B, Table 5, p. 279.
[461] See Chapter IV, pp. 126-27.

and that the apparent roughness of the interior has no bearing on the quality or subtleness of the piece.[462]

One of the breastplates, III.96, can be used to show the difference between planishing and doming. This piece is late fifteenth-century for the joust of peace and as such is extremely thick, heavy, and specialised for that use. Although not heavily shaped for most of its area, it does show evidence of doming done primarily on the interior. The marks are of many different shapes, sizes, and depths, more consistent with hammer blows than stakes and probably resulting from more than one hammer. Several small areas with isolated patterns are the result of the armourer correcting flaws in the shape. Those corrections may have been done during fabrication or may even be from repairing damage sustained in the joust.[463]

In comparison is another jousting breastplate, III.1336 A, possibly Flemish from the end of the fifteenth century. Although it served the same function as III.96, and is likewise only lightly domed, the interior could hardly be less similar. The marks are small, rounded, closely set and, most importantly, quite smooth.[464] This is the pattern of marks which is associated with planishing, the stake leaving a less well-defined mark than the hammer and the quicker, lighter blows keeping them close and shallow.

Only two pieces had marks in a clear and regular pattern, III.1283 and III.84, both German and from the late fifteenth and early sixteenth centuries respectively.[465] III.84, although heavily corroded on the interior, shows evidence of doming with large, broad-faced hammers in an oblong pattern, with the lines of the courses meeting at points at the top and bottom. It is a combination of curling and doming over a flat surface in order to achieve the almost pointed shape on the lower part of the dome.

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[462] See Figure 369.
[463] See Figure 370.
[464] See Figure 371.
[465] See Figures 372-74.

III.1283 also has what appear to be marks from a blend of curling and doming, though in this case the marks are much smaller and in a different pattern. Instead of a rounded lozenge, the pattern is shaped as a chevron, with lines meeting at the medial ridge and slanting down towards the sides. The plate was probably moved in a linear, rather than circular, direction to achieve this effect which domed the lower part of the breastplate while simultaneously curling in the ends.

While most of the pieces' marks are primarily round, or at least semi-circular, these are interspersed with marks which are oblong or shapeless. In fact, it is much more common for a piece to have at least some marks which are not round than to have all round marks. Most of this difference in shape is due to overlapping marks, which obscure the actual shape and make them look oblong. One piece with relatively rough marks, III.4568, a late fifteenth-century breastplate possibly from Flanders, appears to be hot-worked due to the depth and clarity of the marks, both from doming and the curling at the sides.[466] Only the jousting breastplate III.96 has comparable marks, suggesting that the others may have been done cold, or hot with broader hammers.

Although there was more variation in technique than was found with raising, there does not appear to be any tendency of one region to favour one method over another. This may be because of the relative simplicity of the technique, or because of diffusion of the technique which became favoured by armourers all across Europe, though a larger number of pieces may result in a better understanding of its application.

6.5. Curling

The marks found on armour plates from curling represent one of the most common mark patterns encountered because it is used to such a large extent, not only for large plates such as cuisses and upper and lower cannons but also for lames on all armour

[466] See Figure 375.

elements. An examination of a full seventy six pieces, thirty-two German, thirty-one Italian, and thirteen from other regions, shows a range of mark types, from broadly oblong to narrow, with a few pieces which were planished.[467] It is clear from the earlier discussion of the curling process that it was most often accomplished from the interior, rather than the exterior, and that even complex forms could be created using this fairly simple method.[468]

Although ubiquitous, curling is quite simple; while fluting focuses on a relatively small area with a large amount of shaping, and raising requires a great deal of change in shape over the plate, curling is a gradual shaping over an entire plate. This allows gentler hammer work, leaving shallower marks with a possible mark placement from highly overlapped to widely spaced, depending on the armourer. The difference between narrow and oblong marks is most likely due only to hammer shape, the mark width a result of the radius of the hammer peen.

The marks themselves are most often oblong, either long or short, but thin and more rounded marks occur as a result of differences in the shapes of the hammer faces used. Marks on the arm harness of the Avant armour, which are short and broad, are very similar to the leg harness of II.168, both Italian pieces from different workshops. Smaller, narrower marks are found on the German backplate III.1287 and the Italian arm harness of II.168.[469] There is a geographic distinction discernible in the marks, a tendency for the German pieces to have narrower marks, while the Italian pieces had almost all oblong marks with a few having narrow ones. This derives not from a difference in working technique but from a difference in tool shape; German armourers appear to have had hammers with narrower peens than their Italian counterparts.

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467 See Appendix B, Tables 6-8, pp. 280-82.

468 See Chapter IV, pp. 127-29.

469 See Figures 376 and 377.

That the marks usually remain clearly oblong or narrow indicates that planishing was apparently rarely carried out. Because the technique has the potential to be so much gentler than doming and raising, planishing was generally not required to finish the exterior. The arm harness of II.1 was planished lightly, as were the faulds of III.70 and III.1283, among a few other pieces. The use of ball-peen hammers, as was the case with the fauld of III.1284, demonstrates how curling from the interior is closely related to doming, the real difference being the creation of a long curled surface rather than a greater volume.[470] Of course, since flat planes occur so infrequently on armour, curling from the interior allowed for a certain amount of three-dimensional shaping to the plates, and the two techniques were fully integrated to create the breastplate III.1283.

6.6. Planishing

Because of its usefulness in preparing the surface for finishing, planishing seems to have been one of the most common processes used by the medieval armourer. All parts of armour could be planished no matter how they had been shaped or what size plate, and it could be used as its own finish if done well enough or if speed was preferred over quality. Price has noted that it is also useful in work-hardening the plate, although this quality is negated if any heat treatment is performed and it is unlikely that medieval armourers made use of work hardening, though they certainly recognised it as a part of the working process.[471]

As already noted, it is sometimes difficult to differentiate planishing from other techniques, especially doming, and its characteristic closely overlapping marks followed by exterior finishing make it a surprisingly difficult process to identify on armour. In

[470] See Figures 378 and 379.

[471] Price, TOMAR, p. 229, and Williams, ‘To What Extent Can Forgeries be Detected by Metallurgical Analysis?', p. 63.

many cases it may safely be assumed based on other evidence, such as context or the general character of the interior surface which may be consistent with planishing, but on the whole it remains more elusive than most of the other techniques discussed.

A unique feature of planishing is that it may be recognised on the exterior of a finished object. This is best demonstrated on the Lion Armour, II.89, where the surfaces which are not heavily gilt or embossed are lightly faceted, the ideal surface for the planishing stage.[472] It is very possible that no further finishing was required or carried out between planishing and the steps necessary for engraving, gilding, and blueing. The marks on the interior are generally rounded but of very uneven pattern and very overlapped, the result of planishing and possibly refining areas which were slightly rougher from the main shaping operation, either raising or doming.

Planishing may be differentiated from doming by comparing parts of the same object as demonstrated with doming and raising. In those cases parts of the same plate were examined, but it is also possible to compare two similar plates in the same object. In the case of the leg harness for II.6 the cuisse plates are covered in what are clearly small curling marks, but the greaves are covered in round marks on the interior. More shaping was required for the greave, but the cuisse was also very sculpted to the thigh. In addition, given that the whole of the greave, and not just the calf, is covered in round marks, it is clear that they are the result of anticlastic curling and fine planishing.[473]

IV.497, a fourteenth-century Italian basinet, shows very fine planishing that has fully smoothed the interior surface and no doubt resulted in the piece requiring little polishing. The marks are round and irregular, with some patches of even closer marks where the piece was planished even more. In comparison the Lyle basinet, which is contemporary with IV.497, has larger, deeper marks which are also the result of

[472] See Figure 380.
[473] See Figure 381.

planishing.[474] In fact, all the fourteenth-century basinets in the Royal Armouries, five in total, have smoothly planished interiors. The great basinets II.7 and IV.2 are similarly marked. Sallets are more likely to have marks left over from raising, but many of them are also planished perfectly smooth.

Other pieces also exhibit signs of planishing: III.1196 B, a pauldron from *c*. 1500, has a domed and planished upper plate, as is the jousting cuirass III.1336 and the breastplate III.1350, as examples. In general, pieces which are not corroded but have smooth interiors, or are lightly dimpled, may be said to be planished.

6.7. Rolling Edges

Although a plate edge could be left plain, it was very common to do some sort of finishing work to them. The way in which edges are finished is significant not only in terms of style but also structure. Some methods of creating an edge are highly decorative and some are quite plain, but they all serve to stiffen the plate and prevent warping. They also protected the wearer in a few key places from injury from a sharp edge, particularly the inside elbow of arm harnesses, tops of cuisses, and the openings of cuirasses, and served to stop a weapon sliding into an exposed area.

Although edge finishes seem varied, there are only a few basic types which were commonly used. Folded edges, while simple, are comparatively rare. Simple rolls are the most common, and they may or may not be turned over a wire. Rolls may be made somewhat more decorative through shaping by tapering the roll at each end, by making a boxed roll which is square or triangular in cross-section, or by adding roped decoration through embossing or filing.

There are not many simply folded edges in the corpus, a reflection on its lesser popularity stemming from the somewhat crude nature of the technique and its lack of

[474] See Figure 382.

structure compared to a roll. The poleyn wing of III.2459, a sixteenth-century cuisse and poleyn, has a very crudely folded edge, as well as file-roped edges mimicking a piece of higher quality. The late fifteenth-century German sallet IV.13 also has an inwardly folded edge, somewhat more cleanly executed but still relatively crude. Not all folds are found on lower-quality armour, however. III.864, a rather good quality right arm defence for the joust from early sixteenth-century Germany, has a fold on the upper edge of the tendon guard, giving the piece a little extra rigidity.[475]

Simple rolls or turns are common and may be done to the interior or exterior. Formed by hammering an edge over the corner of a stake and then carefully working the edge over to close the roll, they form a tube along the edge which adds rigidity and protection. These rolls could collapse under a blow, so a wire is sometimes added inside the roll to increase strength. Both IV.600 and the Pembridge helm have a wire, which is exposed on the front of the Pembridge due to damage. IV.20, an Italian sallet of *c.* 1470, also has a wire, but in its case it is a flat strip now exposed through corrosion.[476]

Decorative, though still functional, edge treatments become more common in the late fifteenth and early sixteenth centuries. Creases worked into the length of the flute to create the roll, instead of only bending, making boxed rolls.[477] Embossing with a chisel could be used to create rolls, though filing was a less labour-intensive option as seen on III.2459.[478]

There is, in fact, little difference in the making of rolls on armour plate, regardless of the type. The techniques used to create each type are in essence variations on a theme. However, the rolls from object to object are frequently different in their

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475 See Figure 383.
476 See Figure 384.
477 See Figure 385.
478 See Figure 386.

finishing as a result of the care taken with its shaping, especially along the cut edges. III.2459, in addition to its rough folded edge and low-grade filed roping, has a very poorly-closed upper roll. III.4572, a *c*. 1500 breastplate possibly from Flanders, has remarkably rough edges to the inwardly-rolled arm and neck openings.[479] The first is a result of poor hammer work, but the second has very well-formed rolls; it is only the cut edge, completely hidden on the interior, which is rough.

Of course, there are finely-made rolls to be found amongst the objects. III.73, an early sixteenth-century German breastplate has particularly well-made outwardly-turned but inwardly boxed rolls at the arm and neck openings, which are concave on the forward facing surface to more efficiently re-direct blows. The barbuta IV.7, a fifteenth-century Italian piece, has a small continuous outward roll around the edge and face opening which, despite now being damaged by corrosion, shows how finely and around what tight curves the armourer could turn an edge.[480]

An interesting type turned to the exterior but hammered flush creating a welt on the interior is found on two helmets in the Royal Armouries, the war hat IV.537 and the sallet IV.429. This roll ensured that there was no lip for a downward strike to catch on, ensured the rim had the rigidity of a roll, and imparted a bordering line to the exterior which would not have been created if the edge had simply been rolled to the interior. To further increase strength the rolls were done over a wire, which has been exposed on IV.429 as a result of corrosion, which also makes its cut edge appear rougher than that of the war hat, but this is likely due to differences in corrosion and modern cleaning between the two, which are much different.[481]

[479] See Figure 387.
[480] See Figures 388 and 389.
[481] See Figures 390-93.

6.8. Forming Flutes and Creases

Flutes and creases are very common features and appear on every type of armour from all parts of Europe. It is unsurprising, then, that they also show a great deal of variety in their pattern of interior marks. The crease is the point at which two convex arcs meet, while the flute is formed of the meeting of two concave arcs. Both are begun in a similar way, but creases are finished by hammering the concave area in such a way as to bring the surfaces level instead of sunken.[482] The marks on creases are very similar to flutes as a result.

Creases and flutes serve a number of purposes. On the surface they are aesthetically pleasing by drawing attention to certain anatomical features. The long crease from the hip to the ankle on a full leg harness lengthens the leg, while outwardly radiating sprays of flutes on the breastplate create the illusion, along with the exaggerated shapes of the fauld, of a wasp waist. On a more functional note, the addition of creases and flutes adds rigidity to the plates, increasing their resistance to crushing attacks, although Italianate armour in the late fifteenth century did not make great use of flutes, while German 'Gothic' armour is in part defined by its use of them.[483]

There has been a question of whether they were primarily worked from the interior or the exterior. Price maintains that 'contrary to common belief, fluting seems to have been done from the outside, not from the back of the piece with a chisel', and that it was later Maximilian-style armour that had its flutes made with chisels, though he offers no specific evidence to support this claim.[484] He does show that they may be

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[482] For a more detailed discussion of forming flutes, see Chapter IV, pp. 129-30.
[483] The Italians also did not harden their armour to the same extent as the Germans in the later Middle Ages, perhaps because of their greater use of fire gilding. See Williams, *The Knight and the Blast Furnace*, pp. 894-95.
[484] Price, TOMAR, p. 188.

made working entirely on the exterior of a piece, compressing the plate to either side of the apex over a stake, just as the experimental plate work in Chapter IV also demonstrated.[485] The marks left on the interior from this technique when done over an upright stake are very limited since planishing is being done in one with the creation of the flutes. When done over a raising stake the orientation of the plate, and subsequent marks, are different.

The shapes of flute channels are often broad and rounded on medieval armour, not matching the more pointed apex of the flute on the exterior. This in addition to the tool marks indicates a tendency by medieval armourers to start work on the flute on the *interior*, embossing the flute into the plate with a hammer or blunt chisel and then finishing on the exterior. The shape of the stake, with a slightly rounded edge, would maintain the radius of the channel while the hammer sharpened it on the exterior.

There is a great deal of evidence to be found for flutes which were embossed from the interior, beyond the broad, rounded channels. In many cases the flutes themselves flare out at one end, their bases becoming wider towards their termination in a manner which is in keeping with embossing. An excellent example of this is AL.23 107, a shell couter with exceptionally well-formed flutes which widen almost imperceptibly on the exterior. The channels on the interior widen more noticeably, though even here it is a very small amount, giving a subtlety to the piece and demonstrating the skill of the armourer.[486]

More extreme examples are found on pieces such as the backplate III.70, the broad area over the shoulder blades providing space in which to work large sprays of flutes; those on the main upper plate widen towards the centre and then taper at the ends. Another backplate, III.1092, although heavily corroded, shows flute channels that

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[485] Price, TOMAR, pp.184-89 and Chapter IV, pp. 129-30.
[486] See Figure 394 and Chapter V, pp. 219-21.

widen a great deal evenly from top to bottom. Finally, the tilting sockets from II.167, a late fifteenth-century jousting armour, use tapering flutes to good effect to create a sunburst pattern over the thigh.[487]

Some pieces appear to only have the interior working and were not shaped on the exterior, though it is uncommon. IV.579, the visor for an armet from *c*. 1510, has ridges on the lower half which are not fully-developed flutes. The areas on the interior which correspond to the high points on the exterior have very closely set, small oblong marks which are from the peen of a small hammer such as XVIII.98.[488]

As with raising and curling there is a geographic difference in fluting techniques, but here it is much more pronounced. A large number of pieces were available for study owing to the prevalence of creases and flutes on armour, forty three in total, with seventeen from Italy, twenty-one from Germany, and five from elsewhere in Europe.[489]

The German pieces with marks still in evidence are notable for their regularity of patterns. The marks range from narrow to thin and are usually long, though some are short. They are rarely seen beyond the edge of the feature, usually only a few millimetres if they are past the edges.[490] They are always parallel with the crease or flute, or are at the most slightly angled such as on III.1414, a sixteenth-century pauldron, though they at no point extend beyond the borders of the flute.[491] III.1325, a late fifteenth-century backplate from Augsburg, has hammer-embossing marks on the

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[487] See Figures 395-97.
[488] See Figure 398.
[489] See Appendix B, Tables 9-11, pp. 282-83. Because of the heavy use of fluting by German armourers there is a larger number of pieces from Germany, twenty-three compared to seventeen Italian pieces and only five from elsewhere in Europe.
[490] See Figures 399 and 400.
[491] See Figure 401.

main plate which are much more angled than is to be expected.[492] However, these marks are on a tightly curved flute around the opening for the arm, so they are actually following the curve, the angle remaining constant with the flute through its arc.

The Italian pieces are not uniform in their pattern of marks to the same degree as the German pieces. A few, including the cuisses of the Avant armour and the cannons of II.168, do have parallel patterns, but more of them have marks, mainly short oblong ones, which are at a greater angle than any mark on the German armours, often in combination with the parallel marks. This is seen on the legs and breastplate to II.168, and the breastplate III.1282, all of which are late fifteenth-century Milanese, as well as the early fifteenth-century pauldrons of the Avant armour.[493] III.1282 is particularly valuable because the medial ridge of the plackart strongly resembles the keels on some helmets, the marks of which will be covered in the following section.

Overall, Italian pieces, while having parallel marks, are much more likely to have oblique marks in addition or exclusively, and the angle tends to be fairly acute. In addition, they are much more likely to have marks at some distance from the flute itself. In contrast, German pieces nearly always have marks in parallel with the feature, and they rarely stray outside the flute or crease. These differences provide further clues as to the origins of pieces where their place of manufacture is uncertain.

6.9. Forming Medial Combs

Helmets are remarkable for their complexity and the number of forms which developed over the course of the Middle Ages, with styles going in and out of fashion and several being used side by side. The type of head defence was largely dictated by the type of

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[492] See Figure 402.
[493] See Figures 403-05.

combat it was intended for; a helm was exclusively used when mounted while a great basinet, with its profusion of holes for vision and breathing, was used for foot combat.

A common feature, however, is the medial comb, which is on nearly every medieval helmet in some form.[494] They provide some extra protection in terms of volume, and also frequently serve to anchor crests for which they will have holes pierced. They may be described as creases, ridges, which are the same as flutes, and keels, which are similar to flutes but have a flattened top. This analysis is aided by the experimental plate work discussed in Chapter IV, and reveals some interesting details about the creation of the combs.[495]

There were twenty-four helmets from the corpus which were suitable for this part of the analysis, which cover a range of types, dates, and places of origin.[496] Of these, twelve were Italian, seven were German, and five were from other parts of Europe or were of uncertain origin. They also had a range of tool marks on the interior which were compared to determine what working processes had been used to create the medial combs and what, if any, similarities existed. Mark types may be identified as being a result of a hammer, chisel, or stake, and the precise orientation of the marks in relation to the feature, whether they be parallel, oblique, or perpendicular, is also significant.

On the German pieces the marks tend to be narrow oblong marks which run parallel with the combs, staying within the borders and rarely straying outside. Where a keel narrows to a ridge or a crease, as is often the case at the rear of a helmet, the marks remain narrow oblong marks and run parallel with the ridge or crease in close proximity with it. These narrow, parallel marks are found in pieces of such disparate quality as the

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[494] See for example Blair, *European Armour*, p. 153.
[495] See Chapter IV, pp. 129-30.
[496] See Appendix B, Table 12, pp. 284-85. There were twenty-four helmets which were too badly corroded to include, and three which did not have any medial comb.

Nuremberg munitions-grade sallet IV.13, the mid-quality sallet IV.499, and the imperial tilting helmet IV.502. The marks are sometimes faint or difficult to see, as is the case with IV.428, a late fifteenth-century sallet in which the marks are clearest at the rear of the keel where it narrows to a crease.[497] Even through heavy corrosion the deep, straight channel left by a chisel is identifiable on several pieces, such as the sallet visor IV.434.

In contrast, the Italian helmets exhibit a much wider array of marks with some different patterns. The best, if most extreme, example is the great basinet of II.7, Henry VIII's tonlet armour. Within the medial keel are long, thin tool marks which are both oblique and parallel with the keel, but in addition to these on either side of the keel are wide bands of short oblong marks roughly perpendicular to it.[498]

Wide bands of marks are seen on other Italian helmets, particularly at the rear on the tails of sallets and barbutas where they are parallel to the medial crease. The marks themselves need not be perpendicular to the comb as with II.7, and indeed parallel oblong marks appear to be somewhat more common. The barbuta IV.7 has bands of parallel marks at the back of the skull, and another barbuta, IV.17, has very well defined mark bands on the tail, but interestingly there are no marks within the keel. II.168 A, a late fifteenth-century sallet, also has very clear bands on the tail, and some other marks along the keel though most of the marking has been obliterated by planishing, while the slightly later sallet AL.44 1 had a very similar pattern which is now mostly lost to corrosion.[499]

The marks within the skulls of these helmets, which consist mainly of planishing marks with some residual raising marks, show that these bands were all created *after*

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[497] See Figures 406-09.
[498] See Figure 410. For a full discussion of the reason for these wide bands, see the case study for II.7 in Chapter V, pp. 162-66.
[499] See Figures 411-13.

shaping and planishing. Except for II.7 and IV.2, discussed below, all are confined to the rear area where the keel narrows to a crease. They all appear to be from small cross-peen hammers, and are from correcting or refining the curvature of these pieces after making the initial crease or flute. The German helmet IV.12 has a similar pattern over the brow, but it is not clear if they are the result of shaping the front of the skull or if they are related to the front ridge. The pattern is not parallel, instead being oblique on either side, and so while it may be related to the technique used on the Italian helmets it is not the same.

Another example of Italian work is the Blind Basinet, IV.2, roughly dated to 1510 and possibly from the Royal Workshop at Greenwich.[500] There is no making along the medial keel in the helmet skull, but there are bands of marks on the visor. The visor has a medial crease on the lower three quarters, but on the top quarter it broadens to a medial keel which fits over the skull. Within the visor there are long, narrow marks which are parallel to the keel, and to either side are moderately wide bands of shorter oblong marks. Close to the edge these are parallel, but they are bordered by perpendicular marks.[501]

That this mark pattern does not appear on the skull is strong evidence that the skull and visor were made by two different people, but it is also significant that the pattern most closely matches the pattern of marks on the skull of the great basinet from II.7 which is without doubt Italian in origin, and as already demonstrated the wide bands of marks are a uniquely Italian pattern. In July of 1511there is a record of Milanese armourers at work in Greenwich, who were paid £6 13s. 4d. and provided with two hogsheads of wine. According to Richardson, ‘These particular Milanese

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[500] For a full discussion of this object see Chapter V, pp. 166-68.
[501] See Figures 414 and 415.

armourers, who were under contract for two years from March 1511, are not mentioned again', although the records are not complete.[502]

IV.2 has a long history in the collection of the Royal Armouries. The first certain reference is found in an inventory entry from 1660, but entries as early as 1611 may refer to it.[503] The telltale marks on the visor indicate that component at least was made by an Italian armourer, and the fit of the plates show that the visor was made to fit the skull. The Blind Basinet has been roughly dated to when the Milanese armourers arrived in England to work for the king, and if IV.2 is in fact a product of the Greenwich workshop, it is the only piece which can be attributed to those early Italian workmen.

To summarise these differences, the German helmets have marks which are parallel with the comb and which rarely stray beyond it but the Italian helmets may have marks which are both parallel and oblique and which also may be found beyond the borders of the keel. In addition, Italian helmets may have marks which are perpendicular, or wide bands of marks to either side, a pattern which is not found on German helmets.

The oblique marks are the result of creating the combs over raising stakes, which results in deeper, more oblong marks than most other techniques.[504] Both German and Italian helmets have marks which resemble hammer or chisel embossing, though chisels are more likely to be used on the skulls. While Germans appear to have embossed and worked over an upright stake, of the type illustrated in Seusenhofer's workshop and as demonstrated in Chapter IV, it would appear that the Italians more

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[502] Thom Richardson, 'The Royal Armour Workshops at Greenwich', pp. 148-49.
[503] The 1611 inventory cites 'One greate headpeece remayning of old', while the 1660 inventory lists the 'Great Hearce of John of Gaunt's', an attribution which was attached to IV.2 until fairly recently. See Tower Inv., pp. 58 and 85, and Blair, 'Comments on Dr. Borg's "Horned Helmet"', pp. 173-74.
[504] See Chapter IV, p. 130.

often made use of a raising-type stake when forming helmet combs, resulting in deep oblong marks.[505] While the upright stake can also make oblique marks it is also capable of making very finished, smooth flutes, particularly when the feature has been embossed with a chisel beforehand, resulting in the smoother combs of the Germans.

6.10. Conclusion

This chapter has demonstrated that there is a greater variety of mark patterns than would otherwise be expected. Flutes have a number of different associated patterns, and even raising can result in differently textured surfaces depending on how aggressively it was done and how much it was planished. It is these distinctions between patterns from similar forms and features which are significant.

Each shaping technique has patterns of marks which are unique to that process, but the precise alignment of the marks is significant. A mark which is parallel to a feature was not made in the same way as a mark which is at an angle. These differences are indicative of distinct methods on the part of the armourers. The tendency of German armourers to favour one method of creating a certain shape and the Italians another has been confirmed, especially in elements such as flutes and combs.

This represents a significant advancement in the ability to identify the origin of an object, especially those without any kind of identifying stamp. Instead of relying only on stylistic considerations, tool mark patterns which have been identified as being unique to certain regions may be used in conjunction with the usual array of diagnostic criteria. The interiors of pieces of armour, long unnoticed, have provided a wealth of information about the objects and the people who made them.

[505] For the upright stake see Figure 65, and for fluting on a raising stake see Figure 111.

Conclusions

The craft of the armourer was at all times a balance between tradition and experimentation, between defensive and offensive ability, and between the demands of a patron and the limits of time, material, and skill. Perhaps, then, it is no surprise that there was such a profusion of types of armour over a relatively short period of time. Regional styles, changing tastes, and evolving methods of warfare all drove the development of armour throughout the Middle Ages and into the Renaissance.

Armourers, however, knew what worked. Beneath the gold, the embossed lions, and the elaborately fretted borders lay the marks of a metalworking tradition that had proved itself adaptable to these new forms but which had not changed its working practices appreciably. The tools had undergone no major change, though new forms of stakes had been adopted, and the shaping techniques were tied not to the final form of the armour but to the specific way the armourer needed to move the metal to achieve that form.

This examination of the methods of armour production in the late Middle Ages demonstrates the tradition and the experimentation which existed, as well as the individuality of each armourer. It is clear that the ways in which they worked was more complex than was originally thought and that there was more possibility of variety in workshops. If the similarities which are found in armour from disparate times and places are surprising, the differences are even more fascinating.

The results of this research have provided a much clearer view into the armourers' workshops than was previously possible, and we now have a better idea of what actually occurred in it and how the armour was made in detail. Assisted by the documentary evidence, it is the armour itself that has allowed this, and those hidden interiors that have until now passed mostly unnoticed.

The two most influential works on the subject have been Charles ffoulkes' *The Armourer and His Craft* and Brian Price's *Techniques of Medieval Armour Reproduction*. ffoulkes' work, now a century old, was more concerned with the function of armour components and why they were shaped the way they were, an accompaniment to the growing number of works on the style and development of armour, culminating in Laking's *Record* of 1922 which has itself cast a long shadow over the field of armour studies. Price's book, although much more technical than ffoulkes' in terms of the manner in which metal is formed and the small details of construction, is aimed at people in the present day creating reproductions, and as such lacks the rigor of an academic work and the focus on original armour and techniques.

The work done here has allowed the two approaches, one focusing on function and the other on technique, to be brought together in a way that gives precedence to the objects, while still working with an interdisciplinary approach. This was the first time that the interiors of these objects have been systematically studied, and the results have opened up a new avenue in armour studies which had not existed before. This may be linked with the metallographic studies of Williams, Starley, and others to produce a much broader understanding of medieval armour-making than was possible before. It was through an analysis of the tool marks and Williams' previous scientific studies that all the plates of the Horned Helmet were found to have been from the same workshop, answering a longstanding question regarding the piece.

This thesis has developed a typology of tool marks and patterns and methodology for their use which will be useful in the future to provide a diagnostic tool in the analysis of pieces of armour. These marks are essential in deciphering the techniques of armourers; the written and iconographic sources are not enough in themselves to completely explain the intricacies of armour-making, and are in themselves somewhat cryptic without the armour as a guide. Inventories, artwork, and objects have worked together to answer questions which would have been difficult or impossible to answer if only one source type were available.

The interpretation of the artwork and study of the inventories has yielded new insight into the work of the armourers, resulting in a more detailed and accurate identification of what the tools and techniques are, as well as changing some previous interpretations of those sources. It is now clear why an armourer was using the 'toe' of his hammer instead of the face, and what the purpose was of several of the tools in the various inventories which, though filled with difficult and obscure terminology, are the best written sources for the methods of the armourer and partly fill the gap created by the absence of any treatises on the subject.[506]

Understanding the tools, their marks, and being able to recognise their relationship and apply it to actual objects is at the core of the methodology, providing a guide for the investigation, recording, and interpretation of the marks. When reading a piece, the whole of its production, from cutting to polishing, can be seen on its surfaces. This armour-making process must be taken into account when studying tool marks because the interrelation of stages and marks are what show the order of construction, as well as demonstrate some of the ways in which armourers planned ahead when forging a piece. This is most clearly shown in the different levels of planishing found on sallets, as the harder to grind tails were hammered more carefully than the skulls.

The interpretation of tool marks need not be done in isolation from the techniques which actually created them, and it has been through a working knowledge of metalworking that part of this research was carried out. The experimental plate work not only confirmed initial theories about the mark patterns, but also shed light on some unexpected relationships between mark and tool used, specifically the difference in

[506] ffoulkes, *The Armourer and His Craft*, p. 23.

flutes raised on an upright stake and those raised on a single projection raising stake. It also helped to further define the difference between hammer and chisel embossing on flutes.

It also uncovered a previously unknown method of production in the case of greaves. Although anticlastic raising is a standard technique amongst metalworkers, even today, the tool marks inside greaves did not support this method of shaping. The long or oblong marks running the length of the greave on nearly every one examined clearly indicated that the pieces had been curled, but that appeared to be in opposition to the usual shapes of other curled pieces, which are generally gutter-shaped or with very little curvature. However, in the course of the experimental plate work it was found that the mark pattern and accompanying anticlastic shape could be reproduced, and that medieval armourers did most likely curl highly sculpted greaves.

The tool marks may be examined individually on an object to discern the manner in which it was made, or several object may be studied side by side. These comparisons clearly show the great variety in the ways armourers worked, and the ways in which the objects may be analysed using tool marks and construction details to better understand the practices of armourers. The possibility for comparison is diverse, as are the criteria which may be used, but it is through these comparisons that some of the most interesting findings are discovered.

In the workshop environment it has been shown that two armourers can work in very different ways and produce similar results with different tool marks on the interiors. The cuirass of the Avant armour, although made in the same workshop by two brothers, has very different marks on the separate components made by each. This individuality of style could be used to identify particular armourers' works based on tool marks or patterns which may be unique to them, as is likely the case with the armourer who made III.1325.

One of the most significant findings in this thesis was the discovery of a difference in the tool marks between pieces of Italian and German manufacture, something which has not been recognised before. This adds another diagnostic tool in the attribution of objects to particular areas. These comparisons also provide evidence of favoured practices and have demonstrated just how armourers usually worked. The definite attribution of an object to one place or another is sometimes difficult because armour is so often not stamped by an armourer, guild, or city. When the basic stylistic criteria do not result in a satisfactory answer, what then may be used to narrow the field? The identification of tool mark patterns unique to Italy and Germany has provided a whole new criteria to the analysis of armour which may be used to better determine where a piece was made.

This discovery is best demonstrated by the great basinet IV.2, which has been in the Armouries collection for about four hundred years but whose exact origins has been shrouded in mystery in that time. It is now clear that the visor and the rest of the helmet were made by different individuals, and that it was an Italian armourer who made the visor. If IV.2 was a product of the Greenwich armoury, then it is the only piece of armour known by the Milanese armourers of its early phase.

Construction techniques other than those which left marks are also important in the analysis of a piece of armour. Forge welding, as infrequently as it is encountered, has proved of central importance in the comparison of the Pembridge helm and IV.600. In addition to identifying the actual location of the welded seam, the comparison of that and other construction details has confirmed that the two objects came from not only the same workshop but were made by the same hand.

Greater familiarity with tool marks can also be used in separating originals from fakes. The shape of the plates, as well as their fit, decoration, and features are all important aspects in determining the authenticity of a piece of armour, but it is the tool marks which are in some cases a more deciding factor. Such is the case with IV.537, the fifteenth-century kettle hat which has been labelled doubtful by the Royal Armouries. Although it shares a similar maker's stamp with another kettle hat, it is the internal tool marks which best demonstrate that the piece is original.[507]

Even pieces which appear correct may prove otherwise under close scrutiny, and it is construction details which can help to determine the authenticity of a piece. In order to function as a piece of armour the plates must interact correctly with each other, but more importantly they must interact with a human body. Thus the left gauntlet of II.3 can be shown to be modern, since it does not provide enough range of movement, especially in comparison with the right gauntlet.[508] This is coupled with further stylistic analysis which shows several discrepancies between the two pieces. Further scientific investigation could also reveal aspects of the metallurgical composition of the plates and whether or not they are likely to be medieval.

Although the research conducted made use mostly of the collection of the Royal Armouries in Leeds, the methodology may be applied to any collection. More information gathered about the various feature types will continue to expand and refine the mark typology. In particular I hope to further study pieces by known armourers to build upon the work begun here so that individual armourers' works may be identified through their unique tool marks. This has implications for many holdings, which can now be more accurately catalogued. In addition to the pieces already mentioned from

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[507] See Chapter V, pp. 181-83. Direct comparison of the two helmets could also prove if they were the work of the same hand.
[508] See Chapter V, pp. 230-31.

the Royal Armouries, III.1381 was found to be a composite piece which was assembled long before its purchase. This will also aid museums in analysing any new acquisitions that require assessment.

This thesis began with a quote by Charles ffoulkes, ‘Perhaps it may be said as well at the outset both to allay curiosity and to disarm criticism by frankly confessing that very little is definitely known of the methods practiced by the mediæval armourers’.[509] This is no longer the case, as demonstrated here, and it may be said at the close to answer curiosity that we now know much more about the methods of medieval armourers.

[509] ffoulkes, ‘The Craft of the Armourer’, p. 99.

Armourers and their Workshops

The Tools and Techniques of Late Medieval Armour Production

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Volume 2

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Table of Contents

Appendix A: Further Greenwich Inventories

These inventories, from 1611 and 1629, are discussed in detail in Chapter II, pp. 44-47. They are an excellent resource for the contents of an entire workshop because they appear to be nearly complete, and have clearly defined work spaces.[510]

Inventory of 1611

In Mr Pickerings woorkehouse

Ryffe Irons and stakes of Iron	xi
Tonges	xi pr̄e
Vices	ii
Harthstaffe	one
Forging ham̄ers	v^e
Smalle ham̄ers	xx
Cutting sheeres loose	ii pr̄e
Cutting Chissell	one
Blockes furnished w^th stakes	xii
Greate Anviles standerdes	vi
mould of Iron	one
Sheeres standerdes	iii pr̄e
Fyling tonges	one pr̄e
Bellowes	ii pr̄e
Hatchett	one
Raspe	one
Shiver tonges	one pr̄e
Counter borer	one
Compasses	one pr̄e
Bickhorne	one
One panne of Iron for fier with fower wheeles	

[510] Tower Inv., pp. 55-61.

One other greate panne of Iron for fier for thoffice			
Guilding tonges		iiii pr̄e	

In the Cutting house

Foraging ham̄er heades		ii	
Hand ham̄er heades		iii	
Chisselles		iii	
Ham̄ers, viz	greate whereof one for a mill	ii	xviii
	smalle	xvi	
Bickhornes, viz	greate	iiii	vii
	smalle	iii	
Stakes		viii	
Ryffe ham̄ers		viii	
Bellowes		one pr̄e	
Plate sheeres		one p̄re	
Olde sheeres		one pr̄e	
Irons		vi	
Tonges		v pr̄e	
vice		one	

In the Locksmiths Office

Anvile	one
Stake	one
Bickhorne	one
Tonges	iiii pr̄e
Hand ham̄ers	ii
Forging ham̄er	one
Chissell	one
Vice	ii
Bellowes	one pr̄e

Inventory of 1629

In the greate Chamber late Mr Pickeringes

Ryffe irons and stakes of Irons	xi
Tonges	iiii pr̄e
Vices	ii
Harthstaff	i
Forging Ham̄ers	v
Small Ham̄ers	xvii
Cutting Chissell	i
Blockes	xi
Stakes	ix
Greate Anvil Standerdes	viii
Mould of Iron	i
Sheeres Standardes	iii pr̄e
Filing Tonges	i pr̄e
Bellowes	ii pr̄e
Rasp	i
Shiver tonges	i pr̄e
Bickhorne	i
Counter Borer	i
Compasses	ii pr̄e
Panne of Iron for fier w^th fower wheeles	i

In the Cutting House

Ham̄ers	Greate for a mill	i
	Buckle Ham̄ers	ii
	Ryfing Ham̄ers	iiii
Bickhornes Small		ii
Stake greate		i
Grinding stones		iii
Old Sheeres		iii pr̄e

In the Locksmithes Office

Anvile	i
Bickhornes small	ii
Vices	ii
Bellowes	i pr̄e

Appendix B: Comparison Charts

These are the comparison charts which were used during the analysis of mark types, as outlined fully in Chapter VI. The criteria recorded for each technique are different since the precise types of marks encountered are different.

Raising

Table 3. Italian objects with raising marks

Number	*Description*	*Concentric ridges*	*Concentric pattern*	*Clear marks*	*Other*
IV.17	Barbuta	x			
IV.18	Barbuta		x		
IV.20	Sallet	x			
IV.424	Sallet			x	
IV.532	Kettle hat		x		x
IV.580	Skull reinforce			x	
IV.741	Sallet	x			
AL.23 112	Basinet	x			
AL.30 4	Armet	x			
AL.44 1	Sallet	x			

Table 4. German objects with raising marks

Number	*Description*	*Concentric ridges*	*Concentric pattern*	*Clear marks*	*Other*
IV.12	Sallet			x	
IV.13	Sallet			x	
IV.15	Sallet	x			
IV.410	Sallet	x			
IV.411	Jousting helm				x
IV.427	Sallet	x			
IV.428	Sallet	x			
IV.499	Sallet			x	
IV.502	Tilting helmet		x	x	
VI.48	Chanfron		x		

Doming

Table 5. Objects with doming marks

Number	*Description*	*Origin*	*Regular*	*Irregular*	*Not all round*	*Unusual pattern*
II.1	Breastplate	German		x		
II.168 C	Breastplate	Italian		x	x	
II.168D	Backplate	Austrian		x	x	
III.69	Breastplate	German		x	x	
III.84	Breastplate	German	x		x	x
III.96	Breastplate	Austrian		x	x	
III.1116	Couter	German?				x
III.1282	Breastplate	Italian		x	x	
III.1283	Breastplate	German		x	x	x
III.1284	Backplate	Austrian		x		
III.4568	Breastplate	Flemish?		x	x	
III.4572	Breastplate	Flemish?	x			

Curling

Table 6. German objects with curling marks

Number	*Description*	*Oblong marks*	*Narrow marks*	*Round marks*
II.1	Vambraces	x		x
II.1	Legs	x		x
II.3	Vambraces	x		
II.3	Gauntlets		x	
III.69	Breastplate		x	x
III.70	Backplate	x		x
III.73	Breastplate	x		
III.96	Breastplate	x		
III.731	Left pauldron		x	
III.762	Couter	x		
III.782	Gauntlet		x	
III.783	Gauntlet		x	
III.853	Greaves	x		
III.864	Polder mitten	x		
III.1173	Pauldrons		x	
III.1216	Vambrace	x		
III.1230	Gauntlet	x	x	
III.1283	Breastplate		x	x
III.1284	Backplate	x	x	x
III.1287	Backplate		x	x
III.1305	Pauldron	x		
III.1325	Backplate			x
III.1352 A	Cuisse & poleyn	x		
III.1366	Vambrace		x	
III.1412	Breastplate		x	
III.1413	Pauldron	x		
III.2446 A	Backplate		x	
III.2566 B	Culet	x		
III.2593	Couter	x		
IV.411	Jousting helm	x		
IV.502	Tilting helmet	x		
VI.48	Chanfron		x	

Table 7. Italian objects with curling marks

Number	*Description*	*Oblong marks*	*Narrow marks*	*Round marks*
II.168A	Sallet	x		
II.168B	Bevor			x
II.168C	Breastplate			x
II.168E	Right arm		x	
II.168F	Left arm		x	
II.168G	Right leg	x		
II.168H	Left leg	x		
II.168I	Right greave	x	x	x
II.168J	Left greave	x	x	x
III.1111	Lower cannon	x		
III.1122	Pauldron	x		
III.1126	Right cuisse	x		x
III.1127	Left cuisse	x		
III.1130	Cuisse & poleyn		x	
III.1137	Greave	x		
III.1140	Greave	x		
III.1214	Gauntlet	x		
III.1225	Gauntlet	x		
III.1282	Breastplate	x		x
III.1285	Cuisse & poleyn	x		x
III.1286	Cuisse & poleyn	x		x
III.1348	Sabatons	x		
III.2104	Side plates	x		
E.1939.65	Left pauldron	x		
E.1939.65	Right pauldron	x		
E.1939.65	Right arm	x		x
E.1939.65	Left arm	x		x
E.1939.65	Right cuisse	x		
E.1939.65	Left cuisse	x		
E.1939.65	Right greave	x	x	
E.1939.65	Left greave	x	x	

Table 8. Other European objects with curling marks

Number	*Description*	*Oblong marks*	*Narrow marks*	*Round marks*
II.6	Legs	x		x
III.1116	Couter	x		
III.1196 B	Pauldron	x		
III.1300	Bevor			x
III.1351	Vambrace		x	
III.1918	Gauntlet	x		
III.2102	Cuisse	x	x	
III.2459	Cuisse	x		x
III.2460	Cuisse	x		x
III.2534	Greave	x		
IV.1	Tilting helm		x	
IV.340	Bevor	x	x	
AL.90	Vambrace	x		

Flutes and Creases

Table 9. German objects with fluting or creasing marks

Number	*Description*	*Marks angled*	*Marks parallel*	*Marks outside*	*Others*
II.1	Breastplate		x		
II.1	Legs		x		
II.3	Vambraces		x	x	
II.167	Tilting sockets		x		Some odd marks
II.168 D	Backplate	x	x	x	
III.69	Breastplate		x		
III.70	Backplate		x		
III.782	Gauntlet		x		
III.783	Gauntlet		x		
III.864	Polder mitten		x		
III.1216	Left arm		x	x	
III.1283	Breastplate		x		
III.1287	Backplate		x		
III.1293	Backplate		x	x	
III.1321	Bevor		x		
III.1325	Backplate	x	x	x	
III.1413	Right pauldron		x	x	
III.1414	Pauldron	x	x	x	
III.2541	Backplate	x			
III.2593	Couter		x	x	
AL.23 107	Couter		x		

Table 10. Italian objects with fluting or creasing marks.

Number	*Description*	*Marks angled*	*Marks parallel*	*Marks outside*	*Others*
II.7	Basinet visor	x	x		Some perpendicular
II.168C	Breastplate	x		x	
II.168E	Right vambrace	x	x	x	
II.168F	Left vambrace	x	x	x	
II.168G	Right cuisse & poleyn	x		x	
II.168H	Left cuisse & poleyn	x		x	
III.1140	Left greave		x		
III.1282	Breastplate	x			
III.1386	Tasset	x		x	
IV.438	Sallet visor	x	x	x	
E.1939.65	Left pauldron	x		x	
E.1939.65	Pauldron reinforce	x			
E.1939.65	Right pauldron	x			
E.1939.65	Left cuisse		x		
E.1939.65	Right cuisse		x		
E.1939.65	Left greave	x			
E.1939.65	Right greave	x			

Table 11. Other European objects with fluting or creasing marks

Number	*Description*	*Marks angled*	*Marks parallel*	*Marks outside*	*Others*
III.1803	Pauldron		x	x	
III.2460	Leg		x	x	
III.2565	Breastplate	x			
III.4572	Breastplate	x		x	
IV.579	Visor	x			

Helmet combs

Table 12. Objects with marks from creating a comb

Object	*Origin/date*	*Parallel*	*Oblique*	*Chisel*	*Hammer*	*Stake*	*Outside comb*	*Mark bands*
II.6 Close helmet	English, *c.* 1520		x	x		x		
II.7 Great basinet	Italian, early 15th century		x		x	x	x	x
II.168 A Sallet	Italian, *c.* 1460	x			x			x
IV.2 Great basinet	European, *c.* 1510	x	x		x	x	x	x
IV.7 Barbuta	Italian, *c.* 1460	x			x			x
IV.13 Sallet	German, *c.* 1490	x			x		x	
IV.17 Barbuta	Italian, *c.* 1460	x			x		x	x
IV.18 Barbuta	Italian, *c.* 1450	x	x				x	x
IV.425 Kettle hat	European, *c.* 1480-1500		x			x	x	
IV.428 Sallet	German, 1480-90	x						
IV.429 Sallet	German, *c.* 1450-60			x				
IV.434 Sallet visor	German, 1480-90	x		x				
IV.453 Sallet	Italian, *c.* 1490	x					x	
IV.468 Armet	German, *c.* 1500	x						
IV.470 Basinet	Italian, *c.* 1380-1400	x		x			x	
IV.498 Armet	Italian, *c.* 1450	x					x	
IV.499 Sallet	German, *c.* 1480	x		x				
IV.502 Tilting helmet	German, *c.* 1490	x			x	x		
IV.580 Skull reinforce	Italian?, *c.* 1510	x	x	x		x		
IV.741 Sallet	Italian, *c.* 1450				x			

IV.1601 Armet	Flemish, *c*. 1510	x				x		
IV.2057 Sallet	Italian, late 15th century			x				
A.1905.489 Helm	English, *c*. 1360		x		x			
AL.44 1 Sallet	Italian, *c*. 1470	x					x	x

Appendix C: Images

Figure 1. Right sabaton, III.1348, showing its flexibility. This object is shown fully extended in Figure 285.

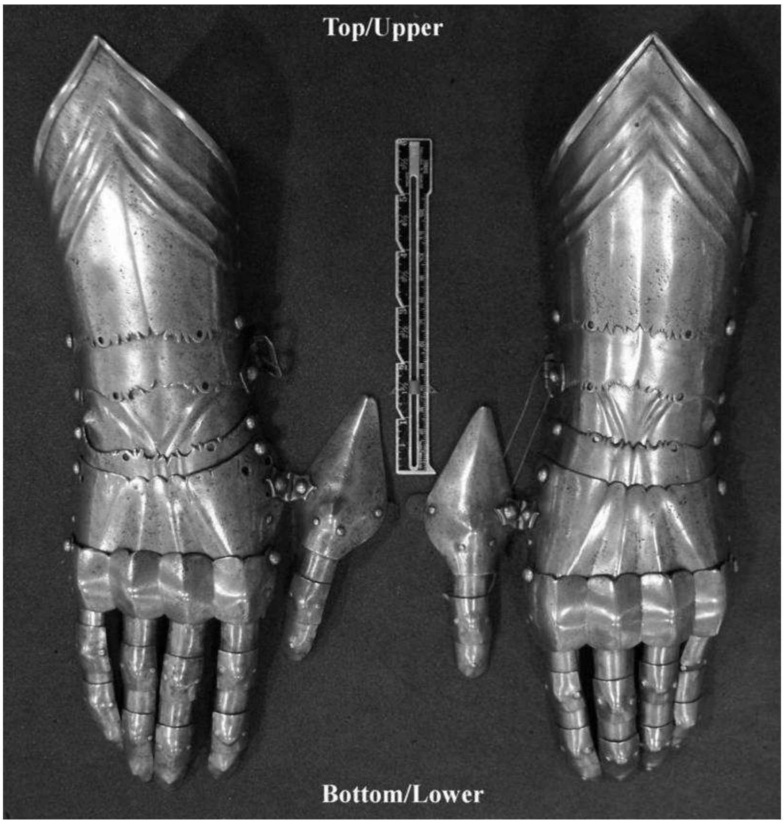

Figure 2. Gauntlets of II.3.

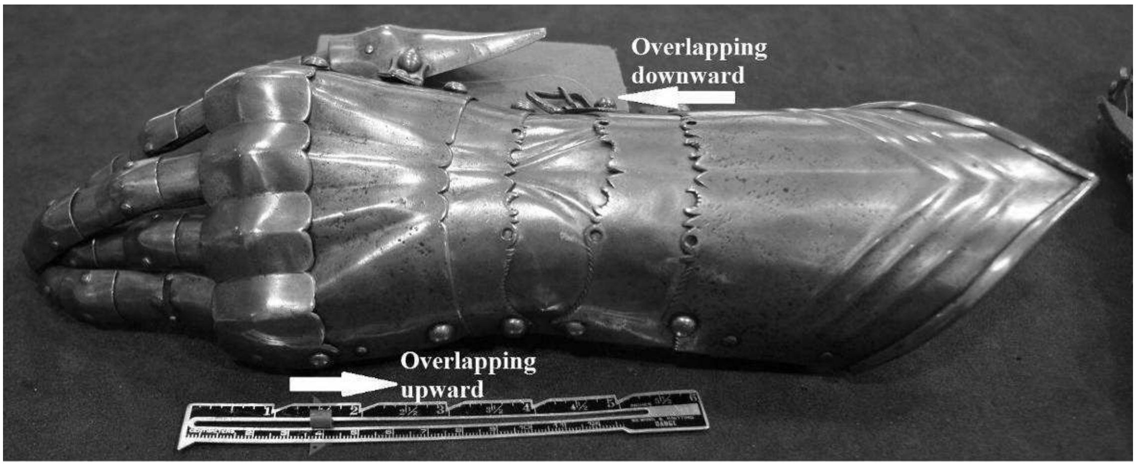

Figure 3. Left gauntlet of II.3.

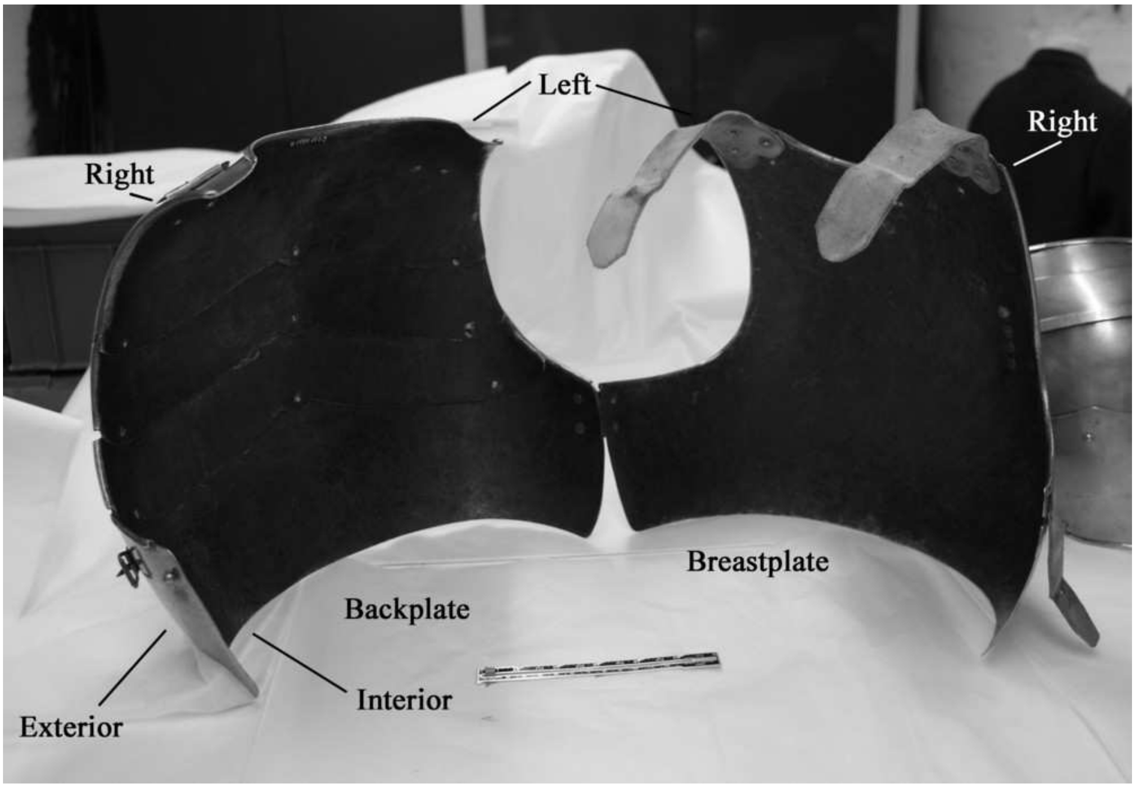

Figure 4. Upper cuirass of the Avant armour, E.1939.65.e.3.

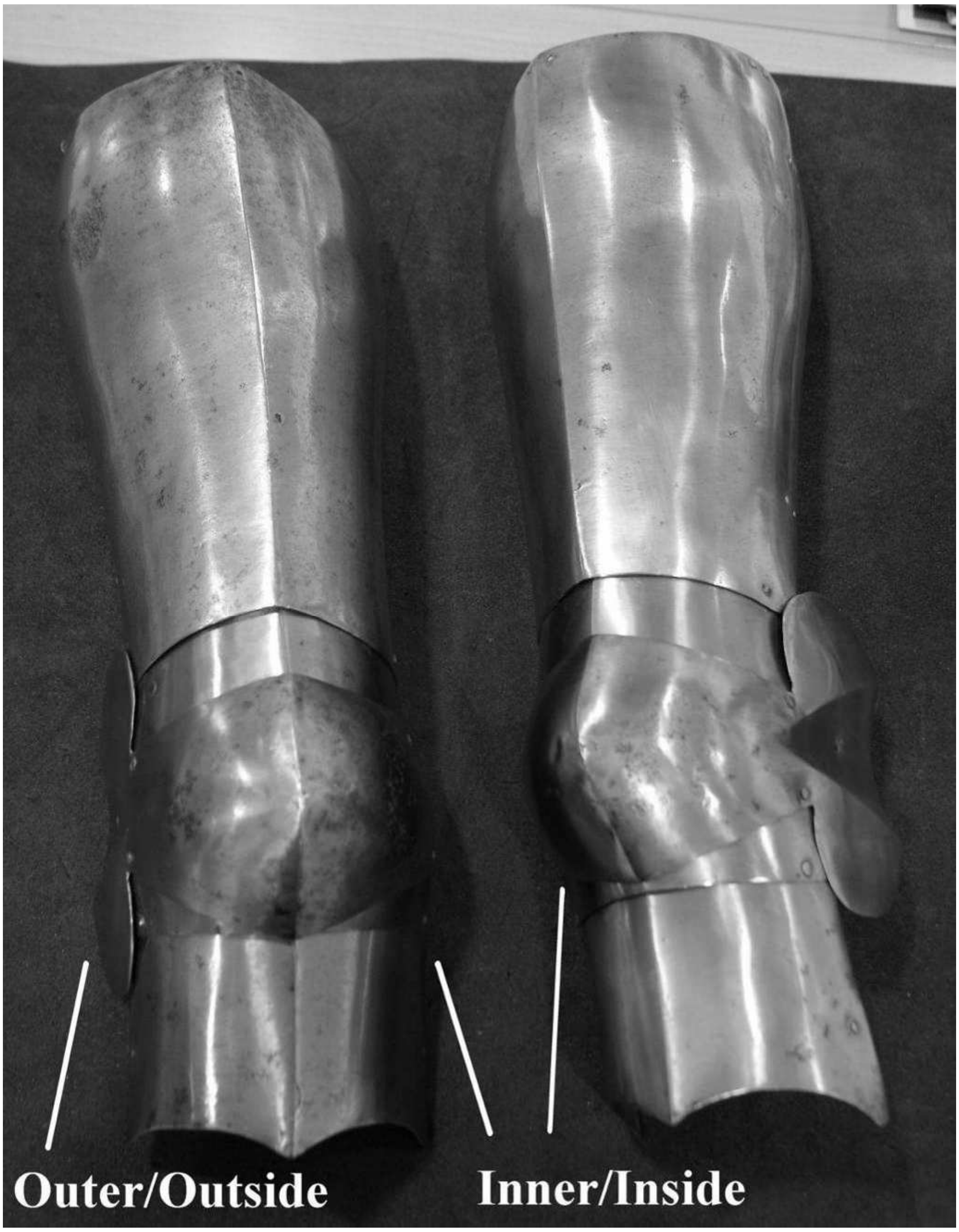

Figure 5. Left and right cuisses, III.1286.

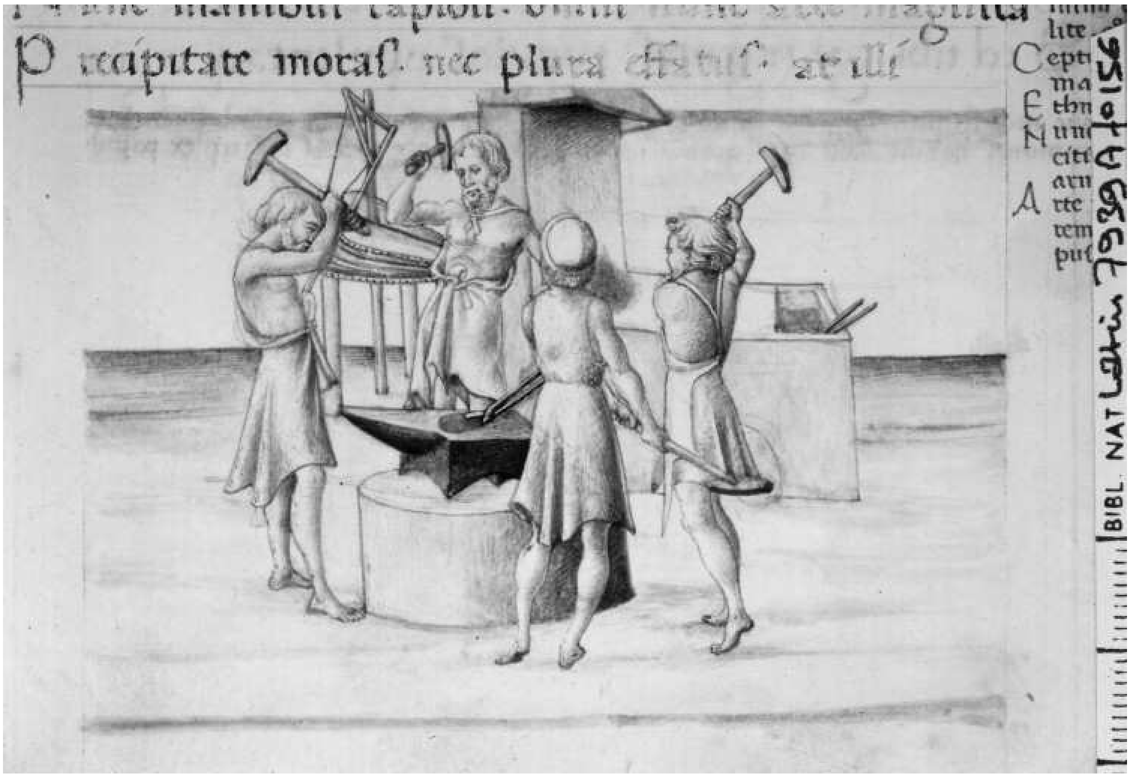

Figure 6. Vulcan, holding the smaller hammer and tongs, forging the arms of Aeneas with apprentices.

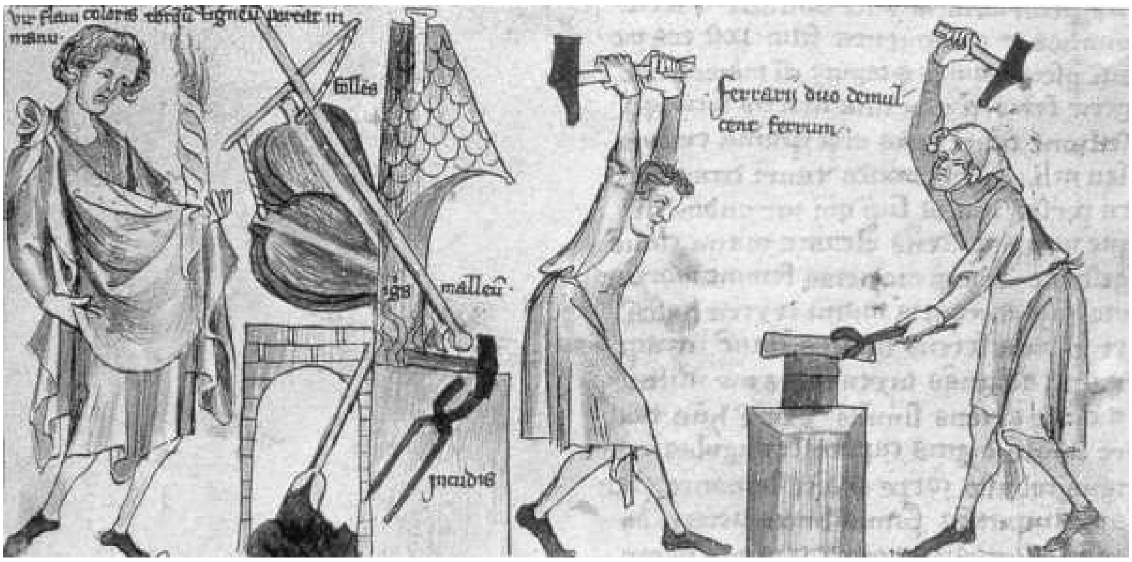

Figure 7. Two blacksmiths at work. Note the twin bellows.

Figure 8. Stump anvil from the Greenwich Armoury. Stamped with the mark of William Pickering.

Figure 9. Raising stake from the Greenwich Armoury.

Figure 10. Mendel I fol. 19^{r}, a nail smith at work. Note the red-hot nail.

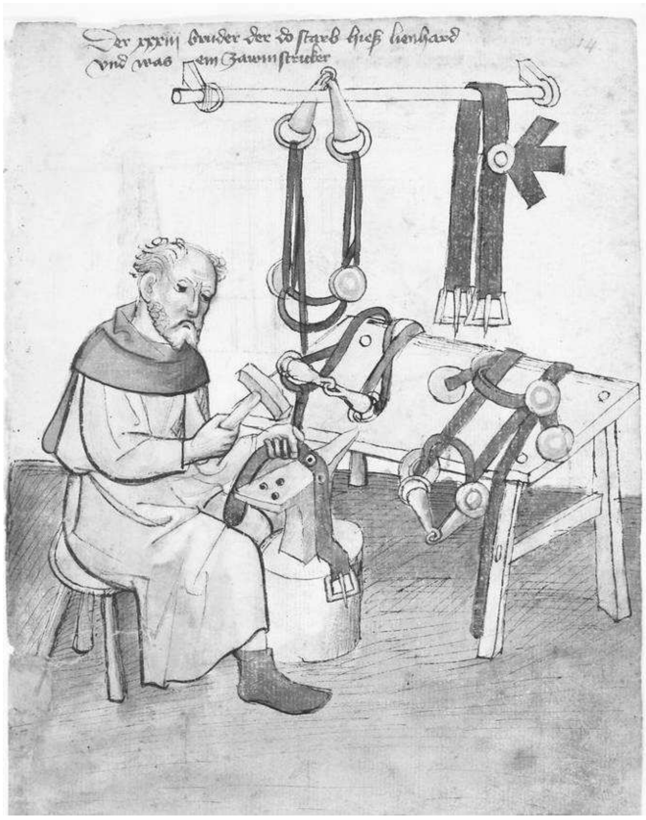

Figure 11. Mendel I, fol. 14^{r}, a belt maker at work.

Figure 12. The Royal Armouries great shears, from the Greenwich workshop.

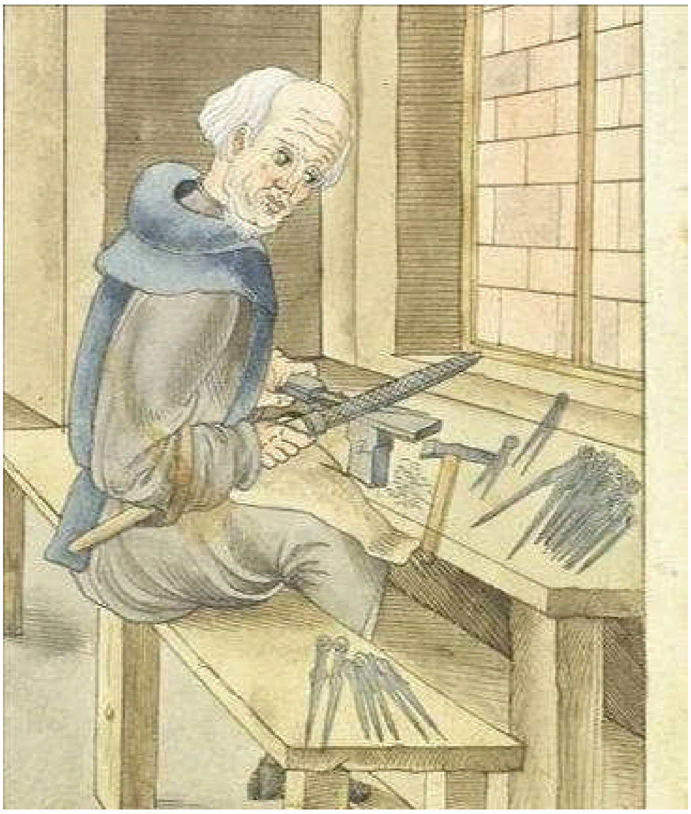

Figure 13. Detail from Mendel II, fol. 3^v, showing a hand vice or 'filing tongs'.

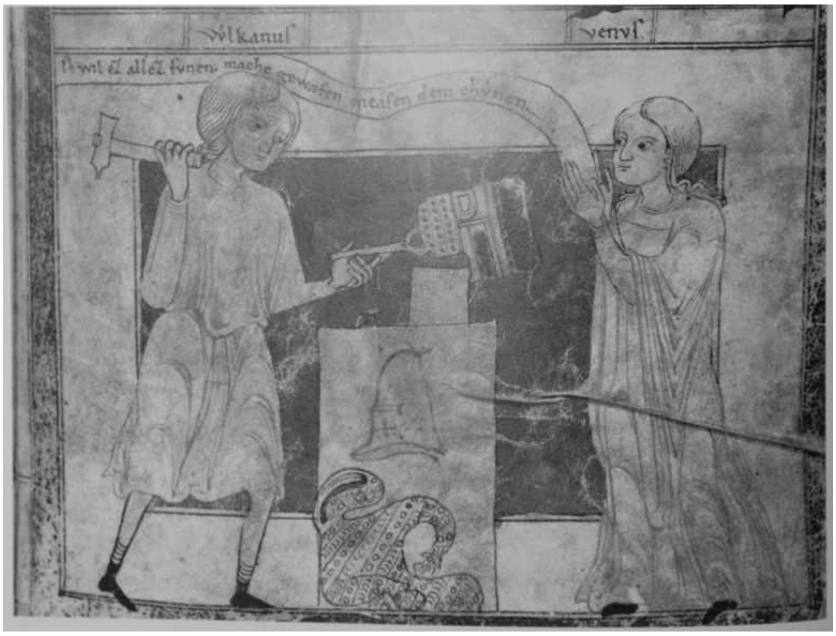

Figure 14. Illustration of a thirteenth-century armourer, hammering a completed helm over a block anvil.

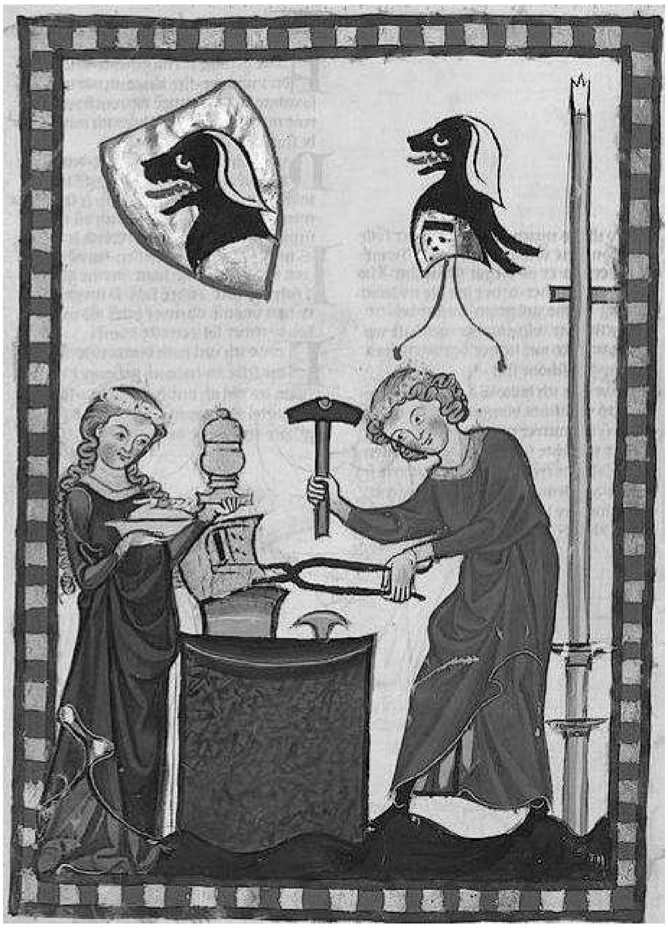

Figure 15. Codex Manesse, fol. 256^{v}, showing an armourer hammering a completed helm.

Figure 16. Codex Manesse, fol. 381[r], showing an armourer identified by the completed object, hammer, and tongs.

Figure 17. *De mulieribus claris*. The armourer hammers a completed helm over a stake.

Figure 18. Detail from *De mulieribus claris*, showing an armourer engaged in raising a basinet skull.

Figure 19. Detail of burgonet by Desiderius Helmschmied, showing the armourer at work (on a burgonet!).

Figure 20. Detail from *Speculum Humanae Salvationis*. Tubal-Cain, as the master, uses a single-handed hammer.

Figure 21. Mendel I, fol. 42^{r}, showing an armourer hammering a completed lower cannon.

Figure 22. Detail from *Chants royaux sur la conception*. The three men are doming over an anvil, while the woman is raising using a stake.

Figure 23. Seusenhofer's workshop by Hans Burgkmair, from *Der Weisskunig*.

Figure 24. Small armourer's hammer in the Royal Armouries, XVIII.98.

Figure 25. Spanner from Leeds, RA, II.167.

Figure 26. Mendel I, fol. 41r, showing a file-maker.

Figure 27. Mendel I, fol. 7v, an armour polisher.

Figure 28. Mendel I, fol. 101v, an armour polisher.

Figure 29. Mendel I, fol. 87r, an armour polisher.

Figure 30. Armourers' workshop, with a polisher.

Figure 31. 'Venus at the Forge of Vulcan' by Brueghel and H. Van Balen.

Figure 32. Detail from 'Venus at the Forge of Vulcan'. The pitch blocks are the two round objects on the bench. Note also the large shears.

Figure 33. St. Eligius' workshop.

Figure 34. Detail from St Eligius' workshop. See the following figure.

Figure 35. Stake in the Royal Armouries from the Greenwich workshop.

Figure 36. Goldsmiths at work, very similar to Figure 33.

Figure 37. Detail from Seusenhofer's workshop, showing cut and partly-finished plates.

Figure 38. Cut edge of a plate, made using Royal Armouries great shears. See also Figure 78.

Figure 39. Detail of interior arm roll of III.4572.

Figure 40. Detail of Venus at Vulcan's Forge by Frans Floris, showing armourers slitting a hot plate with a set chisel.

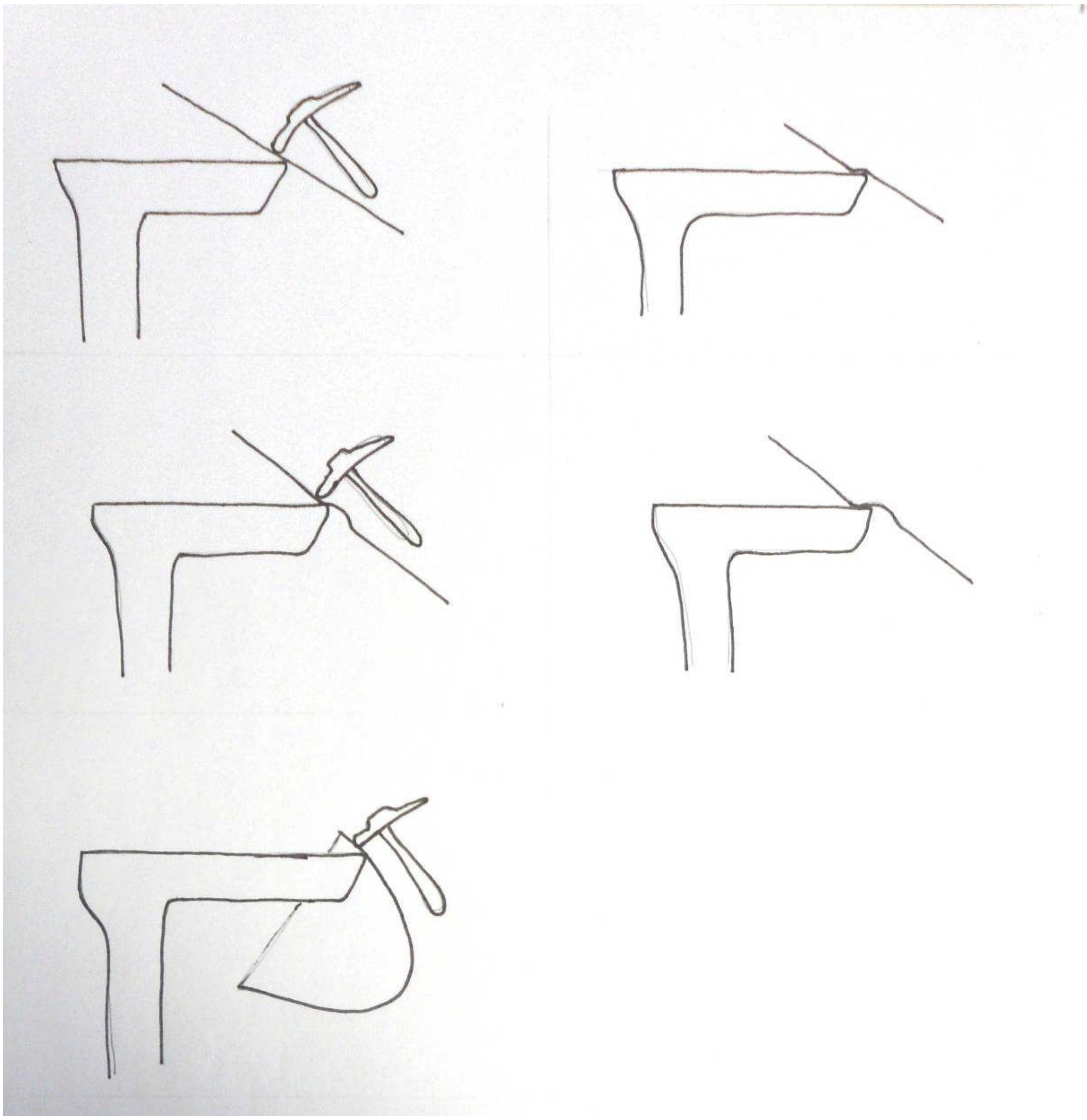

Figure 41. Diagram of the raising process. In each case the hammer strikes the plate above where the plate contacts the stake. The plate is rotated and worked nearer the edge until a vessel is formed.

Figure 42. Detail from *De mulieribus claris*, showing raising. Note that the armourer does not use the face of the hammer, but uses the peen.

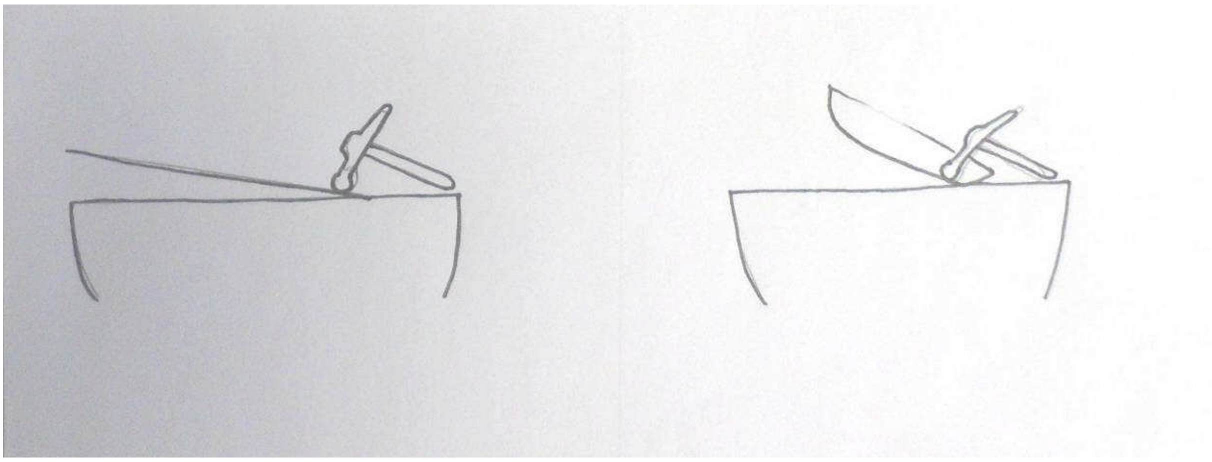

Figure 43. Diagram of doming over a flat surface. As with raising, the plate is rotated and struck just above where it contacts the anvil.

Figure 44. IV.13, the raising marks are clear directly to the right of the visor.

Figure 45. Detail of the Lion Armour, II.89. Notice the unfinished, unpolished area between the gilding.

Figure 46. Detail of Wallace Collection A30, showing finished and unfinished breaths. Photo by Carlo Paggiarino.

Figure 47. Detail of applied copper-alloy decoration on IV.424.

Figure 48. Detail of decoration on the visor of the Lyle Basinet, IV.470.

Figure 49. AL.23 107, showing recessed border with rivet holes for applied decoration.

Figure 50. Detail of etching on the great basinet of II.7. The pattern in the upper left corner is a mistake.

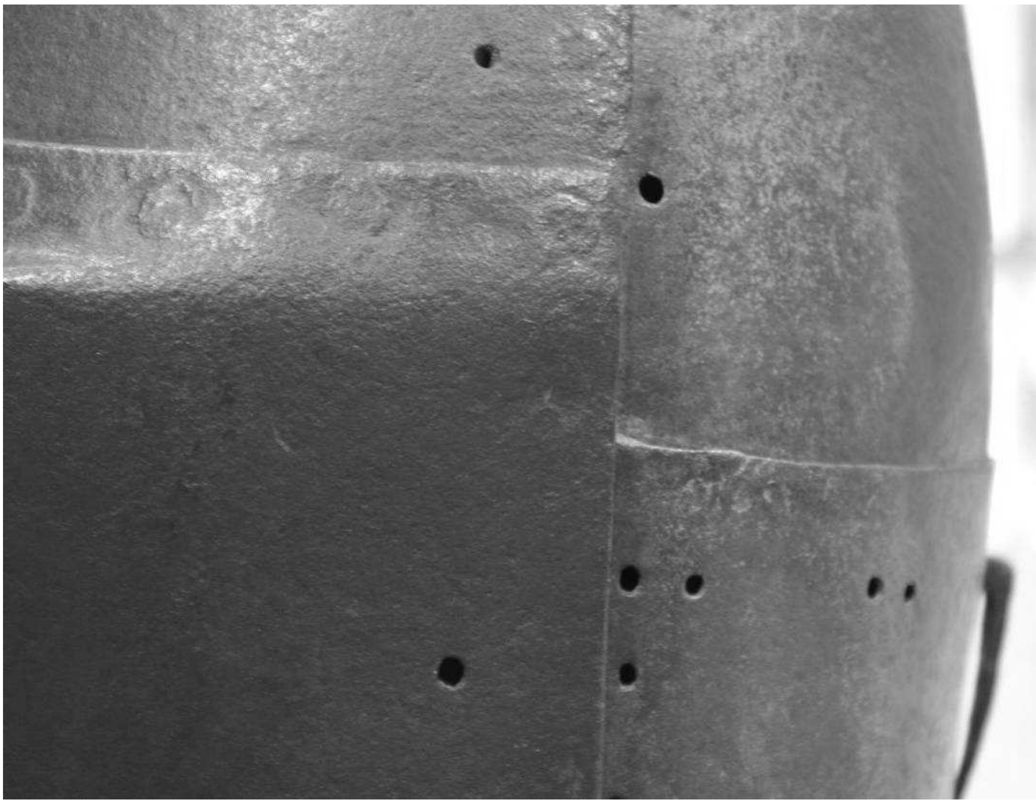

Figure 51. Detail of flush rivets on AL.30 1.

Figure 52. Detail of decorative rivet heads on IV.427. The rivet on the far left has lost its cap.

Figure 53. Detail of IV.411. The rivet in the centre is worn, showing the lead solder and iron rivet head below the copper alloy cap.

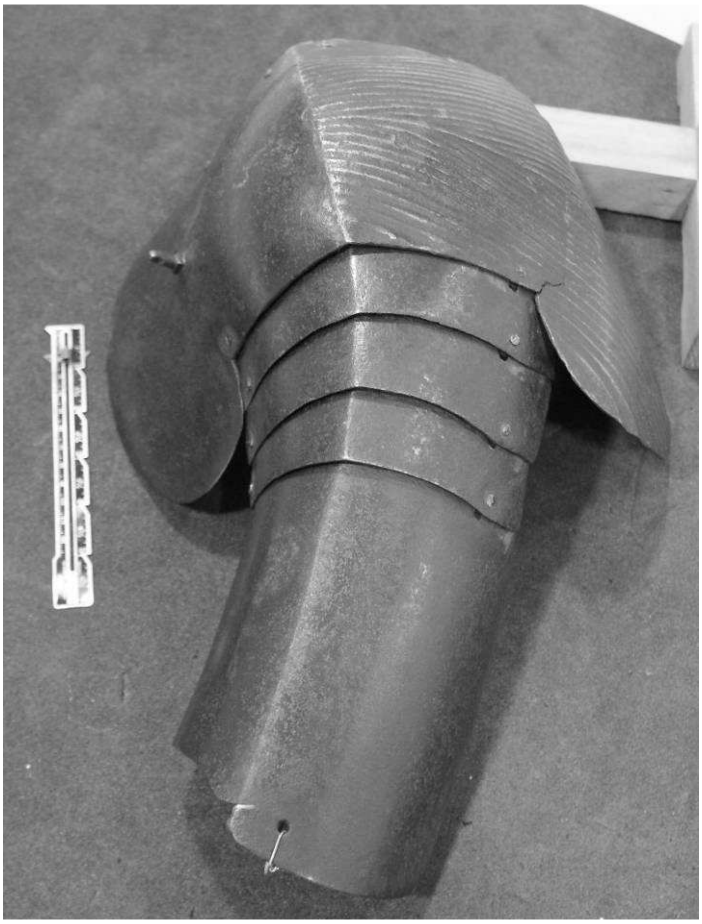

Figure 54. III.1305, showing flexibility possible with sliding rivets. The slots are visible on the right side.

Figure 55. Interior view of III.1196 B, showing two rows of sliding rivets with a central internal leather.

Figure 56. Interior view of IV.499.

Figure 57. Two projection, one projection, and three upright stakes.

Figure 58. Royal Armouries temporary inventory letter Z.

Figure 59. Two-projection stake in the bench. Note the wide central working face.

Figure 60. Royal Armouries raising stake.

Figure 61. Top view of the Royal Armouries raising stake.

Figure 62. Raising stake in use by the author. A modern ball stake is in the foreground.

Figure 63. The versatility of the stake.

Figure 64. Depression at the nose of the raising stake.

Figure 65. Detail from Seusenhofer's workshop. An upright stake, an excellent shape for fluting and making helmet combs.

Figure 66. XVIII.830, William Pickering's anvil stake.

Figure 67. Side view of the anvil stake.

Figure 68. A depiction of Vulcan, note the large single-horned anvil.

Figure 69. Detail from the February fresco at Castello Buonconsiglio with a large single-horned anvil.

Figure 70. Great shears. In actual practice the jaws would extend beyond the bench at the pivot.

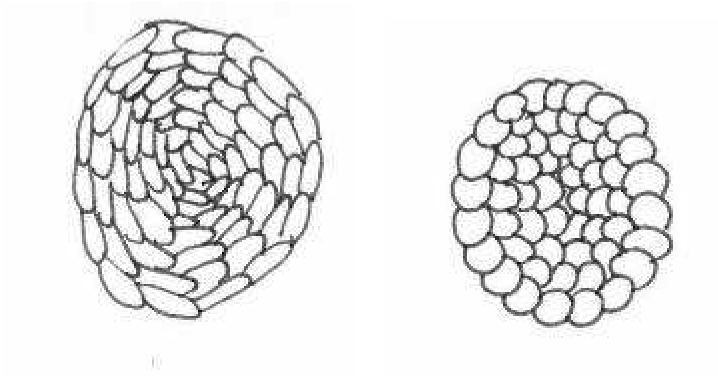

Figure 71. Oblong and round concentric marks.

Figure 72. Royal Armouries IV.580 interior.

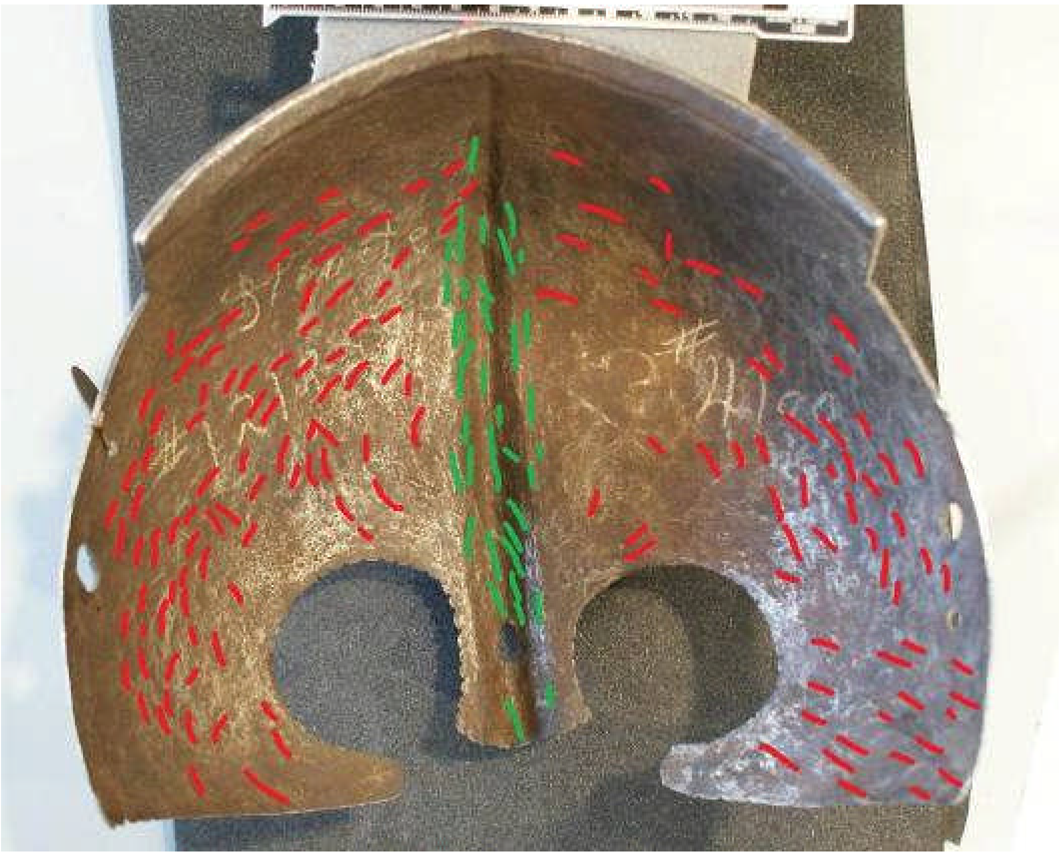

Figure 73. IV.580, showing oblong concentric marks in red and oblong linear marks in green.

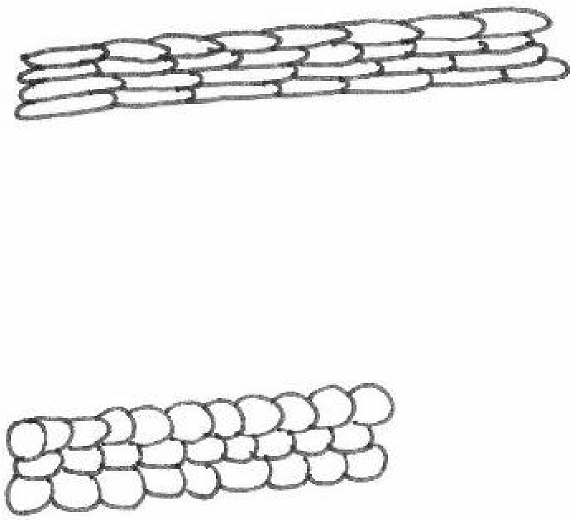

Figure 74. Oblong and round marks in a linear pattern.

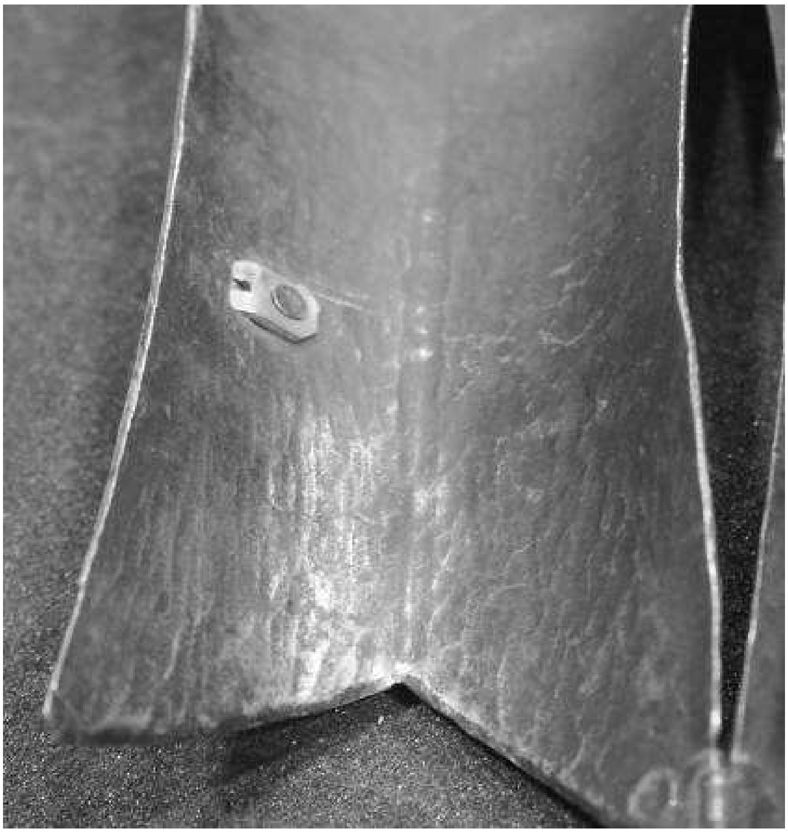

Figure 75. Oblong marks in a linear pattern on the greave II.168 J.

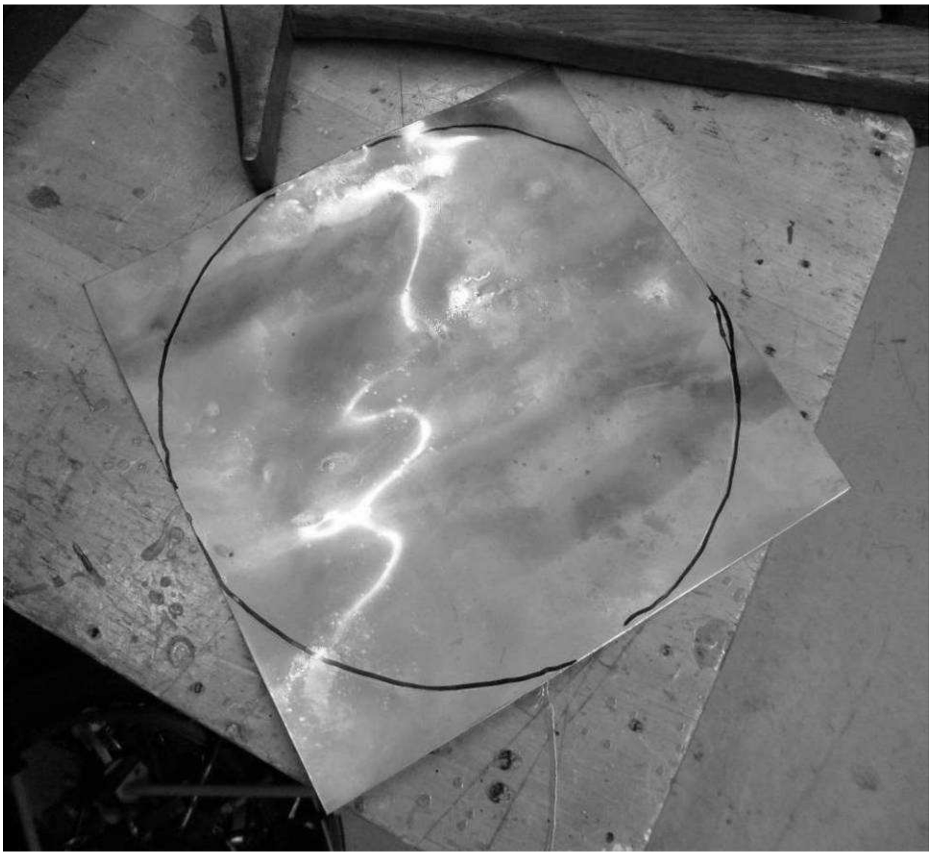

Figure 76. Brass plate annealed and marked for cutting with a felt-tip pen.

Figure 77. Finished plates for the thesis tests, and prepared plates for the Conservation Department.

Figure 78. Cutting with the Greenwich great shears.

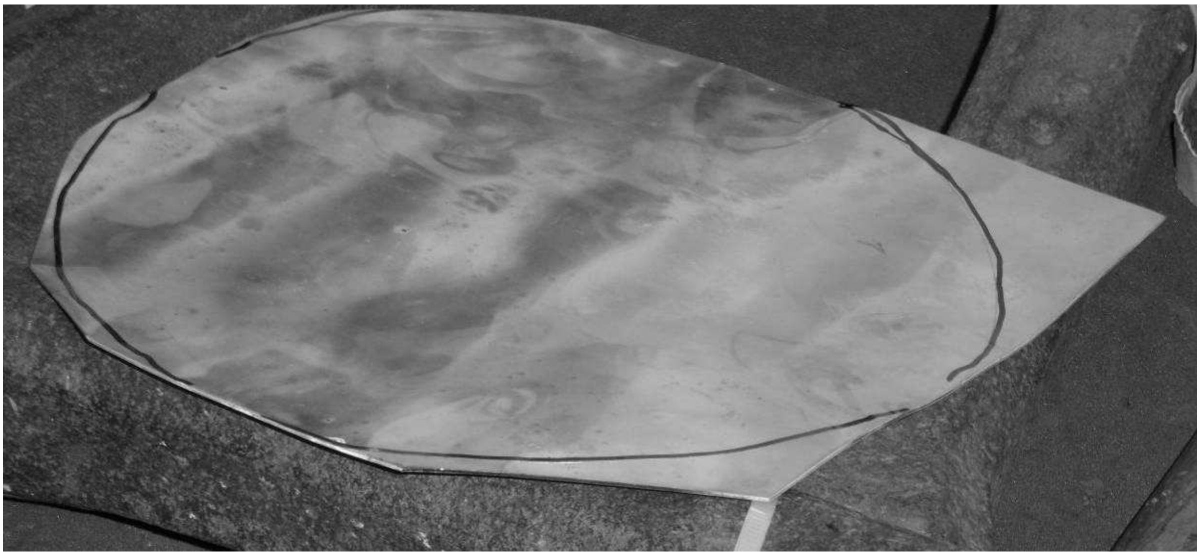

Figure 79. The resulting cuts.

Figure 80. Cutting with a hammer and chisel.

Figure 81. Chisel and shear cuts, before dressing.

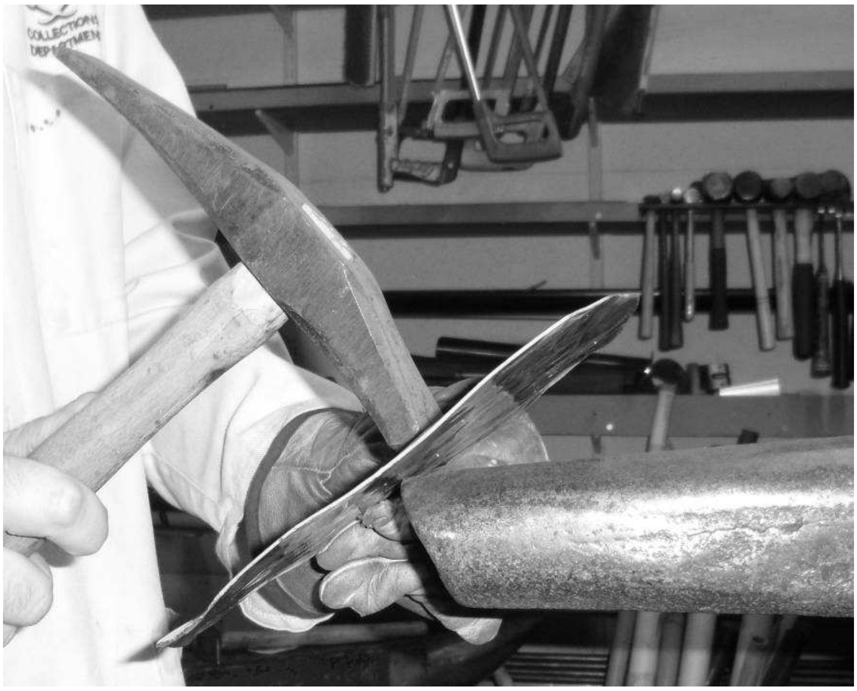

Figure 82. Beginning raising, showing how hammer strikes above where stake and plate meet.

Figure 83. Working in a circular pattern.

Figure 84. Halfway through a pass, showing deformation and compression of the edge.

Figure 85. Interior of the same pass. Round marks are from the plate being driven onto the stake, while oblong marks from the hammer are more difficult to see in the photo.

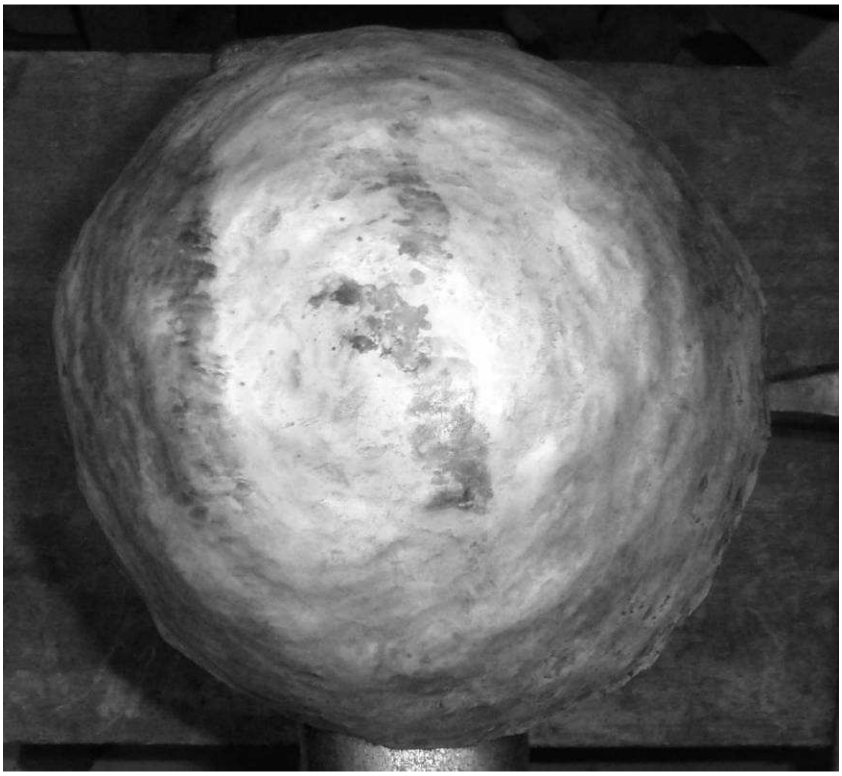

Figure 86. Completed raising, showing concentric ridges from successive courses.

Figure 87. The completed interior. Marking is not heavy and is mostly composed of oblong bumps and some round marking.

Figure 88. One half of dome planished, with hammer and ball stake.

Figure 89. Interior of planished dome. The roughness of the unplanished half is apparent, and the oblong marks are more visible on the planished half.

Figure 90. Doming over the flat anvil face.

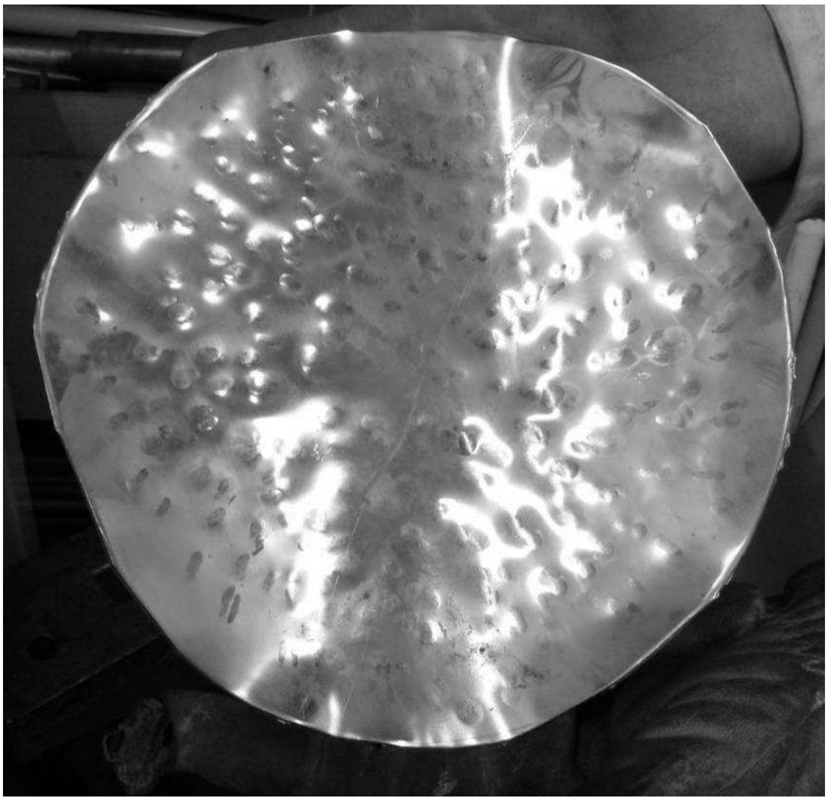

Figure 91. First doming pass complete, showing the interior.

Figure 92. Interior of completed dome.

Figure 93. Fixing irregularities in a lead block.

Figure 94. Planishing over the ball stake.

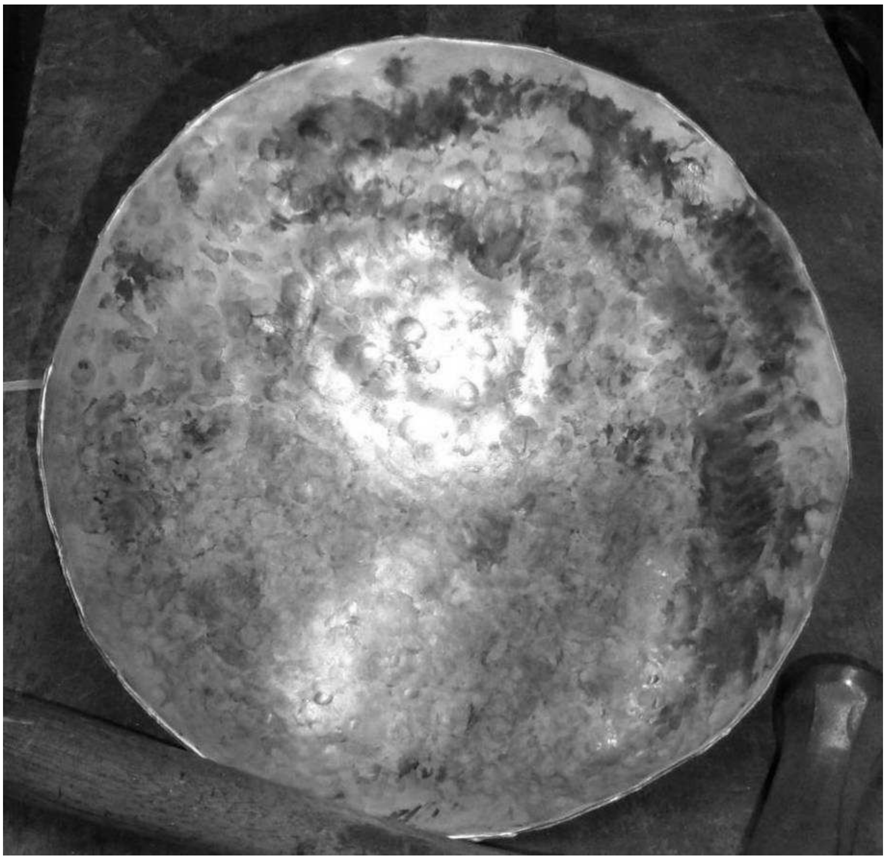

Figure 95. Top half is unplanished, lower half is planished.

Figure 96. Curling from the exterior.

Figure 97. Internal marks from external curling (portion marked ‘1’).

Figure 98. Three hammers used for interior curling.

Figure 99. Curling from the interior with a small hammer.

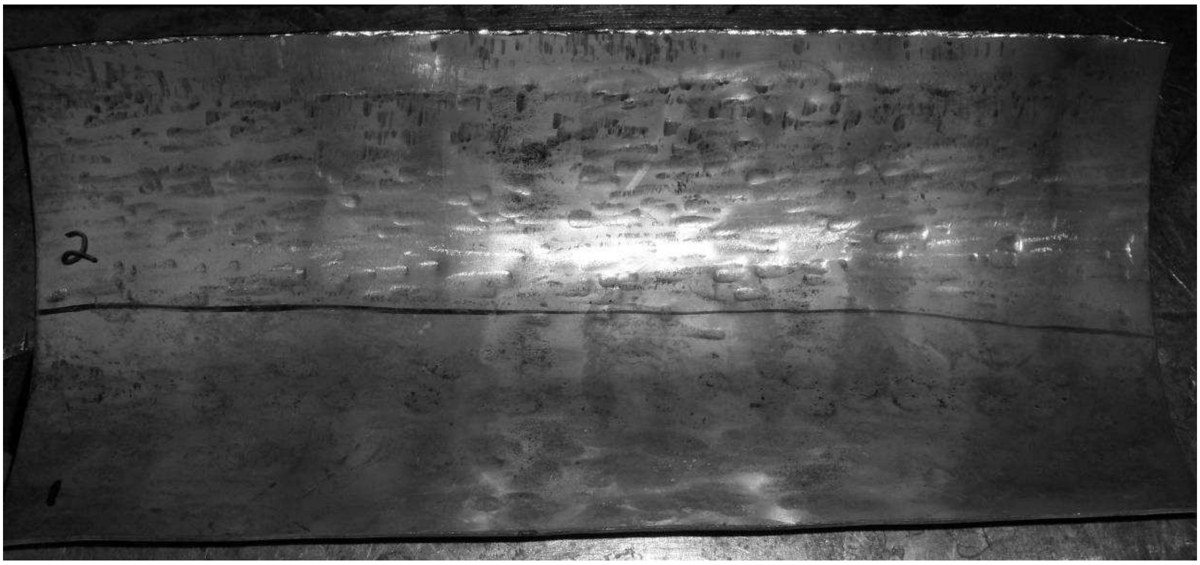

Figure 100. **M**arks from internal curling with a small hammer (2).

Figure 101. Internal marks from medium hammer (3) and large hammer (4).

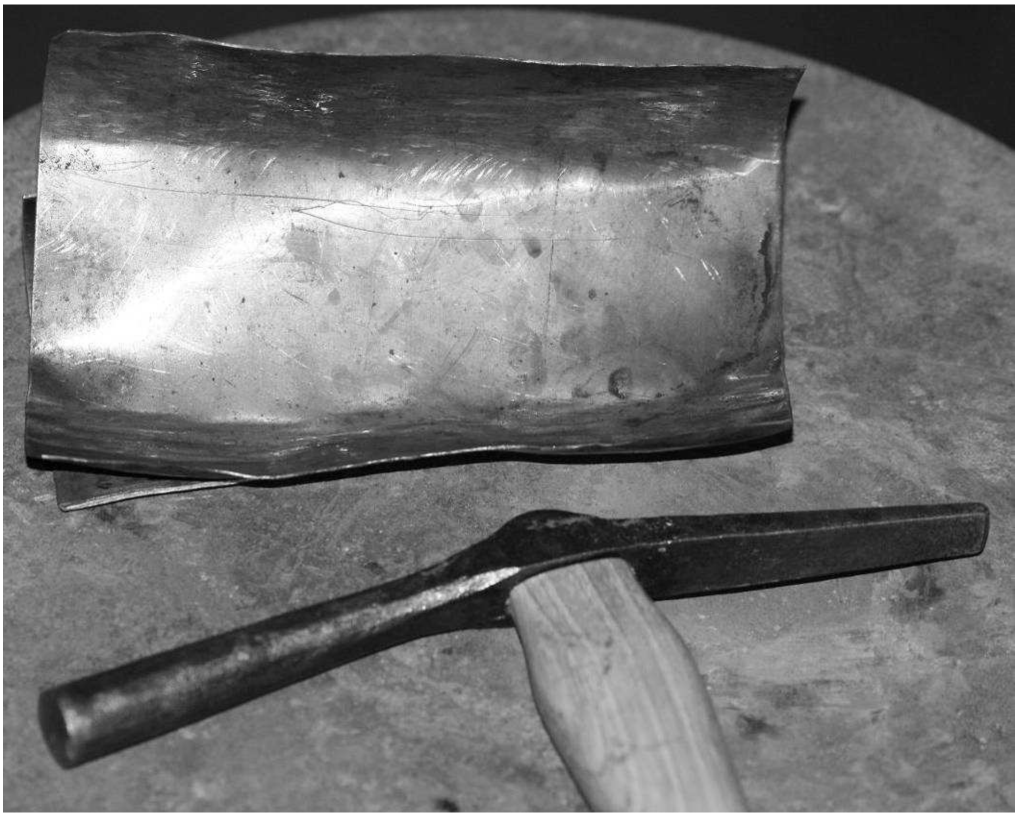

Figure 102. Initial passes to create an anticlastically curled form.

Figure 103. Internal linear marks on final anticlastic form.

Figure 104. Final anticlastic form from the exterior.

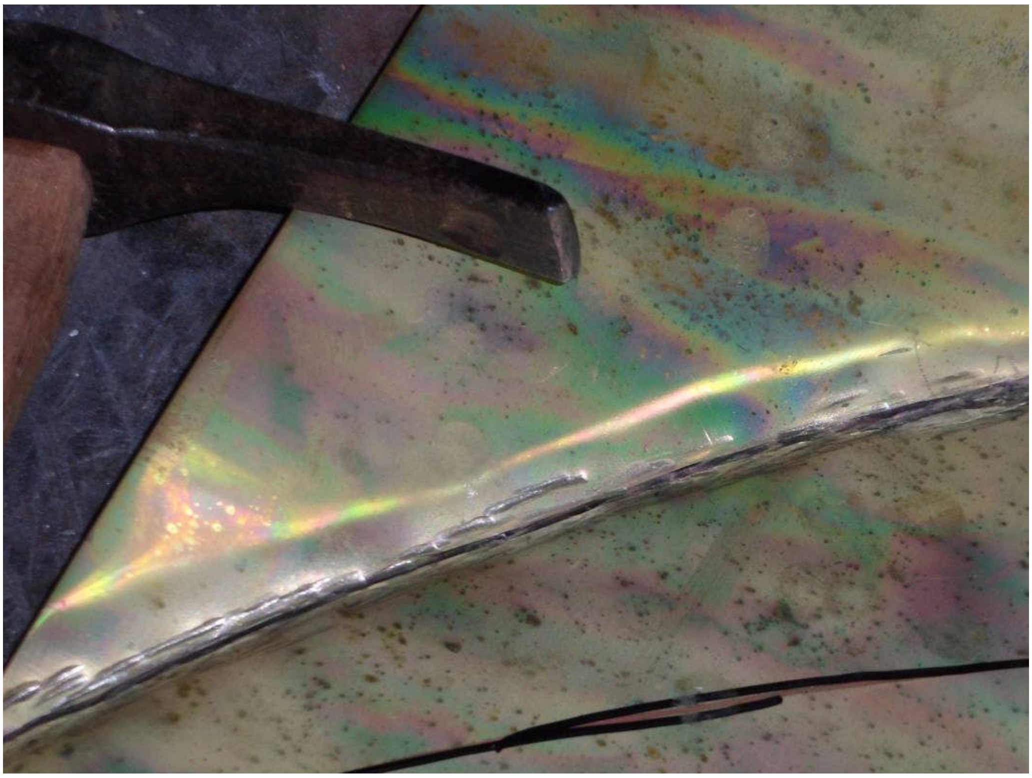

Figure 105. Flute embossed into a lead block.

Figure 106. Planishing the flute over the upright fluting stake.

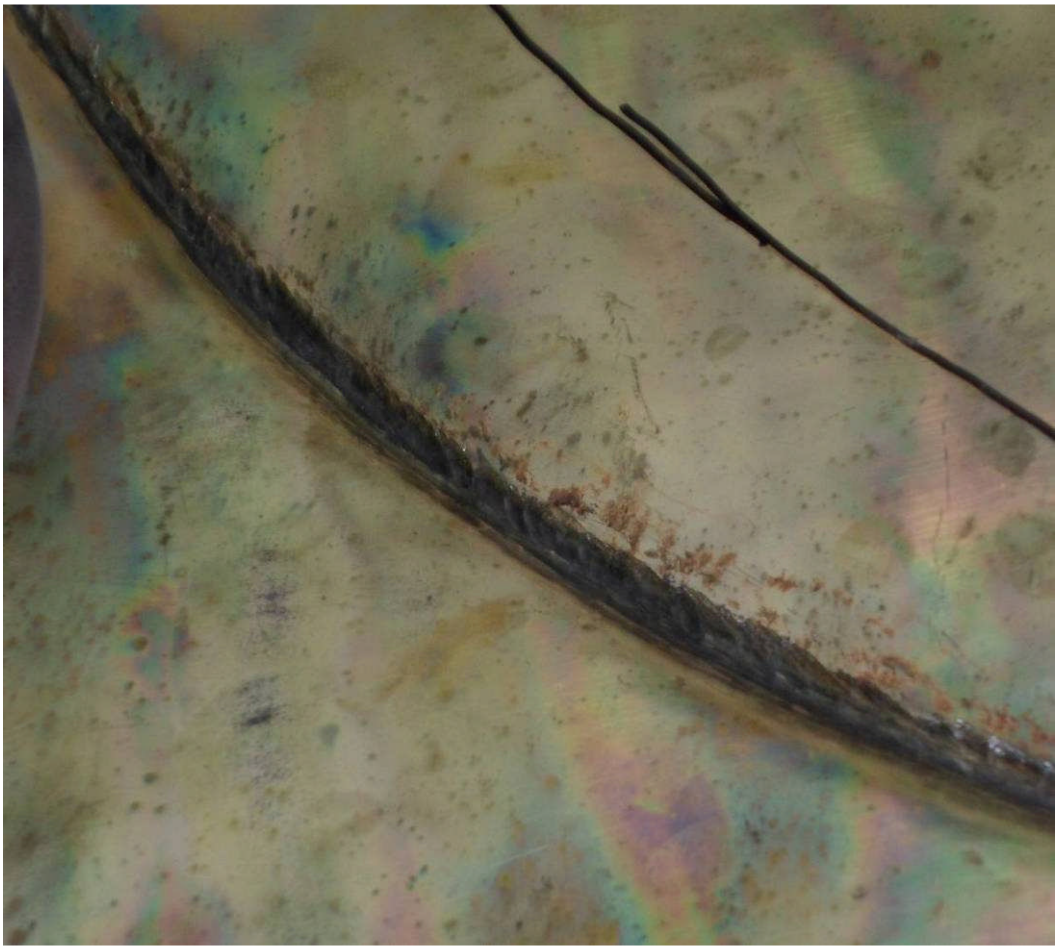

Figure 107. Internal marks from hammer embossing.

Figure 108. Embossing a flute with a chisel.

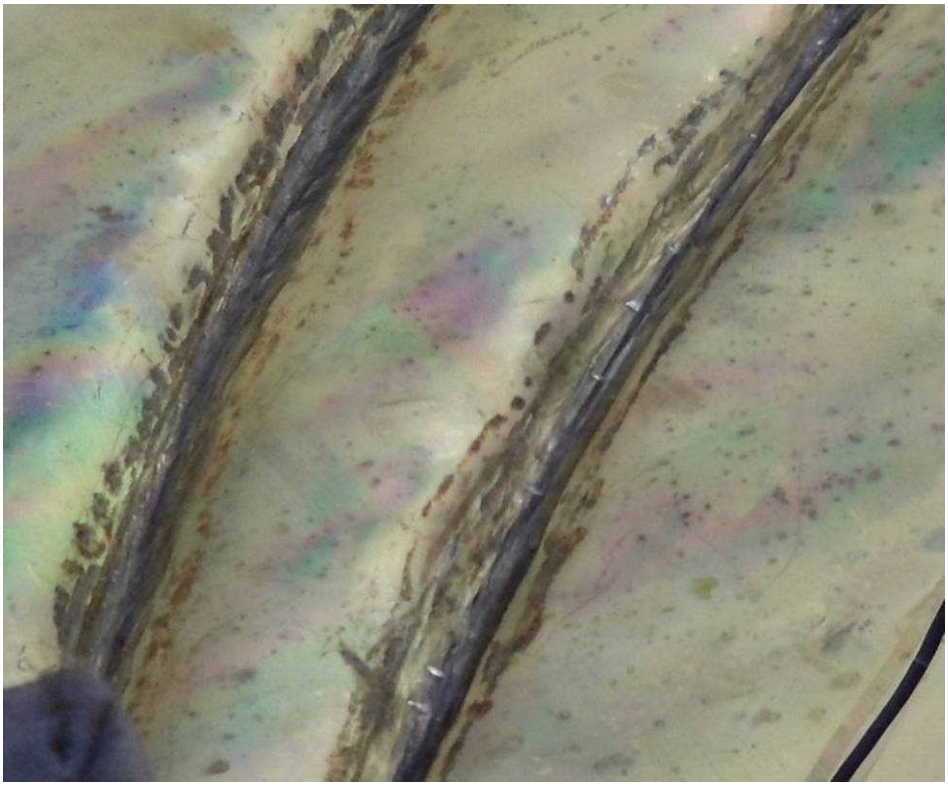

Figure 109. Internal marks of hammer embossed, left, and chisel embossed, right.

Figure 110. Raising a flute from the exterior over an upright stake.

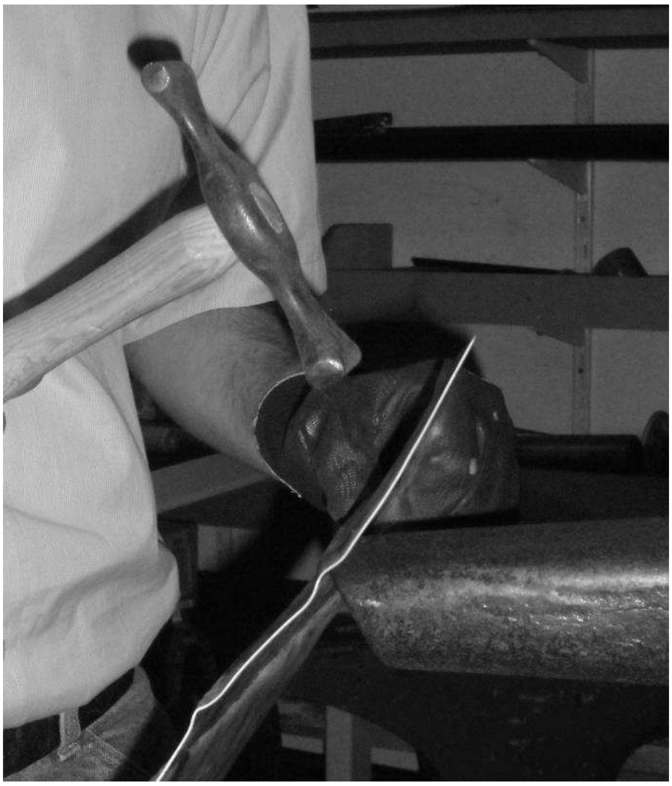

Figure 111. Raising a flute over the raising stake.

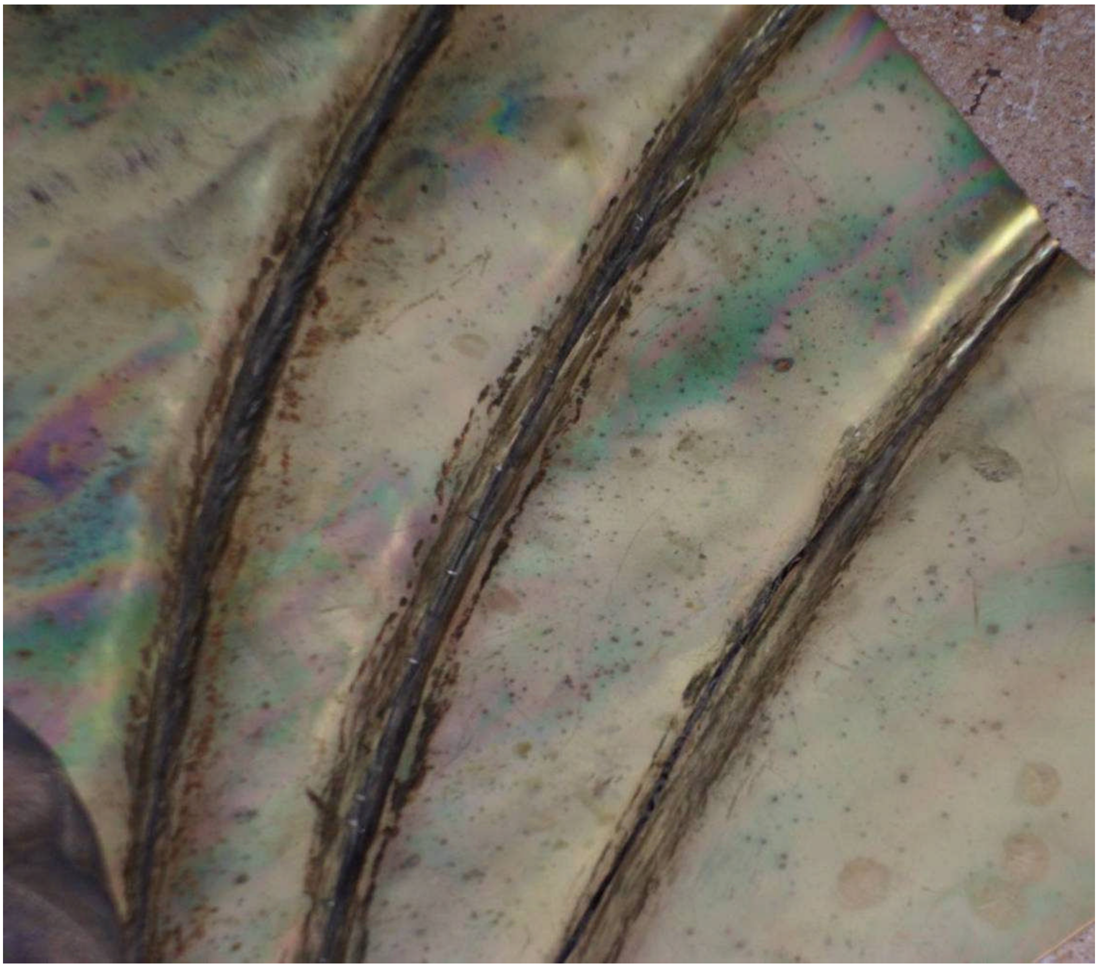

Figure 112. Interior of raised flute, far right.

Figure 113. All the completed pieces.

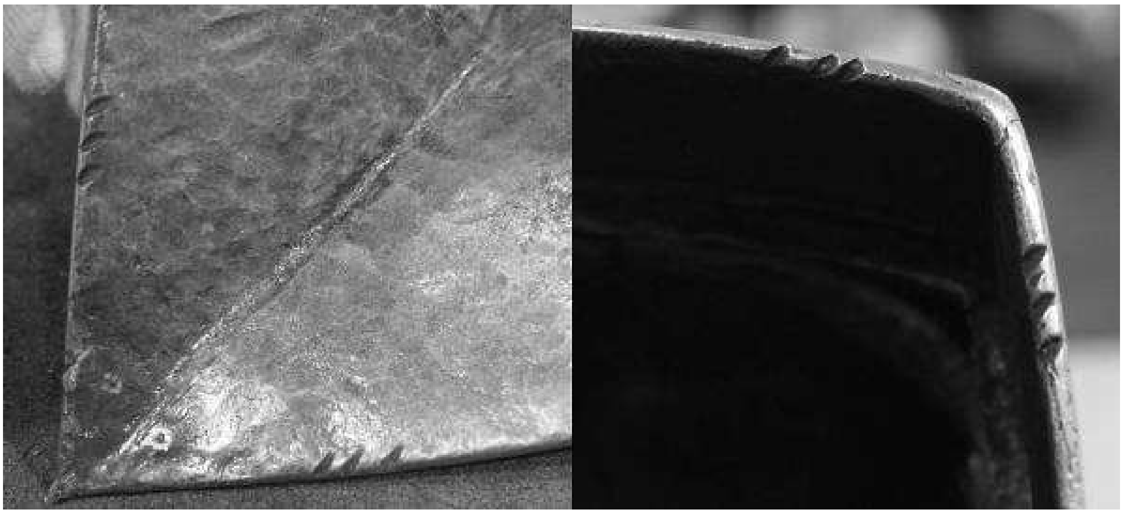

Figure 114. Assembly marks on tail (right) and visor (left) of IV.499.

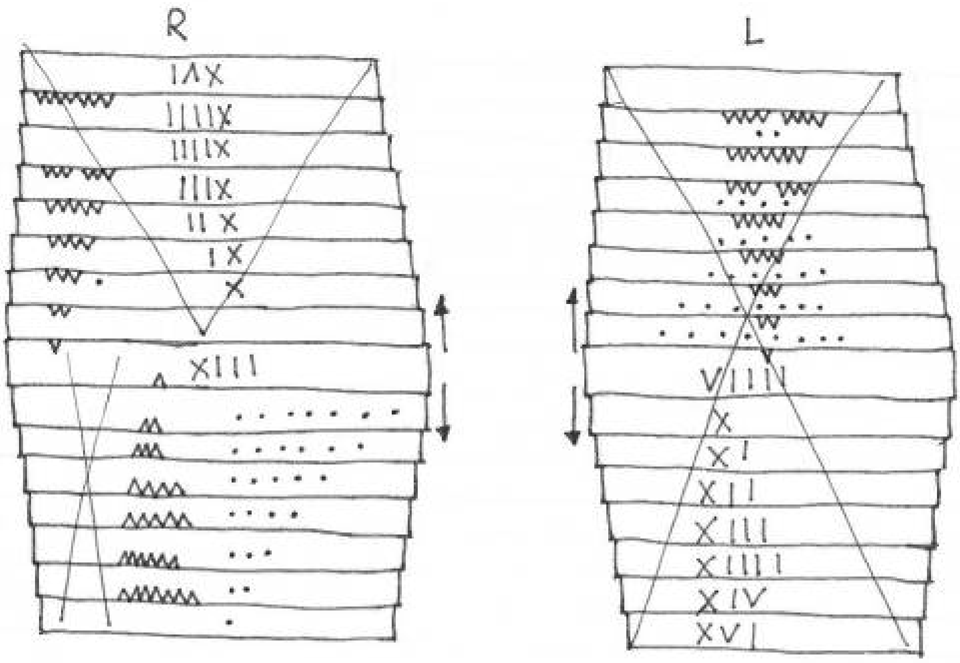

Figure 115. Diagram of assembly marks on legs of II.6.

Figure 116. Assembly mark on the Avant armour, on the lower edge of the left poleyn.

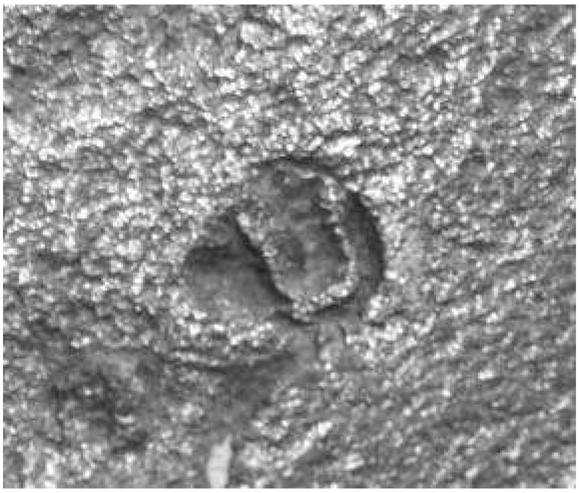

Figure 117. Unidentified maker's stamp on Royal Armouries AL.30 2.

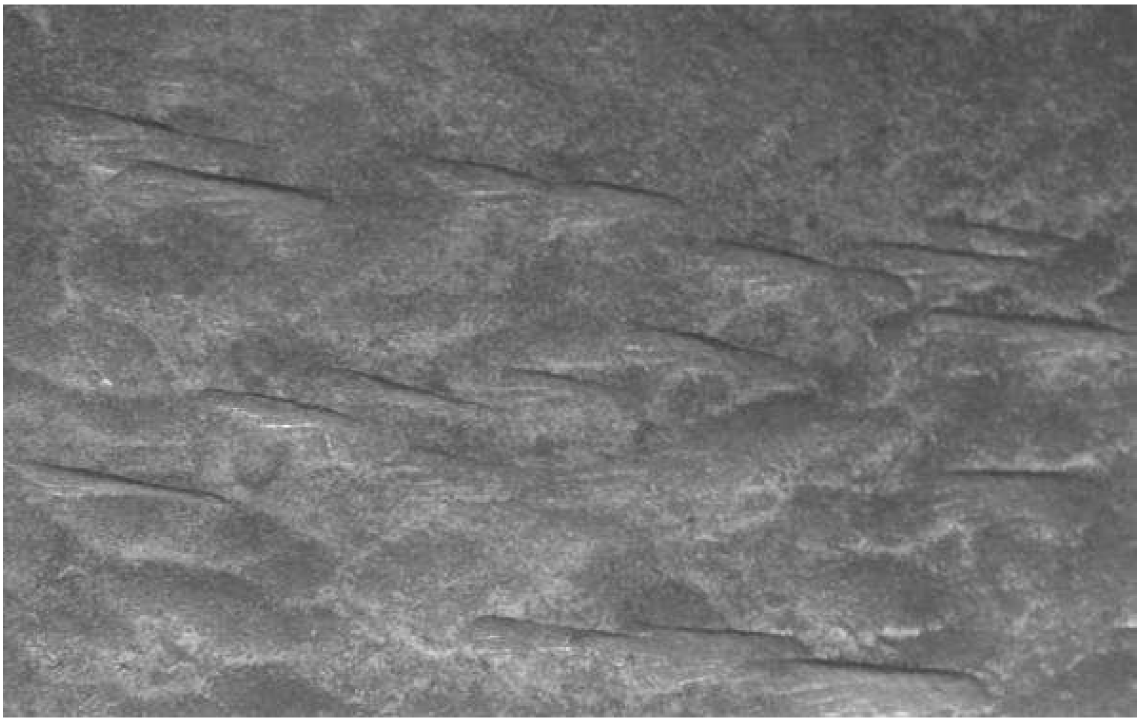

Figure 118. Mar marks in the Avant's left pauldron caused by file marks on the hammer face.

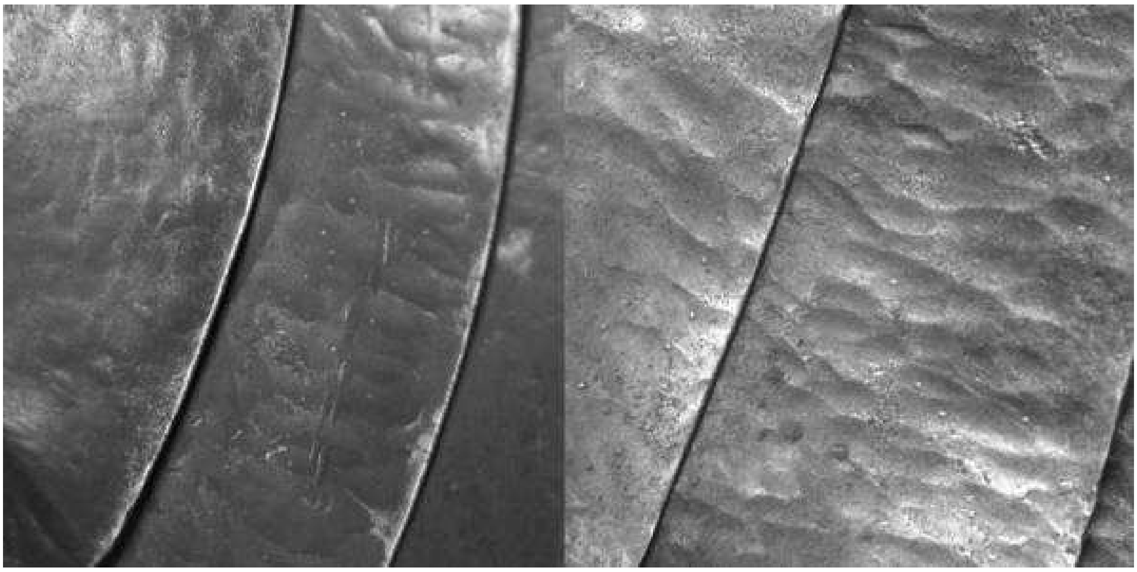

Figure 119. Mar marks in the right and left pauldrons of the Avant armour.

Figure 120. Mar marks in the Lyle Basinet, the Pembridge helm, and III.2446A.

Figure 121. Interior of IV.502's back gorget plate, also showing riveted thread plates at the shoulders.

Figure 122. Thread plate brazed on to right side of IV.502's skull.

Figure 123. Interior of III.96.

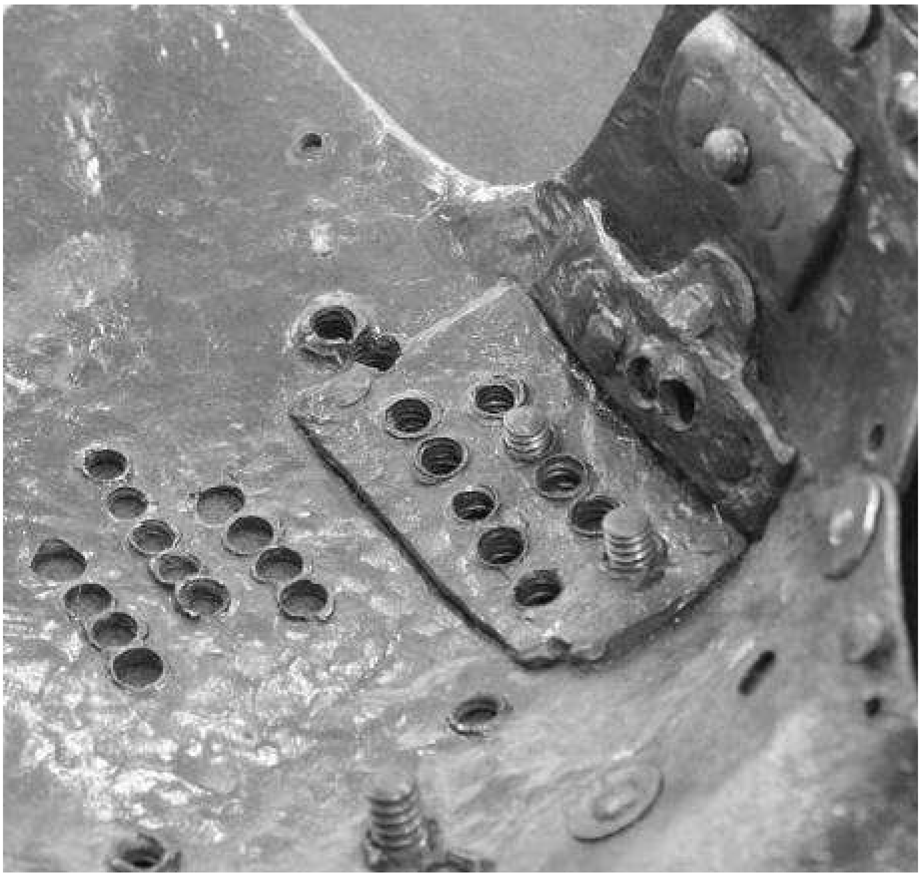

Figure 124. Detail of threaded holes and plates on III.96.

Figure 125. Interior of threaded holes on II.1.

Figure 126. Detail of base of III.69's lance rest.

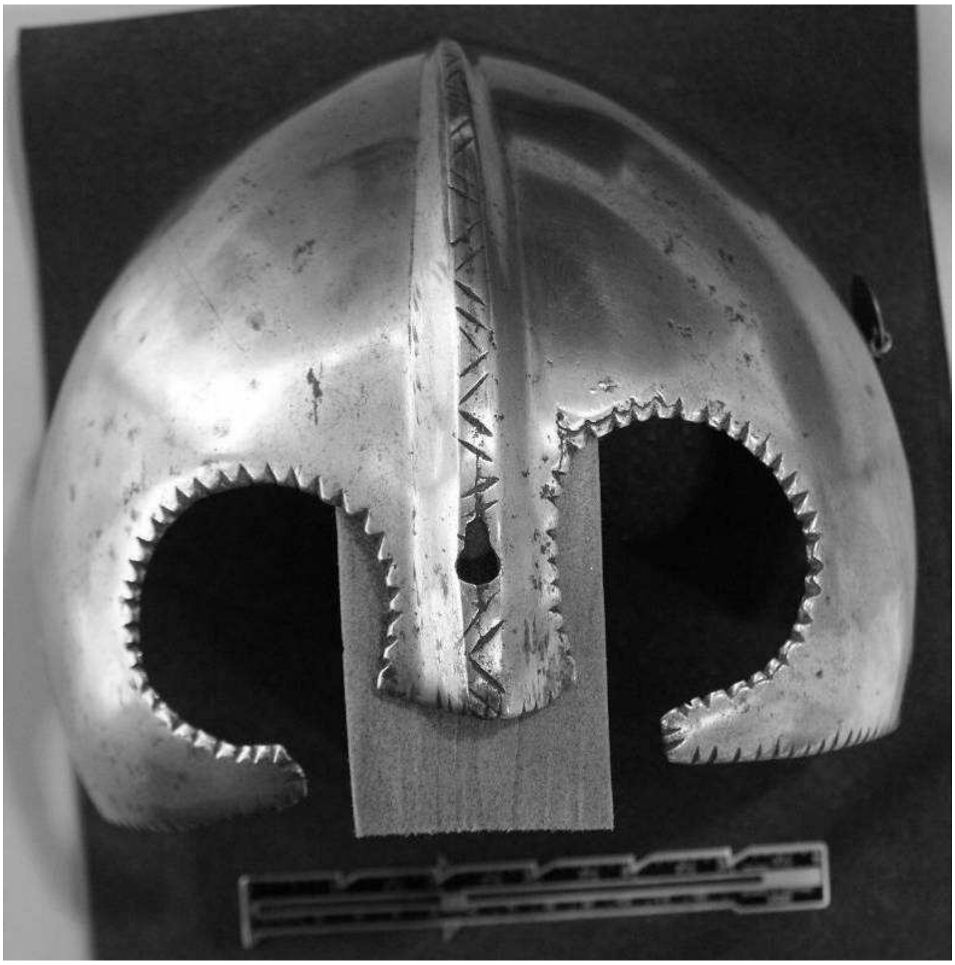

Figure 127. Skull reinforce IV.580.

Figure 128. Side of IV.580.

Figure 129. Interior of IV.580.

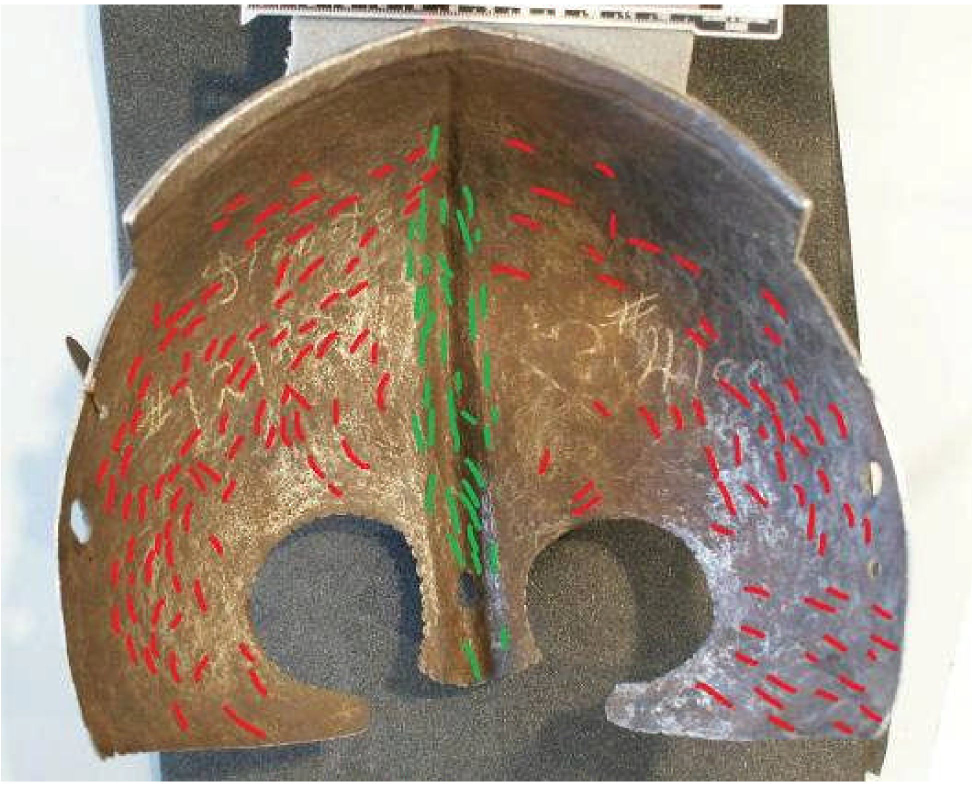

Figure 130. Mark patterns highlighted. Red marks indicate shaping of the piece, green indicate the keel forming marks.

Figure 131. IV.22, the Horned Helmet.

Figure 132. Interior of IV.22's skull. Note the planishing marks and marks along the raised and recessed panels.

Figure 133. Interior of the left cheek-piece to IV.22, showing long marks in the gorget channel. These marks are also found on the skull and right cheek piece.

Figure 134. Interior of IV.22's mask.

Figure 135. IV.29, the 'Moustached Masked Helmet'.

Figure 136. Tourney visor for IV.29. The small square feature above the visor on the left is its now defunct locking mechanism.

Figure 137. Nut and post of the chin-piece locking mechanism. Turning the nut causes the post extend.

Figure 138. Back of the moustache. Note the cracks which follow the line of compression, and also that the back is not embossed with the 'twists'.

Figure 139. Upper left of the moustache.

Figure 140. Underside of the moustache. Again, note how the cracks along the grain boundaries follow the line of compression.

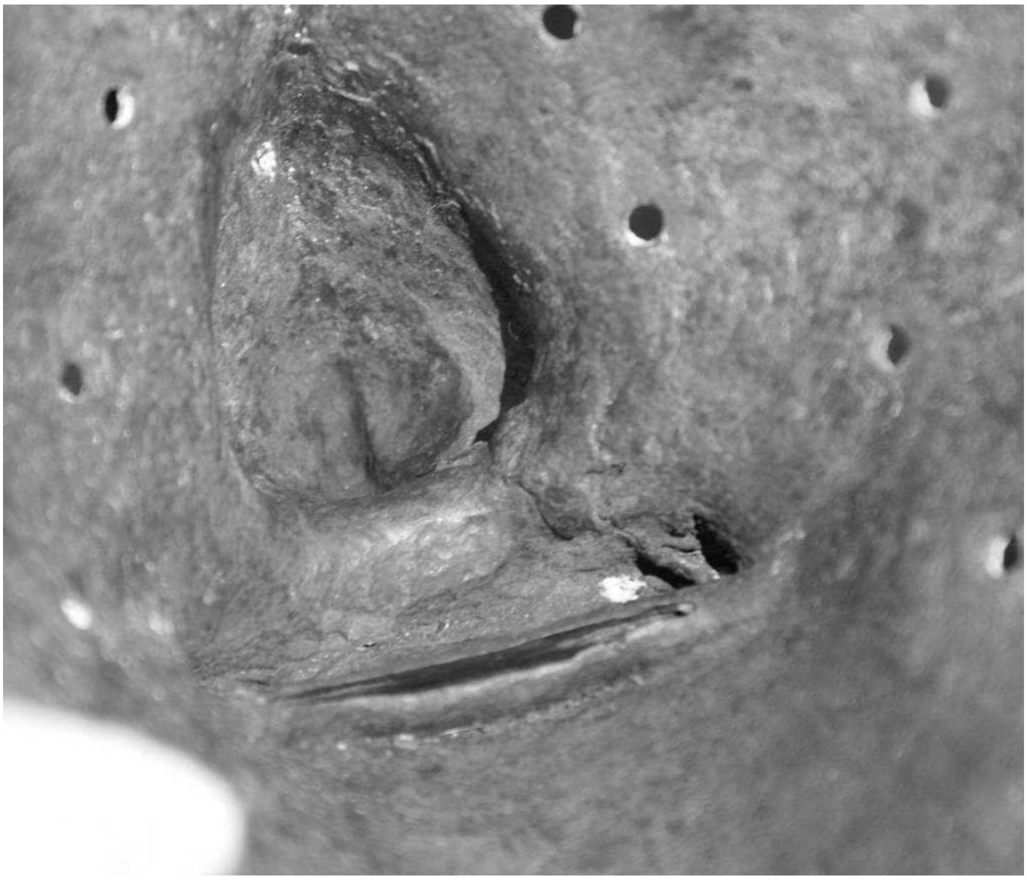

Figure 141. Interior of the nose, mouth, and moustache.

Figure 142. Under side view of the visor.

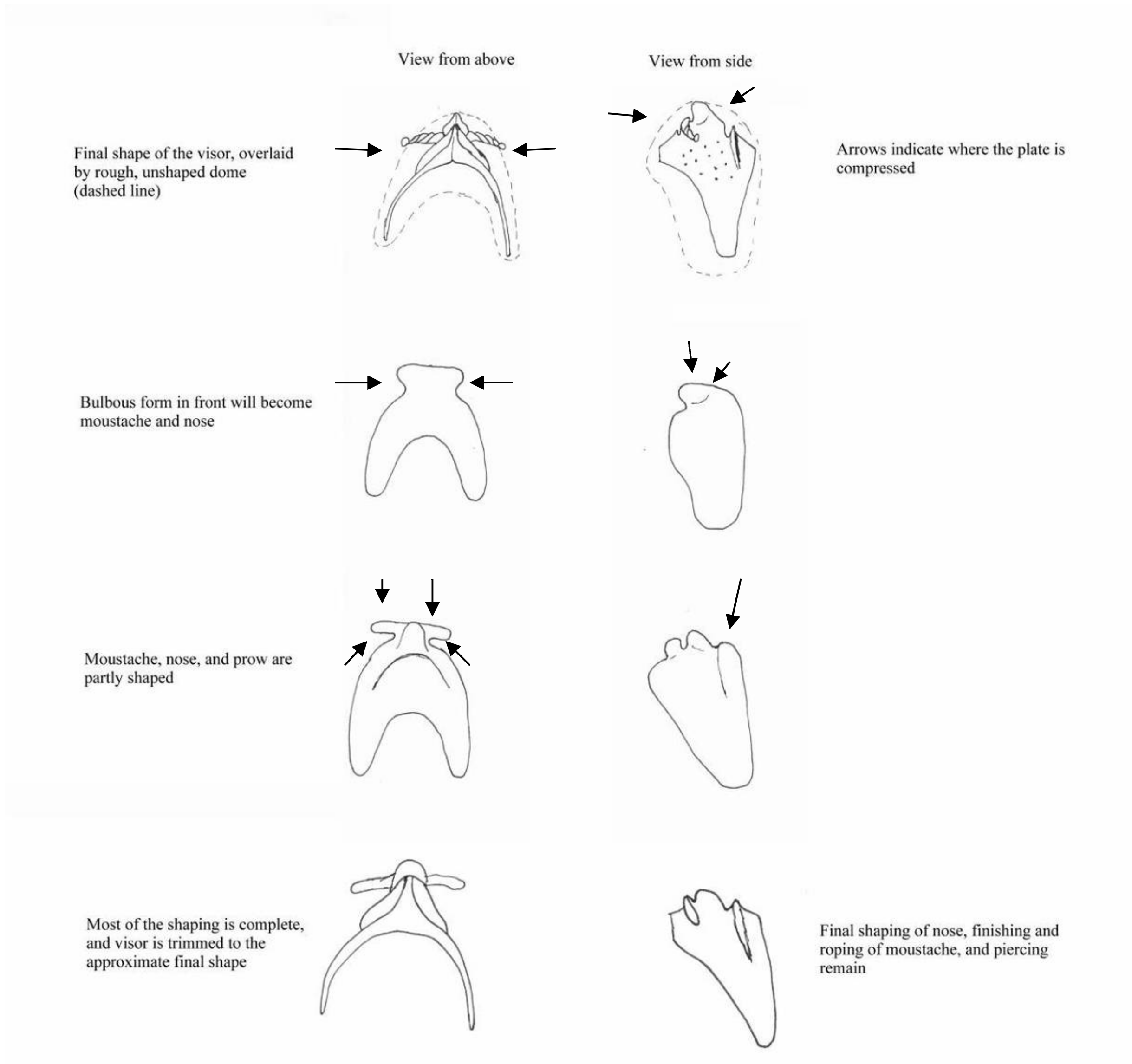

Figure 143. Possible order of construction of the visor

Figure 144. Close helmet of II.6.

Figure 145. Interior of the chin-piece to II.6, showing curling marks.

Figure 146. Interior to the skull of II.6.

Figure 147. Interior of visor of II.6, showing the inwardly-folded lip of the lower sight.

Figure 148. Great basinet II.7.

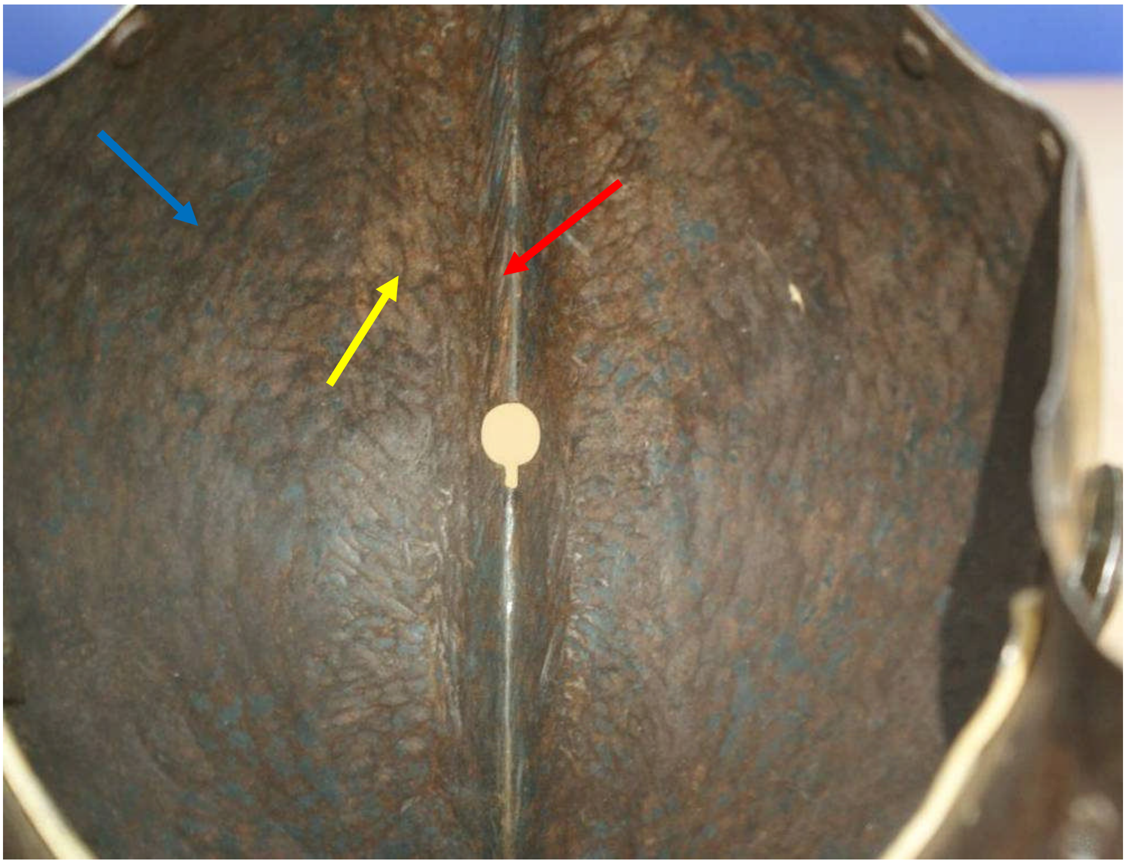

Figure 149. Interior to the skull of II.7. Note the raising marks (blue), wide bands of perpendicular marks along the medial keel (yellow), and oblique marks in the keel (red).

Figure 150. Interior to the visor of II.7.

Figure 151. Interior of II.7 visor, showing roughness of the holes.

Figure 152. Breaths on II.7's visor, showing evidence of round filing.

Figure 153. Accidental foliage pattern on the visor.

Figure 154. Great basinet IV.2 Note roughness of breaths and lack of sights.

Figure 155. Interior of the skull of IV.2. Note the lack of separate marks along the keel.

Figure 156. Interior detail of IV.2's visor, showing the bands of marks along the medial keel. Compare this with the skull of IV.2 and skull of II.7.

Figure 157. Comparison of the embossed lip on IV.2, left, and II.6, right. The work on IV.2 is slightly less regular and is incomplete.

Figure 158. IV.470, the Lyle Basinet.

Figure 159. Basinet IV.470.

Figure 160. Components of IV.470.

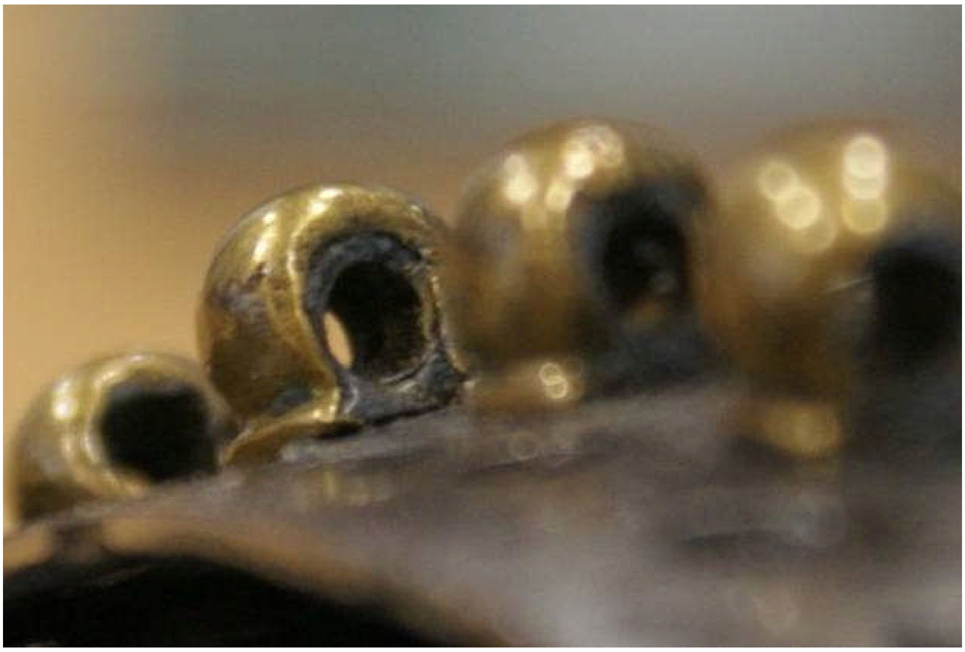

Figure 161. Brass-capped vervelles on IV.470.

Figure 162. Interior of IV.470's skull, showing both the overall marks and the medial crease.

Figure 163. Interior of IV.470's visor.

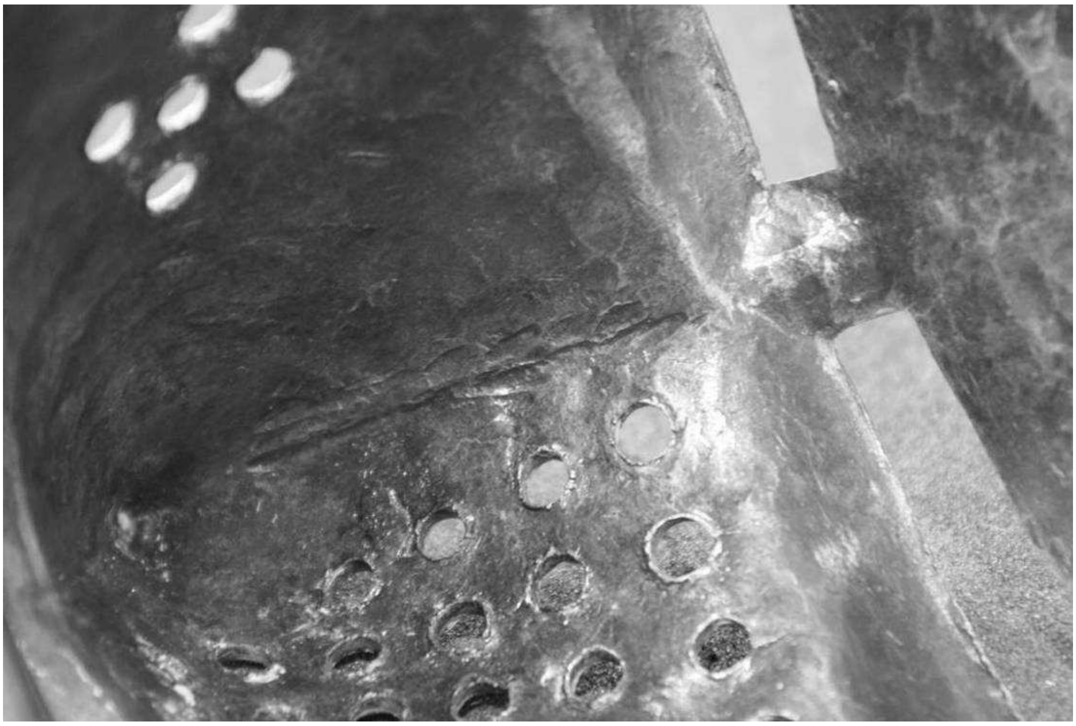

Figure 164. Interior of IV.470. Note the heavy marking along the crease.

Figure 165. Detail of IV.470's visor. Note the parallel marks along the crease.

Figure 166. Interior sights on IV.470.

Figure 167. Mail-maker's links on the aventail, all reading 'MAGISTER'.

Figure 168. Basinet IV.497.

Figure 169. Countersunk holes over the face opening on IV.497.

Figure 170. Interior of IV.497. The arrows indicate areas of uneven planishing.

Figure 171. Sallet II.168 A.

Figure 1721. Interior of II.168 A. Note the wide bands of marks on the tail.

Figure 173. Interior of the visor of II. 168 A.

Figure 174. Sallet IV.13.

Figure 175. IV.13 without its visor. Rasing marks are prominent along the bottom half, planishing marks on the skull.

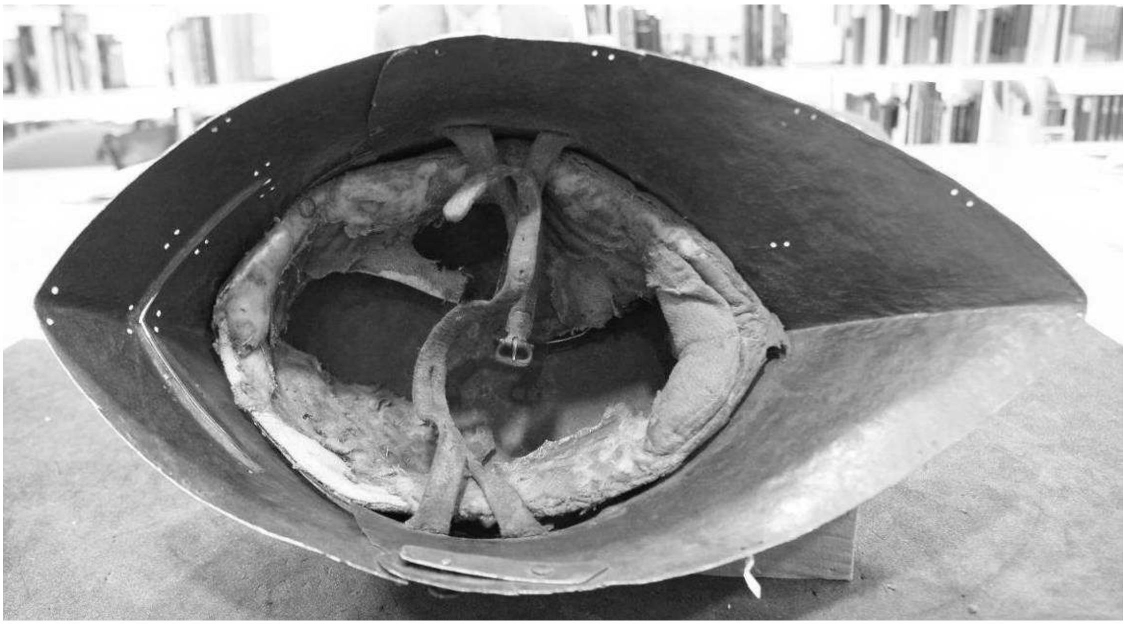

Figure 176. Interior of IV.13.

Figure 177. Tail of IV.13. Note the folded edge and marks along the medial ridge.

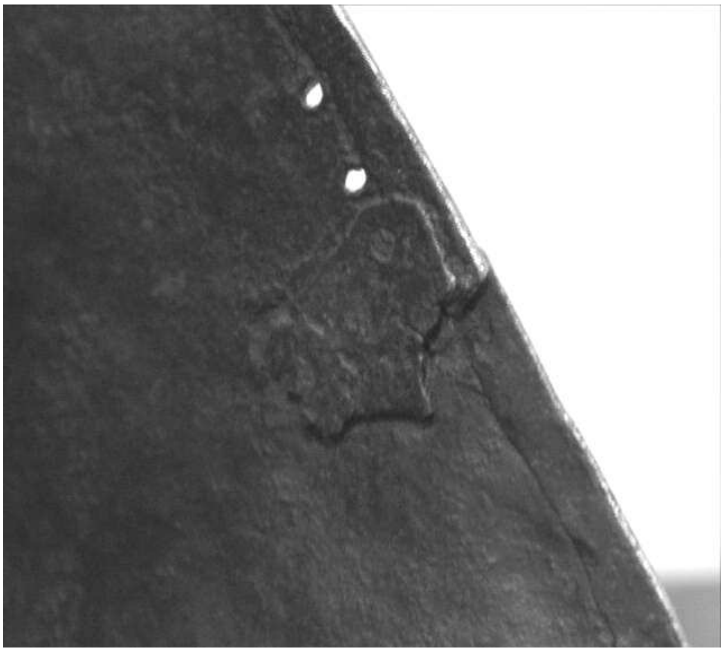

Figure 178. Medieval repair on lower edge of IV.13, made from an off-cut from a piece of recycled armour.

Figure 179. Sallet IV.499.

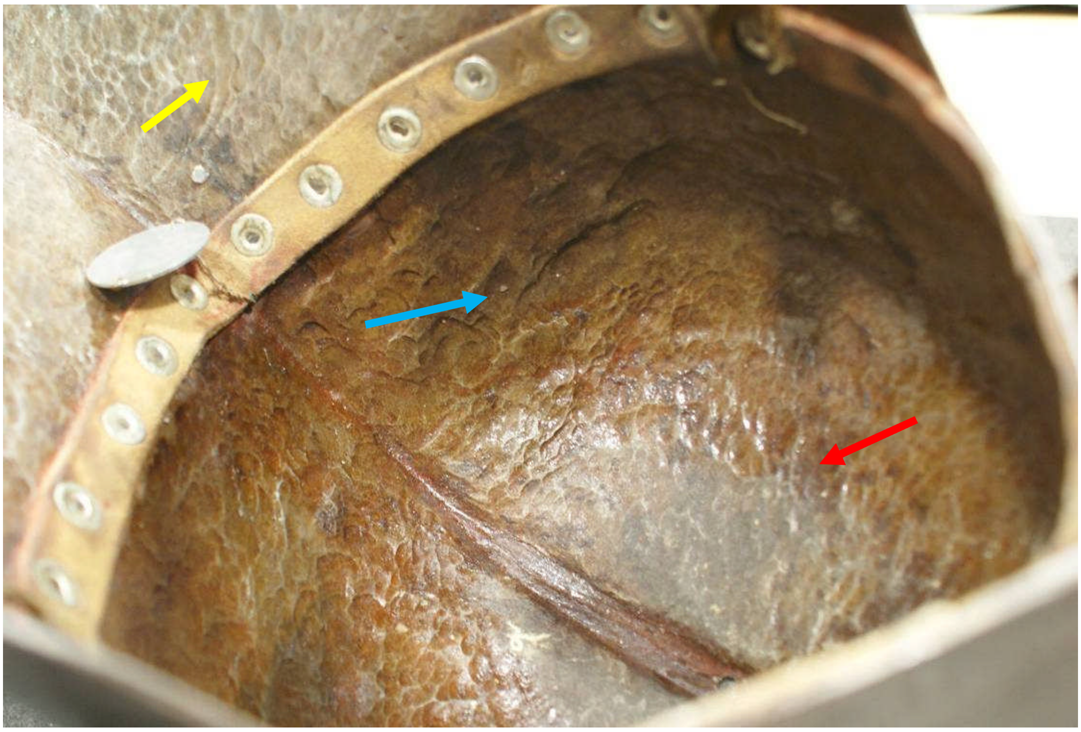

Figure 180. Interior of skull of IV.499, showing different patterns of marks, the upper skull (red), rough middle band (blue) and tail (yellow).

Figure 181. Interior of tail of IV.499.

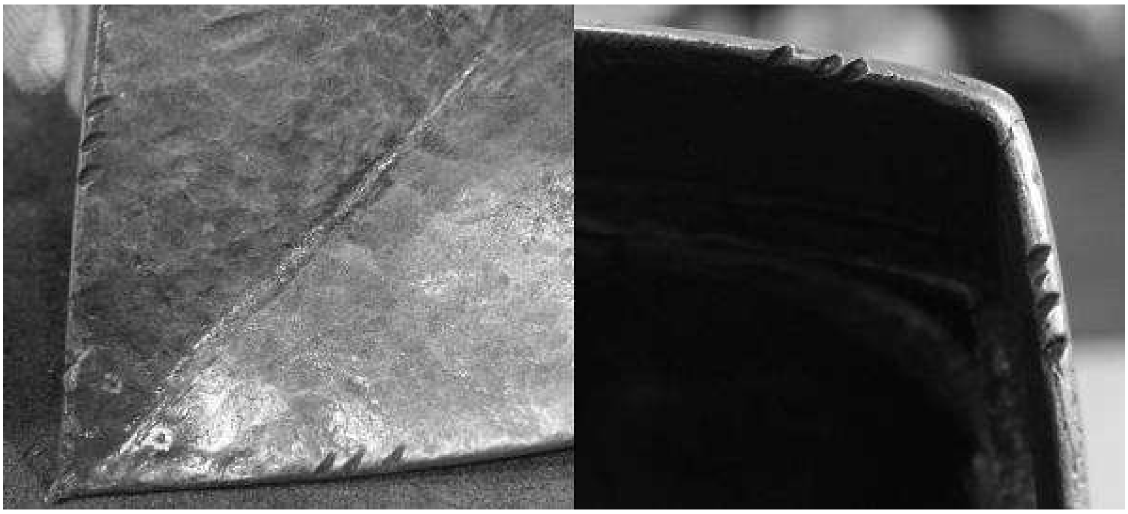

Figure 182. Assembly marks on tail and visor of IV.499.

Figure 183. Sallet IV.2056.

Figure 184. Medial ridge of IV.2056. Note the slight depression to the sides of the ridge.

Figure 185. War hat IV.537.

Figure 186. Front of IV.537.

Figure 187. Interior of IV.537.

Figure 188. Interior brim detail.

4

Figure 189. Interior of skull, showing bands of marks.

Figure 190. Edge finish detail.

Figure 191. IV.411, the Brocas Helm.

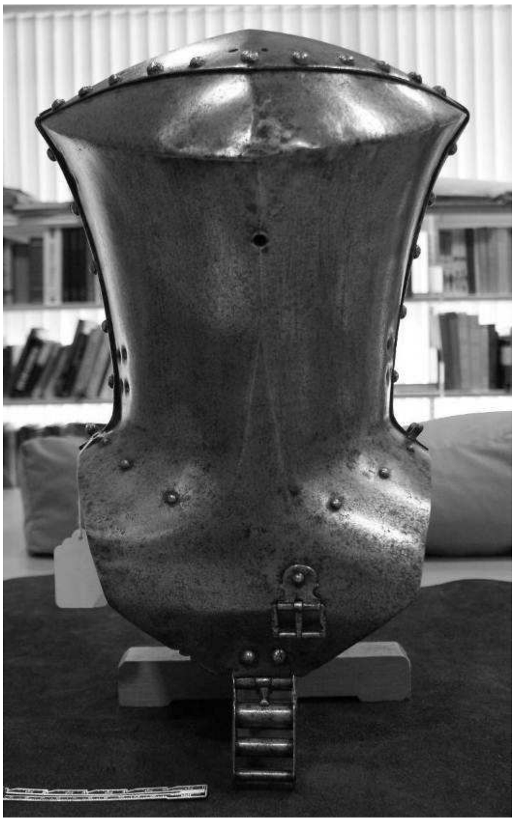

Figure 192. Rear view of IV.411.

Figure 193. Damaged brass-capped rivets, showing the brass cap, lead solder, and iron rivet.

Figure 194. Front plate interior of IV.411, showing curling marks.

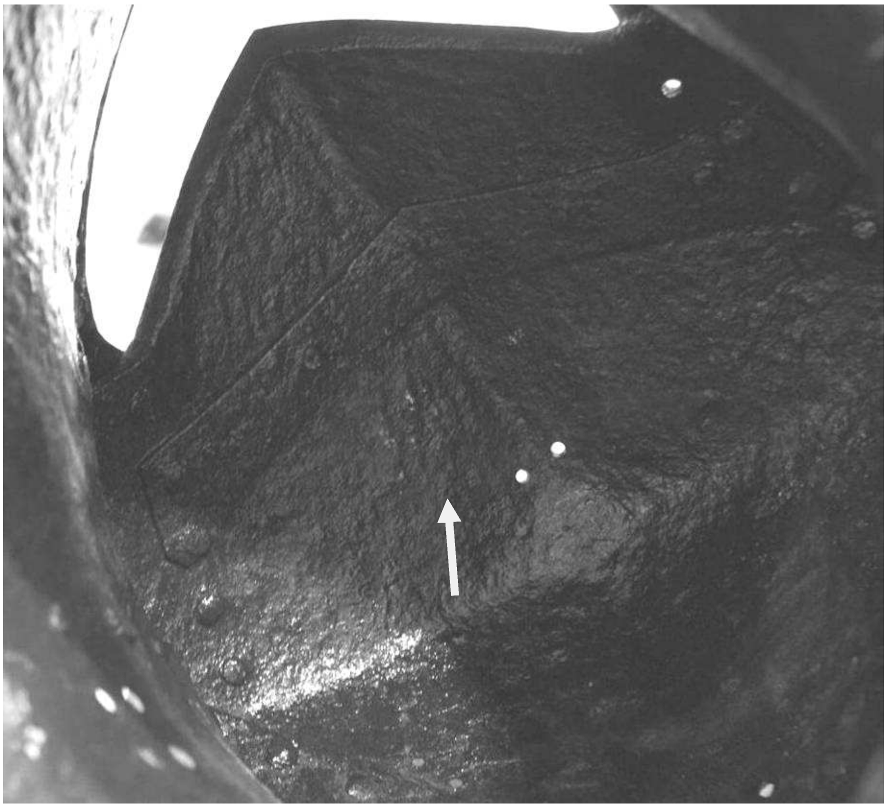

Figure 195. Interior skull of IV.411. The angled front forming lines are faintly visible.

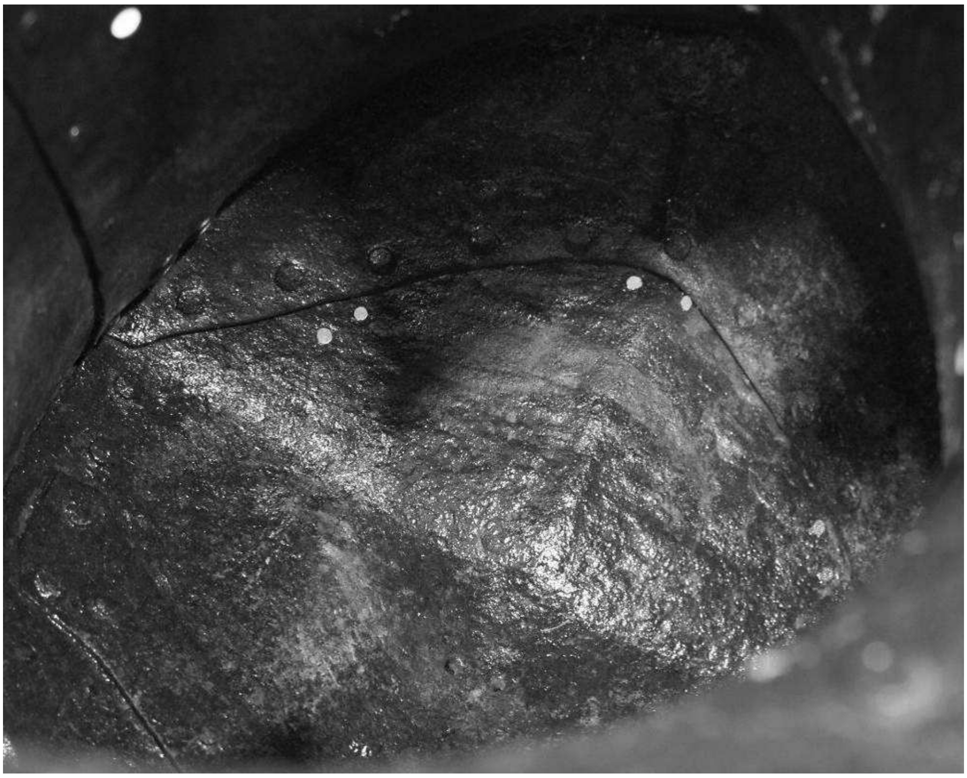

Figure 196. Interior skull of IV.411, looking towards the back.

Figure 197. Tilting helmet IV.502.

Figure 198. Components of IV.502.

Figure 199. Skull interior of IV.502.

Figure 200. Interior of IV.502's skull reinforce.

Figure 201. Interior of IV.502's back gorget plate, also showing riveted thread plates at the shoulders.

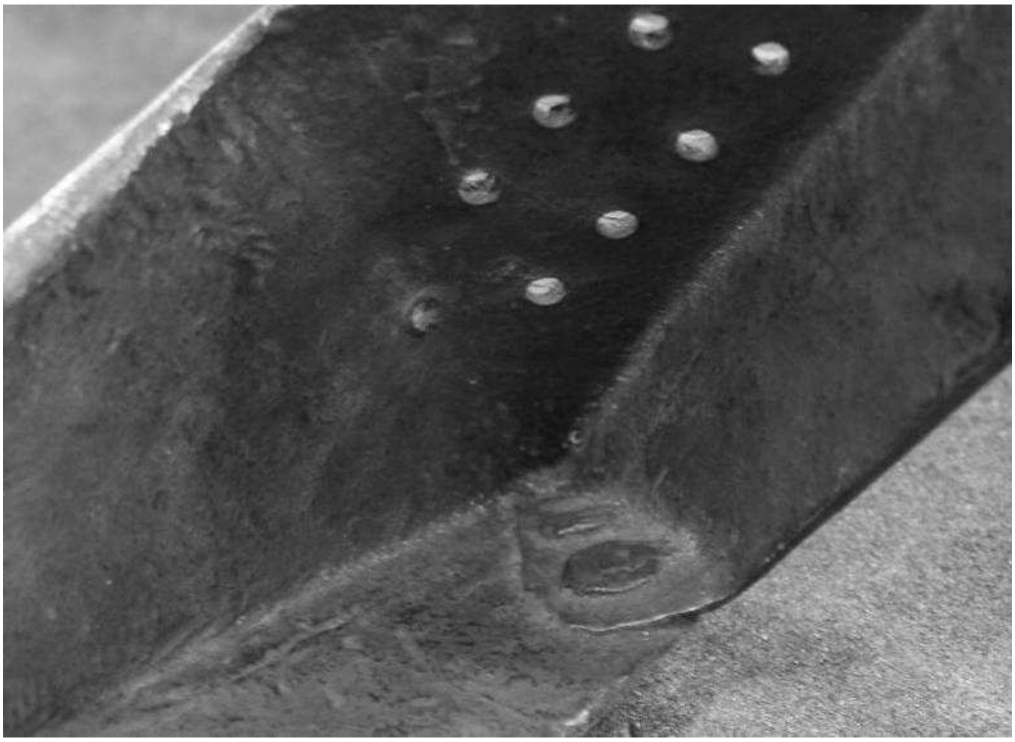

Figure 202. Interior of IV.502's visor, showing riveted construction.

Figure 203. Joint on the bevor and gorget plates of IV.502, showing evidence of modification.

Figure 204. Thread plate brazed on to right side of IV.502's skull.

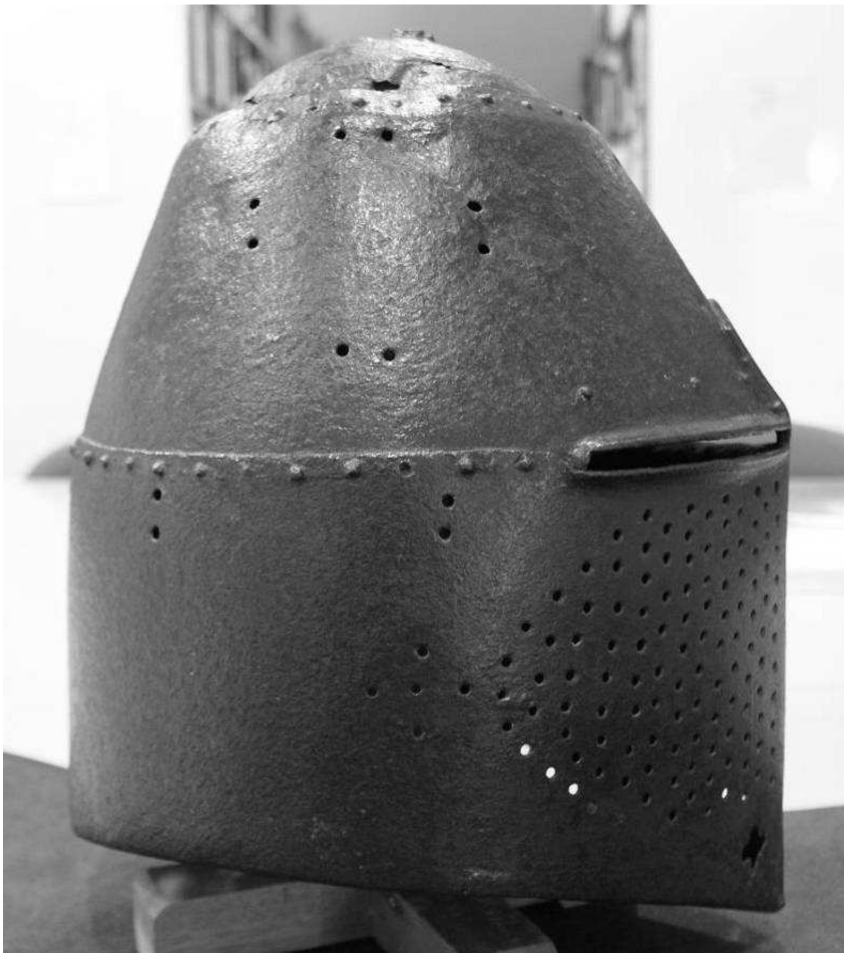

Figure 205. Great helm IV.600.

Figure 206. Front of IV.600.

Figure 207. Interior of IV.600.

Figure 208. Interior detail of IV.600. The ruler is just to the right of the welded seam, which is not visible.

Figure 209. A.1905.489, the Pembridge helm.

Figure 210. Side view of the Pembridge helm.

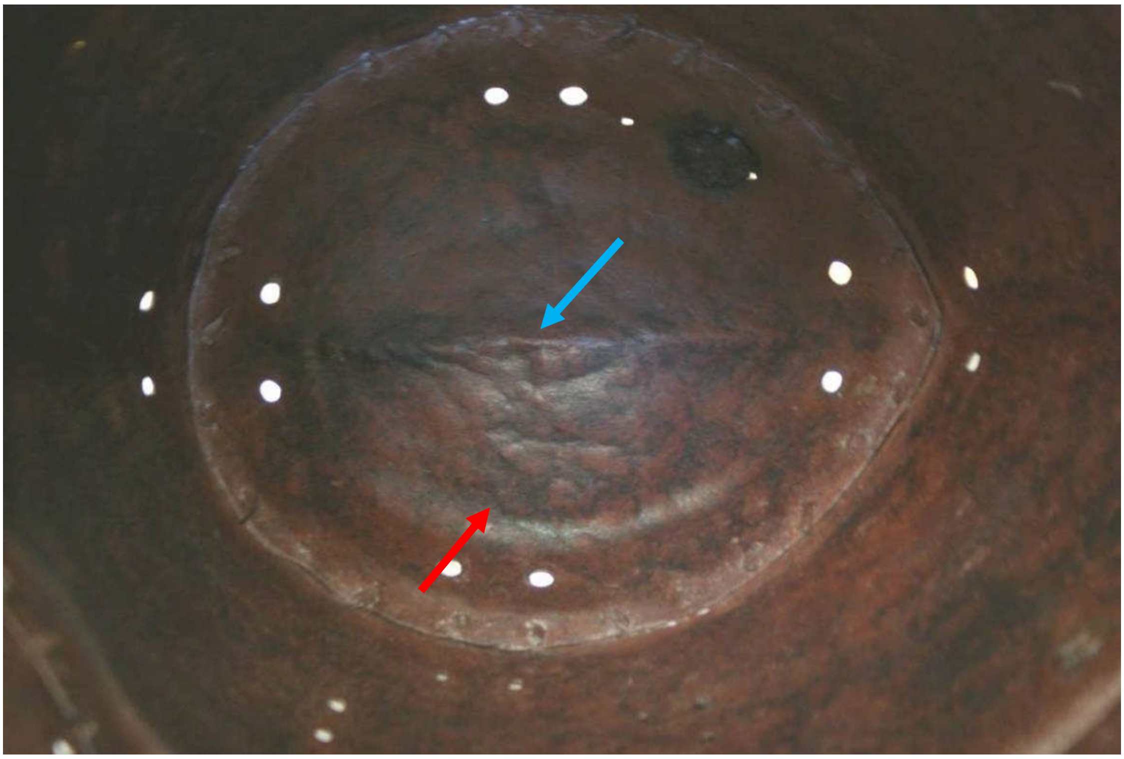

Figure 211. Interior of the Pembridge helm, showing the concentric rings in the cap (red), and crease marks (blue).

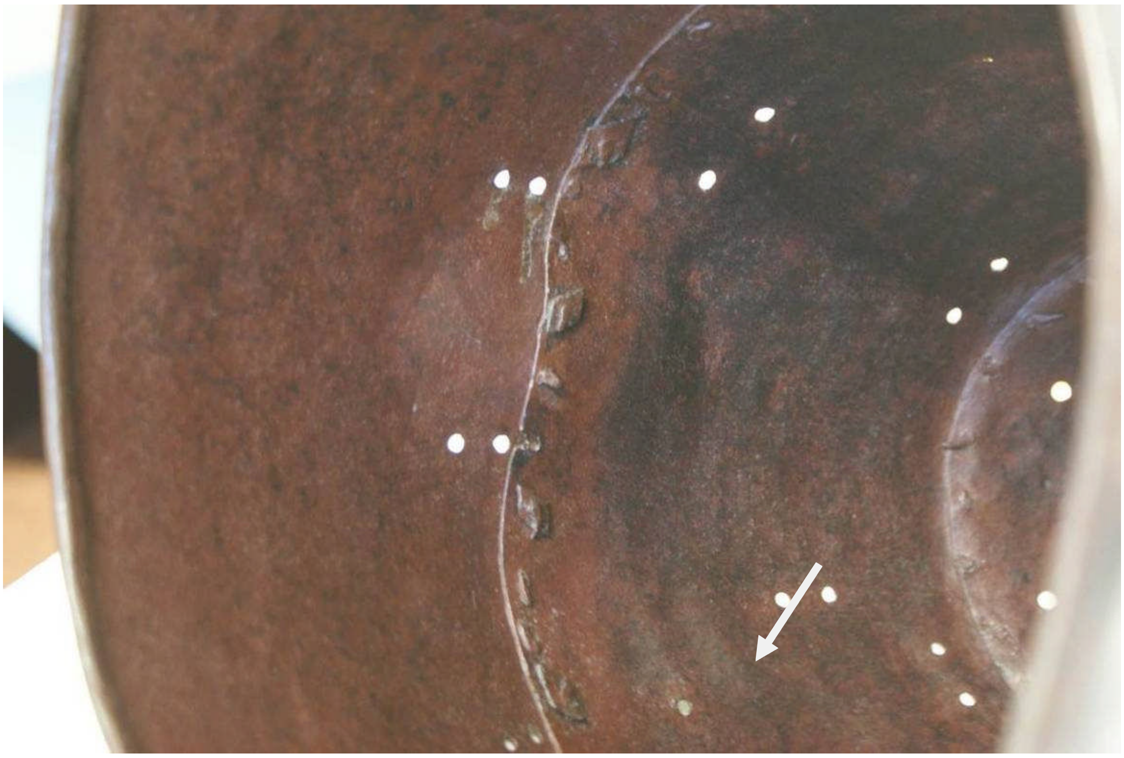

Figure 212. Interior of the sides of the Pembridge helm. Faint curling marks are visible on the middle hoop.

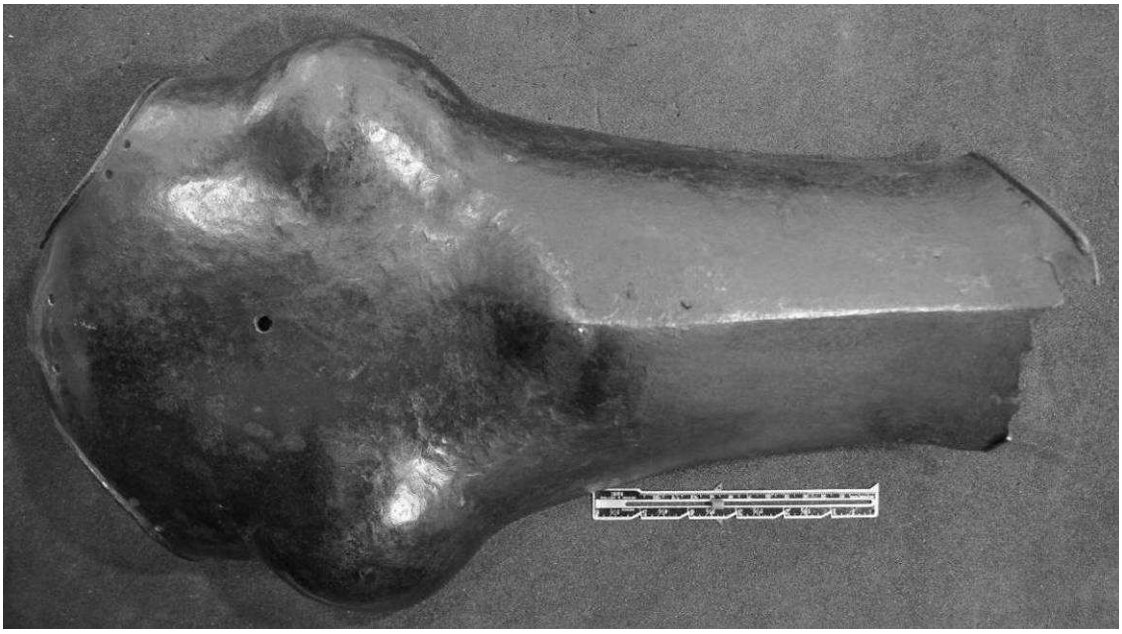

Figure 213. Chanfron VI.48.

Figure 214. **Si**de of chanfron.

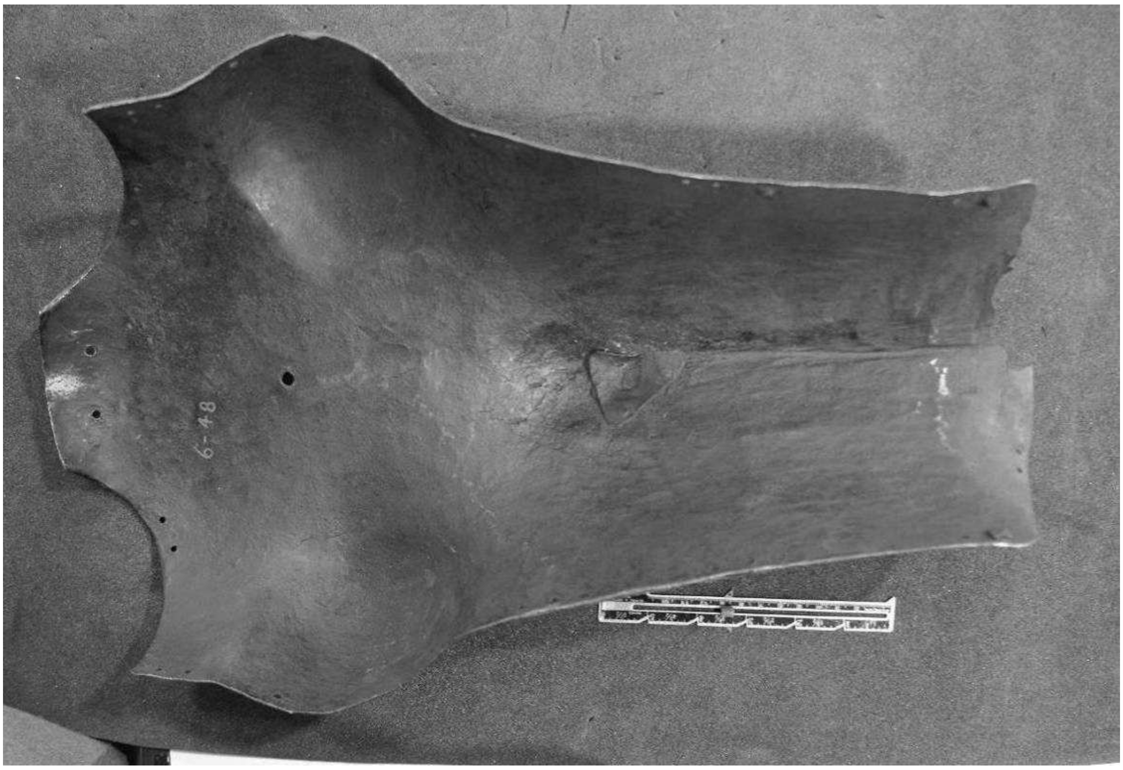

Figure 215. Interior of VI.48.

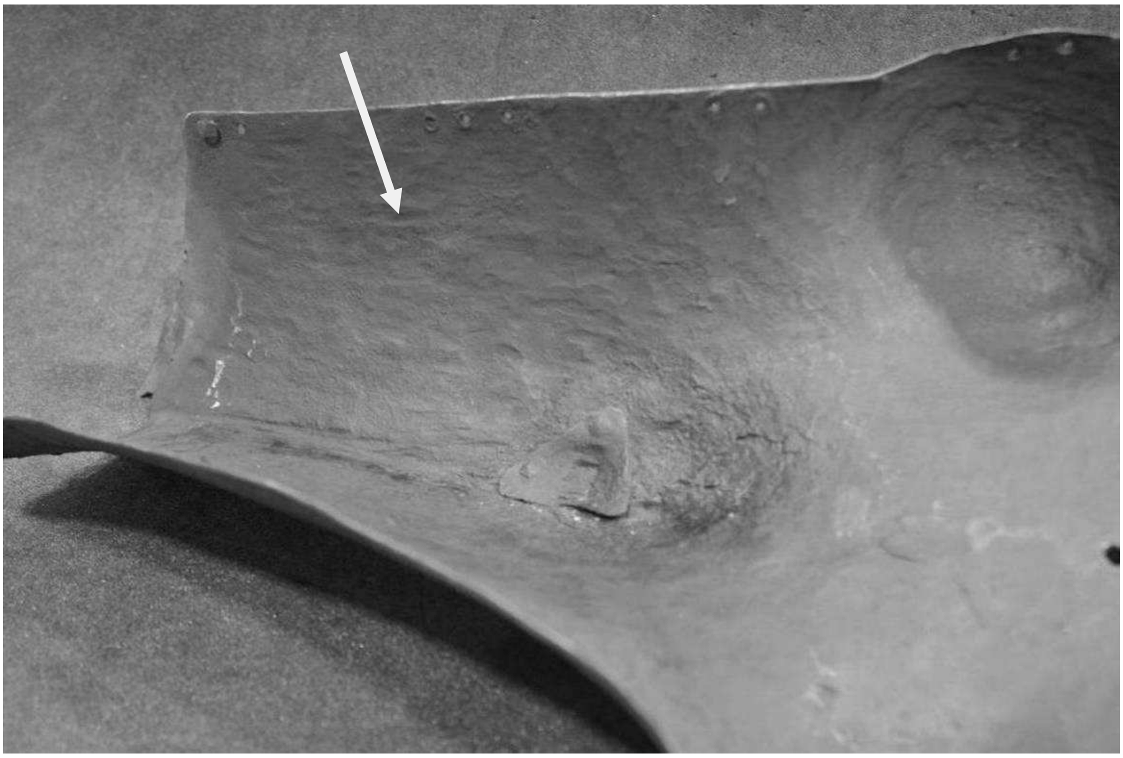

Figure 216. Curling marks in VI.48.

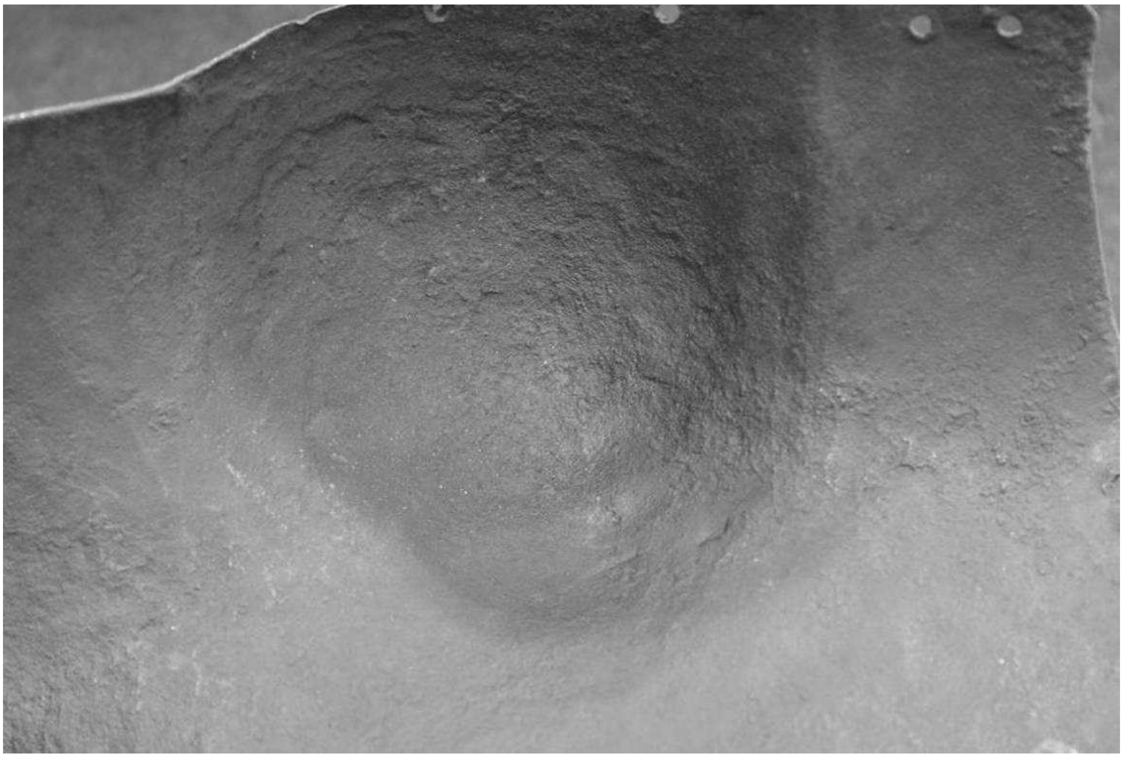

Figure 217. Concentric raising pattern in VI.48.

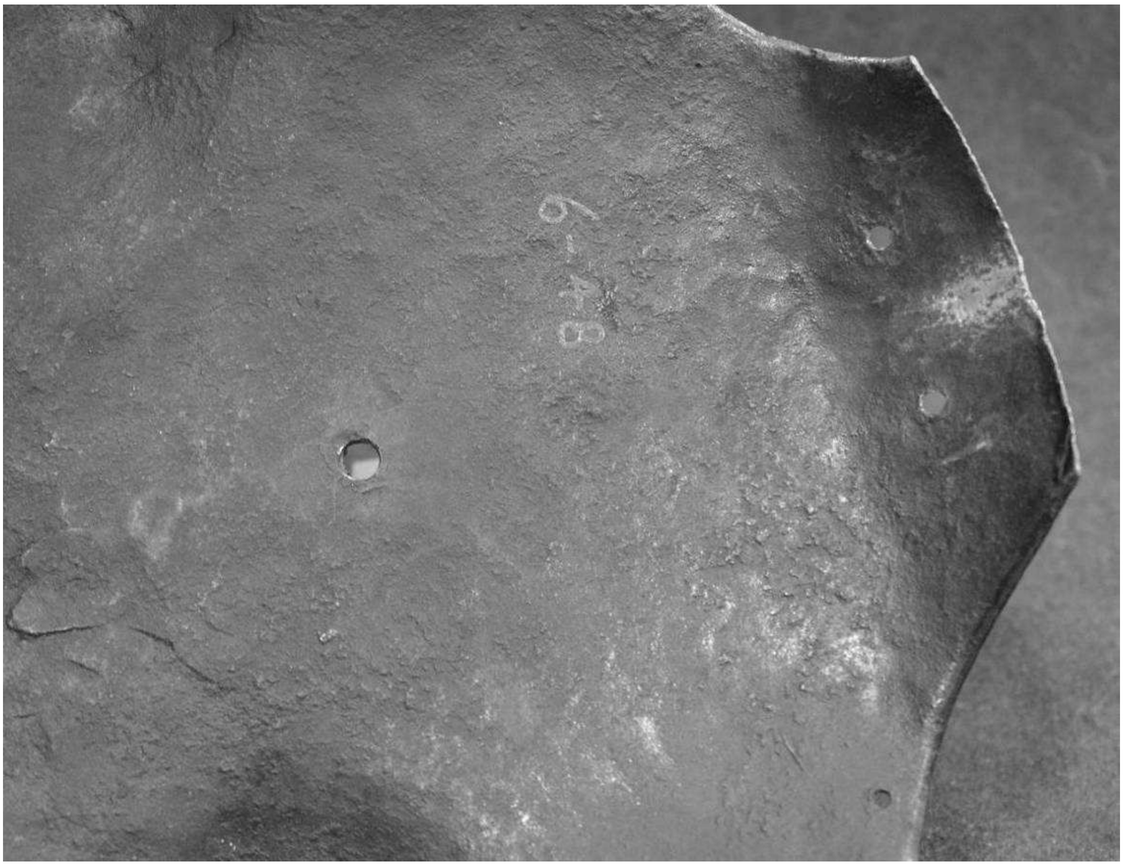

Figure 218. Faint planishing pattern on VI.48.

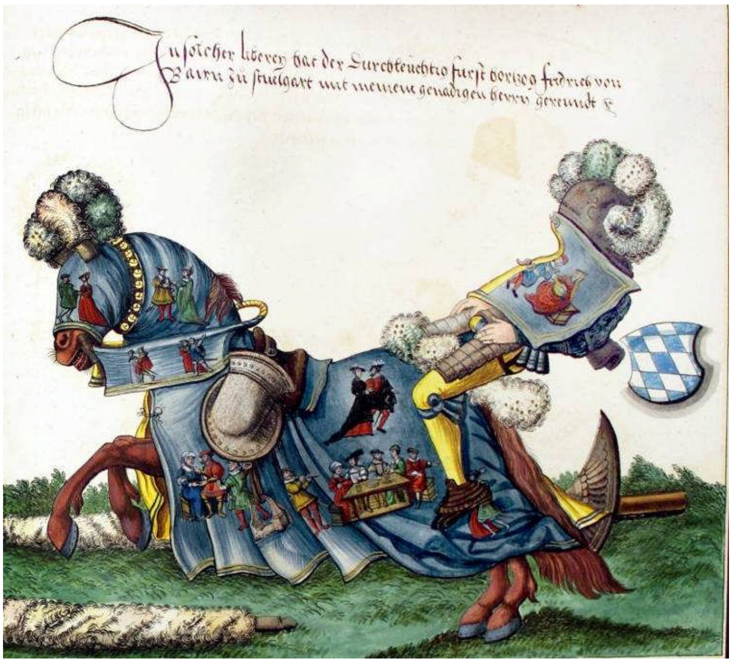

Figure 219. A blind chanfron in use. Note that the horse is not only blinded, but is deafened by the collar of bells.

Figure 220. Breastplate III.96.

Figure 221. Interior of III.96.

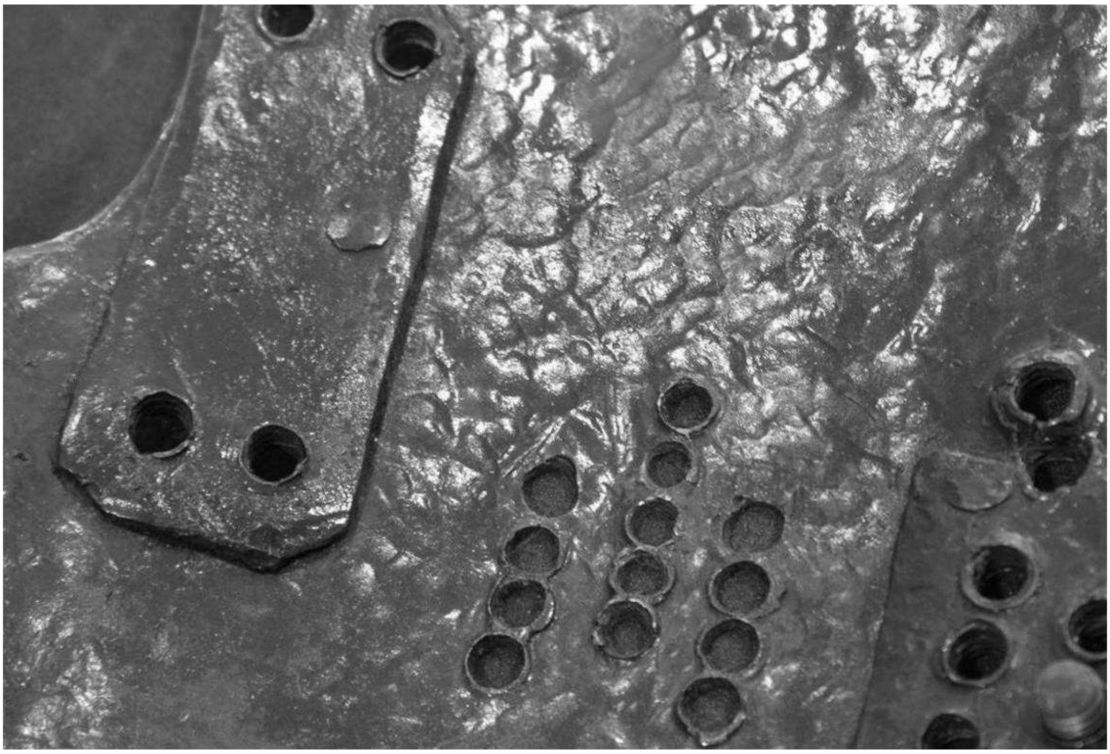

Figure 222. Detail of III.96 interior.

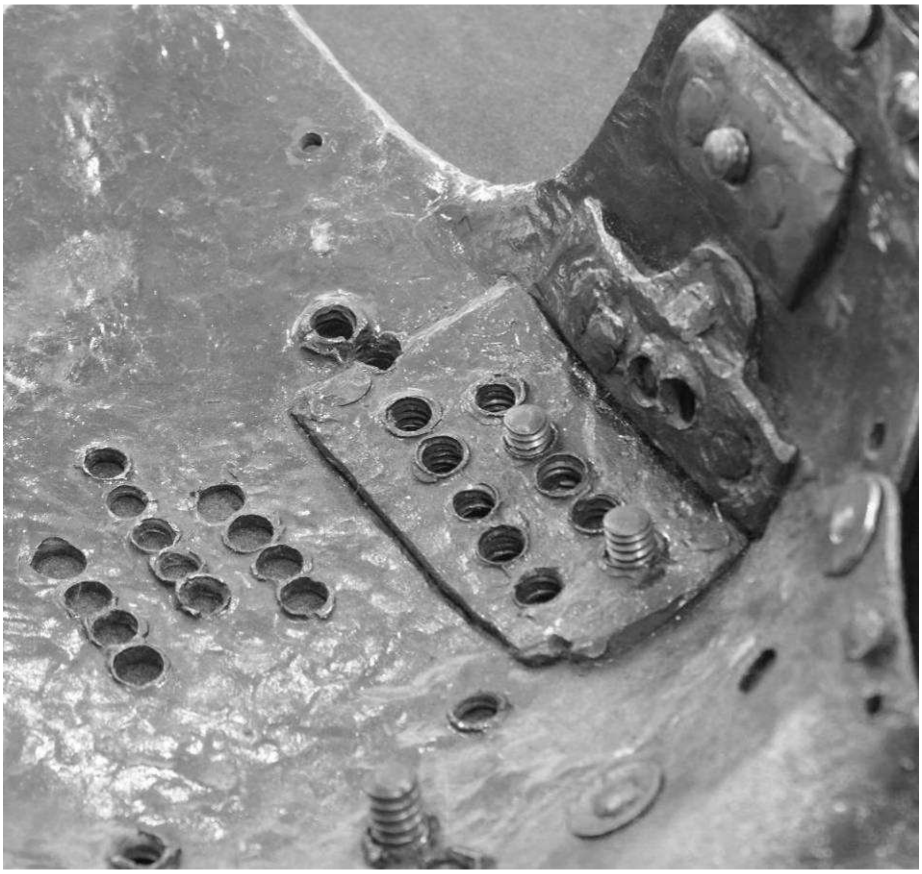

Figure 223. Detail of threaded holes and plates on III.96.

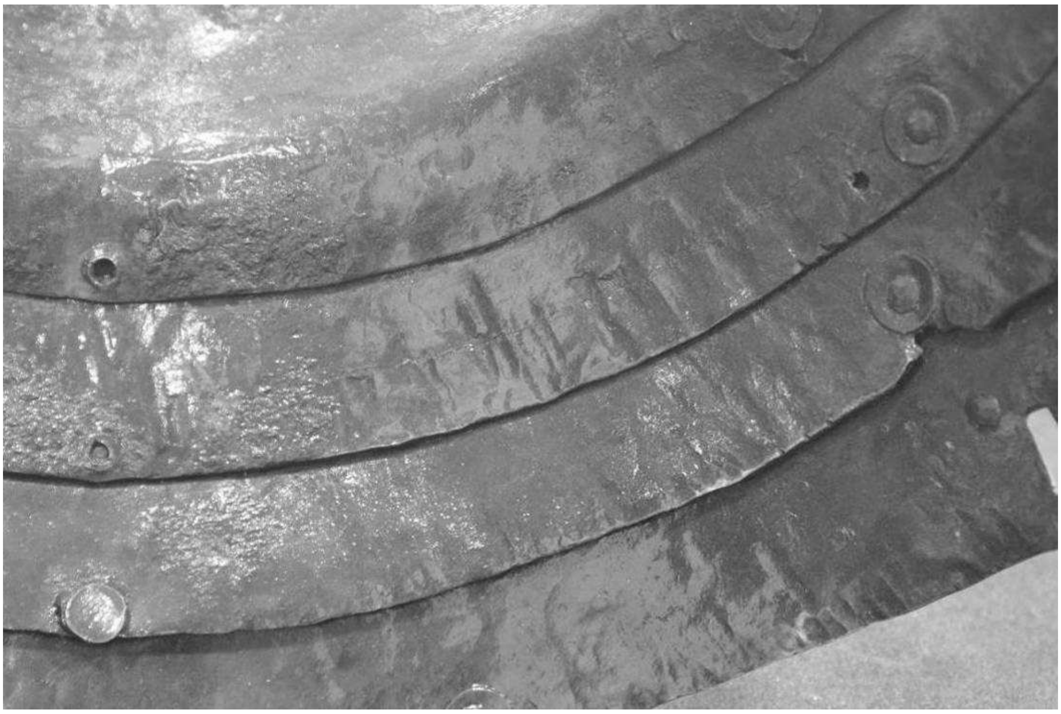

Figure 224. Interior of III.96's fauld.

Figure 225. Breastplate III.1281.

Figure 226. Interior of III.1281.

Figure 227. Parallel marks in the flutes of the upper breastplate.

Figure 228. Oblique marks in the flutes of the plackart.

Figure 229. Front and back of the Avant armour's upper cuirrass.

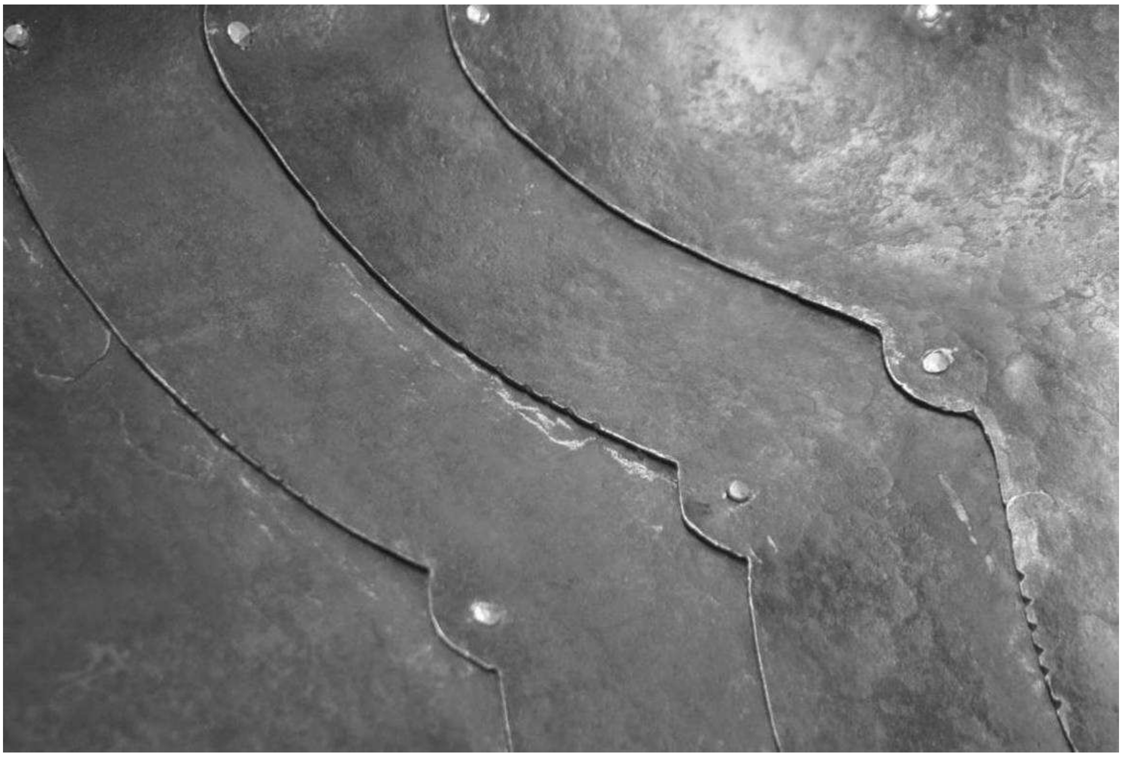

Figure 230. Interior of Avant's backplate.

Figure 231. Interior of Avant's breastplate.

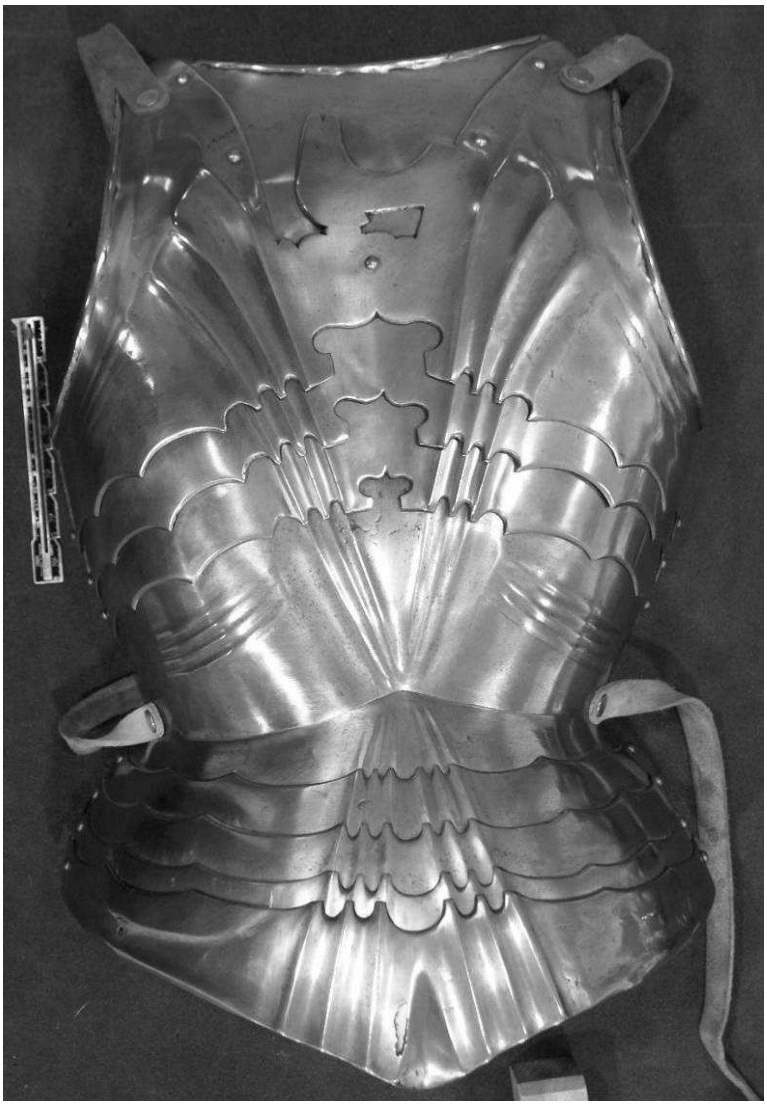

Figure 232. Backplate III.70.

Figure 233. Interior of III.70.

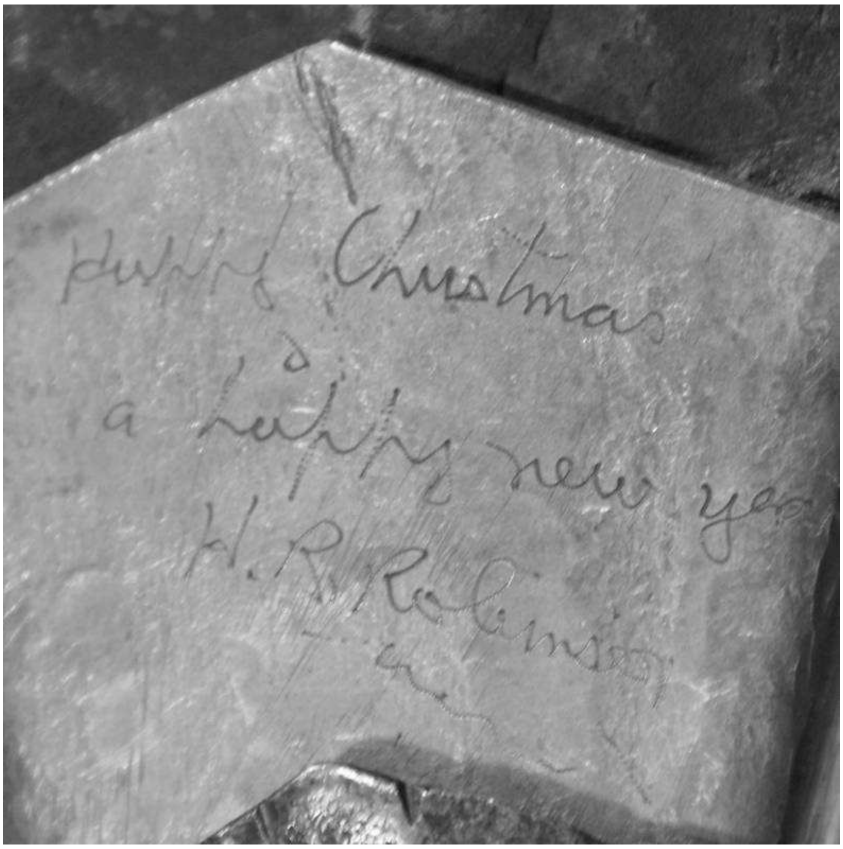

Figure 234. Detail of restoration plate on III.70.

Figure 235. Interior of flutes on III.70.

Figure 236. Interior of III.70's culet

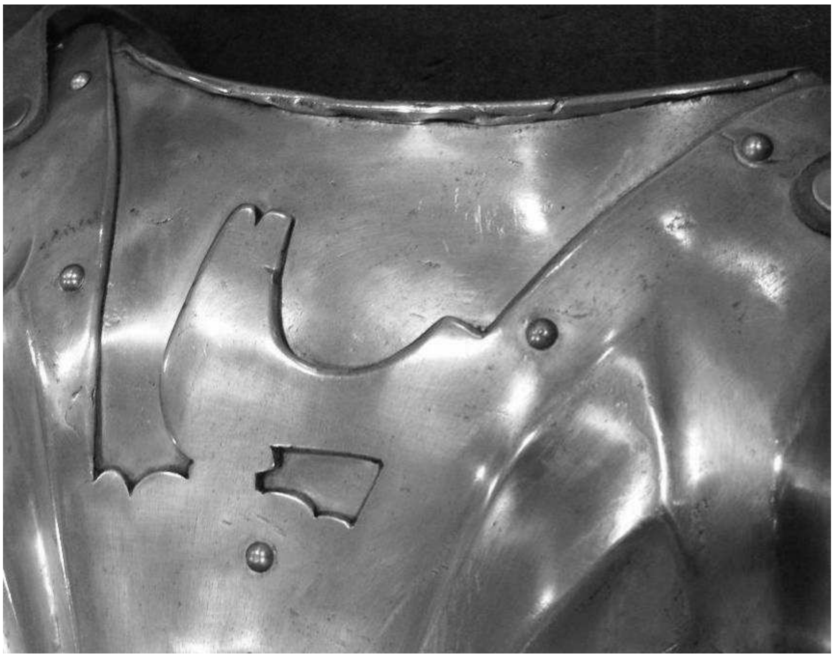

Figure 237. Unusual asymmetric cutout on III.70.

Figure 238. Backplate II.168 D.

Figure 239. Interior of II.168 D.

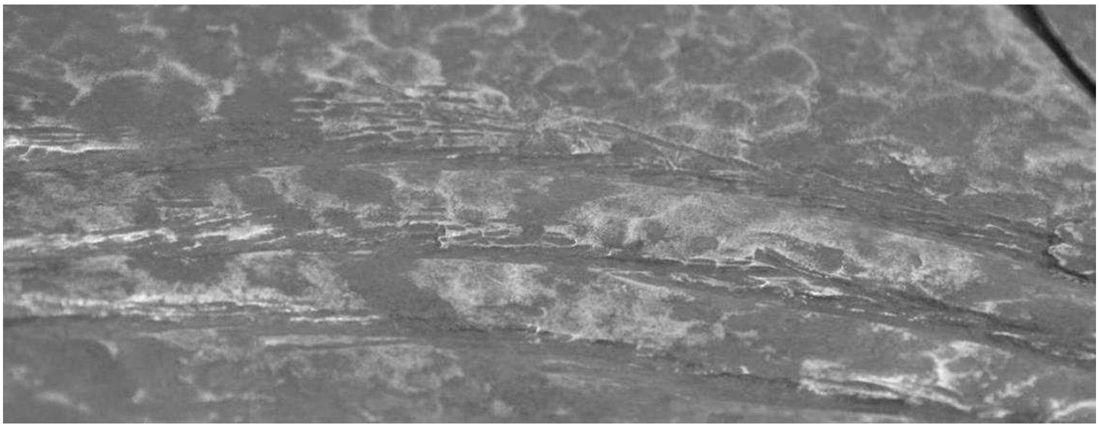

Figure 240. Detail of flutes on interior of II.168 D.

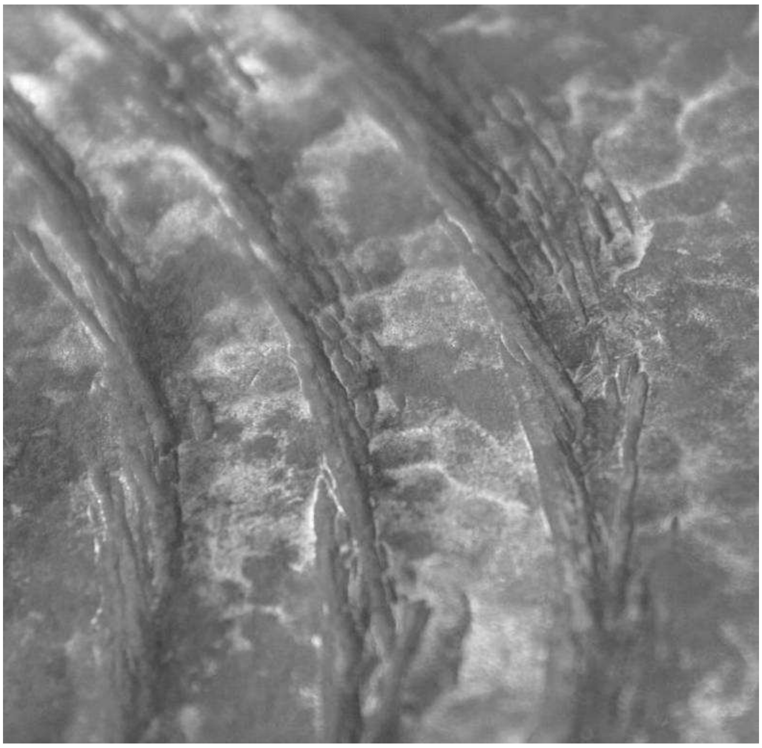

Figure 241. Detail of flutes on interior of II.168 D.

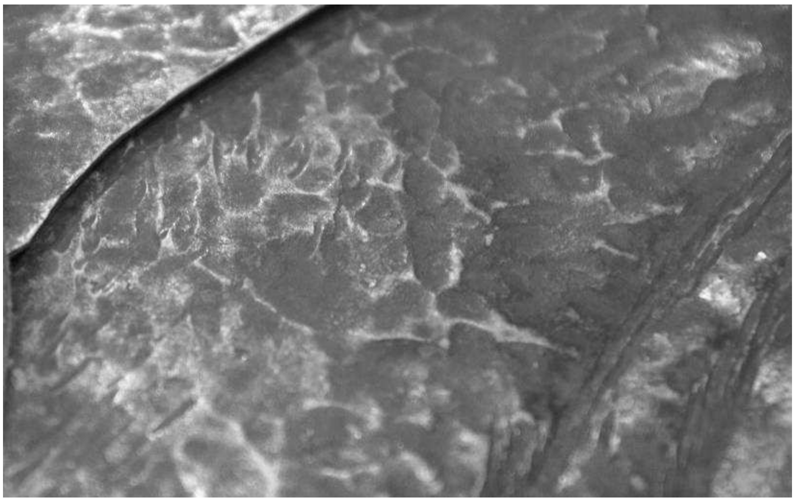

Figure 242. Thin marks on interior of II.168 D.

Figure 243. Rough embossing marks on interior of II.168 D.

Figure 244. Restored fauld on II.168 D.

Figure 245. Backplate III.1284.

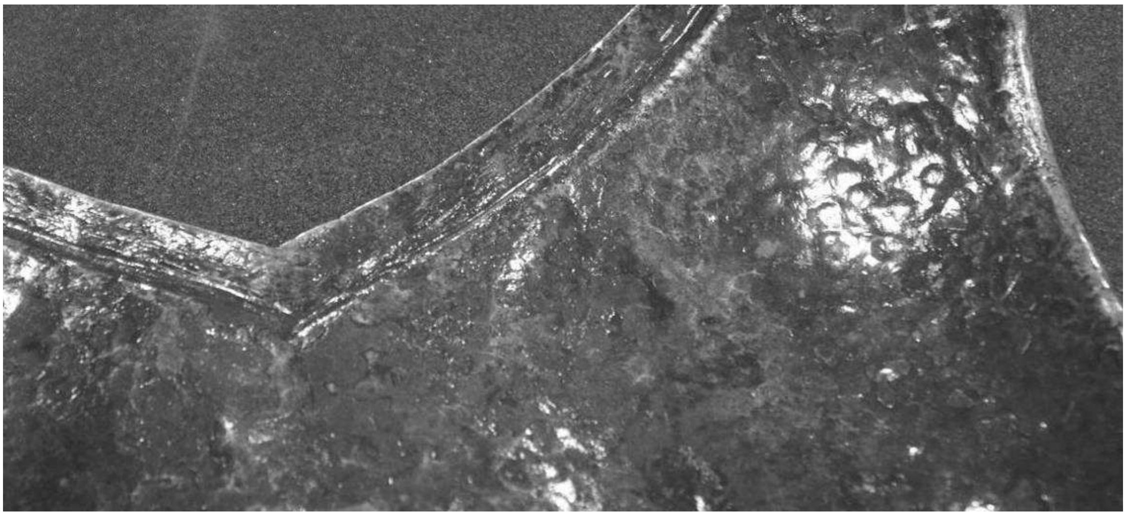

Figure 246. Interior detail of III.1284.

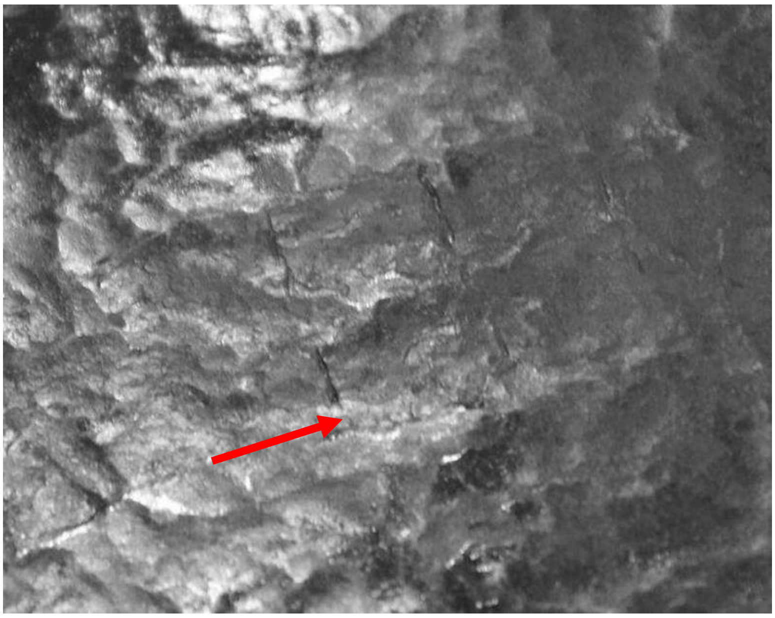

Figure 247. Long, thin marks on the interior of III.1284.

Figure 248. Backplate III.1325.

Figure 249. Interior of III.1325.

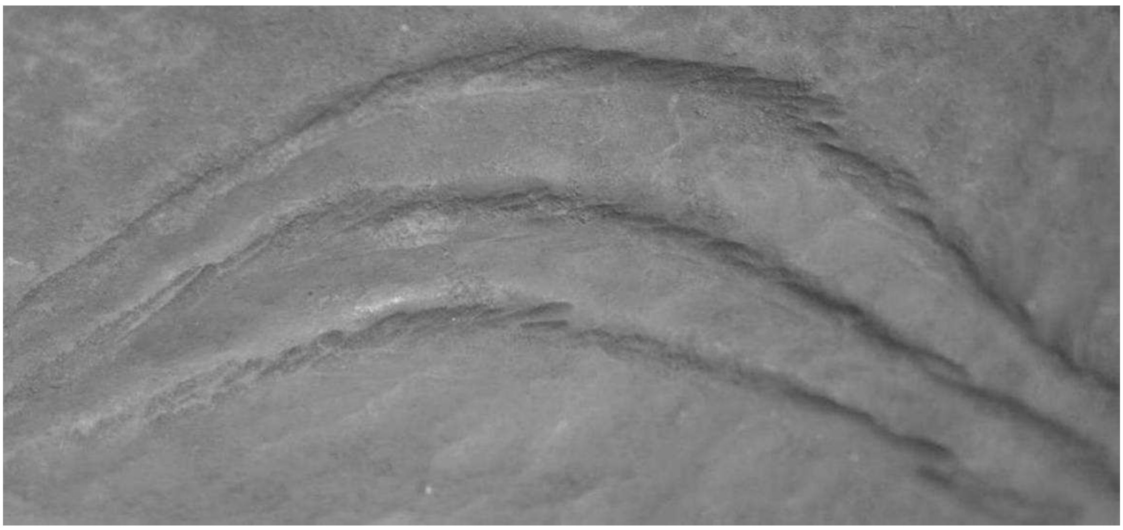

Figure 250. Interior detail of III.1325.

Figure 251. Interior detail of III.1325.

Figure 252. Interior of III.1325's fauld.

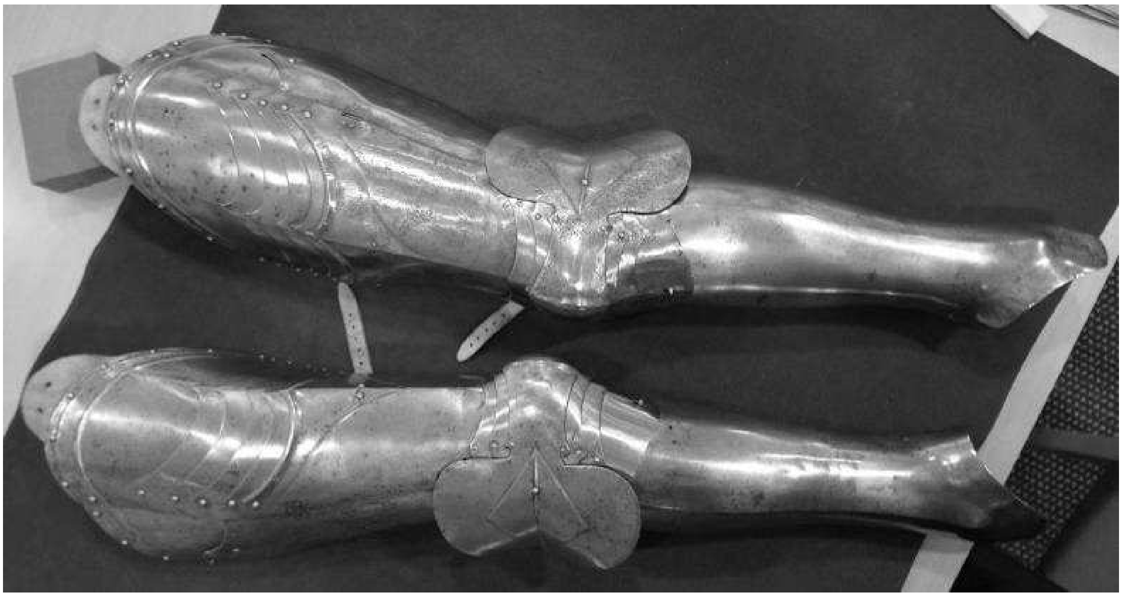

Figure 253. Leg harness II.3.

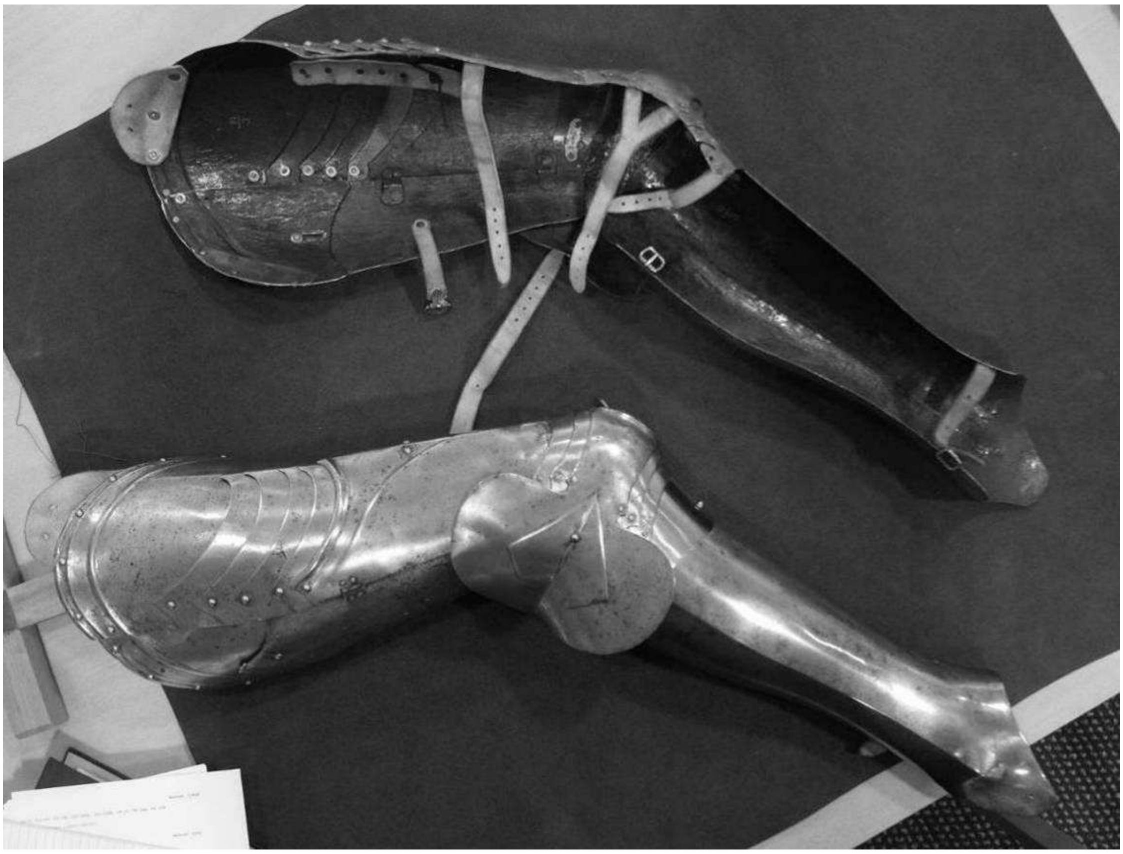

Figure 254. Leg harness II.3.

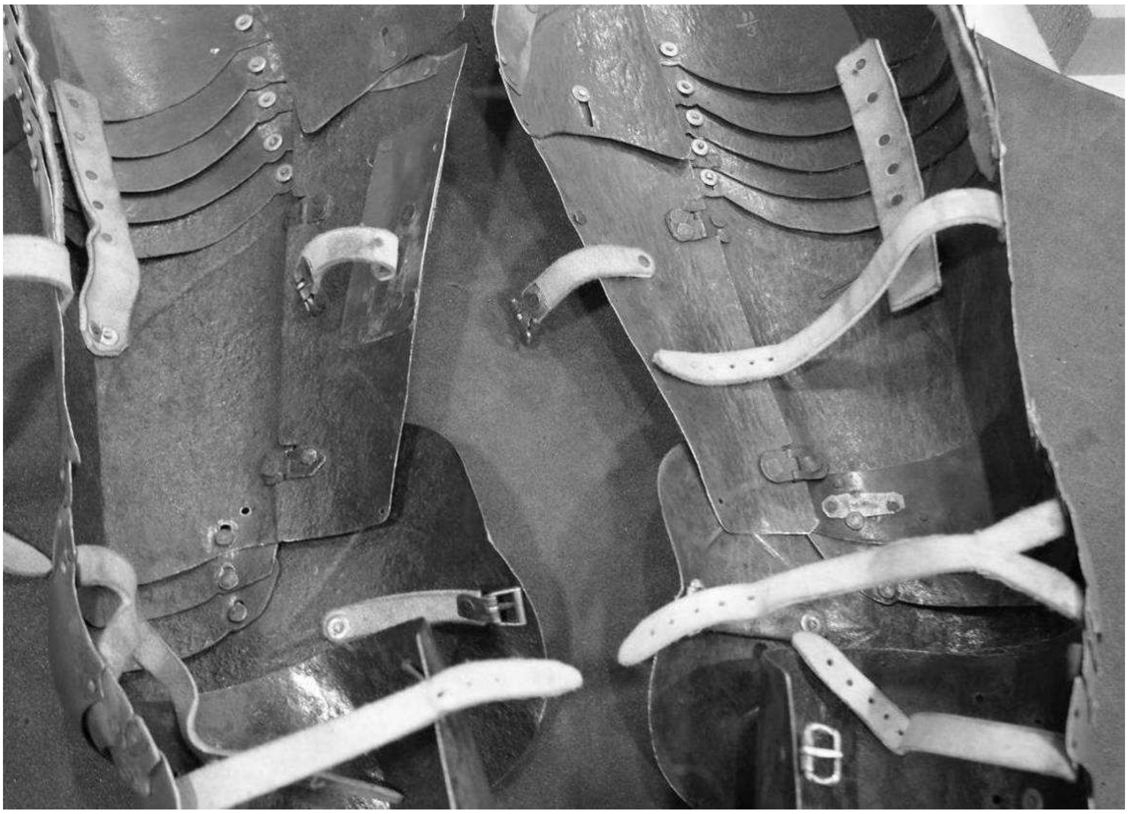

Figure 255. Comparison of the interior of II.3. Note how corrosion has only obliterated the marks on the right cuisse (left side of photo).

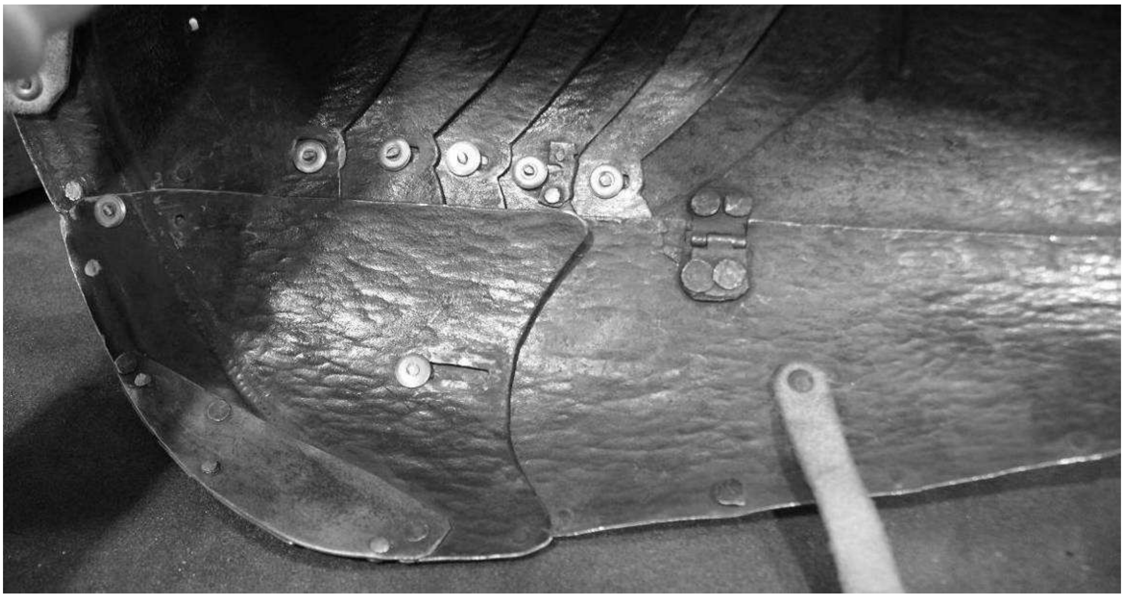

Figure 256. Interior of leg harness II.3, left.

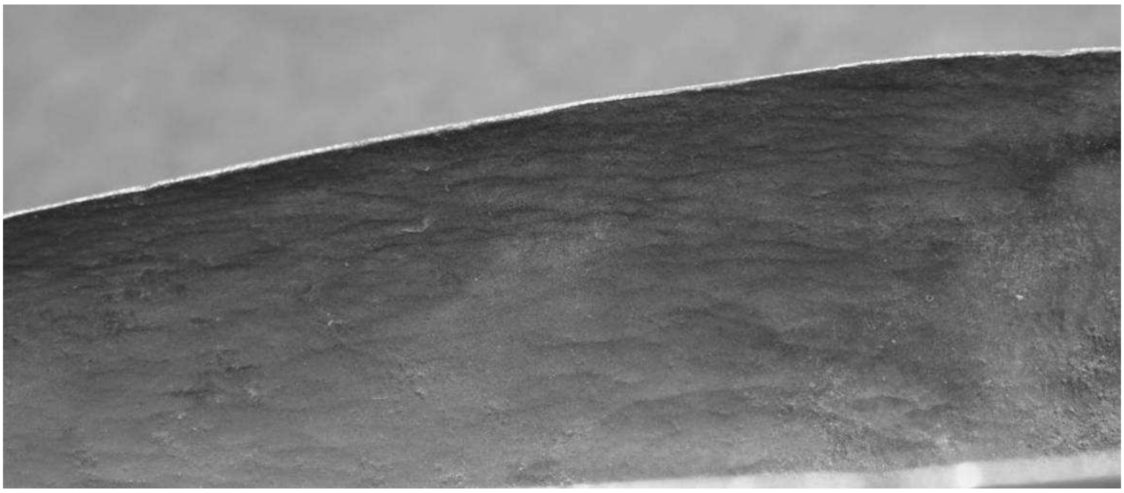

Figure 257. Interior of greave of II.3, showing oblong curling marks.

Figure 258. Interior of greave of II.3, showing oblong curing marks.

Figure 259. Tilting sockets from II.167.

Figure 260. Interior knee of II.167.

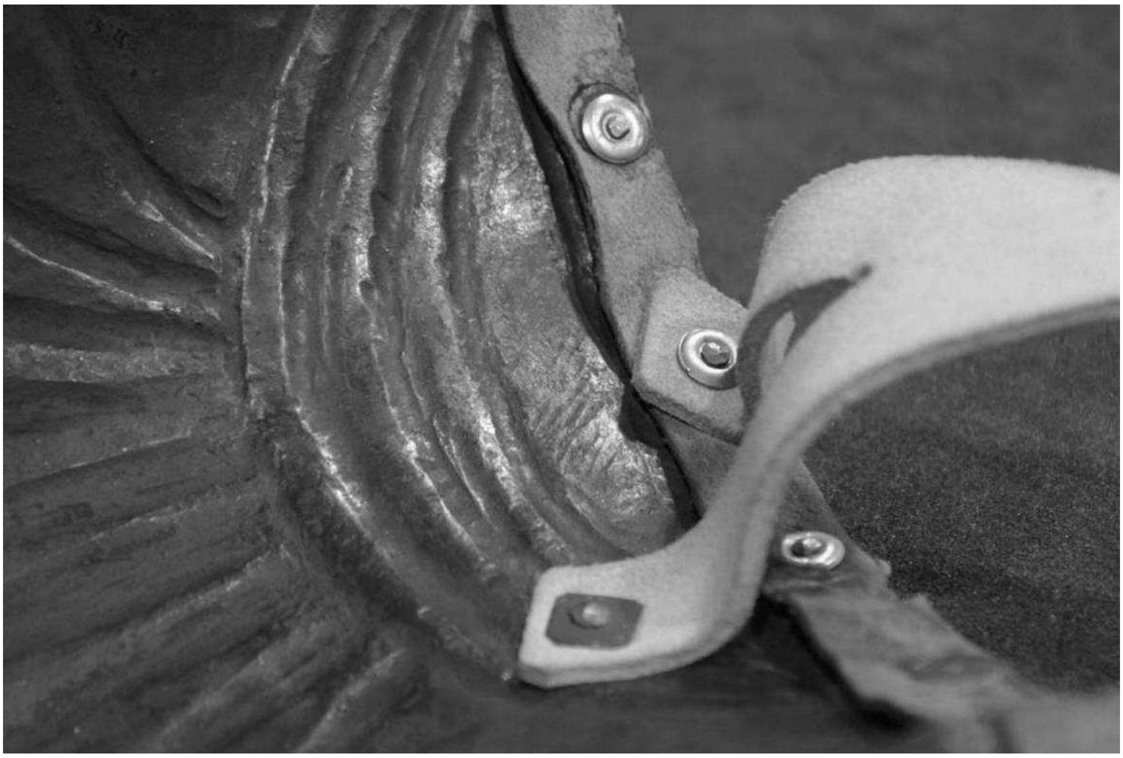

Figure 261. Interior thigh of II.167.

Figure 262. Leg harness II.168 G and H.

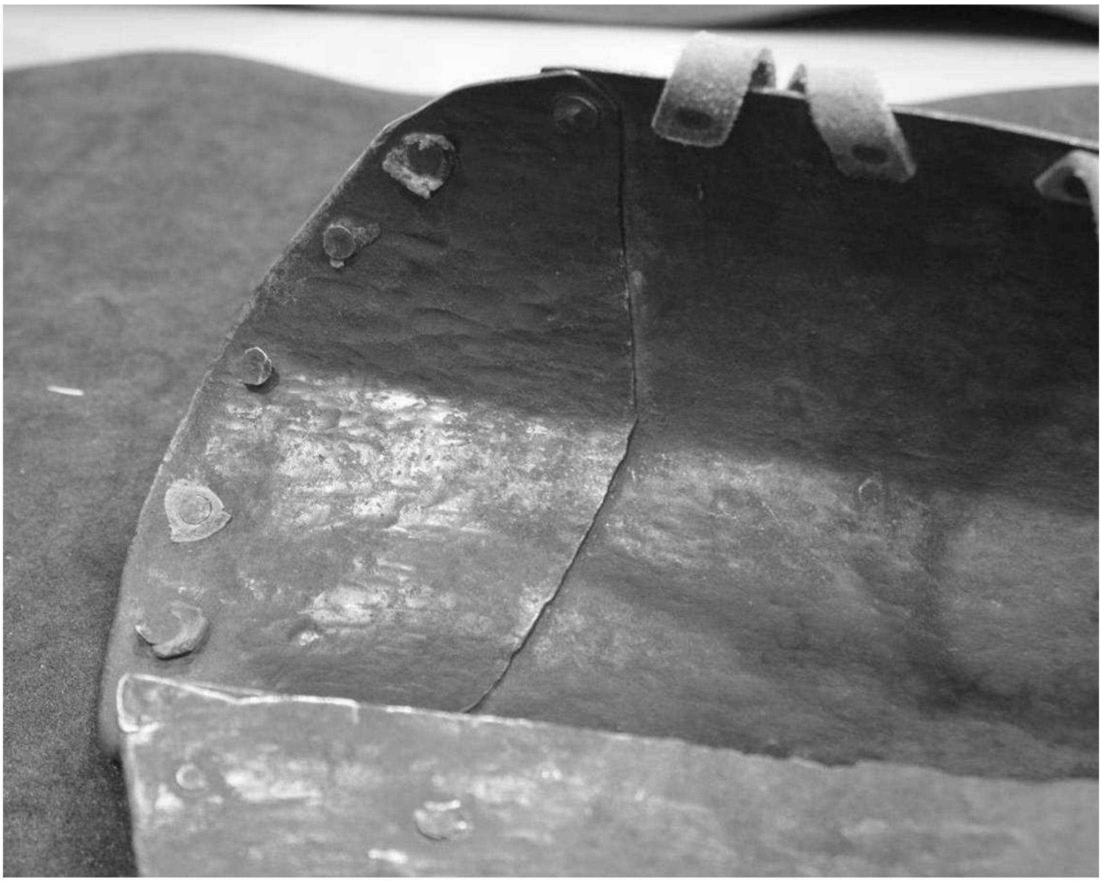

Figure 263. Interior of II.168 H.

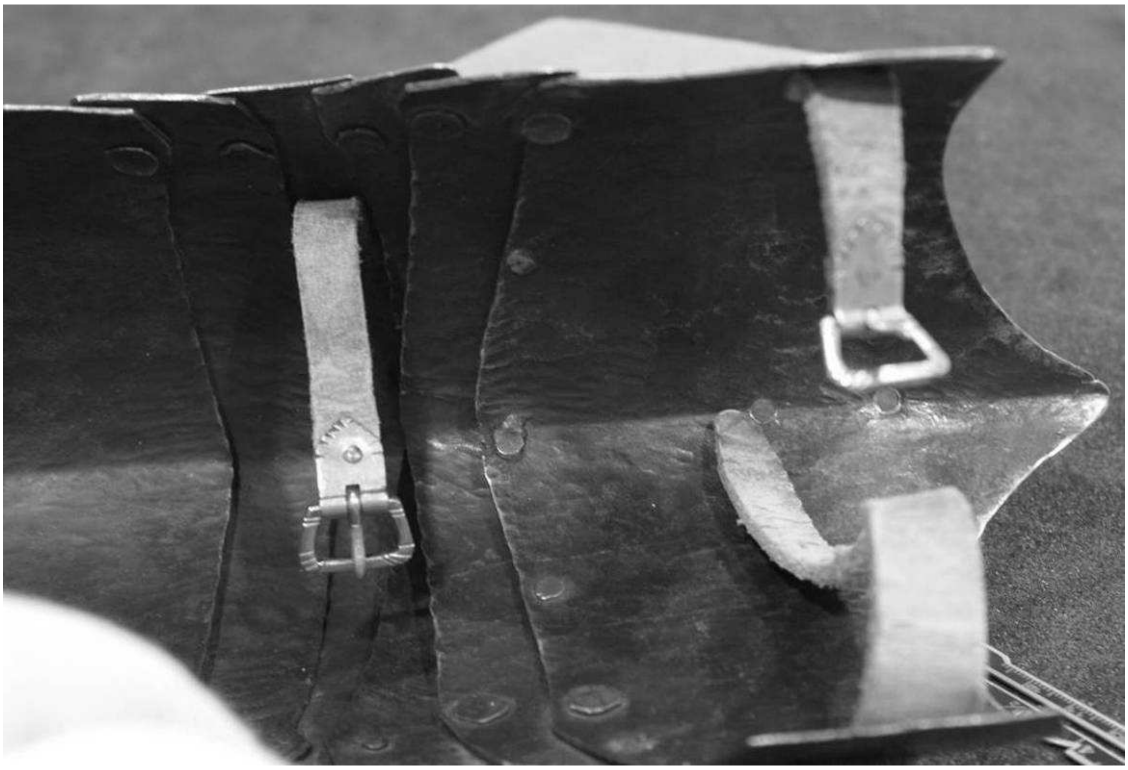

Figure 264. Interior of II.168 H.

Figure 265. Interior of II.168 G.

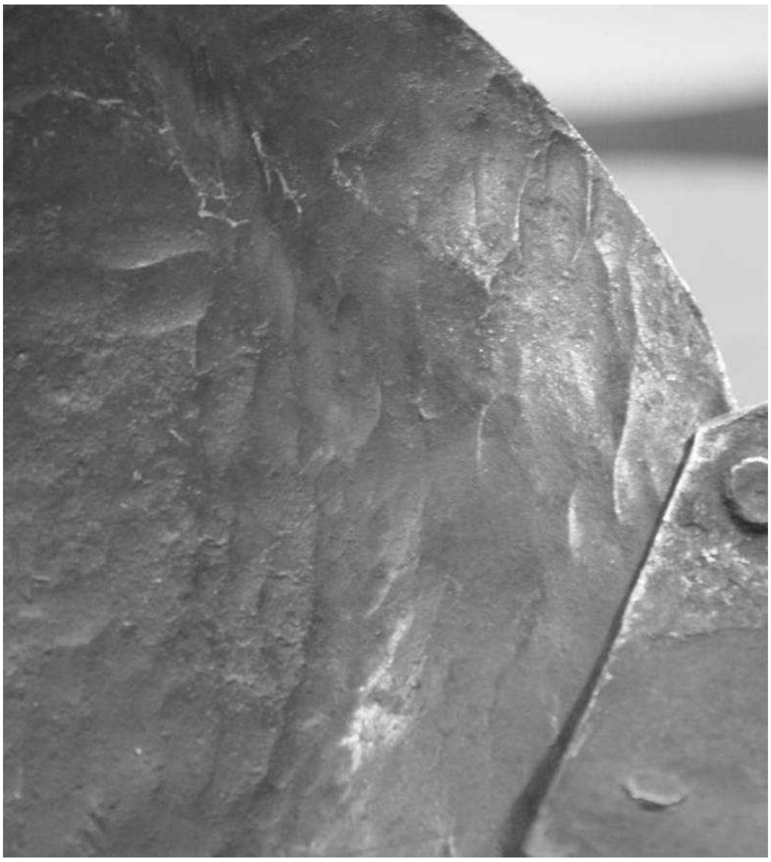

Figure 266. Wing detail, II.168 G.

Figure 267. Leg harness II.168 G, H, I, and J.

Figure 268. Interior of II.168 J.

Figure 269. Interior of II.168 J. Note the oblique marks along the crease.

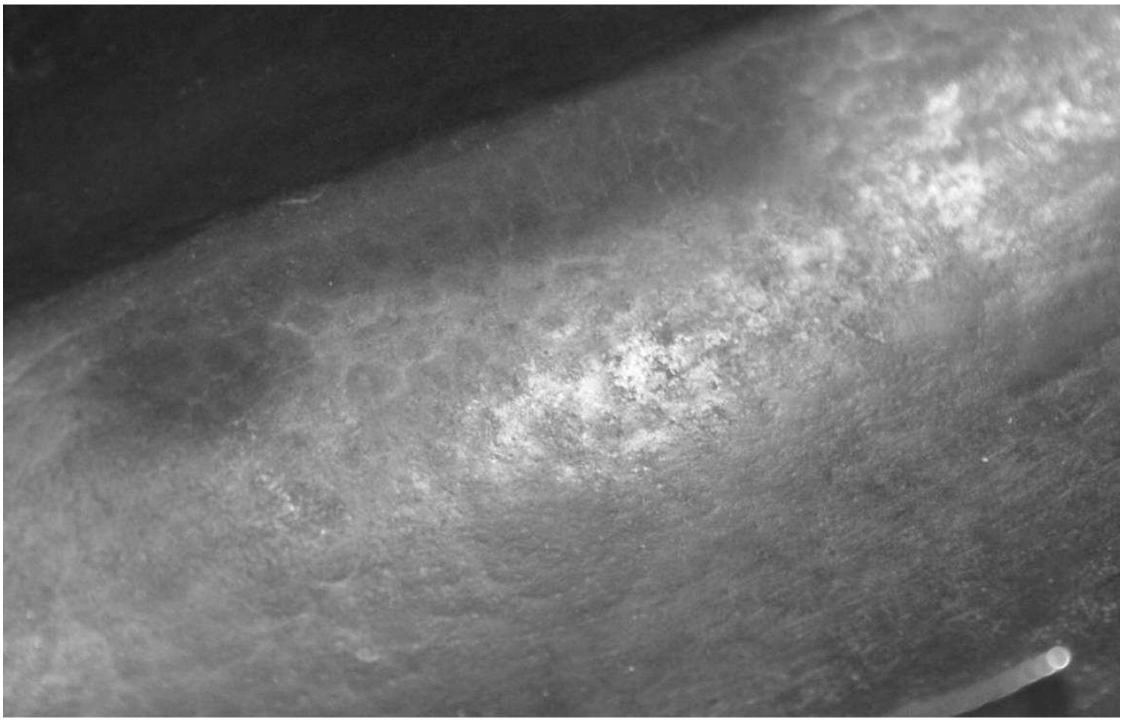

Figure 270. Interior of II.168 J.

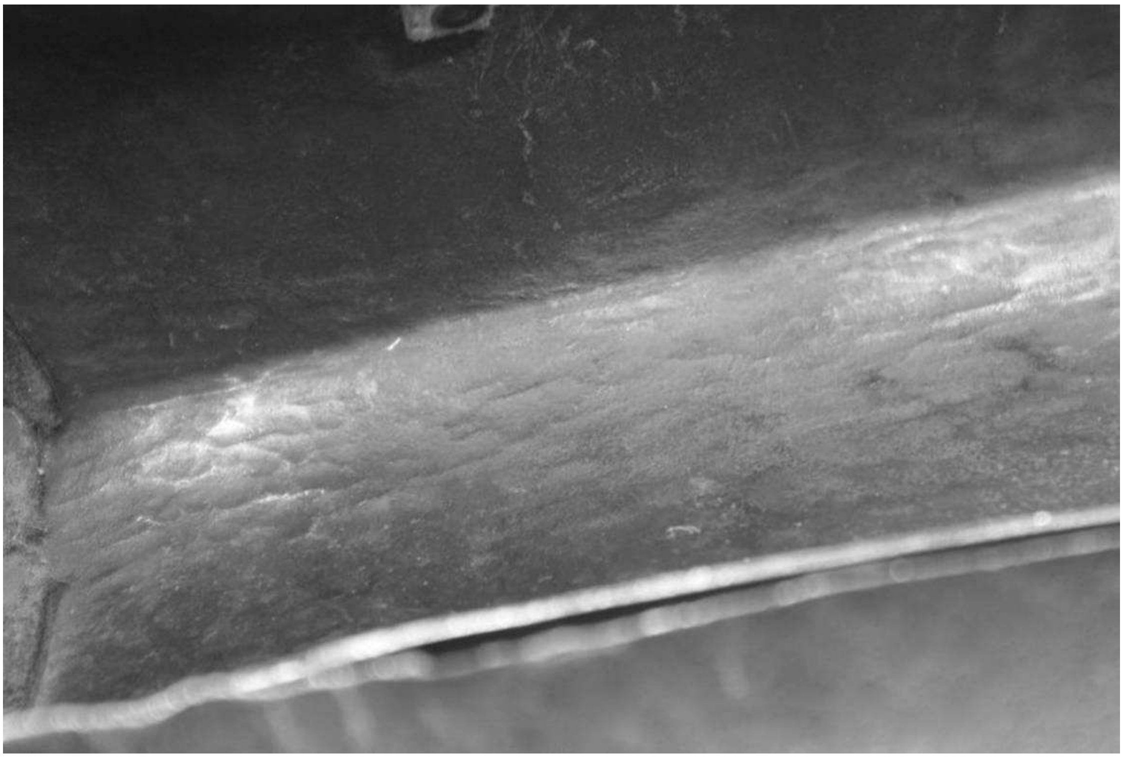

Figure 271. Interior of II.168 I. Note the oblong curling marks.

Figure 272. Interior of II.168 I.

Figure 273. Interior of II.168 I.

Figure 274. E.1939.65.e.10 and 11, left and right greaves of the Avant armour.

Figure 275. Mail sabaton on the left greave.

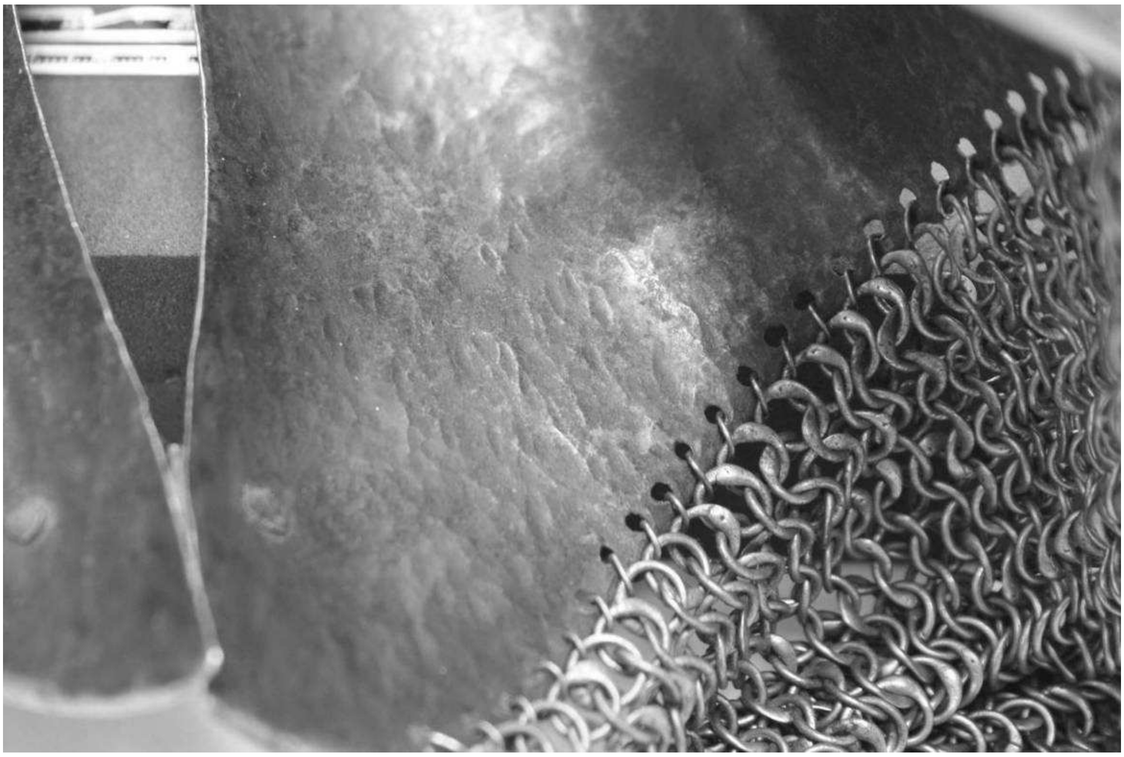

Figure 276. Greave lower interior.

Figure 277. Greave interior.

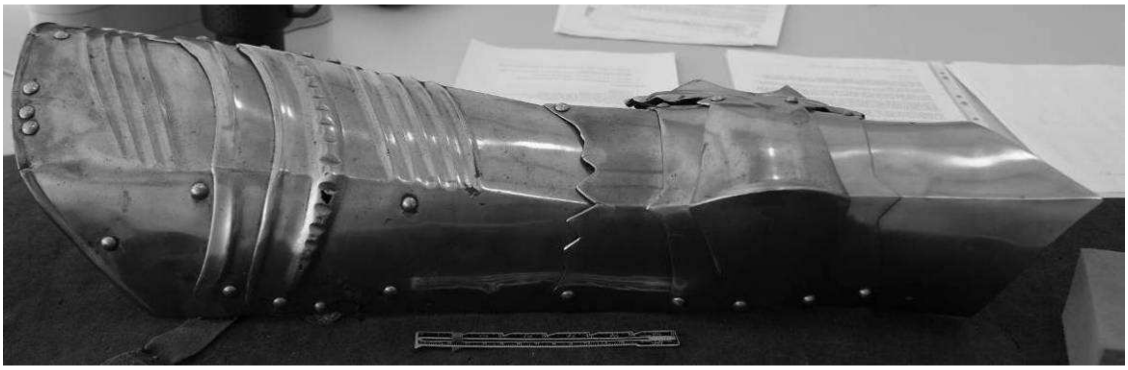

Figure 278. Leg harness III.828.

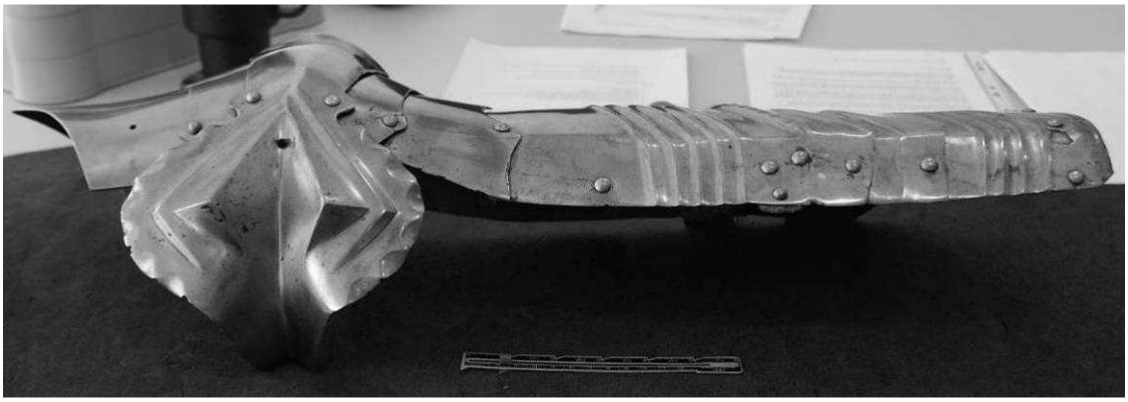

Figure 279. Leg harness III.828.

Figure 280. Bottom of poleyn to III.828. Note the assembly marks on the edge.

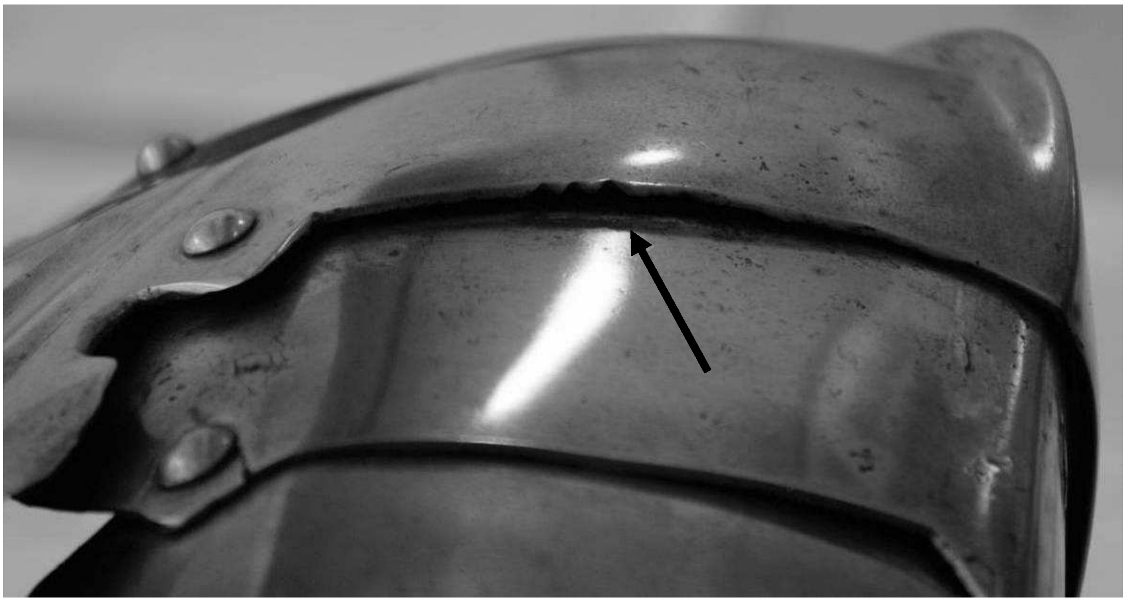

Figure 281. Top of poleyn to III.828. Note assembly marks on the edge.

Figure 282. Interior of cuisse of III.828. Note different colour and quality of upper extension plate.

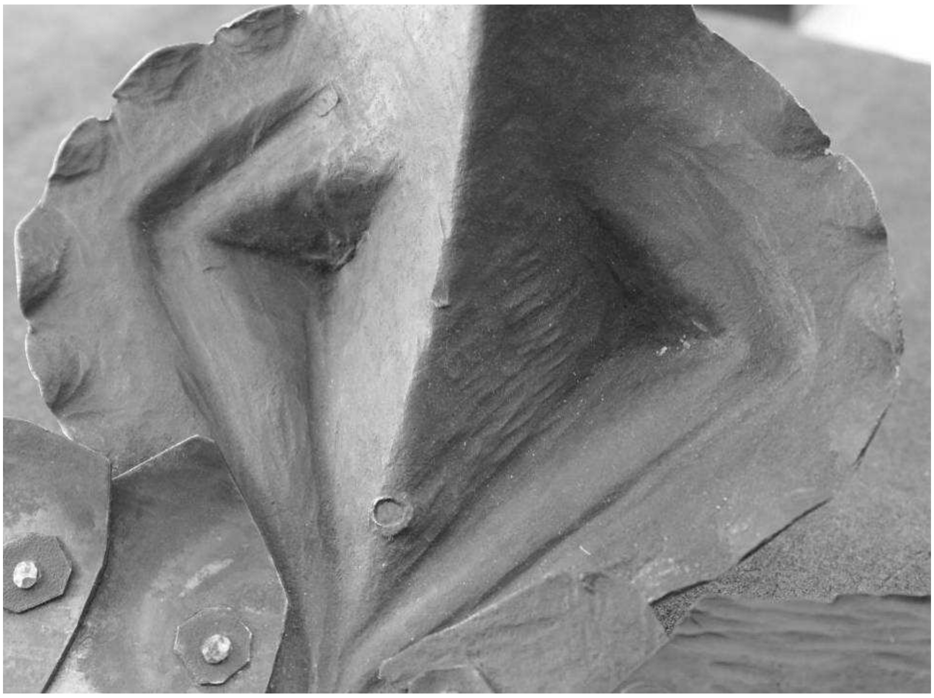

Figure 283. Interior of the wing on III.828.

Figure 284. Sabatons III.1348.

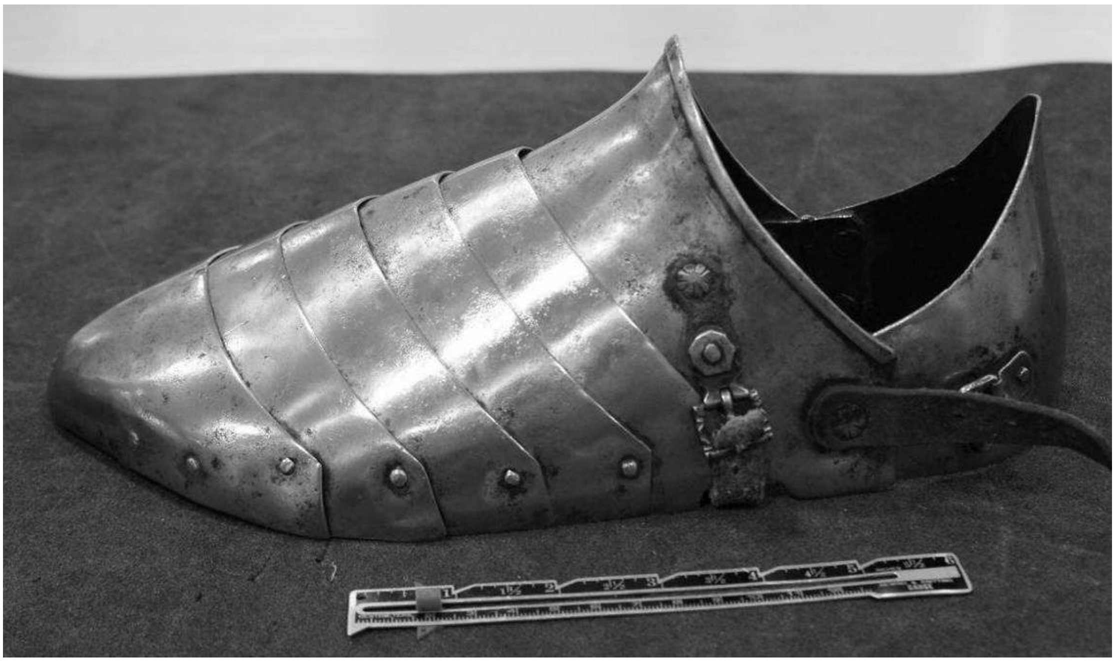

Figure 285. Sabaton III.1348.

Figure 286. Two double-struck maker's stamps.

Figure 287. Interior of the toe of III.1348, showing curling marks.

Figure 288. Flexibility of III.1348.

Figure 289. Couter III.1116.

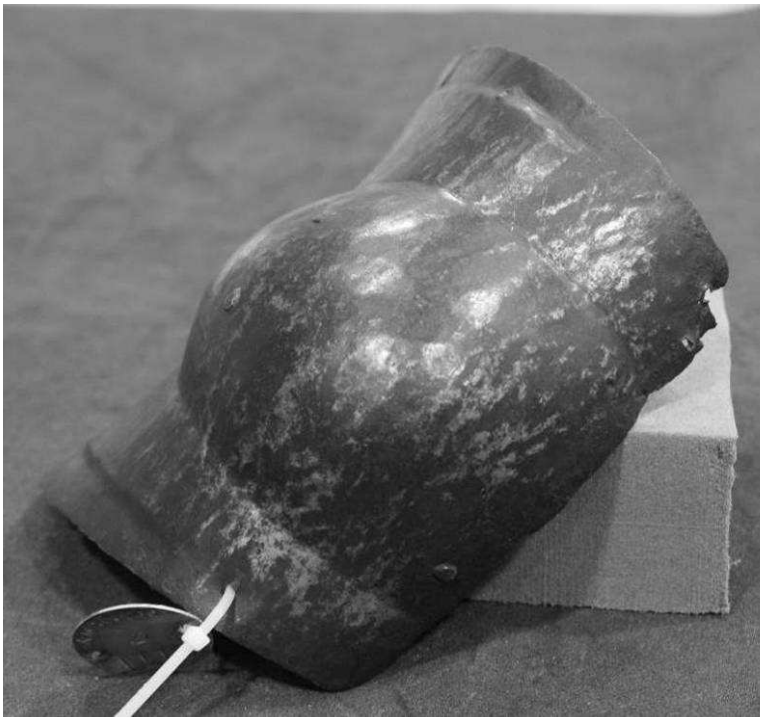

Figure 290. Back of III.1116.

Figure 291. Couter AL.23 107.

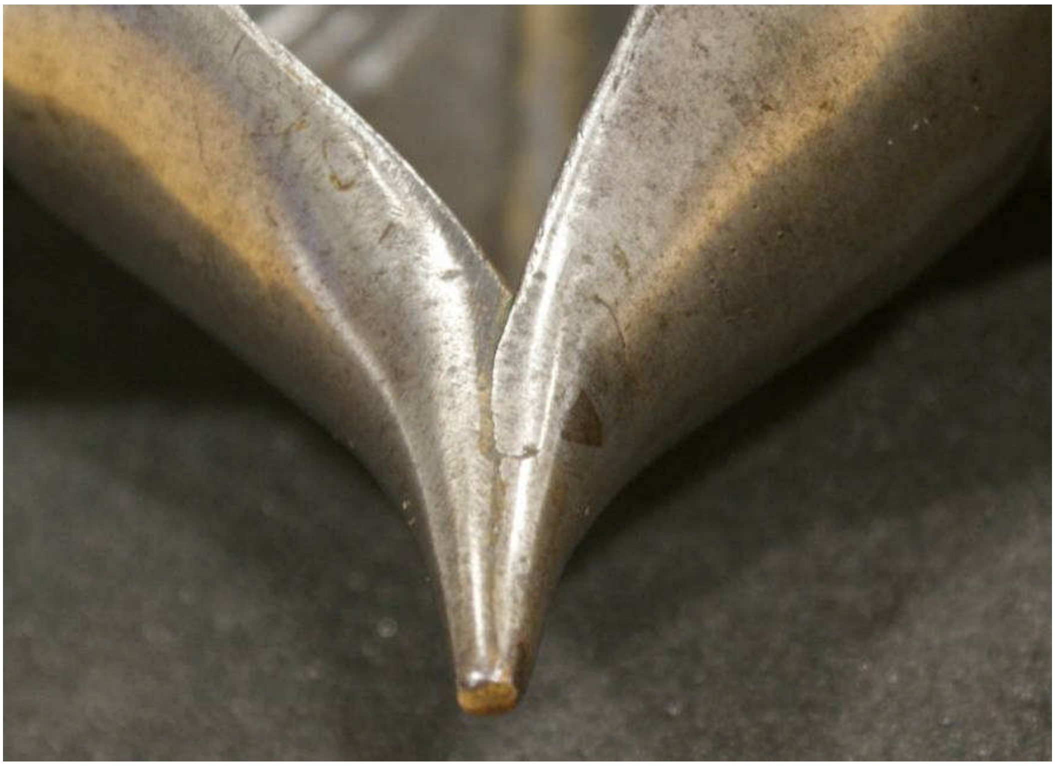

Figure 292. Cone of AL.23 107, showing brazed construction.

Figure 293. Interior of AL.23 107.

Figure 294. Interior of cone of AL.23 107.

Figure 295. Arm harness III.1216.

Figure 296. Interior of III.1216's lower cannon.

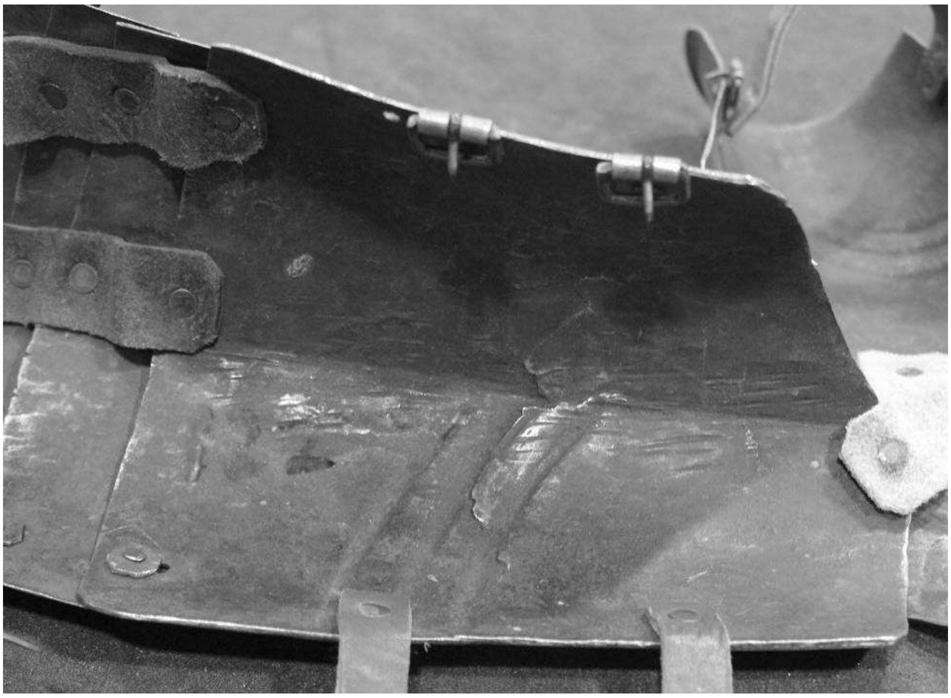

Figure 297. Interior of III.1216's upper cannon. Note long thin marks along the medial crease.

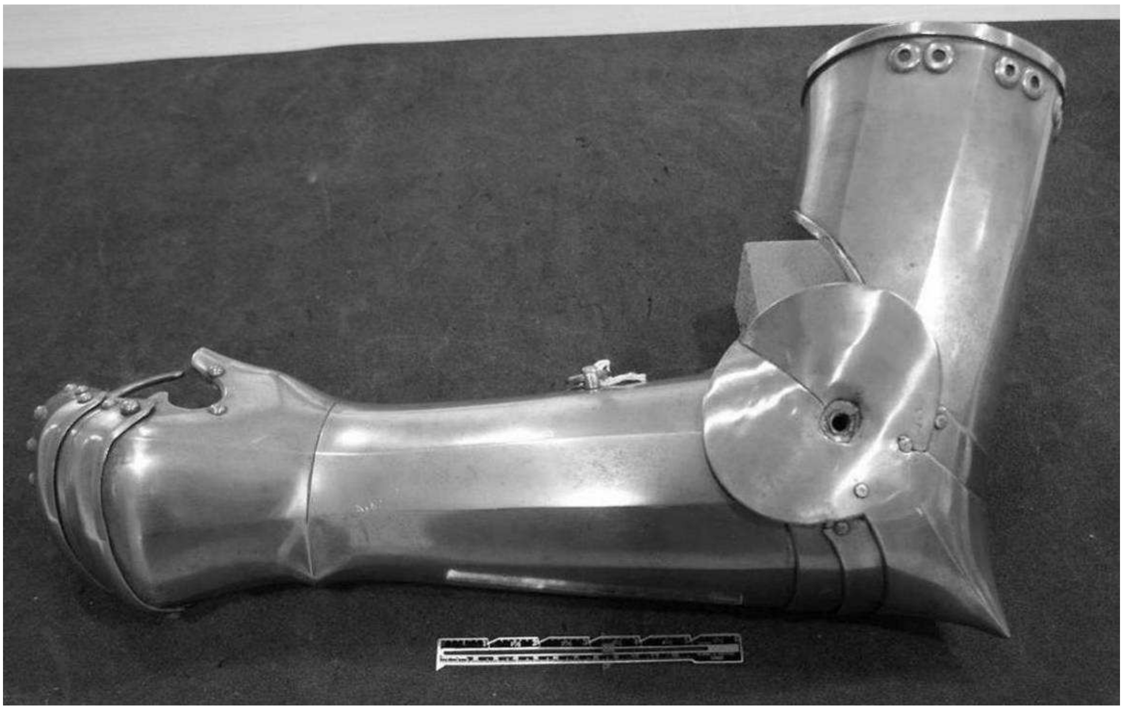

Figure 298. Arm harness AL.90.

Figure 299. Inserted thread plate on AL.90.

Figure 300. Interior of couter of AL.90, showing welded seam.

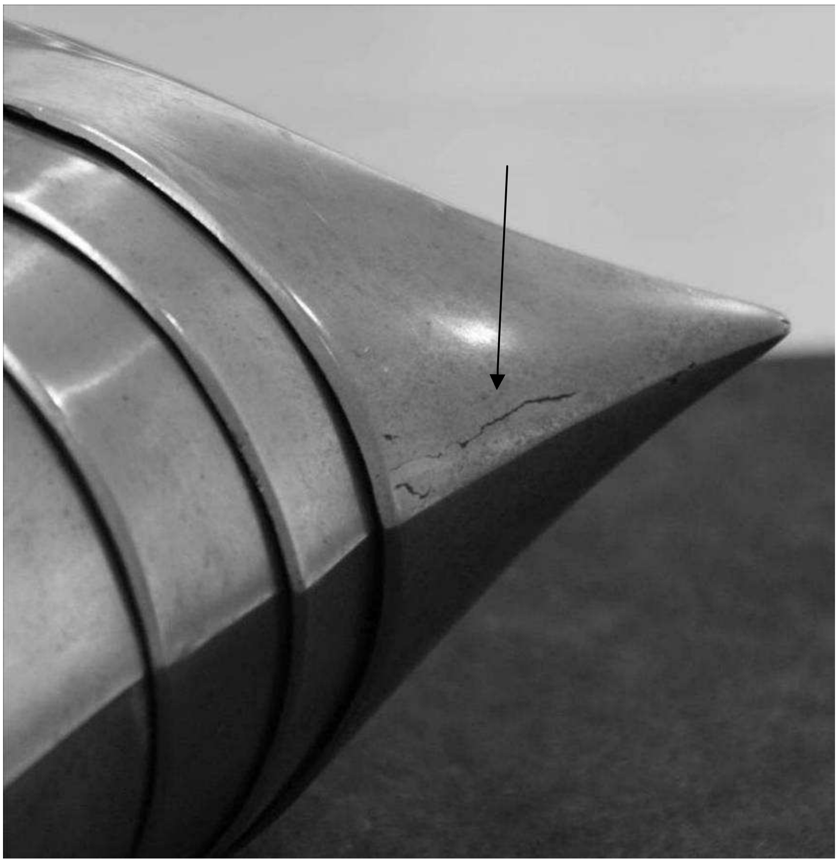

Figure 301. Seam visible on couter of AL.90.

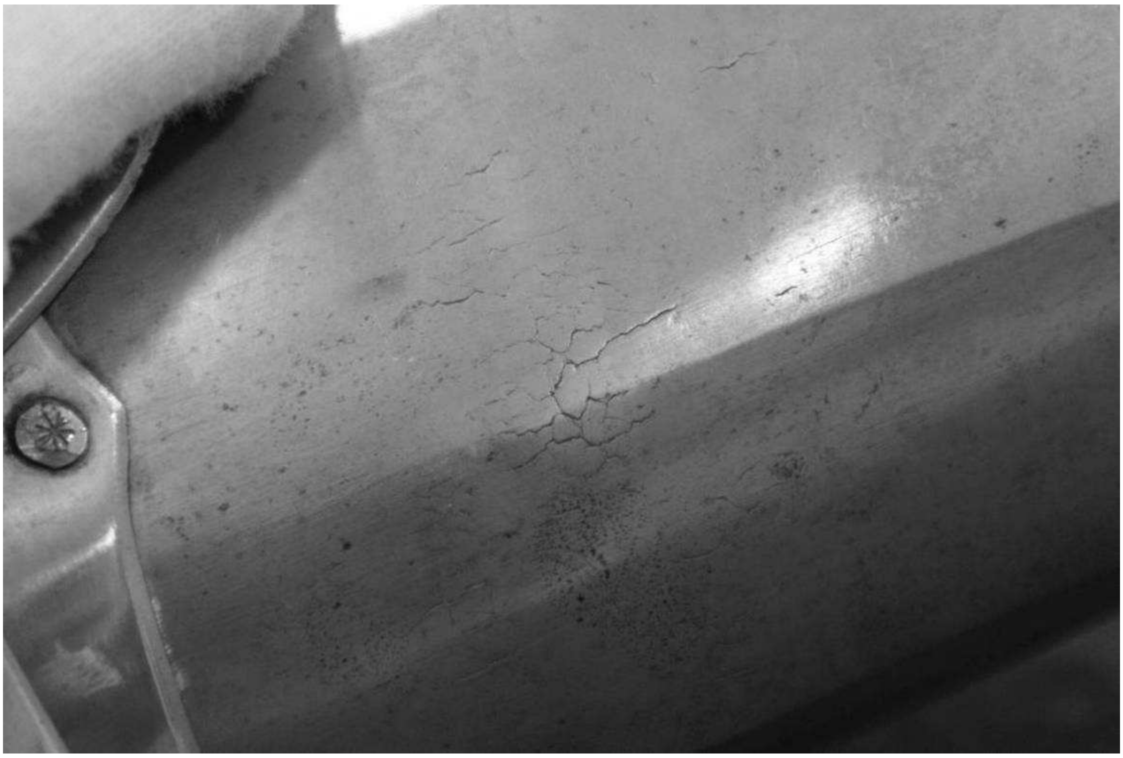

Figure 302. 'Crumbling' caused by hammering above the proper working temperature or overheating.

Figure 303. E.1939.65.e.6, left arm harness of the Avant armour.

Figure 304. Interior of upper cannon, showing broadly oblong curling marks.

Figure 305. Interior of lower cannon.

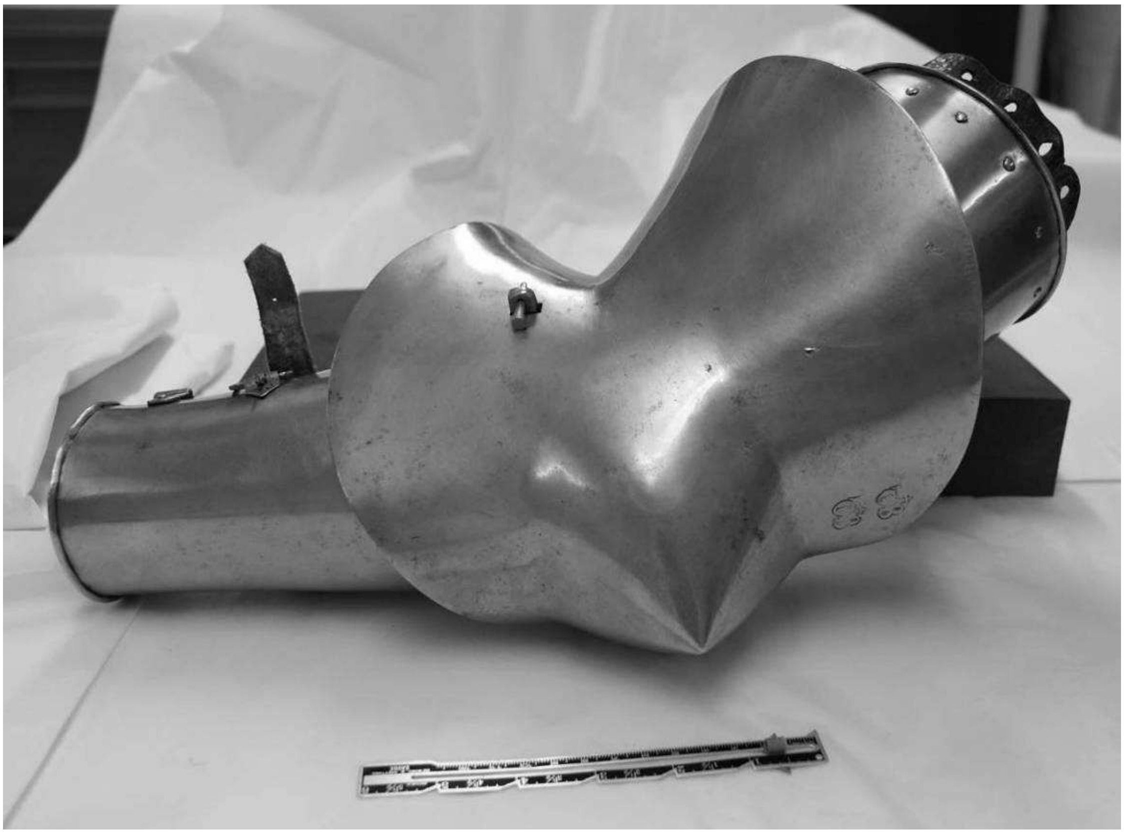

Figure 306. Couter reinforce in place on the arm harness.

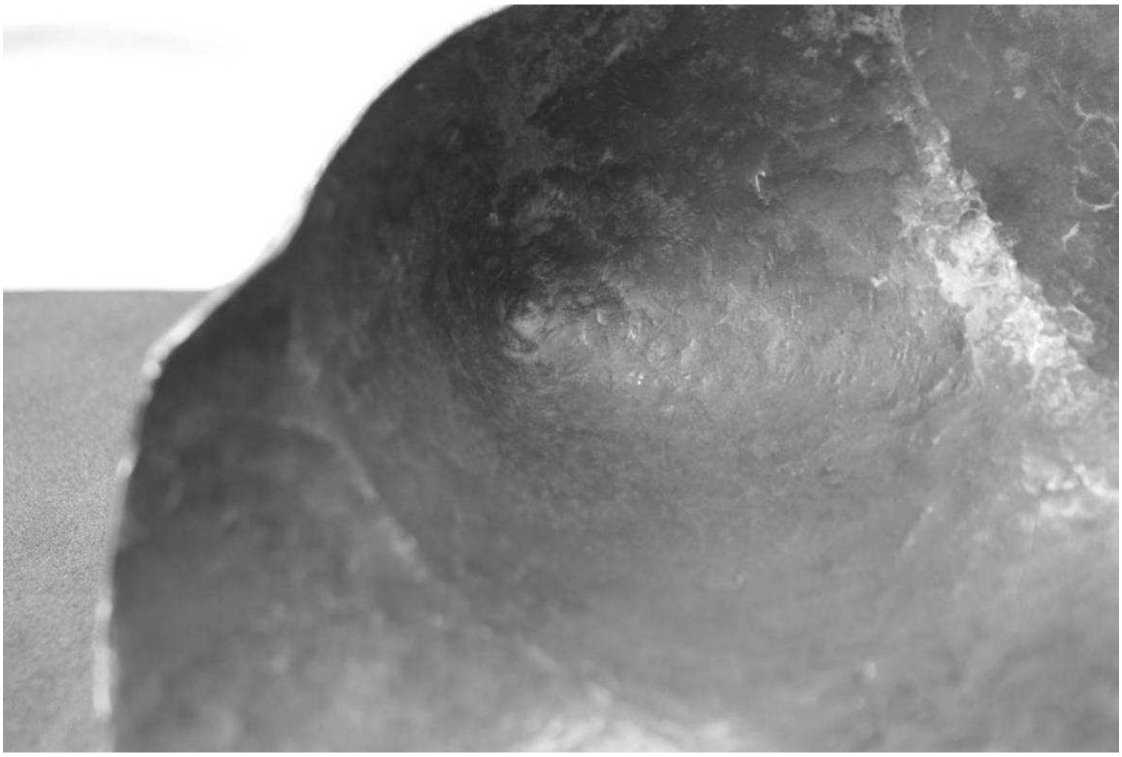

Figure 307. Interior of the reinforce.

Figure 308. Interior of reinforce's wing.

Figure 309. E.1939.65.e.4, left pauldron and reinforce of the Avant armour.

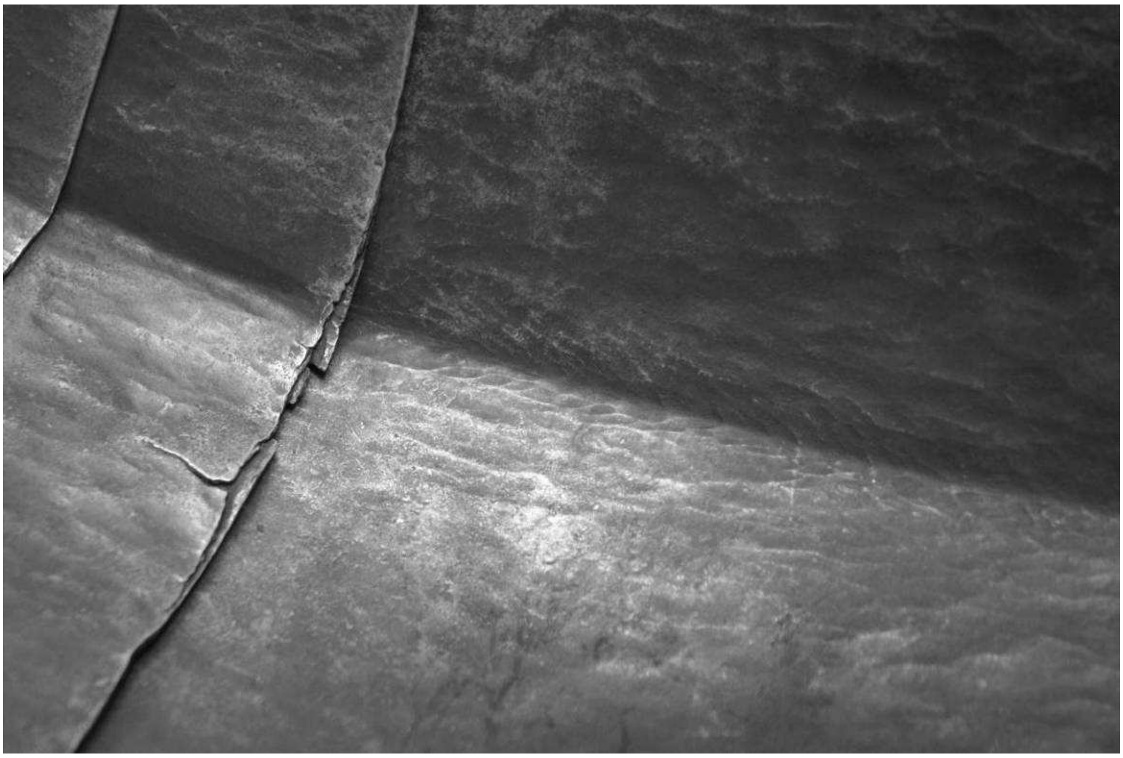

Figure 310. Interior of Avant armour left pauldron. Note the oblique marks.

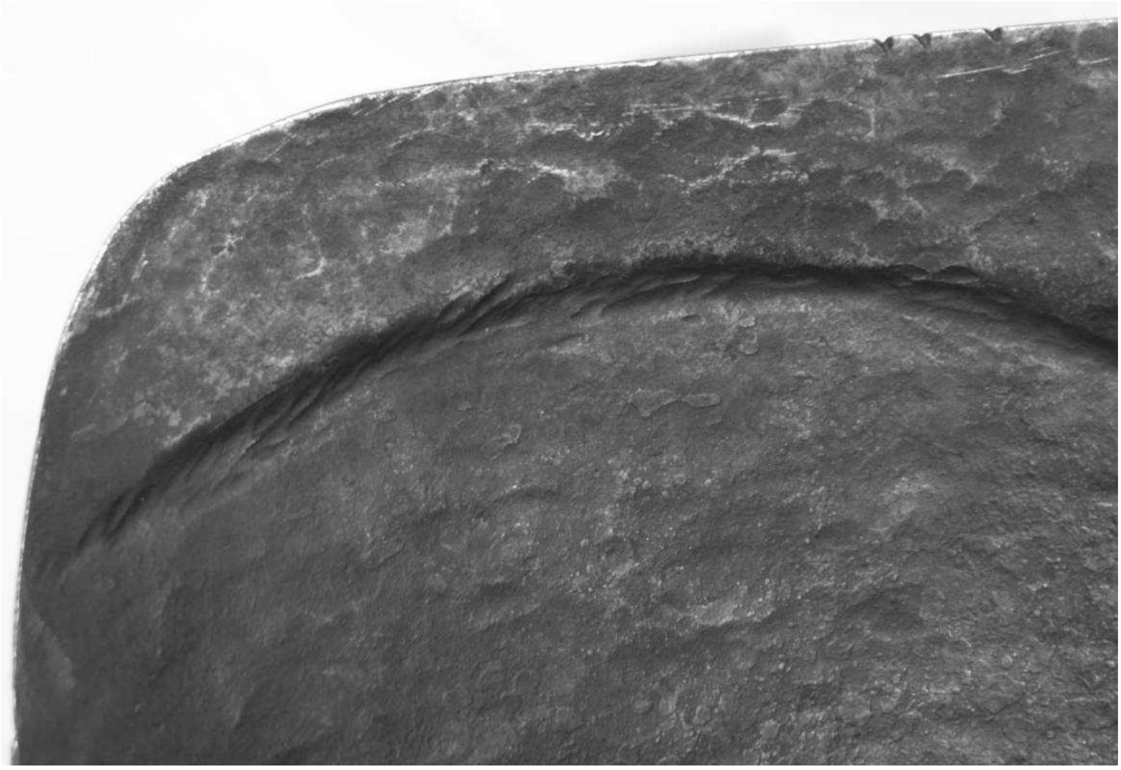

Figure 311. Interior of Avant armour left pauldron, again showing oblique marks.

Figure 312. Pauldron reinforce plate.

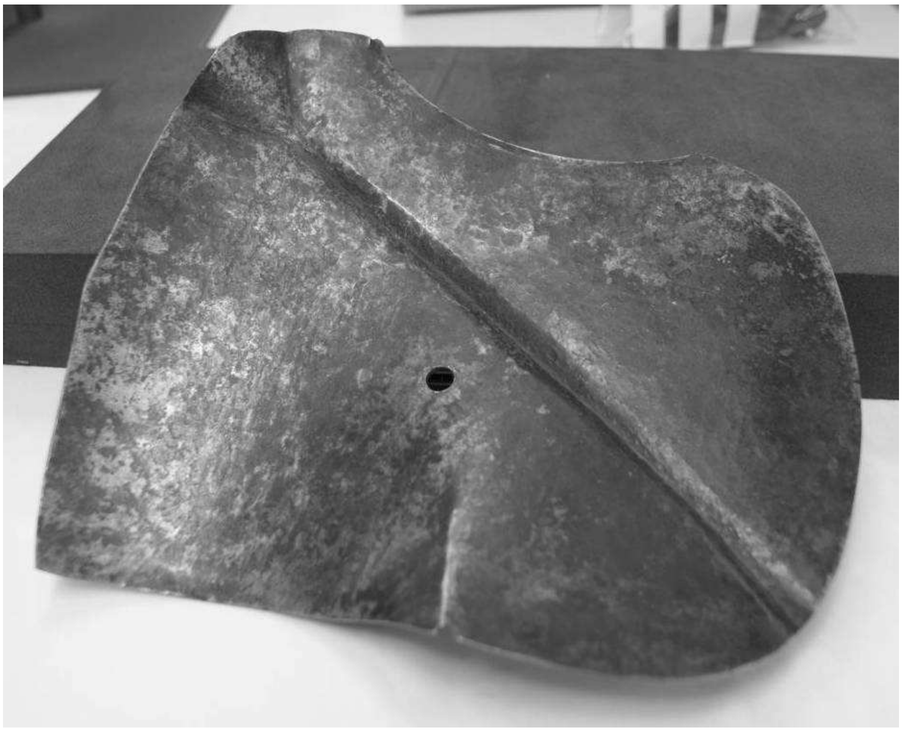

Figure 313. Pauldron reinforce plate interior.

Figure 314. E.1939.65.e.5, right pauldron of the Avant armour.

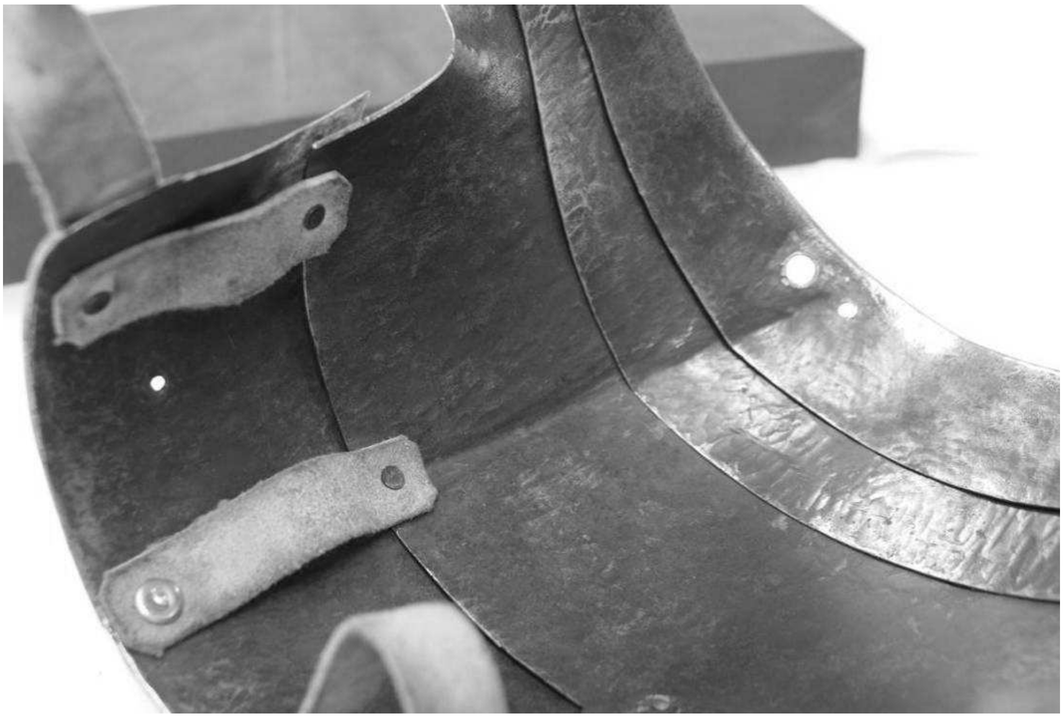

Figure 315. Interior of Avant armour's right pauldron.

Figure 316. Gauntlet III.1918.

Figure 317. III.1918.

Figure 318. Traces of decoration on III.1918.

Figure 319. Curling marks inside III.1918.

Figure 320. Seam in cuff of III.1918.

Figure 321. Seam in III.1918 showing signs of modification.

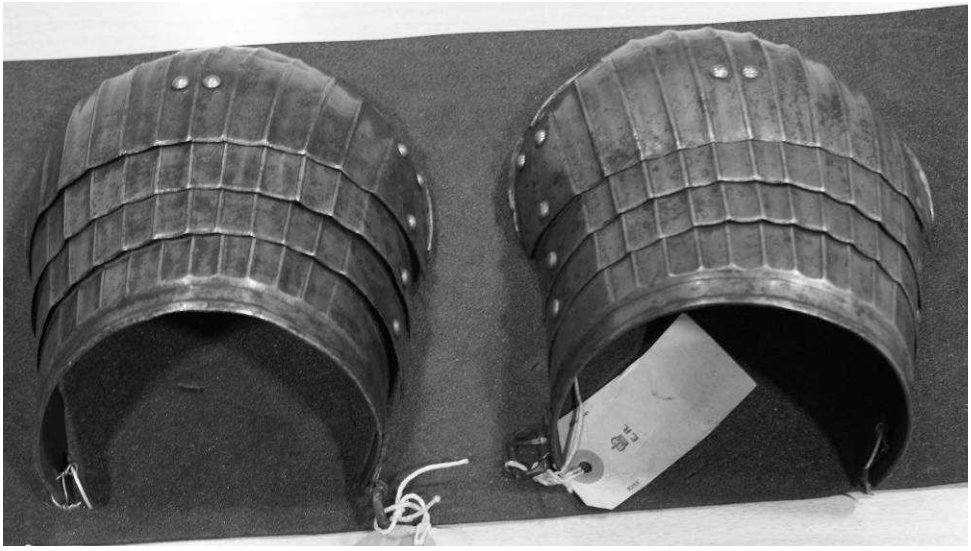

Figure 322. III.1698 and III.1699.

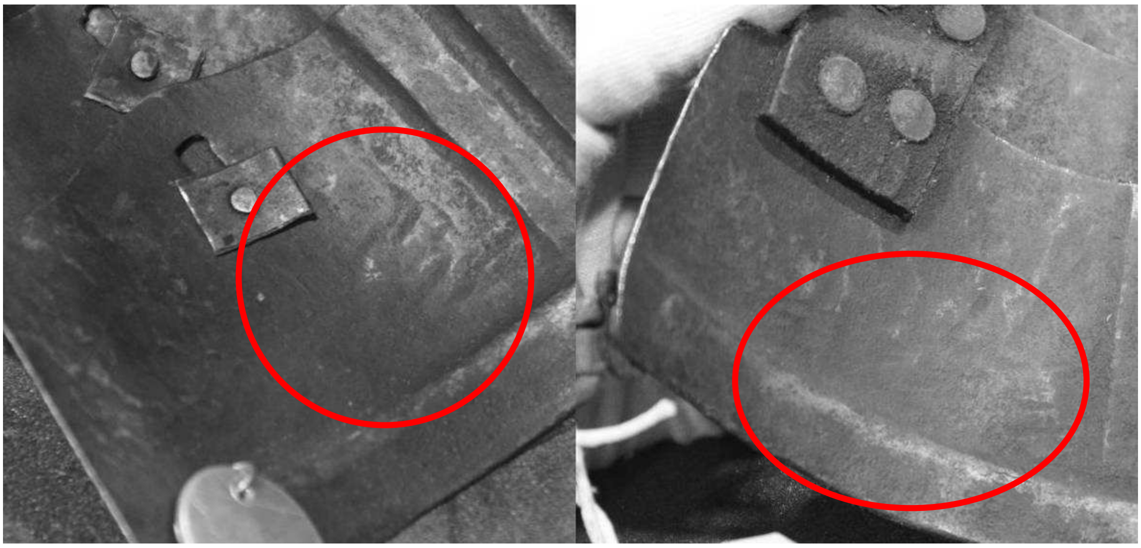

Figure 323. Interesting mark pattern in III.1698 and III.1699.

Figure 324. Gauntlets II.3. The left-hand gauntlet is not original.

Figure 325. Interior of II.3's gauntlets.

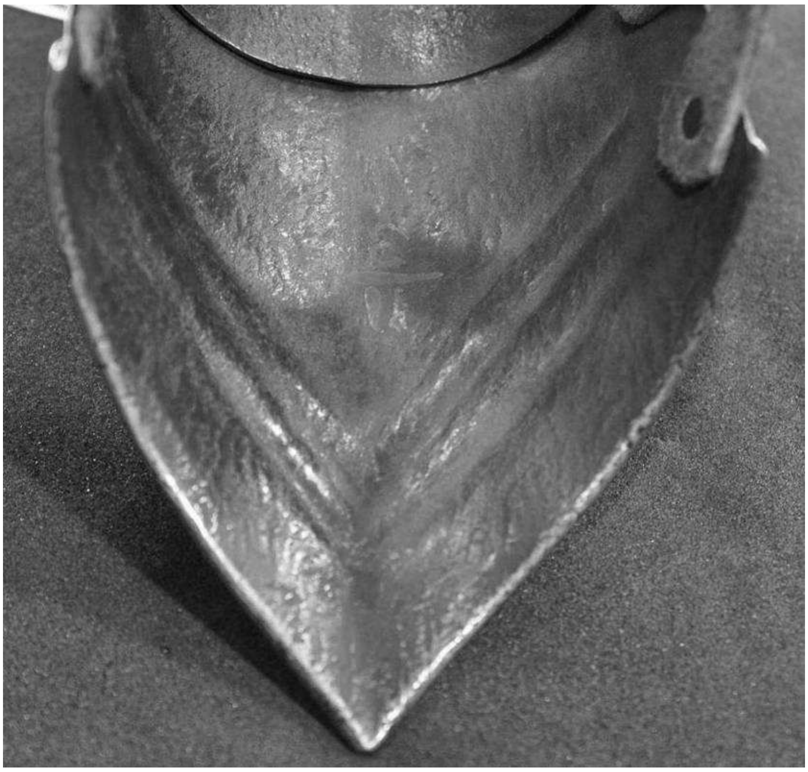

Figure 326. Interior of cuff of II.3.

Figure 327. Comparison of modern (left) and medieval (right) patina and decoration.

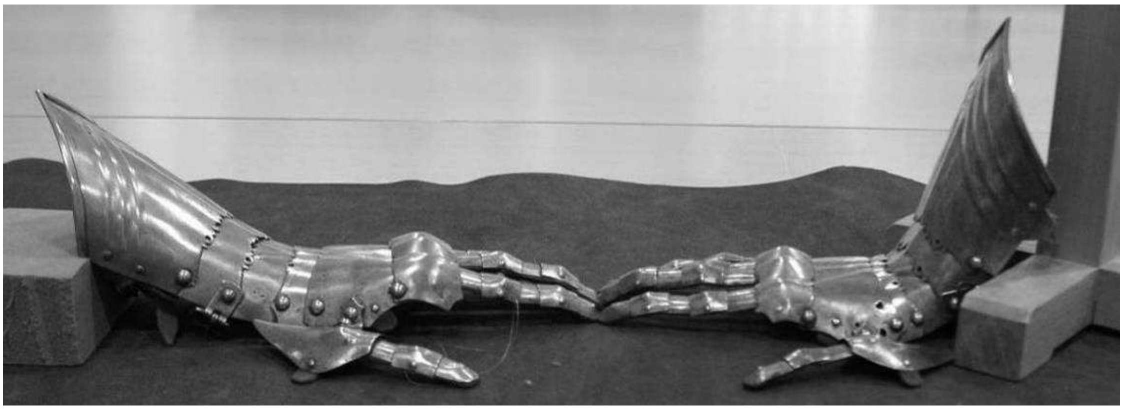

Figure 328. Comparison of flexibility of the gauntlets. Both are flexed as far as their articulations allow.

Figure 329. II.168 D, III.1284, and III.1325.

Figure 330. III.1284 and II.168 D side by side.

Figure 331. Interiors of II.168 D and III.1325.

Figure 332. Interior flute channels of III.1325.

Figure 333. Interior flute channels of II.168 D.

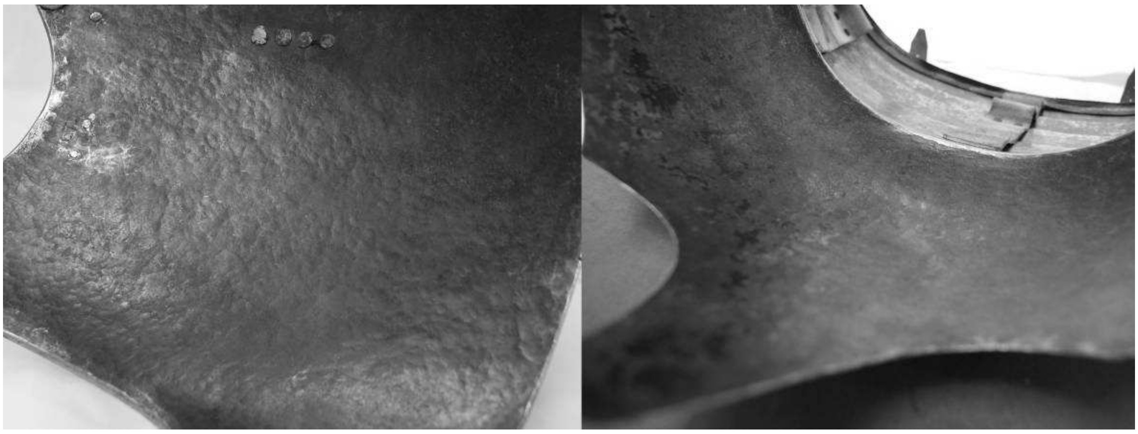

Figure 334. Interiors of the Avant's upper breast (left) and plackart (right).

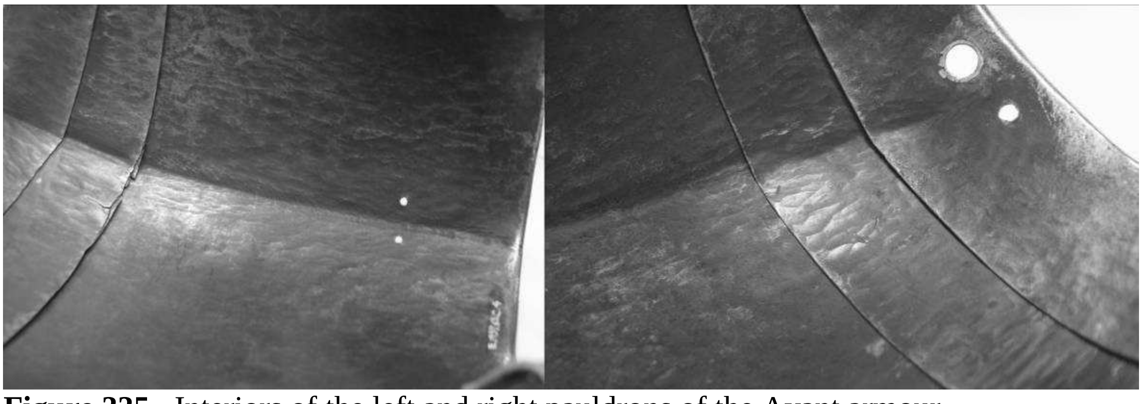

Figure 335. Interiors of the left and right pauldrons of the Avant armour.

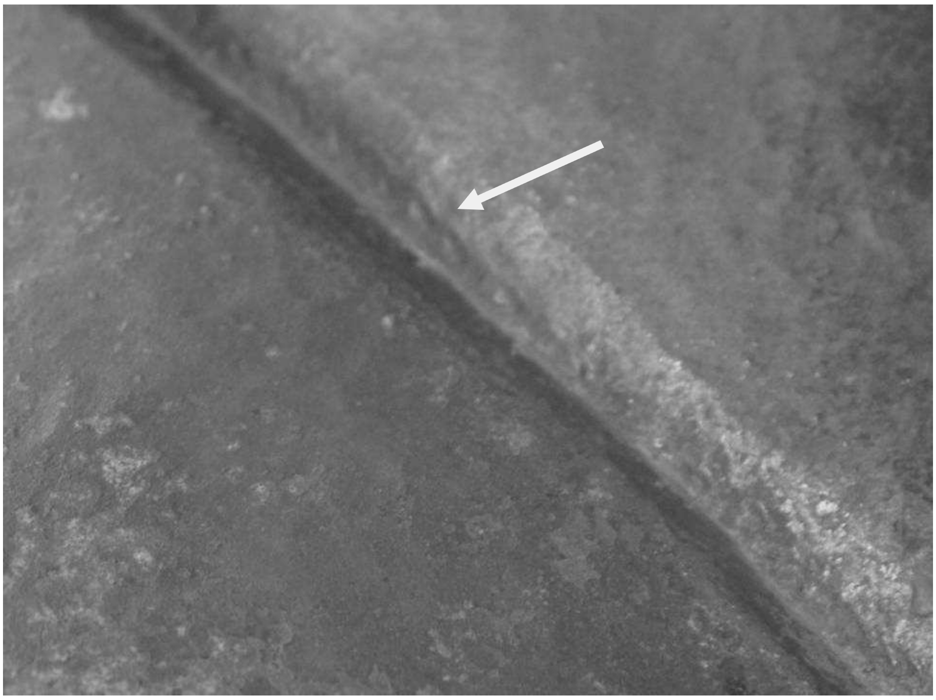

Figure 336. Interior of pauldron reinforce, showing oblique marks.

Figure 337. Left upper cannon of the Avant.

Figure 338. Left upper cannon of the Avant.

Figure 339. Right upper cannon of the Avant.

Figure 340. Right lower cannon of the Avant.

Figure 341. Right couter.

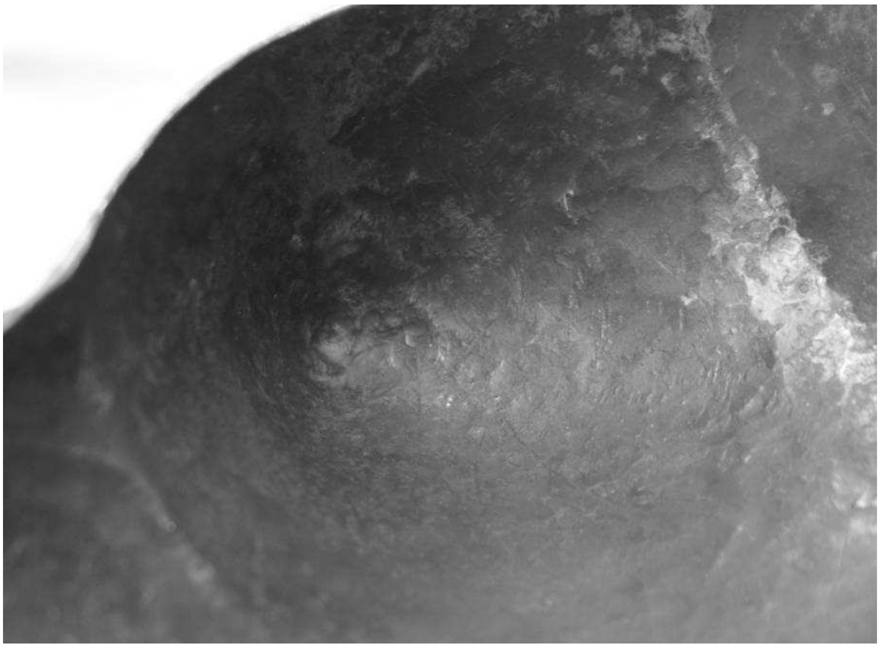

Figure 342. Interior of the couter reinforce.

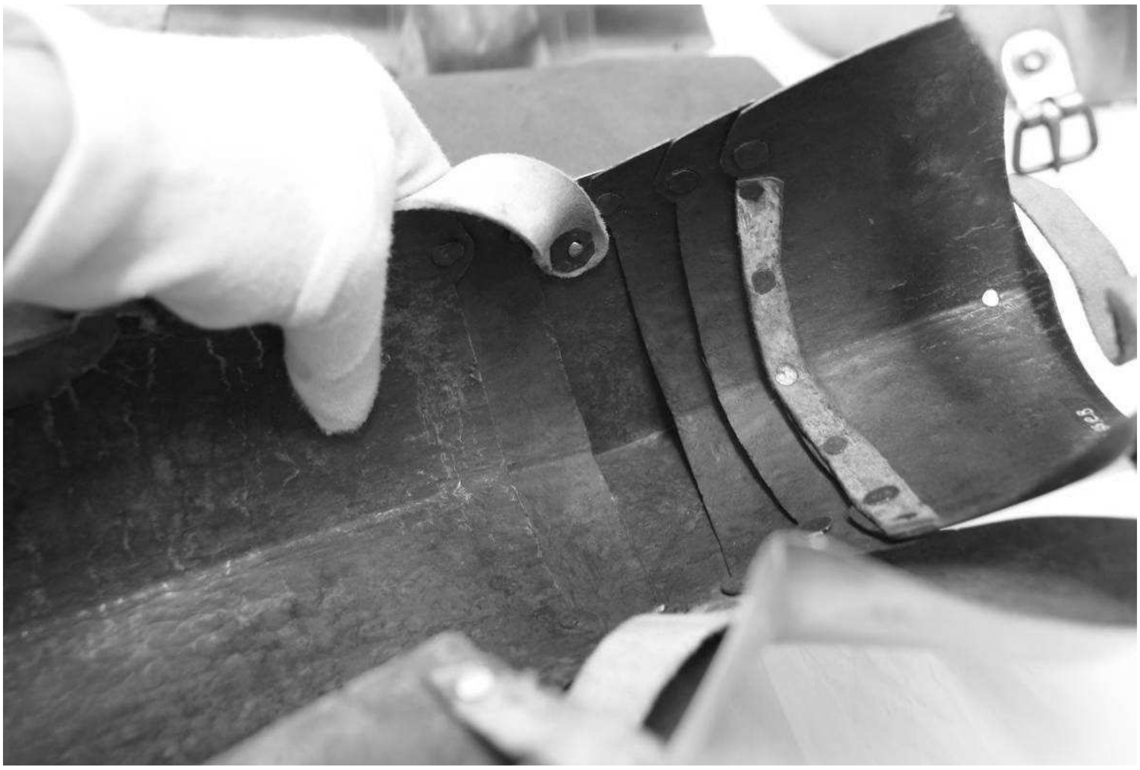

Figure 343. Interior of the left cuisse and poleyn of the Avant.

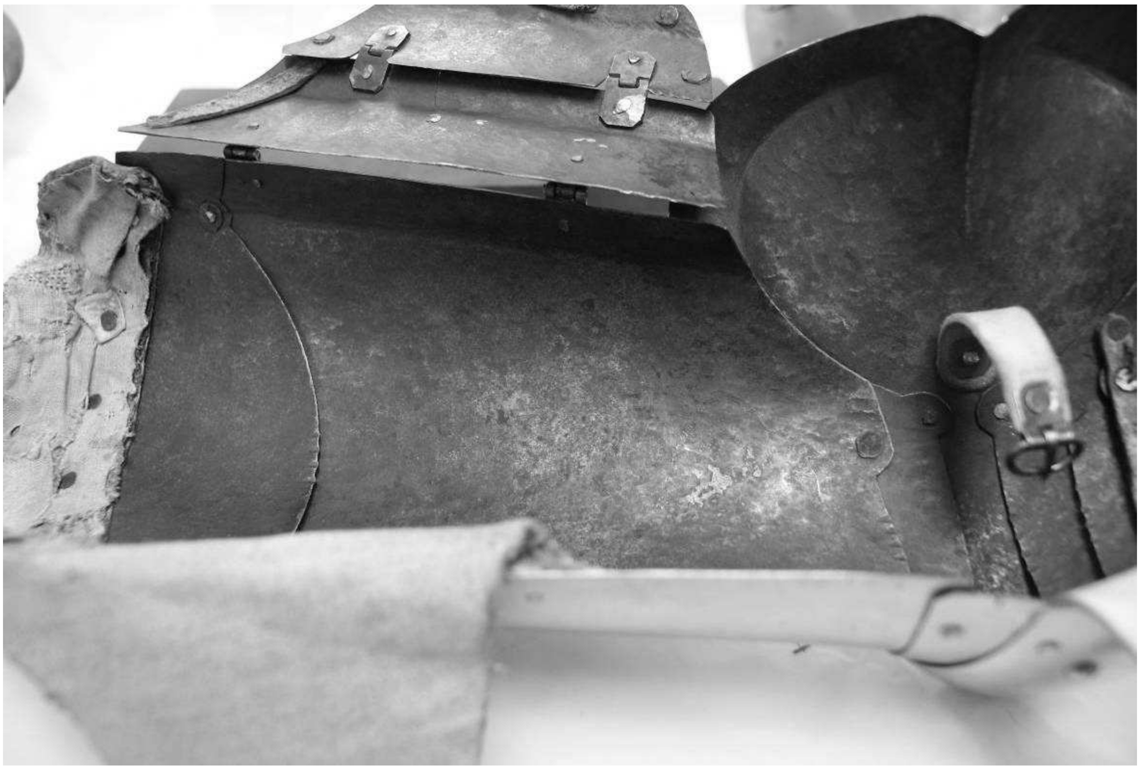

Figure 344. Interior of the right cuisse and poleyn.

Figure 345. Avant armour greave interior.

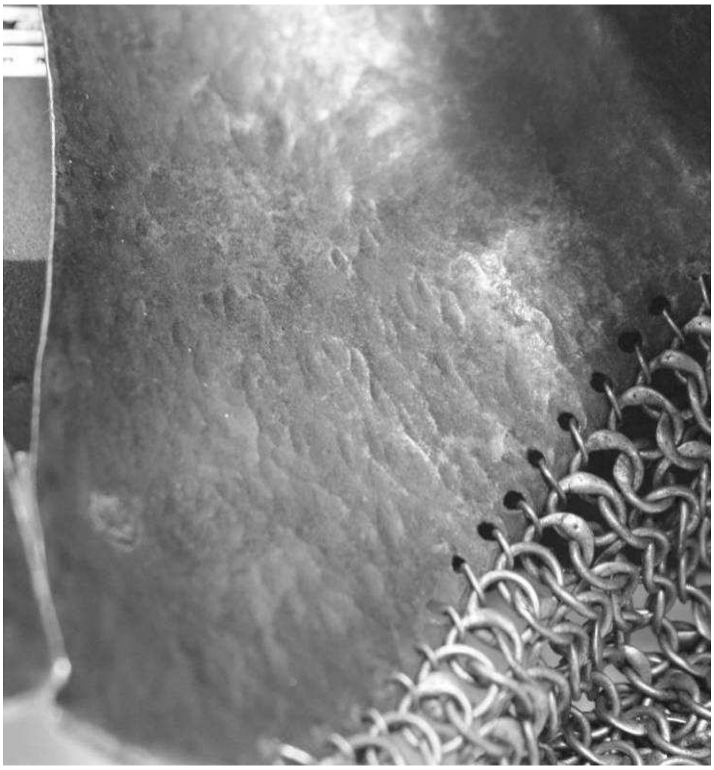

Figure 346. Lower left front of the left greave.

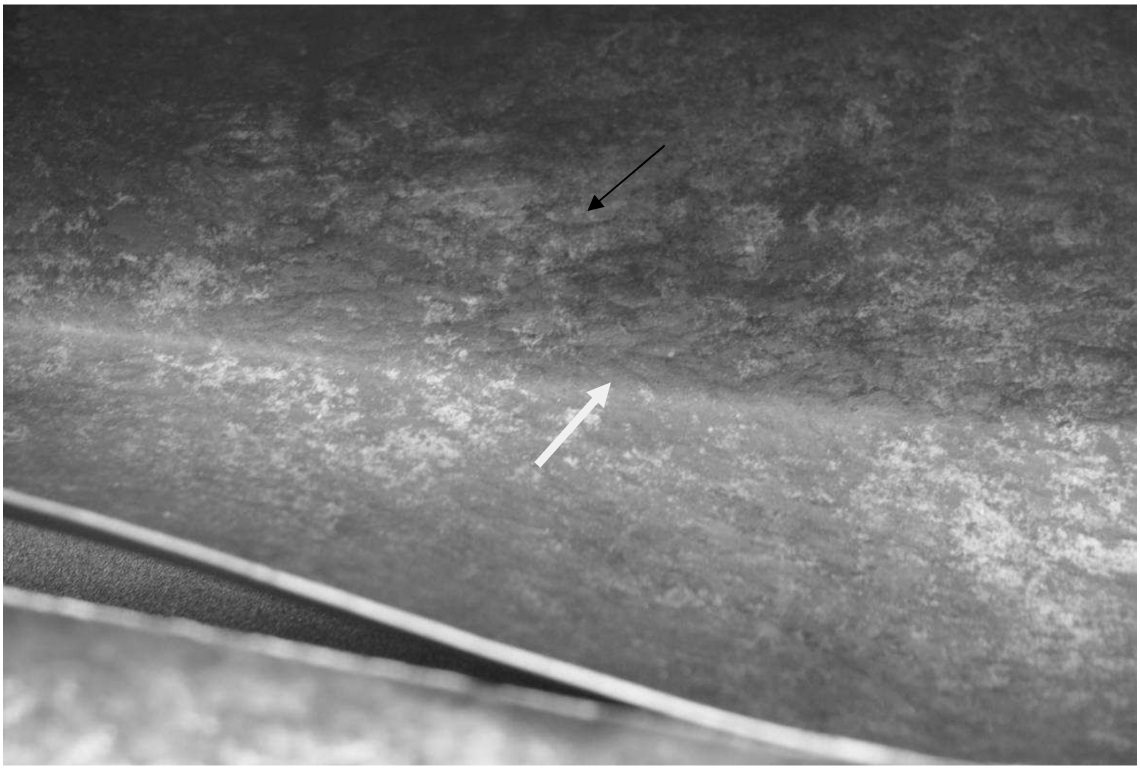

Figure 347. Greave interior, with oblong curling marks and oblique marks from creasing.

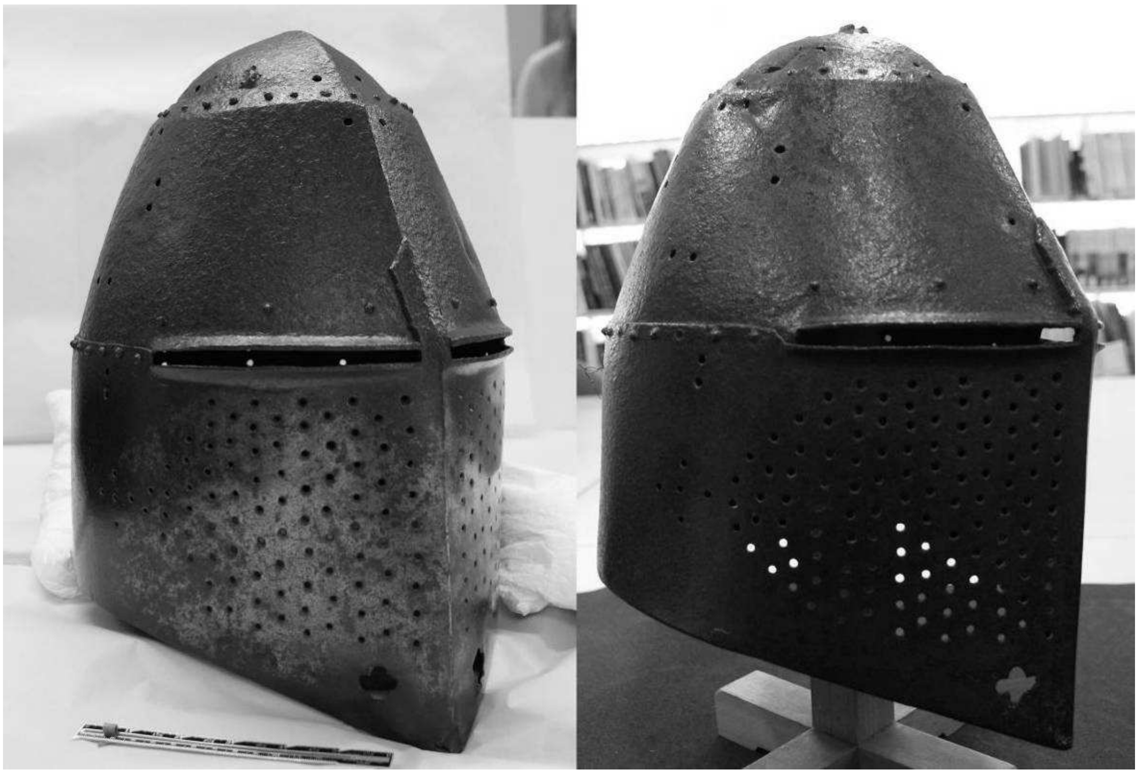

Figure 348. Two of a kind: the Pembridge helm (left) and IV.600 (right).

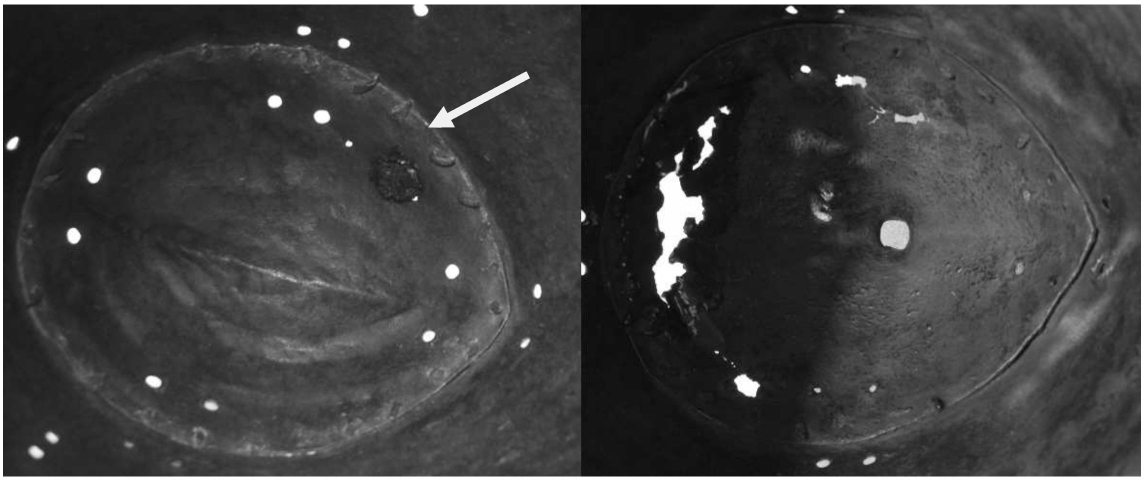

Figure 349. Cap interiors of the Pembridge and IV.600. The flange is more visible on the Pembridge, marked with the arrow.

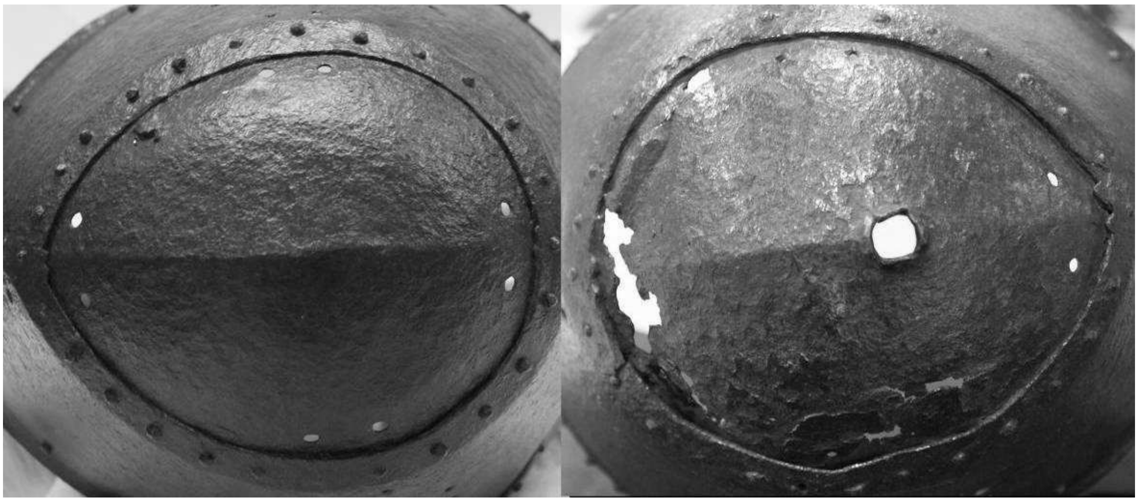

Figure 350. Caps and upper hoop edges. The small double cusps can be seen at the front and back of each cap.

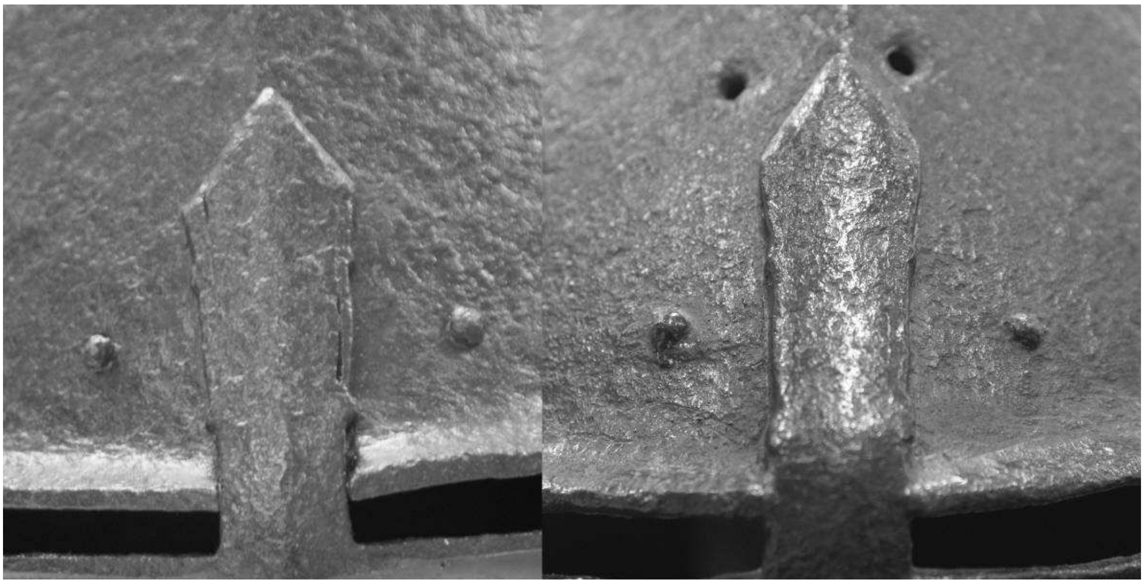

Figure 351. Comparison of the nasals. The border on IV.600, right, is barely visible through the corrosion.

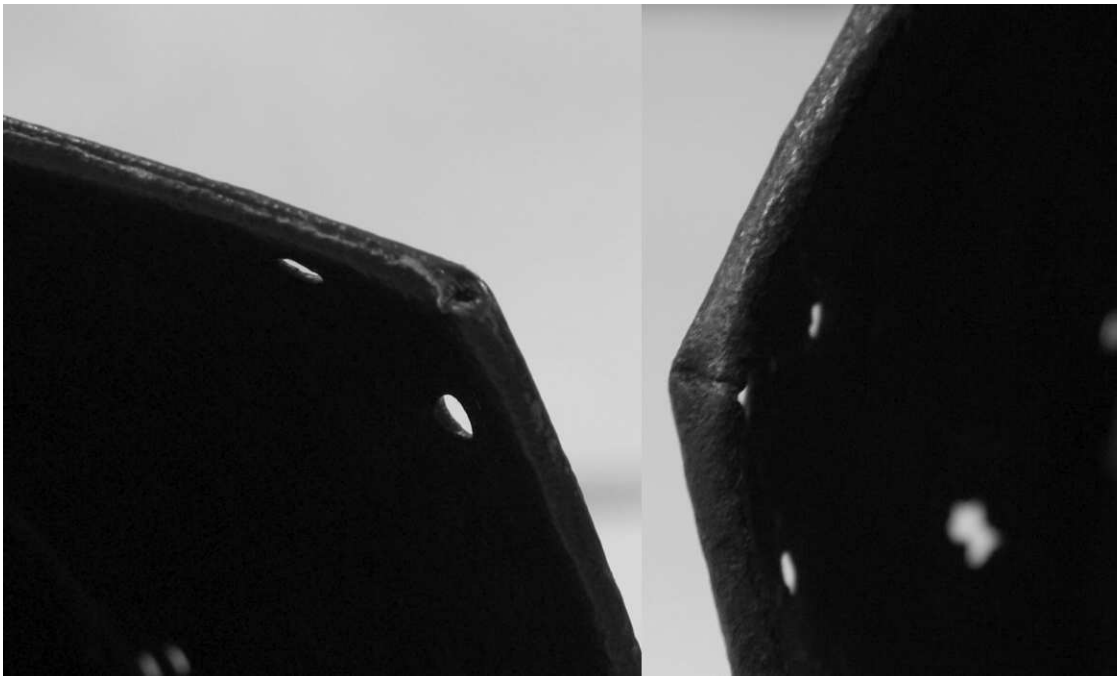

Figure 352. Rear point of each helm's roll. The front points share this feature, but are both slightly damaged.

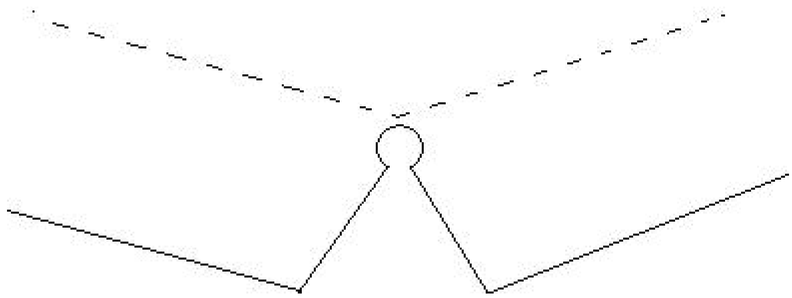

Figure 353. Diagram of the edge before rolling. The dashed line indicates the final bottom edge of the helm.

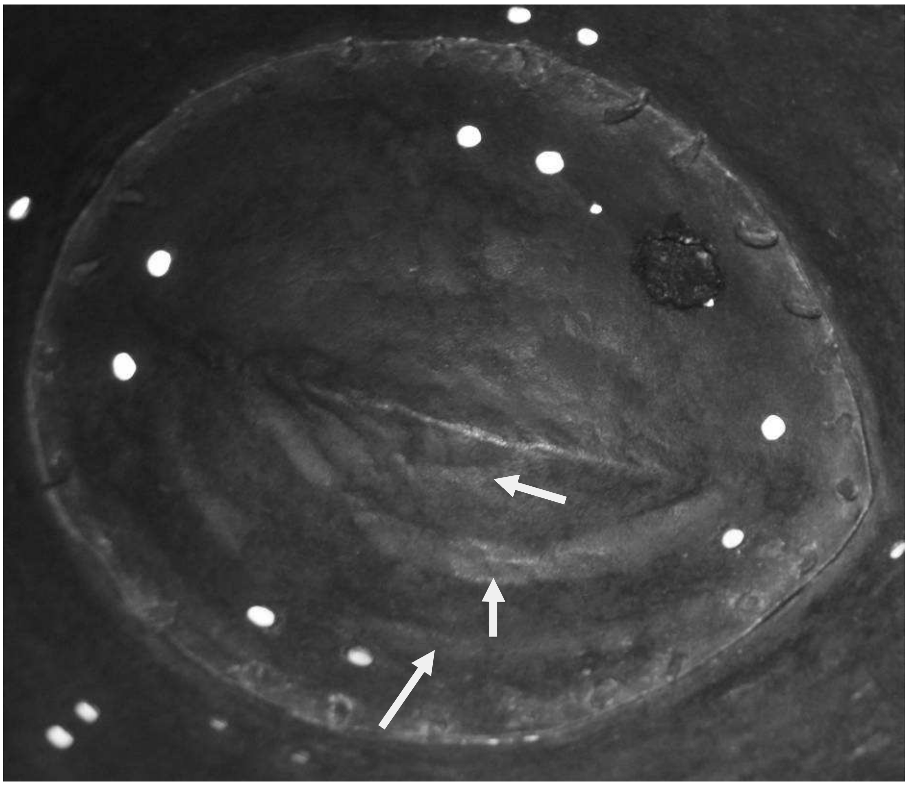

Figure 354. Interior of the Pembridge helm's cap plate, showing ridges from raising.

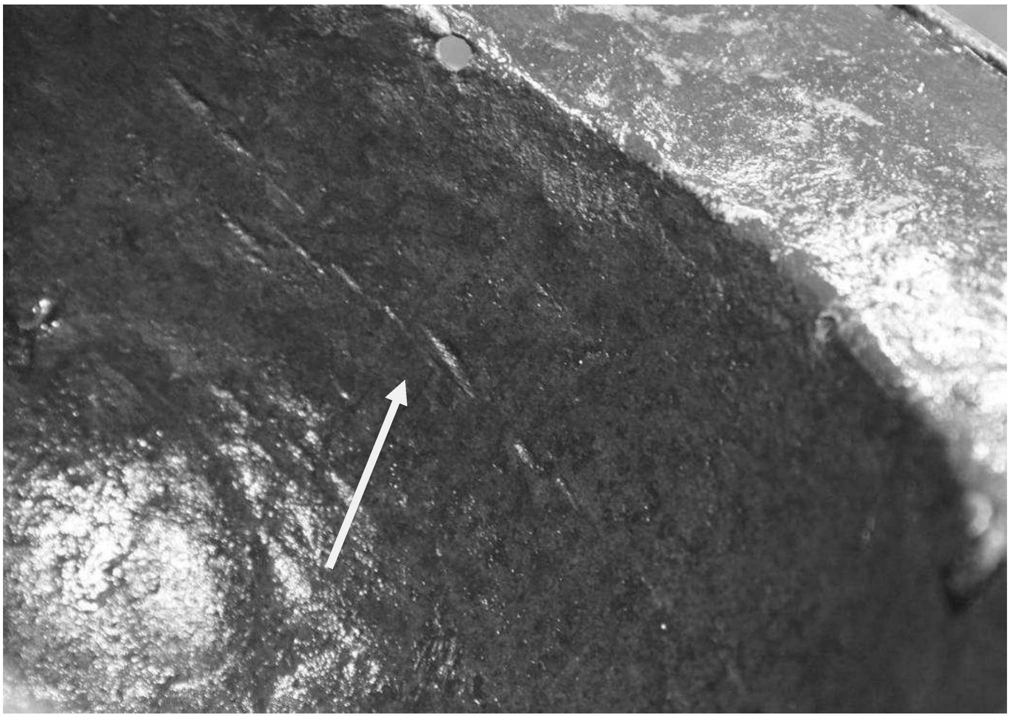

Figure 355. Residual raising marks inside IV.532.

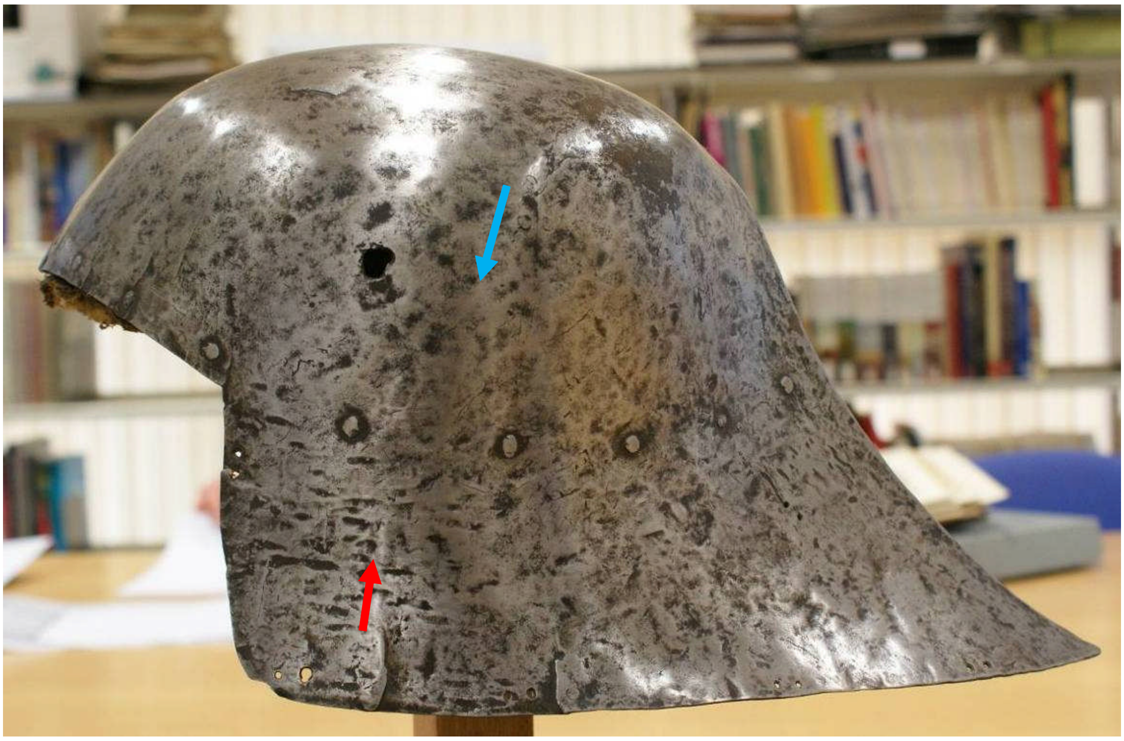

Figure 356. Exterior of IV.13, showing oblong marks from raising (red) and round marks from planishing (blue).

Figure 357. Interior of IV.13, showing oblong marks from raising (red) and round marks from planishing (blue).

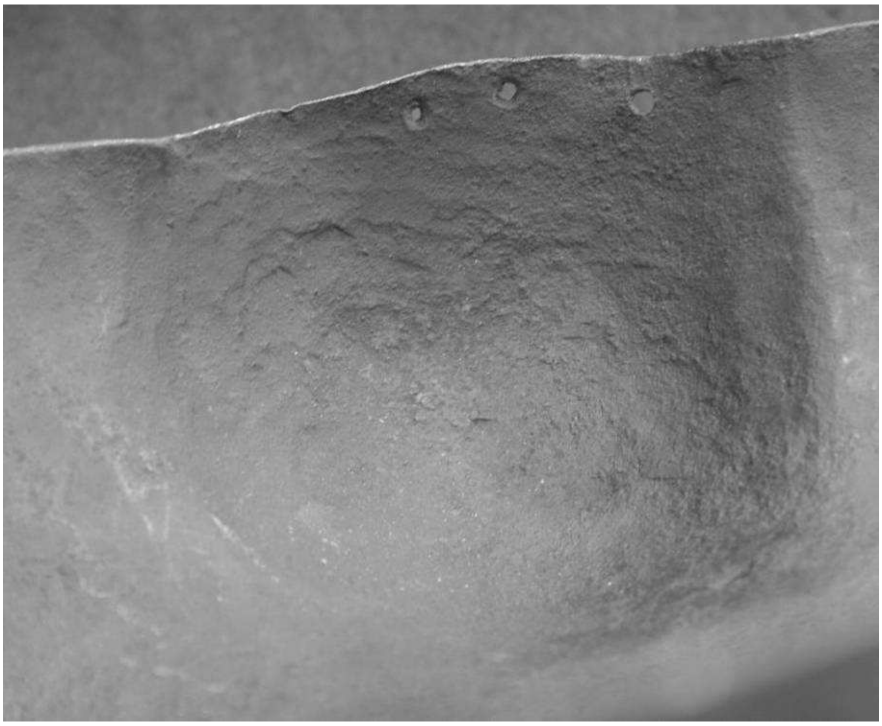

Figure 358. Rough, concentric pattern in VI.48.

Figure 359. Exterior of VI.48.

Figure 360. Concentric pattern of marks in the skull of IV.424.

Figure 361. Set of remaining raising marks at the side of the skull of IV.12.

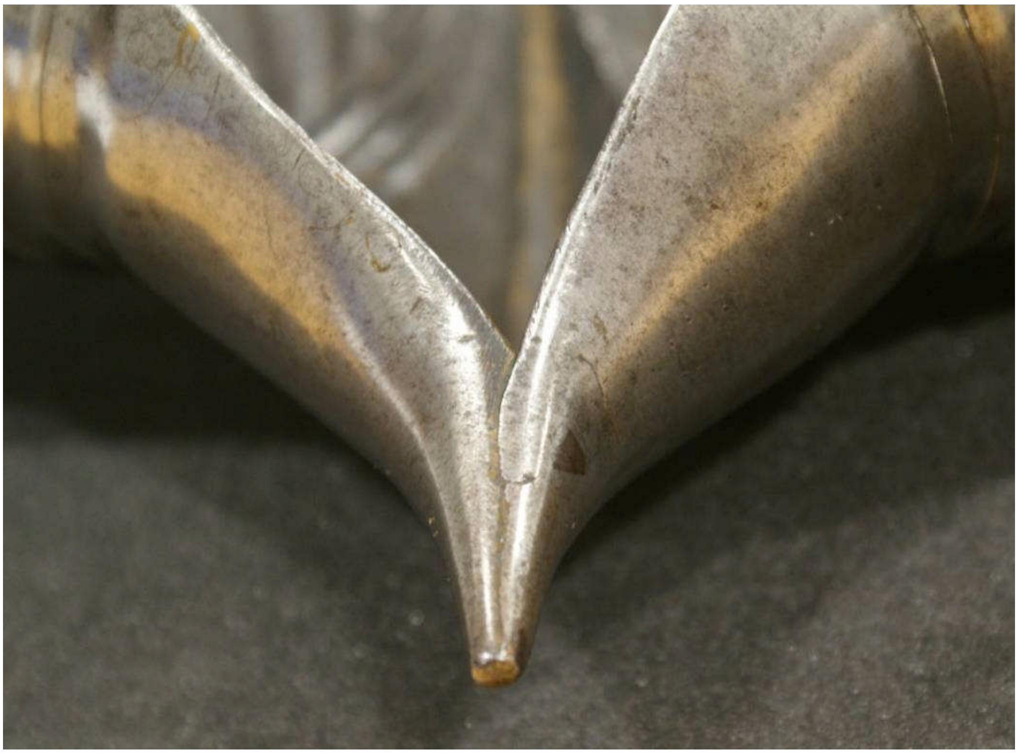

Figure 362. The brazed cone of AL.23 107.

Figure 363. The riveted and brazed couter of III.864. The rivets are barely visible and are indicated by arrows.

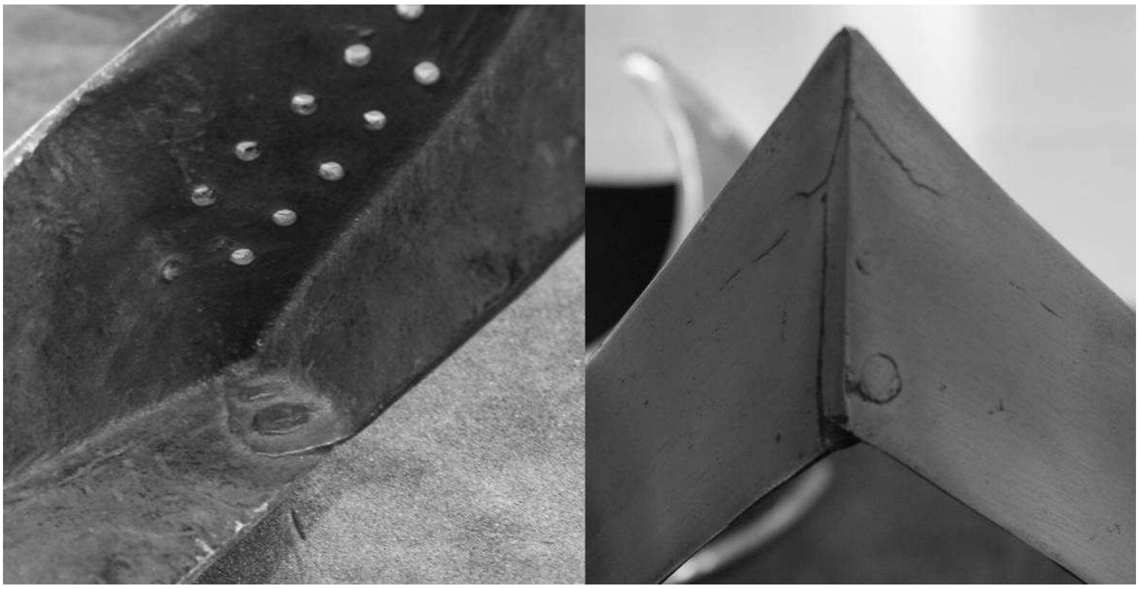

Figure 364. Interior and exterior of the visor of IV.502, which is simply riveted.

Figure 365. Couters of III.1808 B, left, and AL.90, right.

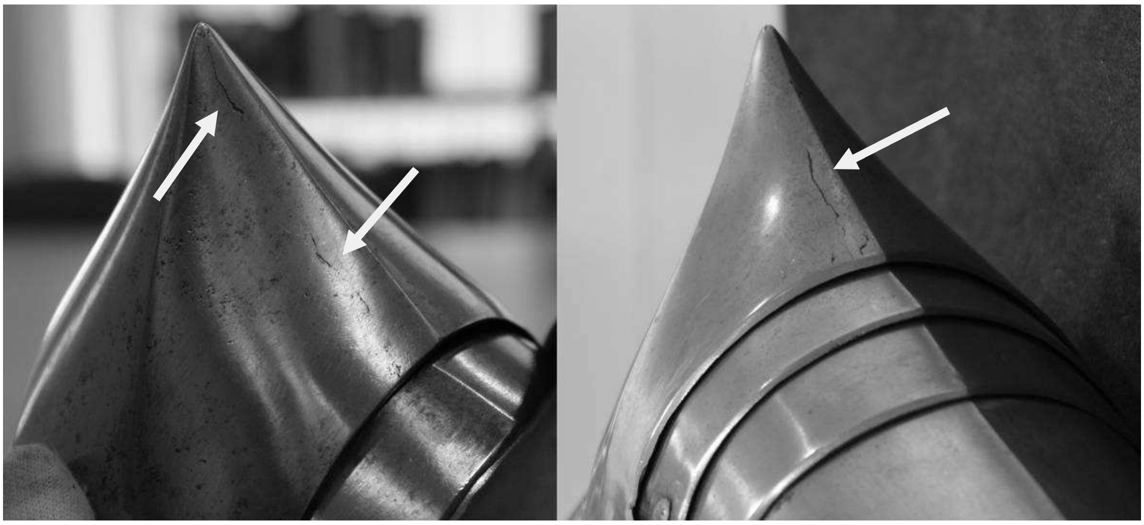

Figure 366. Forge welding seams visible on III.1808 B and AL.90.

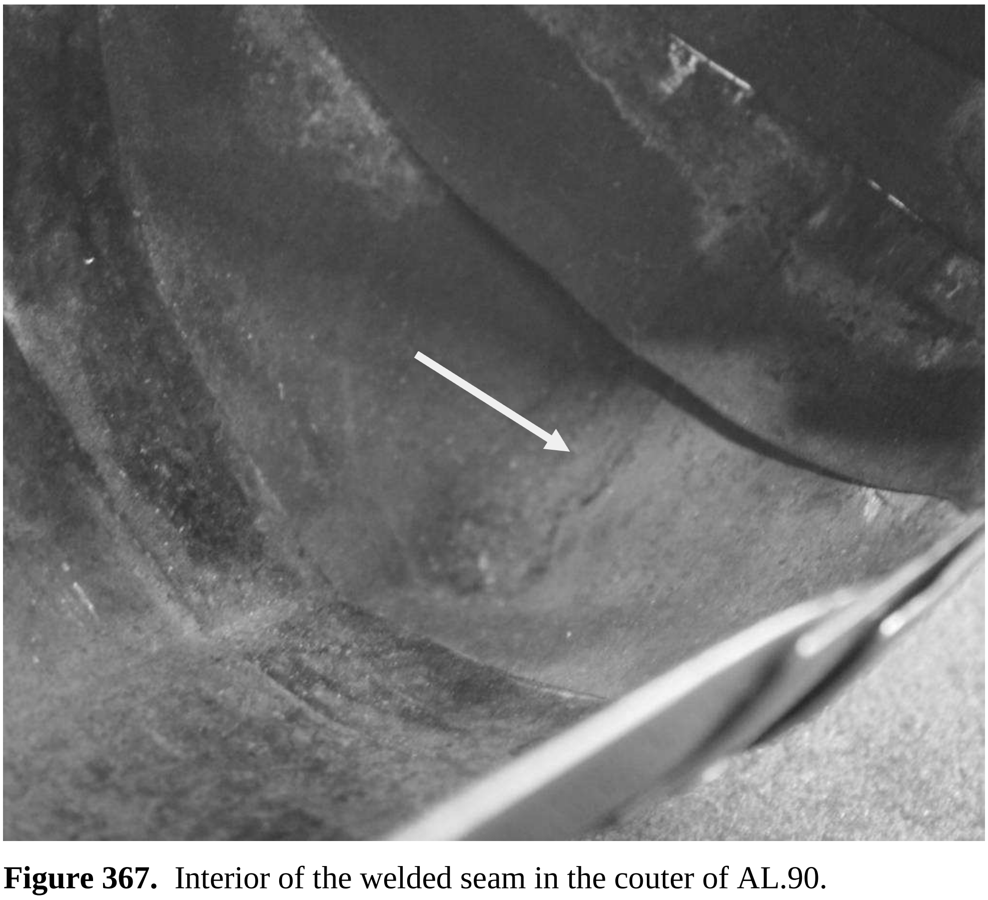

Figure 367. Interior of the welded seam in the couter of AL.90.

Figure 368. Doming a breastplate from the interior, detail *Chants royaux sur la conception.*

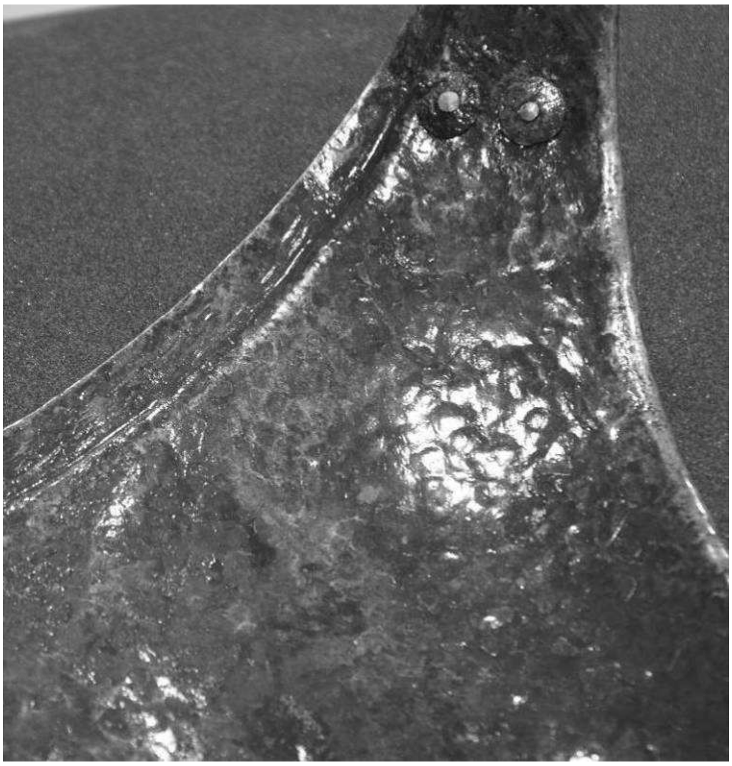

Figure 369. Interior detail of III.1284.

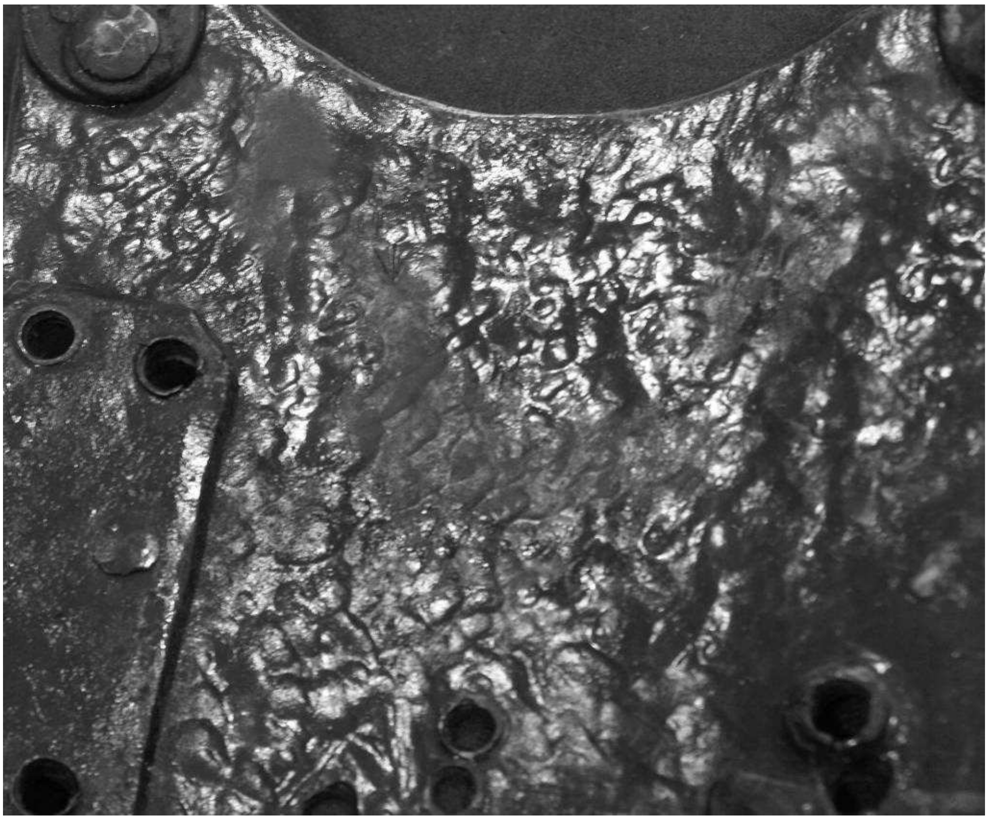

Figure 370. The extremely rough interior of III.96, with several mark shapes apparent.

Figure 371. The much smoother interior of III.1336 A.

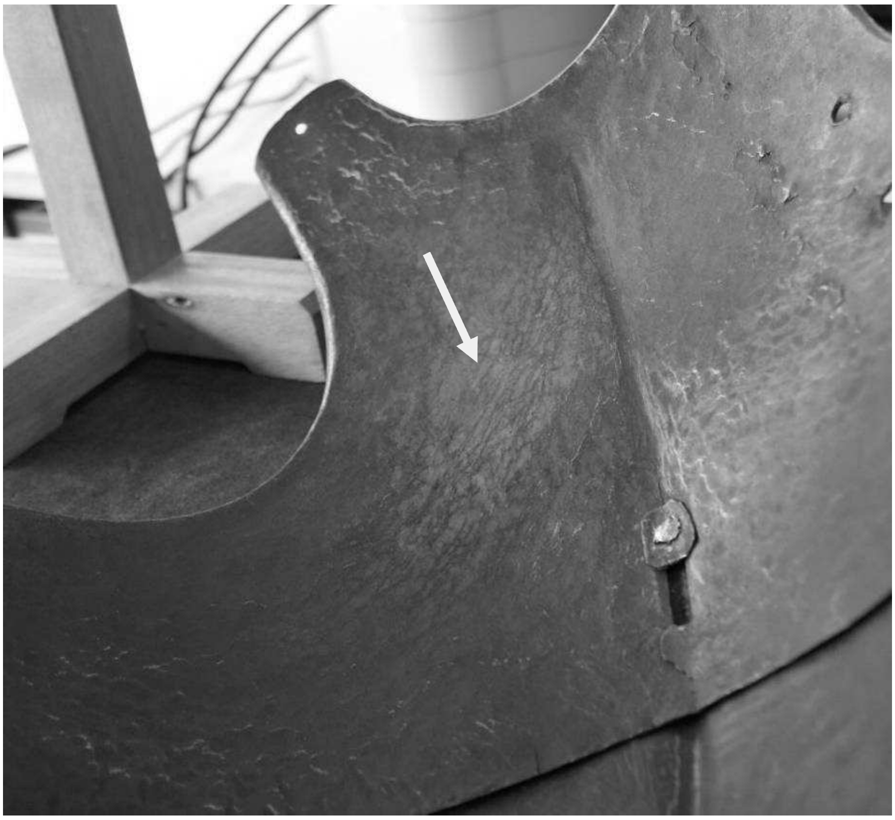

Figure 372. Interesting pattern on the left side of III.1283.

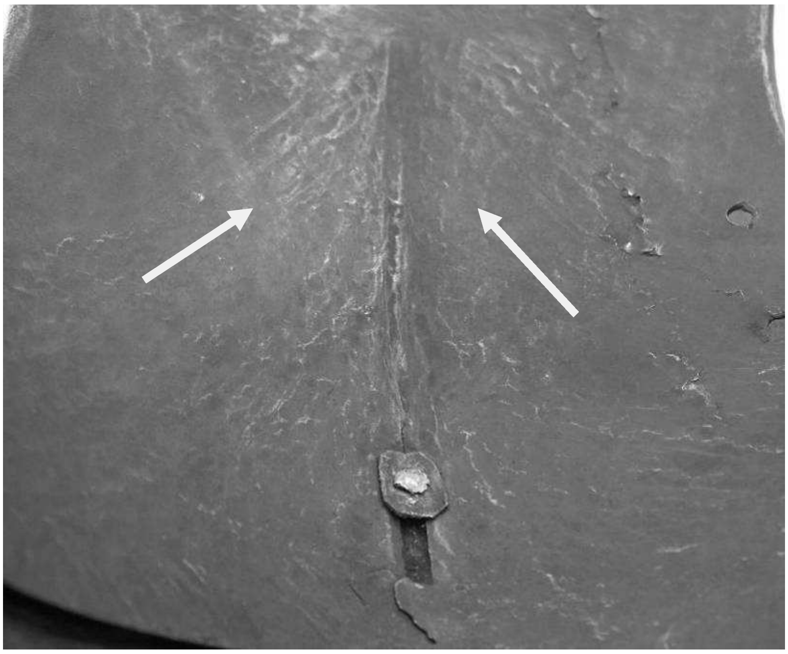

Figure 373. Pattern on both sides of III.1283.

Figure 374. Faint pattern in III.84.

Figure 375. The extremely rough interior of III.4568, with marks from both doming and curling.

Figure 376. Interior of II.168 H and the left arm of the Avant armour.

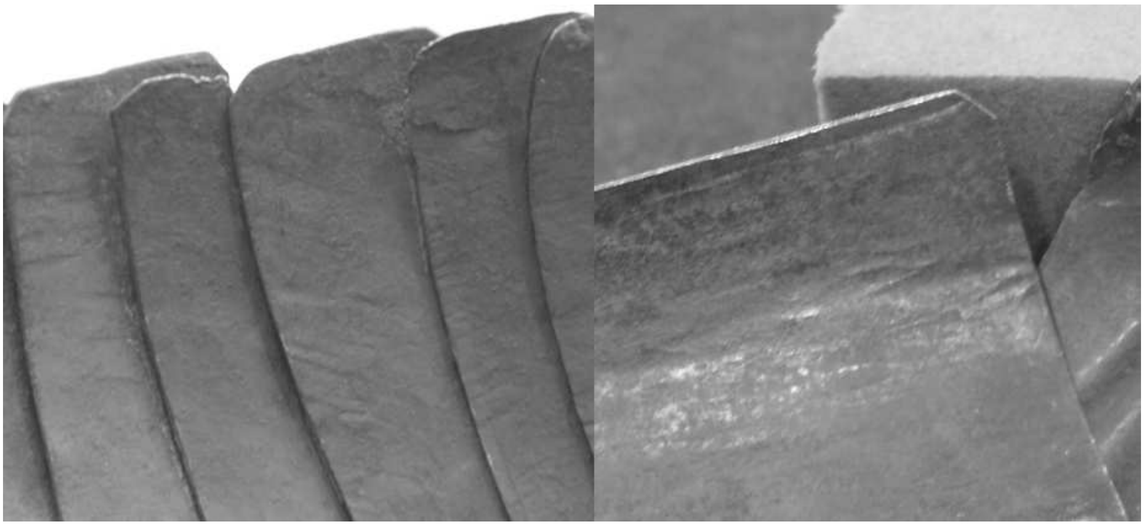

Figure 377. Long, narrow marks inside III.1287 and II.168 E.

Figure 378. The partly planished fauld of III.70.

Figure 379. Round marks on the lower lames of III.1284.

Figure 380. The unpolished exterior of II.89.

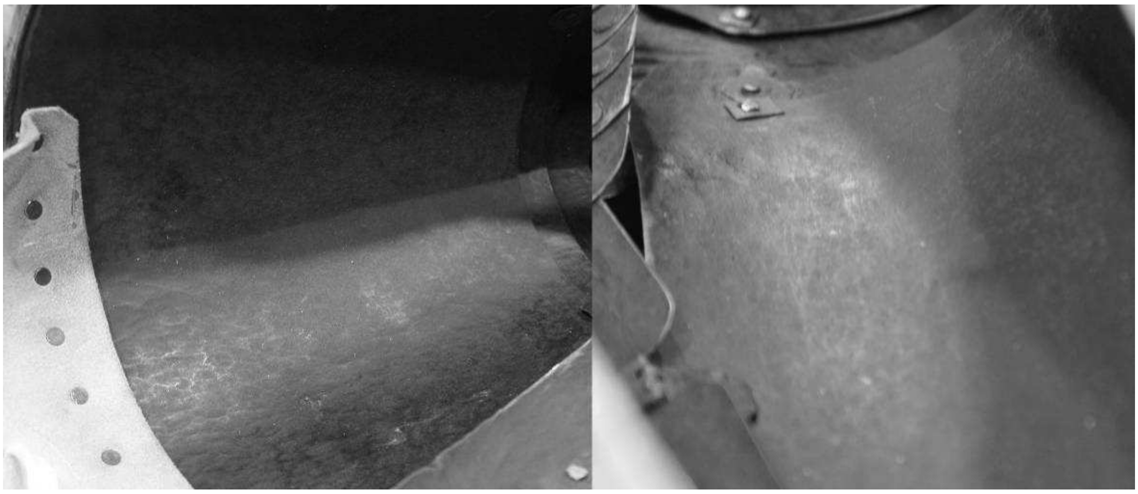

Figure 381. Curling marks in the cuisse and planishing in the greave of II.6.

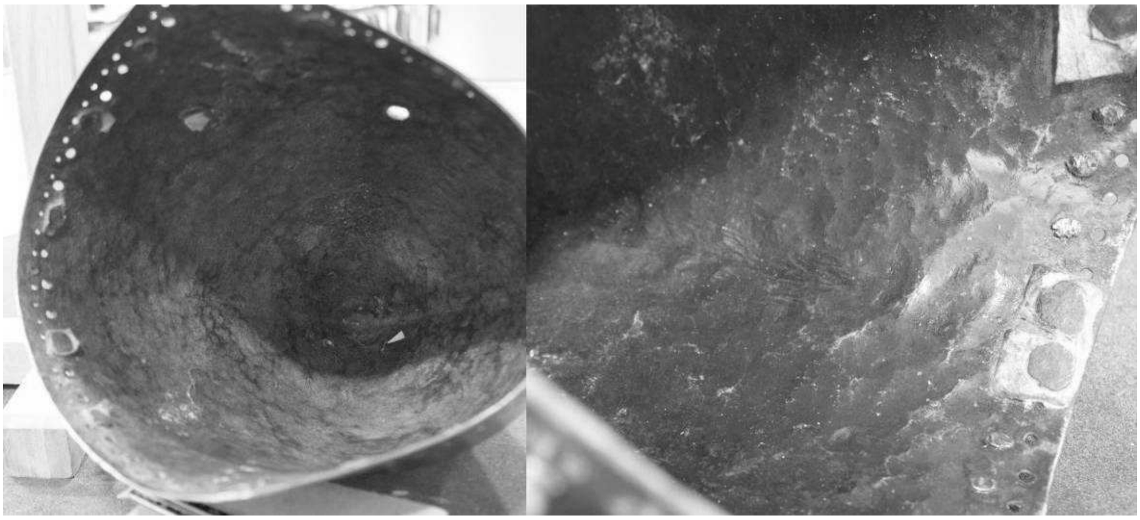

Figure 382. The smoothly planished interior of IV.497 (left) and the slightly rougher interior of IV.470 (right).

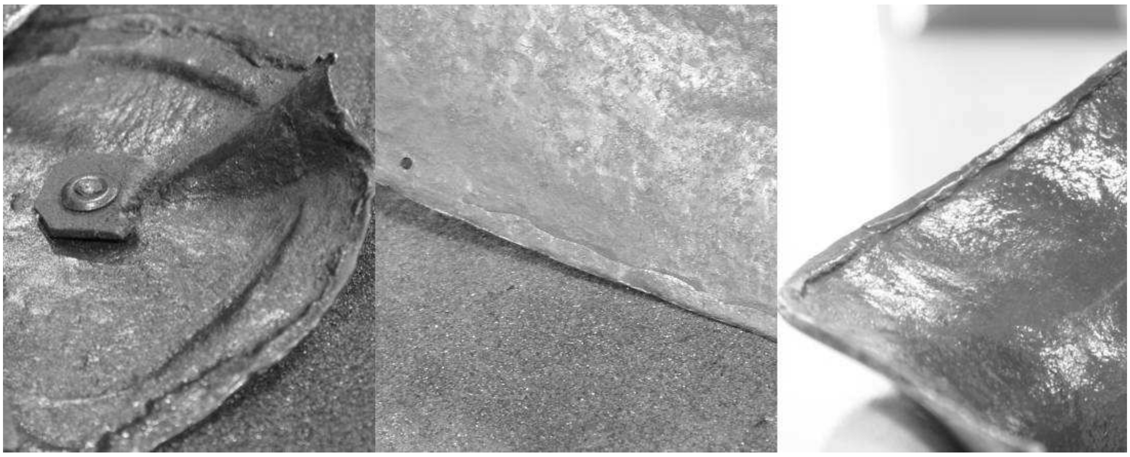

Figure 383. Inwardly folded edges on III.2459, IV.13, and III.864.

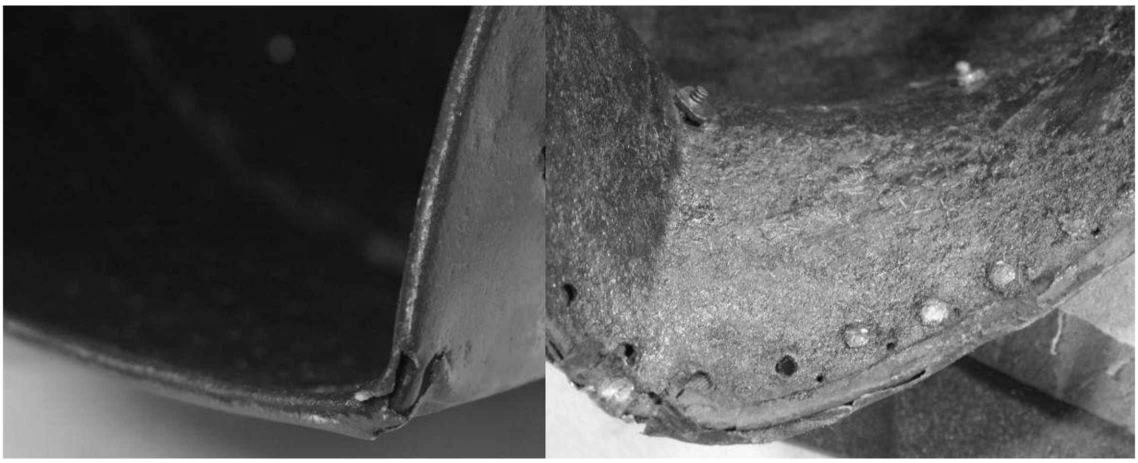

Figure 384. Simple rolls over a wire on the Pembridge helm and IV.20. Damage and corrosion have exposed the round wire on the left and the flat wire on the right.

Figure 385. Boxed roll of III.1088.

Figure 386. The finely embossed collar on IV.29, which is repeated on the comb, compared with the crude filed roping on III.2459.

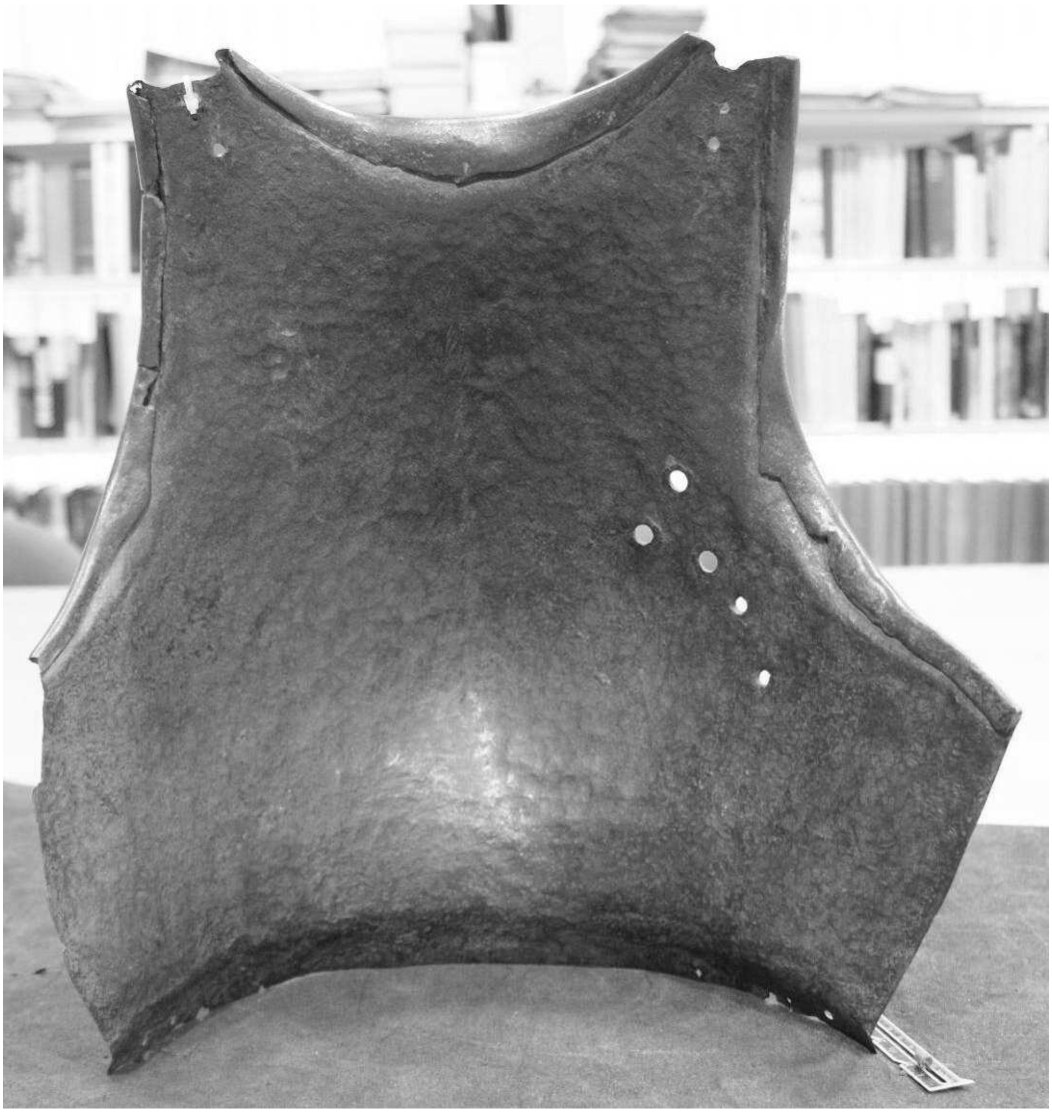

Figure 387. Interior of III.4572.

Figure 388. Arm rolls of III.73.

Figure 389. Barbuta IV.7 with a very small, finely formed outward roll.

Figure 390. War hat IV.537.

Figure 391. Sallet IV.429.

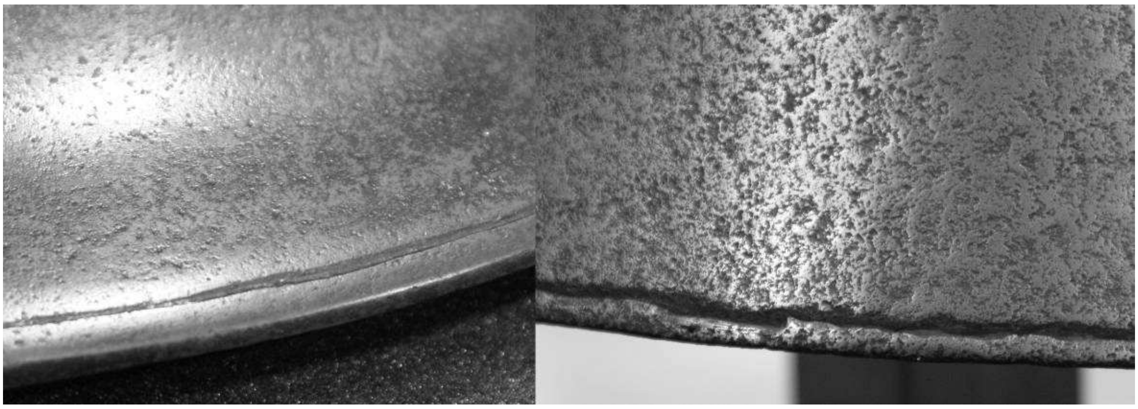

Figure 392. Rolls of IV.537 (left) and IV.429 (right).

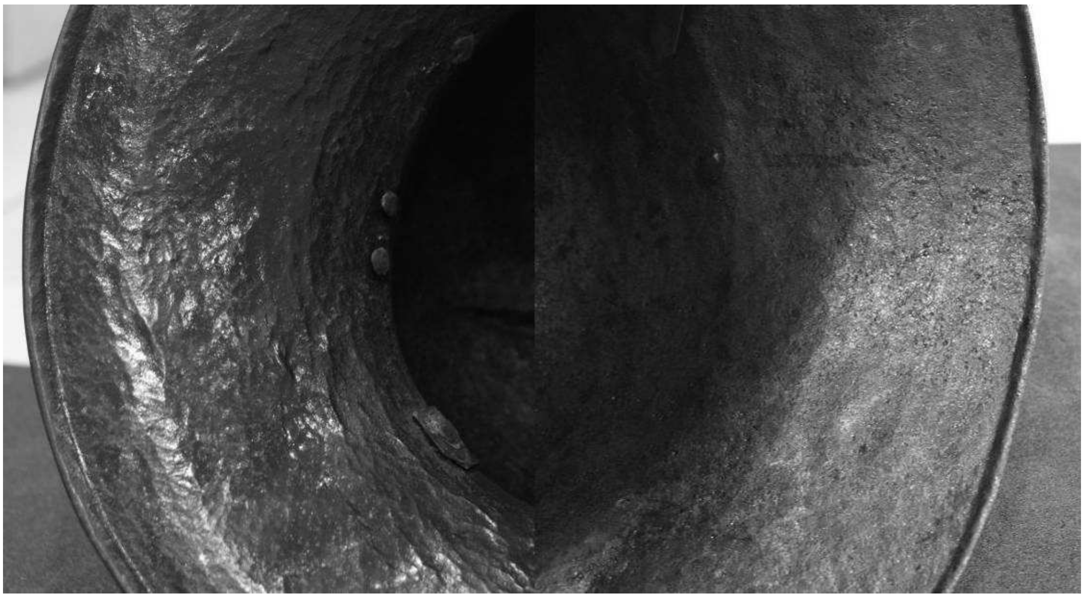

Figure 393. Interior of IV.537 (left) and IV.429 (right).

Figure 394. Exterior and interior of flutes of AL.23 107.

Figure 395. Shaped flute channels on the backplate III.70.

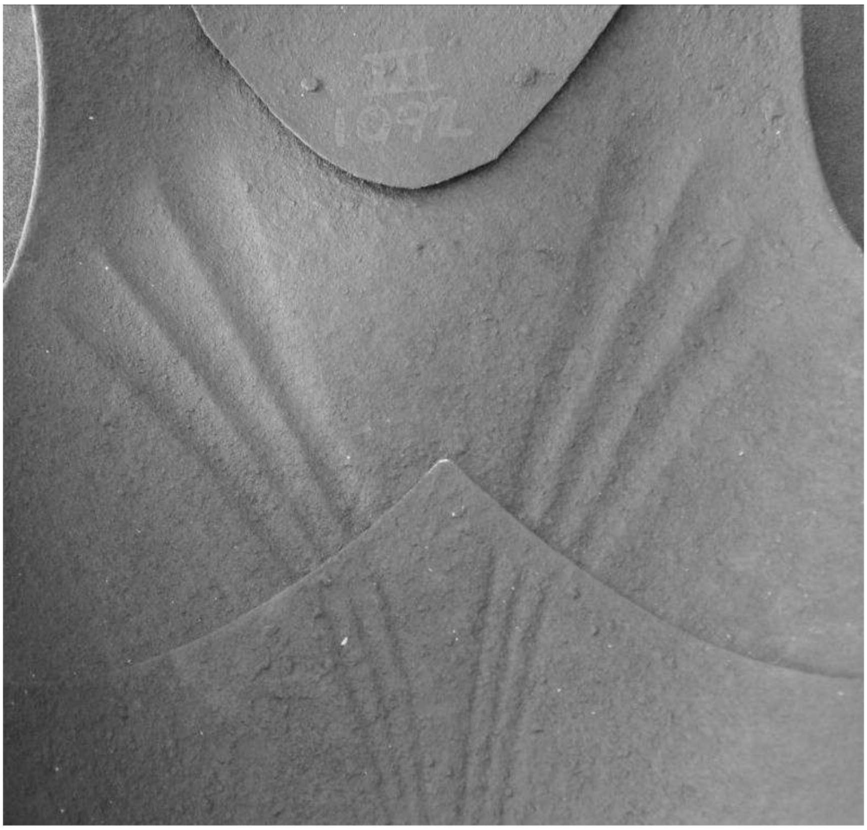

Figure 396. Flaring flute channels on III.1092.

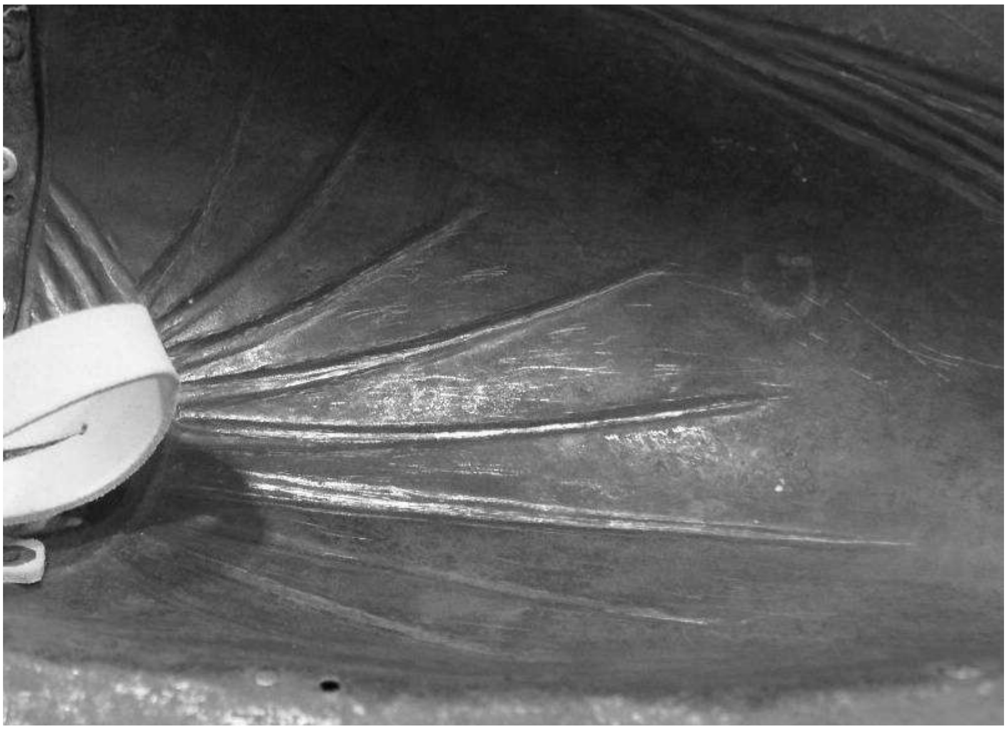

Figure 397. Shaped flute channels in II.167.

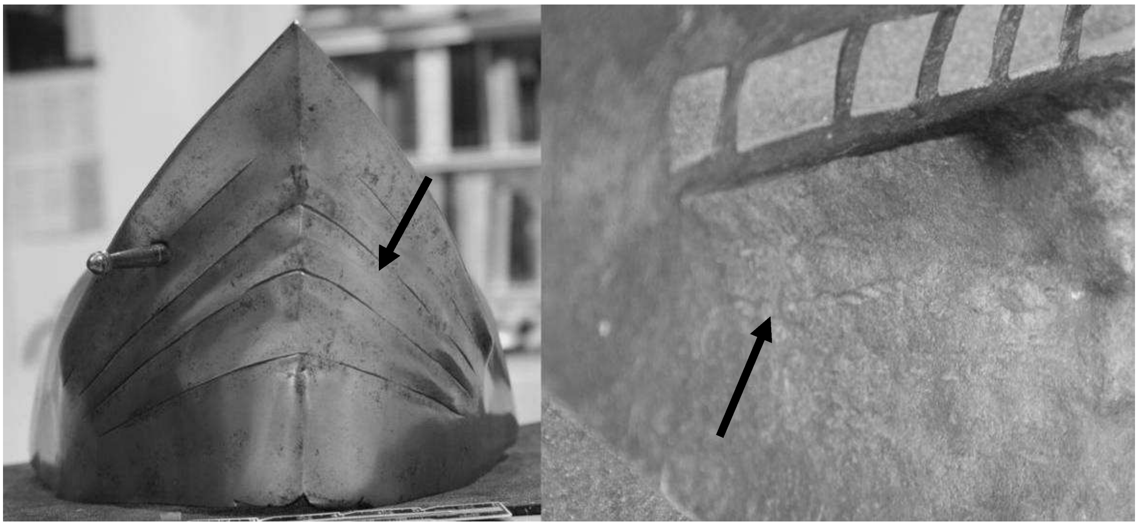

Figure 398. Exterior and interior of IV.579, showing low flutes and corresponding tool marks.

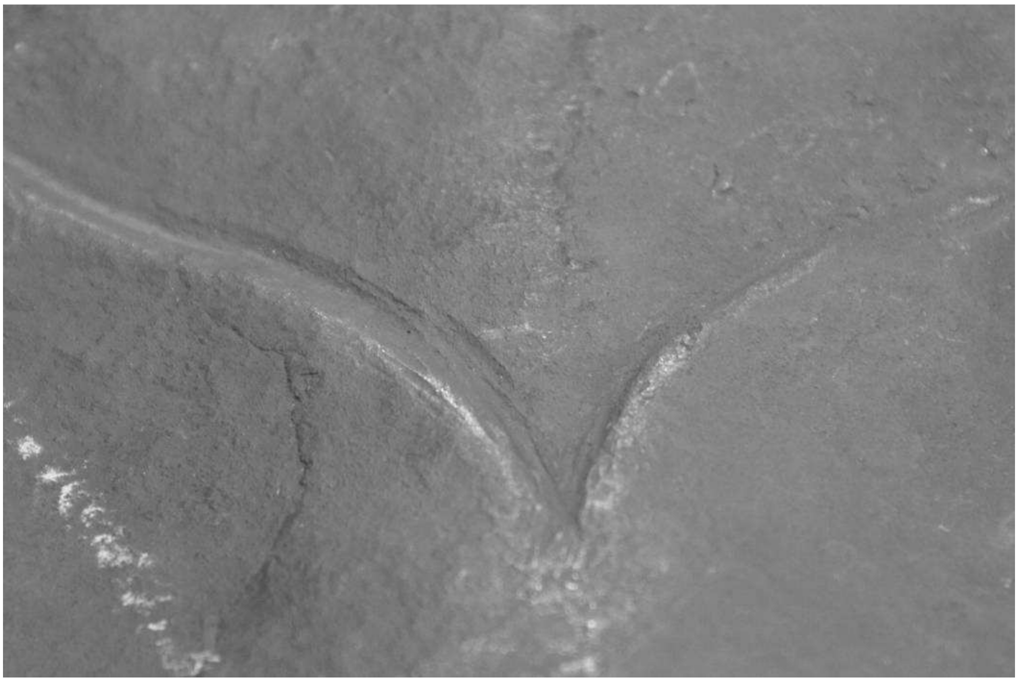

Figure 399. Parallel marks in the backplate III.1293.

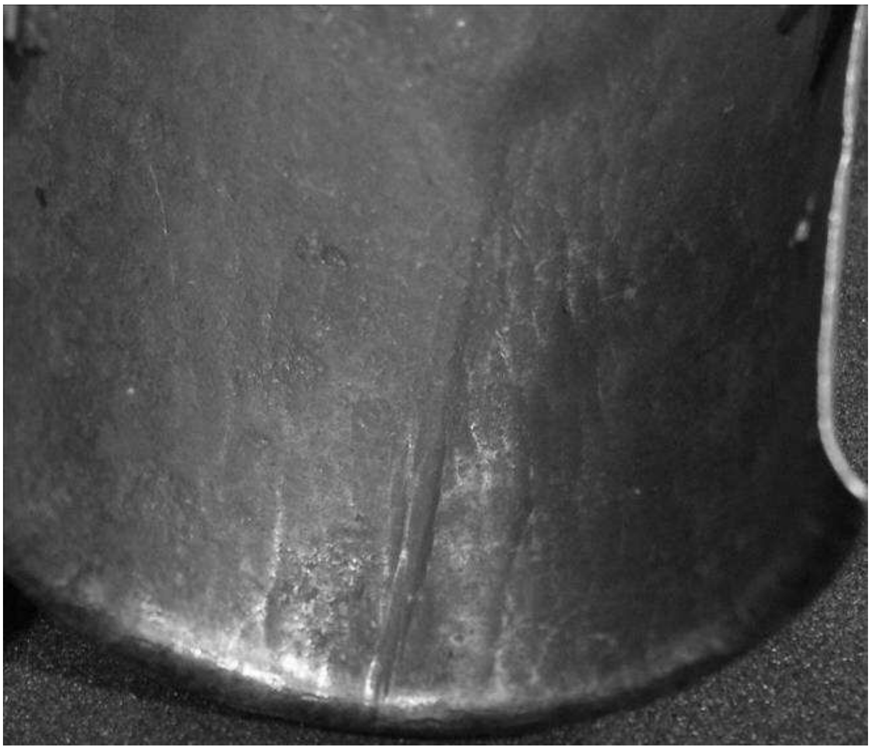

Figure 400. Parallel marks in the medial crease of the lower cannon of III.1216.

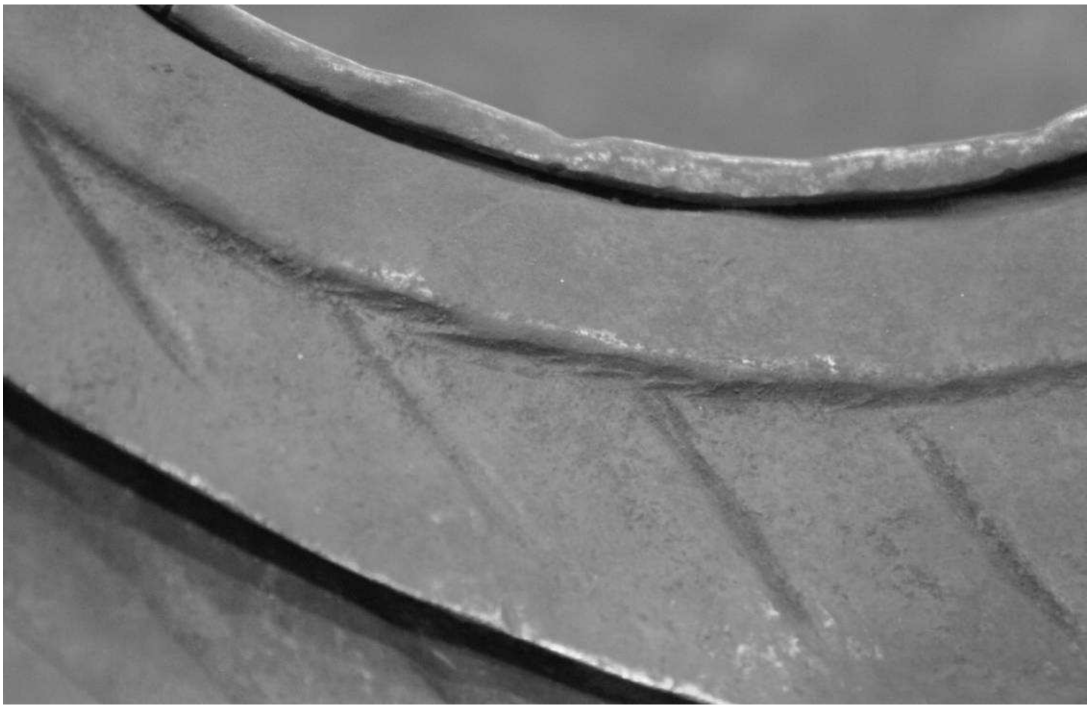

Figure 401. Slightly oblique fluting marks in III.1414.

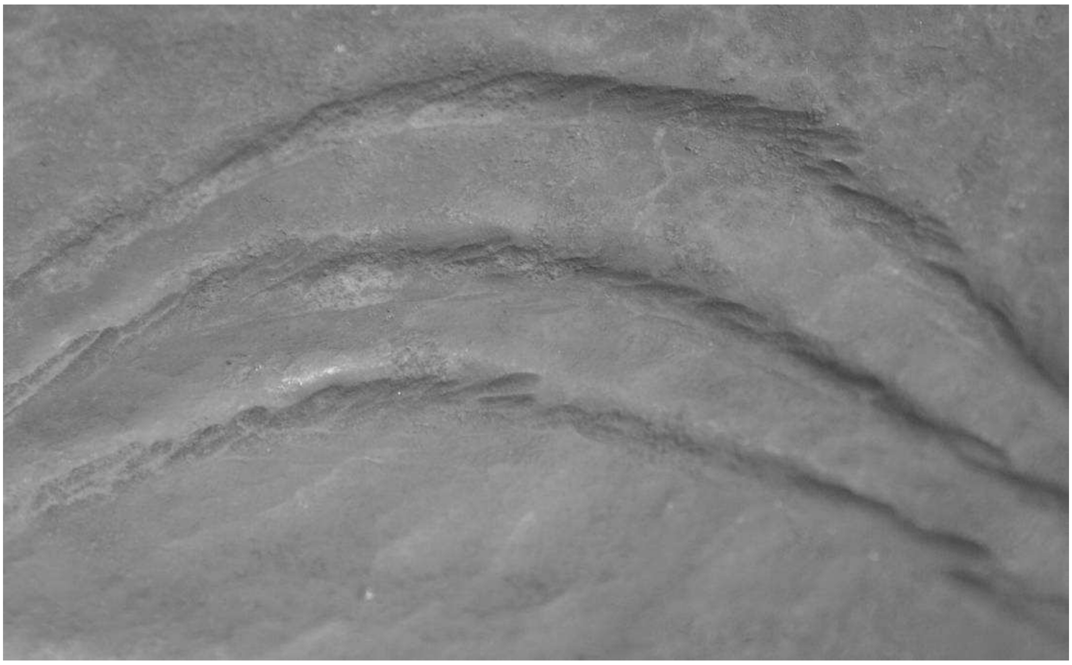

Figure 402. Rough, hammer-embossed flute channels in III.1325.

Figure 403. Heavily marked poleyn wing on II.168 G.

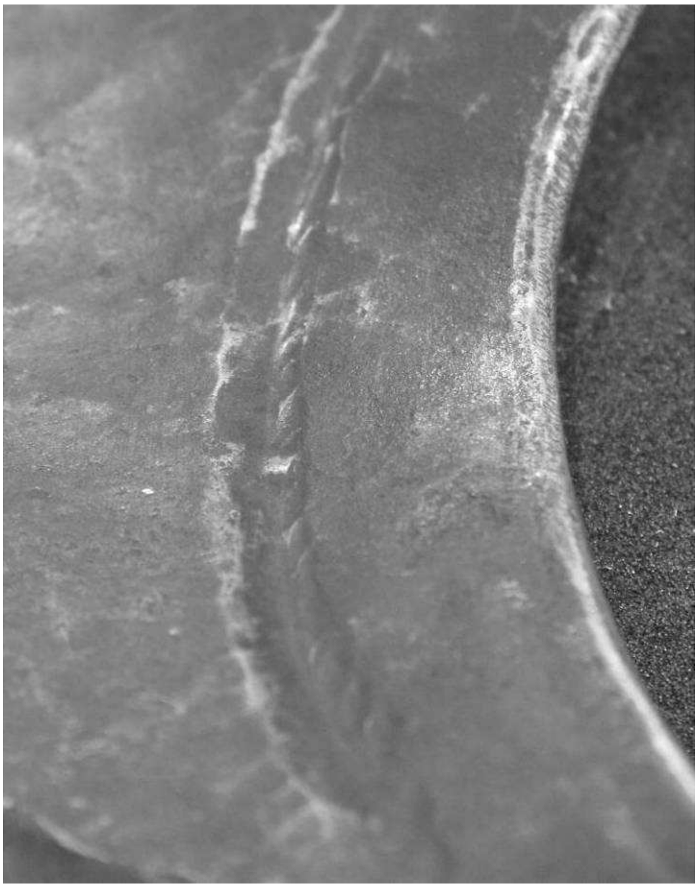

Figure 404. Heavily marked flute in II.168 C.

Figure 405. Oblique marks in the medial ridge of III.1282.

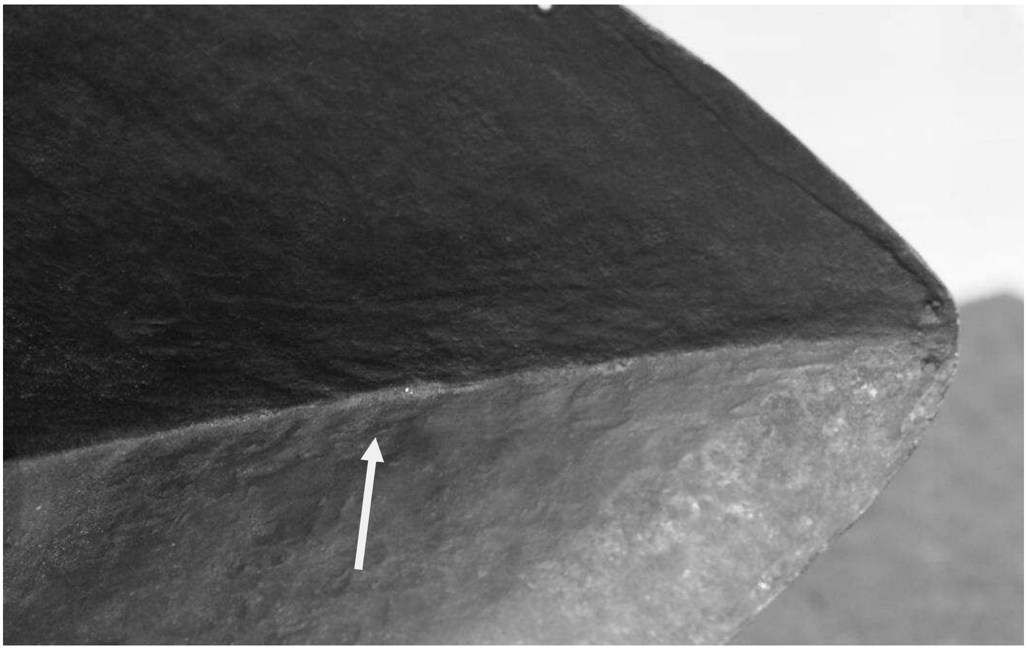

Figure 406. Parallel marks in the tail of IV.13.

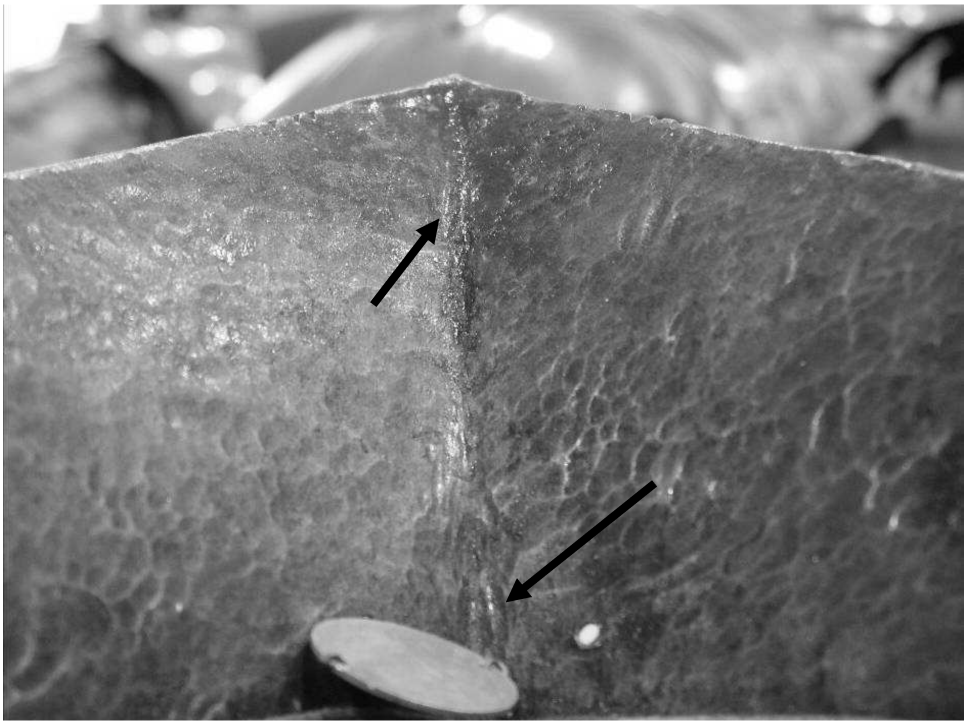

Figure 407. Rear medial crease of IV.499, showing parallel marks.

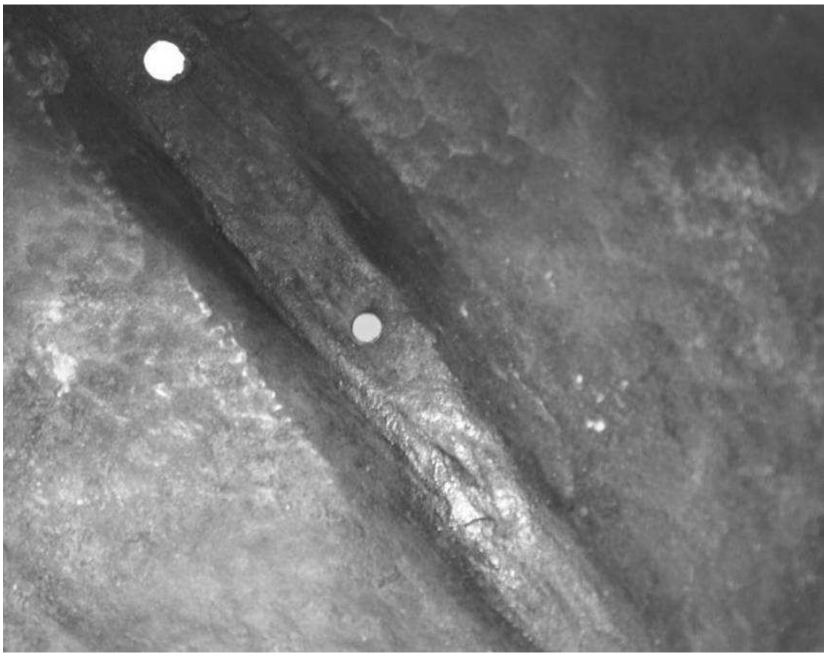

Figure 408. Medial keel of IV.502. Marks are parallel and do not extend beyond the keel.

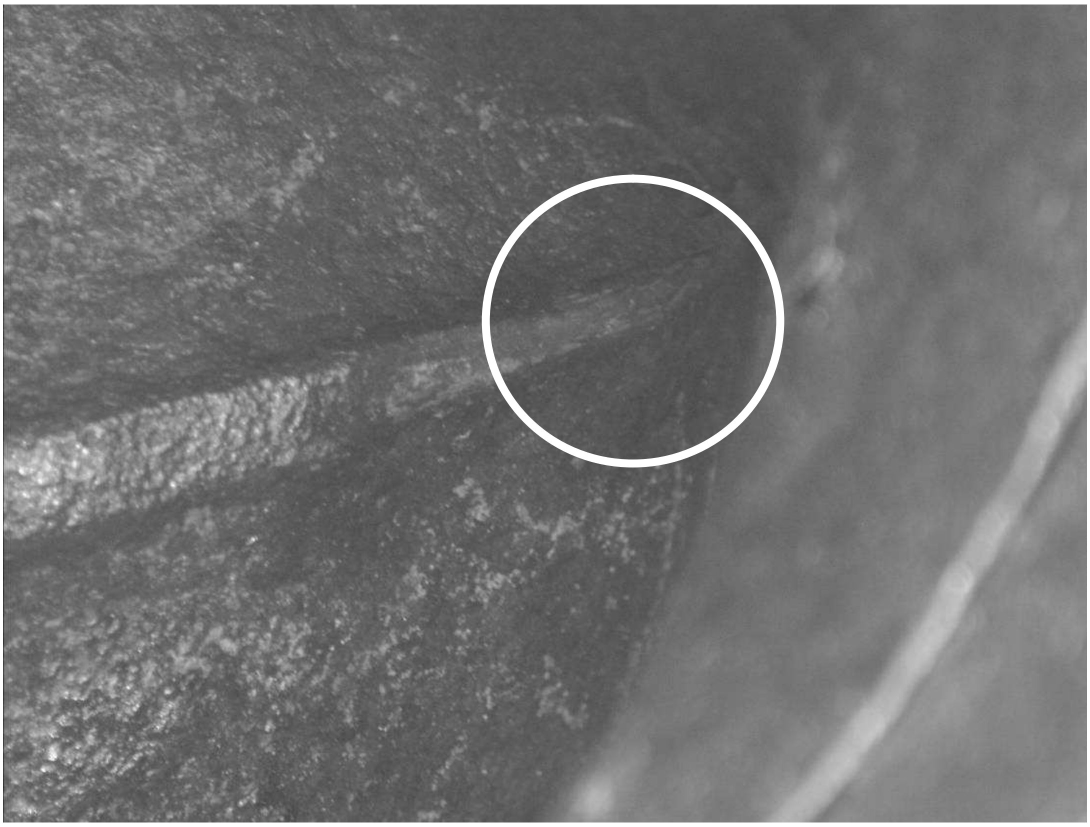

Figure 409. Very faint parallel marks in the medial keel of IV.428.

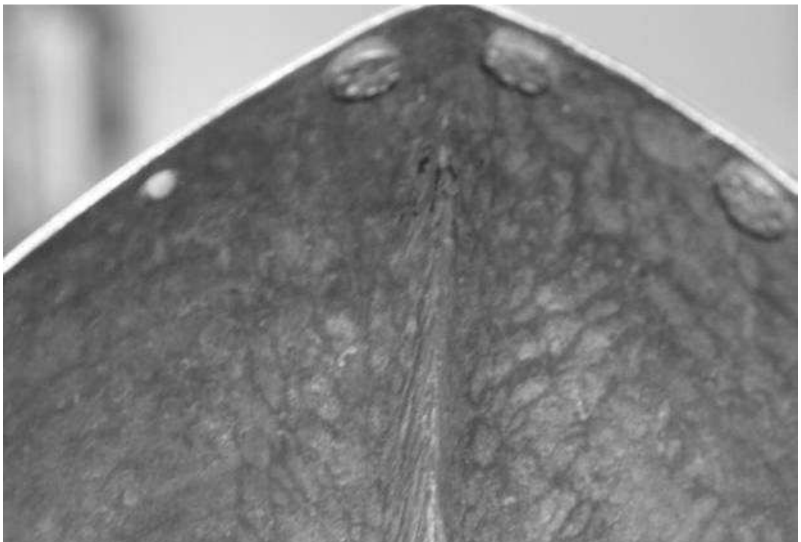

Figure 410. Mark pattern in the medial ridge of II.7.

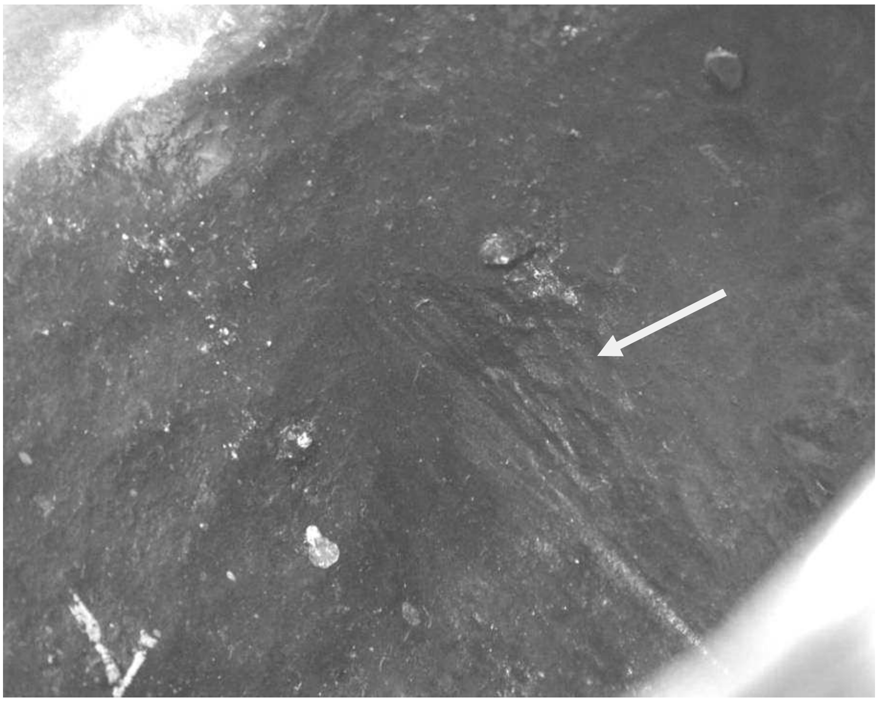

Figure 411. Band of marks at the back of IV.7's skull.

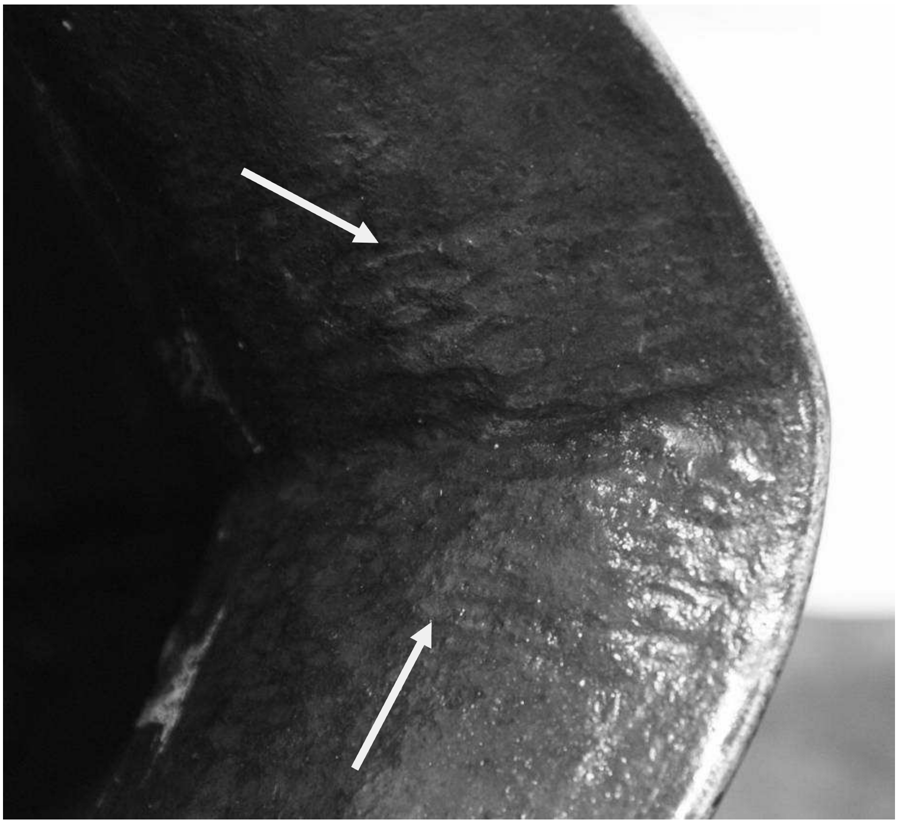

Figure 412. Bands of marks on tail of IV.17.

Figure 413. Bands of marks on tail of II.168 A.

Figure 414. Interior of IV.2's skull. The medial keel has little or no independent marking.

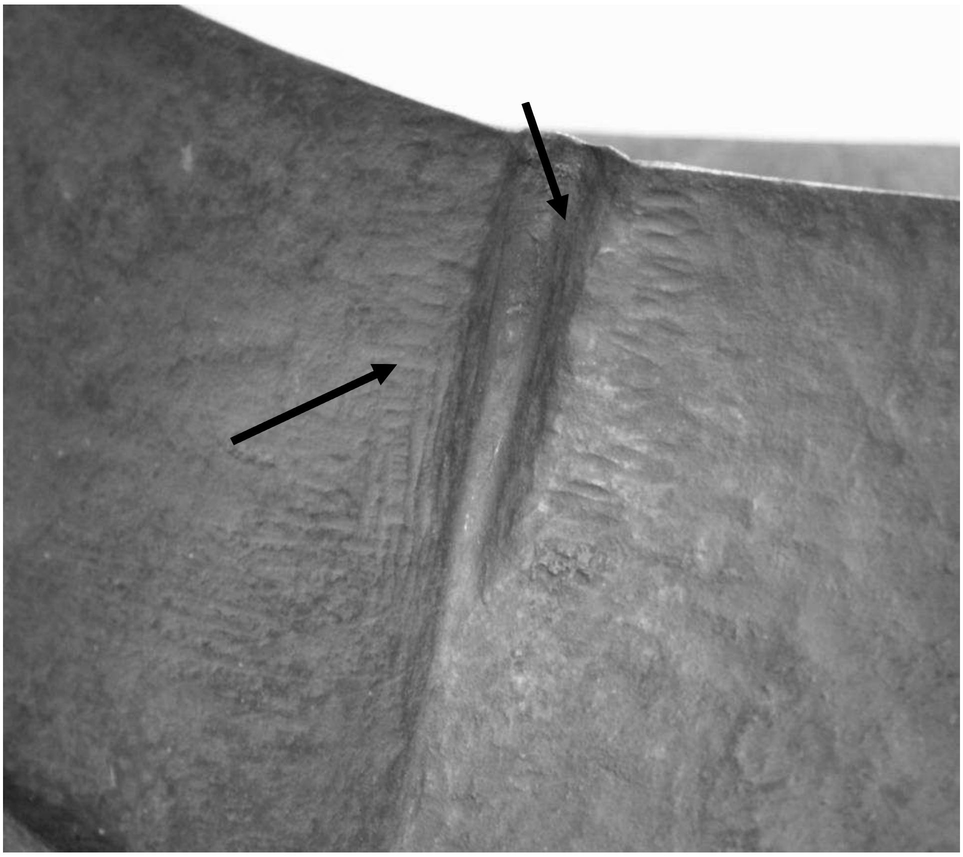

Figure 415. Interior of IV.2's visor, showing the heavy marking in and bordering the keel.

Appendix D: Glossary of Terms

Anticlastic

A shape curved in two planes. Comparable to a saddle.

Anvil

A block of iron used for forging billets and plates of iron, as the lower die in shaping operations.

Anvil stake

A stake with the main working surface and centred on the vertical shaft.

Articulation

A joint designed to allow plates to move past each other allowing body movement.

Bellows

Leather and wood chambers used to create a forced blast in a furnace or forge. In the Middle Ages, two would be used to create a continuous blast.

Bloom

The accumulation of smelted iron which forms at the bottom of a smelting furnace.

Brazing

A hard soldering technique using copper or copper alloy as the solder.

Buffing

A final finishing step where the fine scratches from filing and sanding are removed through a fine abrasive. A surface can be buffed to a matte finish or a mirror finish.

Cold Shunt

A crack which has formed in the metal due to unrelieved stresses built up along grain boundaries.

Carbon

The primary element alloyed with iron, creating steel. An overabundance of carbon creates cast iron.

Copper Alloy

A metal, particularly bronze or brass, created by the alloying of copper with another substance, such as tin and zinc respectively.

Crease

A line or peak placed on a plate by hammering, formed by the intersection of two convex arcs.

Curling

A simple shaping on a plate to create a curve by hammering the exterior over a round surface or the interior over a flat surface.

Delaminate

The tendency for wrought iron to separate at grain boundaries, coming apart in layers.

Direct Process

A method of iron smelting whereby the ore does not melt and a solid bloom is removed from the furnace and hammered into a useable form.

Doming

Stretching a sheet of metal by hammering from the interior. This can be done over a flat surface or, more commonly, into a shaped depression in a stump. Also known as sinking and doming.

Drifting

The process of enlarging or refining a roughly punched hole.

Embossing

A decorative and forming technique where small specific areas are hammered to create a shape or pattern.

Engraving

A decorative technique. An engraver uses small chisels known as gravers to cut a pattern into the surface of a plate.

<u>Etching</u>

A decorative technique where a piece of protected metal is lowered into an acid bath, with parts of the resist removed to allow the acid to create a pattern on the surface.

<u>Flute</u>

Raised ridges hammered into a plate, often in groups, which add strength through corrugation, provide channels to deflect weapons, and as a decorative enhancement. They are formed where two concave planes meet.

<u>Forge</u>

The hearth at which an armourer or smith reheats metal for shaping, annealing, or heat treating. Usually consists of bellows, a tuyere, ventilation, and a bed to contain the fire.

<u>Forge Welding</u>

A joining technique. Two or more pieces of iron or steel are heated to a critical temperature in a forge and hammered together, allowing the molten surfaces to flow together. An integral part of iron-making.

<u>Forging</u>

A metalworking technique, mostly associated with blacksmiths, where the metal is compressed by being struck between two dies (hammer and anvil).

<u>Furnace</u>

Any enclosed structure used for smelting metallic ores.

<u>Gilding</u>

A decorative technique where a non-ferrous metal, typically gold, is bonded or fused onto the surface of a ferrous plate.

<u>Hardening</u>

The process of hardening steel by changing its crystalline structure. The metal is cooled quickly when it has been heated past the point where it loses ferromagnetism.

<u>Heat Treatment</u>

Any of a number of processes which are applied to metals to change their crystalline arrangement in order to harden or soften them.

<u>Inclusion</u>

Impurities found within the granular structure of ferrous metals.

<u>Indirect Process</u>

A method of iron smelting whereby the ore melts in the furnace and is cast into ingots, which are then re-melted in a separate furnace to remove carbon and are then hammered into wrought iron.

<u>Medial Comb</u>

A flute or crease created on the centreline of a helmet.

<u>Medial Crease</u>

A crease set on an armour plate, usually along the vertical axis.

Munitions Grade

Lower-quality armour which may show hammer marks on the outside surface, crude construction techniques, or a less fitted shape.

Planishing

A stage in shaping, where the whole surface is hammered over a stake to achieve a clean, faceted surface.

Pritchel Hole

A small hole in the face of an anvil used in punching holes.

Quench

The process of cooling hot metal, usually by dipping it in water, brine, or oil.

Raising

A technique of shaping a sheet of metal, where the hammering is done on what will be the exterior of the piece, over a stake. The metal is thereby compressed into its final shape, instead of being stretched.

Reduction

The removal of oxygen from iron ore, during the creation of metallic iron within the smelting furnace.

Riveting

A mechanical join between two or more separate pieces, using punched holes and rivets.

<u>Slack Quenching</u>

A method of quenching to harden and temper steel in one step. Also called an interrupted quench.

<u>Slag</u>

A waste product of smelting and smithing consisting of impurities which have come from the ore, metal, and flux.

<u>Sliding Rivet</u>

A rivet set in two plates where one is pierced with a slot to allow more movement between the plates.

<u>Smelting</u>

The process by which a useable metal is extracted from ore.

<u>Stake</u>

A forming tool set in a bench or stump and used as a bottom die for shaping plates. A stake differs from an anvil in having a wide range of surface shapes, all designed to facilitate a certain shape.

<u>Tempering</u>

Reheating a hardened steel to soften it enough to reduce brittleness yet retain hardness.

Tilt Hammer

A mechanical hammer driven by a waterwheel, with an axle and cams, which engaged the end of the hammer shaft. Used largely in forging the iron sponge from a smelting furnace.

Tuyere

The tube which connects the bellows to the forge and directs the airflow towards the fire.

Peen

Any hammer face which is shaped to move metal in a particular way. *Also* to hammer a rivet head.

Loup

The product of iron formed in the fining hearth.

Quenchant

Any medium, such as water or oil, in which heated metal is cooled.

Appendix E: List of Objects Examined

Edinburgh, National Museum of Scotland, A.1905.489, great helm, English, mid-fourteenth century

Glasgow, Kelvingrove Art Gallery (KAG), E.1939.65.e.1, barbuta, Italian, *c*. 1440

Glasgow, KAG, E.1939.65.e.10, left greave, Italian, *c*. 1440

Glasgow, KAG, E.1939.65.e.11, right greave, Italian, *c*. 1440

Glasgow, KAG, E.1939.65.e.13, right gauntlet, Italian, *c*. 1440

Glasgow, KAG, E.1939.65.e.2, lower cuirass, Italian, *c*. 1440

Glasgow, KAG, E.1939.65.e.3, upper cuirass, Italian, *c*. 1440

Glasgow, KAG, E.1939.65.e.4, left pauldron, Italian, *c*. 1440

Glasgow, KAG, E.1939.65.e.5, right pauldron, Italian, *c*. 1440

Glasgow, KAG, E.1939.65.e.6 left vambrace, Italian, *c*. 1440

Glasgow, KAG, E.1939.65.e.7, right vambrace, Italian, *c*. 1440

Glasgow, KAG, E.1939.65.e.8, left cuisse, Italian, *c*. 1440

Glasgow, KAG, E.1939.65.e.9, right cuisse, Italian, *c*. 1440

Leeds, Royal Armouries (RA), AL.12 1, great basinet, English, *c*.1510

Leeds, RA, AL.23 107, couter, German, *c*. 1480

Leeds, RA, AL.23 112, basinet skull, Italian, mid-fourteenth century

Leeds, RA, AL.23 224, cuisse, Italian, early fifteenth century

Leeds, RA, AL.30 1, great helm, English, *c*.1380

Leeds, RA, AL.30 2, great helm, English, *c.*1380

Leeds, RA, AL.30 4, armet, Italian, late fifteenth century

Leeds, RA, AL.30 5, wrapper, Italian, late fifteenth century

Leeds, RA, AL.32 1, skull and visor of an armet, Northern European, *c.*1510

Leeds, RA, AL.44 1, sallet, Italian, *c.*1470

Leeds, RA, AL.50 1, armet, Western European, late fifteenth century

Leeds, RA, AL.63 1, great basinet, Western European, late fifteenth century

Leeds, RA, AL.90, left vambrace, Flemish, *c.*1500

Leeds, RA, temporary letter H, great shears, English, late sixteenth century

Leeds, RA, temporary letter U, raising stake, English, late sixteenth century

Leeds, RA, temporary letter Z, armourer's stake, English, late sixteenth century

Leeds, RA, II.1, backplate, German, late fifteenth century

Leeds, RA, II.1, breastplate, German, late fifteenth century

Leeds, RA, II.1, pair of besagews, German, late fifteenth century

Leeds, RA, II.1, pair of cuisses and poleyns, German, late fifteenth century

Leeds, RA, II.1, pair of gauntlets, German, late fifteenth century

Leeds, RA, II.1, pair of vambraces and spaudlers, German, late fifteenth century

Leeds, RA., II.89, the Lion Armour, Italian, *c*. 1550

Leeds, RA, II.167, pair of tilting sockets, German, late fifteenth century

Leeds, RA, II.168 A, sallet, Italian, *c*. 1460

Leeds, RA, II.168 B, bevor, Italian, *c*. 1460

Leeds, RA, II.168 C, breastplate, Italian, *c*. 1480

Leeds, RA, II.168 D, backplate, German, *c*. 1480

Leeds, RA, II.168 E, right pauldron and vambrace, Italian, *c*. 1480

Leeds, RA, II.168 F, left pauldron and vambrace, Italian, *c*. 1480

Leeds, RA, II.168 G, right cuisse and poleyn, Italian, 1450-60

Leeds, RA, II.168 H, left cuisse and poleyn, Italian, 1450-60

Leeds, RA, II.168 I, right greave, Italian, *c.* 1440

Leeds, RA, II.168 J, left greave, Italian, *c.* 1440

Leeds, RA, II.3, left cuisse and greave, German, late fifteenth century

Leeds, RA, II.3, pair of gauntlets, German, late fifteenth century

Leeds, RA, II.3, pair of vambraces, German, late fifteenth century

Leeds, RA, II.3, right cuisse and greave, German, late fifteenth century

Leeds, RA, II.6, foot combat armour (close helmet), English, *c.*1520

Leeds, RA, II.6, foot combat armour (leg harness), English, *c.*1520

Leeds, RA, II.7, tonlet armour (great basinet), Italian and English, *c.*1500

Leeds, RA, III.1082, plackart, Italian, 1480-90

Leeds, RA, III.1088, breastplate, Spanish, *c.*1500

Leeds, RA, III.1092, backplate, German, *c*. 1480

Leeds, RA, III.1094, upper backplate, German, *c*. 1490

Leeds, RA, III.1098, backplate waist lame, German, 1450-60

Leeds, RA, III.1100, lower backplate, German, 1480-90

Leeds, RA, III.1101, culet, German, *c*. 1480

Leeds, RA, III.1102, culet lower lame, German, 1480-90

Leeds, RA, III.1105, gauntlet, Italian or West European, *c*. 1500

Leeds, RA, III.1111, left lower cannon of a vambrace, Italian, *c*. 1500

Leeds, RA, III.1112, lower cannon, Italian, *c*. 1500

Leeds, RA, III.1115, couter, Italian, *c*. 1495

Leeds, RA, III.1116, couter, German or Italian, 1500-10

Leeds, RA, III.1118, couter, German, *c*. 1510

Leeds, RA, III.1121, right pauldron, Italian, 1490-1500

Leeds, RA, III.1122, right pauldron, Italian, 1460-70

Leeds, RA, III.1123, left pauldron, Italian, 1430

Leeds, RA, III.1124, right pauldron, Italian, *c*. 1500

Leeds, RA, III.1125, plates from a pauldron, Italian, *c*. 1500

Leeds, RA, III.1126, right cuisse, Italian, *c*. 1500-10

Leeds, RA, III.1127, left cuisse, Italian, 1500-10

Leeds, RA, III.1130, cuisse and poleyn, Italian, 1500-10

Leeds, RA, III.1131, right cuisse, Italian, *c.* 1490

Leeds, RA, III.1132, left cuisse, Italian, *c.* 1485

Leeds, RA, III.1134, left poleyn, Italian, 1500-10

Leeds, RA, III.1136, right poleyn, Italian, 1500-10

Leeds, RA, III.1137, front of a greave, Italian, *c.* 1510

Leeds, RA, III.1138, front of a greave, Italian, 1500-1510

Leeds, RA, III.1140, left greave, Italian, *c.* 1500

Leeds, RA, III.1147, wrapper, Italian, 1500-10

Leeds, RA, III.1148, bevor, Western European, *c.*1500

Leeds, RA, III.1173, pair of pauldrons, German, late fifteenth century

Leeds, RA, III.1196 B, pauldron, Flemish, *c.*1500

Leeds, RA, III.1214, left mitten gauntlet, Italian, *c.* 1470

Leeds, RA, III.1216, left pauldron and vambrace, German, 1480-90

Leeds, RA, III.122, backplate, German, *c.* 1480

Leeds, RA, III.1225, gauntlet, Italian, 1470-80

Leeds, RA, III.1227, bevor, German, *c.* 1480

Leeds, RA, III.1228, breastplate, German, *c.* 1480

Leeds, RA, III.1230, gauntlet, German, *c.* 1490

Leeds, RA, III.1281, breastplate, German or Italian, *c.* 1470

Leeds, RA, III.1282, breastplate, Italian, *c.* 1470

Leeds, RA, III.1283, breastplate, German, *c.* 1480

Leeds, RA, III.1284, backplate, German, *c.* 1480

Leeds, RA, III.1285, right cuisse and poleyn, Italian, *c.* 1420

Leeds, RA, III.1286, left cuisse and poleyn, Italian, *c.* 1420

Leeds, RA, III.1287, backplate, German, 1480-90

Leeds, RA, III.1291, tilting socket, German, *c.* 1490

Leeds, RA, III.1292, tilting socket, German, *c.* 1490

Leeds, RA, III.1293, backplate, German, *c.* 1490

Leeds, RA, III.1294, breastplate, German, *c.* 1500

Leeds, RA, III.1300, bevor, European, nineteenth century

Leeds, RA, III.1305, pauldron and rerebrace, German, *c.* 1450

Leeds, RA, III.1321, bevor, German, 1470-80

Leeds, RA, III.1325, backplate, German, late fifteenth century

Leeds, RA, III.1326, bevor, Spanish, late fifteenth century

Leeds, RA, III.1336 A, breastplate, Flemish, 1490-1500

Leeds, RA, III.1336 B, backplate, Flemish, 1490-1500

Leeds, RA, III.1348, pair of sabatons, Italian, *c.* 1450

Leeds, RA, III.1350, breastplate, German, *c.* 1520

Leeds, RA, III.1351, vambrace, Flemish, *c.*1510

Leeds, RA, III.1352 A, cuisse and poleyn, German, *c.* 1500

Leeds, RA, III.1352 B, cuisse and poleyn, German, sixteenth cetury

Leeds, RA, III.1353, vambrace, Flemish, *c.*1510

Leeds, RA, III.1366, polder-mitten, German, *c.* 1500

Leeds, RA, III.1382, bevor, German, *c.* 1480

Leeds, RA, III.1386, tasset, Italian, 1470-80

Leeds, RA, III.1387, tasset, Italian, 1470-80

Leeds, RA, III.1406, breastplate, German, *c.* 1490

Leeds, RA, III.1412, breastplate, German, *c.* 1520

Leeds, RA, III.1413, right pauldron, German, *c.* 1520

Leeds, RA, III.1414, pauldron, German, sixteenth century

Leeds, RA, III.1457 B, fauld, German, *c.* 1520

Leeds, RA, III.1698, spaudler, German, *c.* 1510

Leeds, RA, III.1699, spaudler, German, *c.* 1510

Leeds, RA, III.1709, vambrace, Italian, 1420-30

Leeds, RA, III.1713, gauntlet, Italian, late fourteenth century

Leeds, RA, III.1714, part of a vambrace, Italian, late fourteenth century

Leeds, RA, III.1803, pauldron, Flemish, *c.*1500

Leeds, RA, III.1807, bevor, Spanish, late fifteenth century

Leeds, RA, III.1808 B, vambrace and couter, Flemish, *c.*1500

Leeds, RA, III.183, breastplate, German, *c.* 1495

Leeds, RA, III.1915, fauld, Spanish, *c.*1500

Leeds, RA, III.1918, mitten gauntlet, Flemish, *c.*1510

Leeds, RA, III.2102, right cuisse, Flemish, *c.*1480

Leeds, RA, III.2103, left cuisse, Italian or Western European, *c.* 1480

Leeds, RA, III.2104, cuisse side plates, Italian or Western European, *c.* 1480

Leeds, RA, III.2446 A, backplate, German, early sixteenth century

Leeds, RA, III.2459, cuisse and poleyn, European, sixteenth century

Leeds, RA, III.2460, cuisse and poleyn, European, sixteenth century

Leeds, RA, III.2534, greave, European, early sixteenth century

Leeds, RA, III.2535, greave, European, early sixteenth century

Leeds, RA, III.2541, backplate, German, *c.* 1510

Leeds, RA, III.2561, cuisse and poleyn, British, nineteenth century

Leeds, RA, III.2562, left cuisse and poleyn, German, *c.* 1490

Leeds, RA, III.2563, gauntlet, German, *c.* 1480

Leeds, RA, III.2564, gauntlet, German, *c.* 1480

Leeds, RA, III.2565, breastplate, European, fifteenth century

Leeds, RA, III.2566 B, waist plate and culet, German, *c.* 1485

Leeds, RA, III.2593, couter, European, sixteenth century

Leeds, RA, III.2605, couter, European, *c.*1500

Leeds, RA, III.2744, gauntlet fragment, Western European, late fifteenth century

Leeds, RA, III.2745, thumb scale, Western European, *c.*1400

Leeds, RA, III.2757, knuckle plate, Western European, *c.*1400

Leeds, RA, III.3220, poleyn, European, 1340-60

Leeds, RA, III.3441, breastplate, German, *c.* 1490

Leeds, RA, III.413, part of a backplate, German, *c*. 1490

Leeds, RA, III.417 B, culet, German, early sixteenth century

Leeds, RA, III.4209, scale, English, fourteenth century

Leeds, RA, III.4210, scale, English, fourteenth century

Leeds, RA, III.4330, knuckle plate, English, *c.*1400

Leeds, RA, III.4331, knuckle plate, English, *c.*1400

Leeds, RA, III.4332, knuckle plate, English, *c.*1400

Leeds, RA, III.4333, knuckle plate, English, *c.*1400

Leeds, RA, III.4334, knuckle plate, English, *c.*1400

Leeds, RA, III.4484, culet, German, early sixteenth century

Leeds, RA, III.4568, breastplate, Flemish, *c*.1490

Leeds, RA, III.4572, breastplate, Flemish, *c*.1500

Leeds, RA, III.4599, plackart, Italian, *c*. 1430

Leeds, RA, III.4739, breastplate, Italian, late fifteenth century

Leeds, RA, III.4740, waist plate, Italian, late fifteenth century

Leeds, RA, III.4779 A, tasset, Italian, late fifteenth century

Leeds, RA, III.4779 B, tasset, Italian, late fifteenth century

Leeds, RA, III.69, breastplate, German, late fifteenth century

Leeds, RA, III.70, backplate, German, late fifteenth century

Leeds, RA, III.73, breastplate, German, *c*. 1510

Leeds, RA, III.731, left pauldron, German, late fifteenth century

Leeds, RA, III.732, right pauldron, German, *c*. 1485

Leeds, RA, III.762, couter, German, 1510-20

Leeds, RA, III.773, gauntlet, English, *c*.1370

Leeds, RA, III.782, mitten gauntlet, German, *c*. 1490

Leeds, RA, III.783, mitten gauntlet, German, *c*. 1490

Leeds, RA, III.80, breastplate, German, *c*. 1510

Leeds, RA, III.828, cuisse, Flemish or Italian, late fifteenth century

Leeds, RA, III.84, breastplate, German, *c*. 1510

Leeds, RA, III.853, pair of greaves, German, late fifteenth century

Leeds, RA, III.86, breastplate, German, early sixteenth century

Leeds, RA, III.864, vambrace, German, *c*. 1520

Leeds, RA, III.96, breastplate, German, *c*. 1485

Leeds, RA, IV.1, tilting helm, Flemish, 1490-1500

Leeds, RA, IV.1023, armet skull, Italian, early sixteenth century

Leeds, RA, IV.12, sallet, German, *c.* 1490

Leeds, RA, IV.13, sallet, German, *c.* 1490

Leeds, RA, IV.15, sallet, German, late fifteenth century

Leeds, RA, IV.1601, armet, Flemish, *c.*1510

Leeds, RA, IV.1677, skull of a great basinet, European, late fourteenth century

Leeds, RA, IV.17, barbuta, Italian, *c.*1460

Leeds, RA, IV.18, barbuta, Italian, *c.*1450

Leeds, RA, IV.1841, jousting helm, English, early fifteenth century

Leeds, RA, IV.2, great basinet, Western European, *c.*1510

Leeds, RA, IV.20, sallet, Italian, *c.*1470

Leeds, RA, IV.2056, sallet, Western European, mid-fifteenth century

Leeds, RA, IV.2057, sallet, Italian, late fifteenth century

Leeds, RA, IV.22, armet, German, 1512-14

Leeds, RA, IV.29, close helmet, German, *c.* 1520

Leeds, RA, IV.3, great basinet skull, Italian, 1430-40

Leeds, RA, IV.327, buffe, German, *c.* 1470

Leeds, RA, IV.338, falling buff, German, 1520-30

Leeds, RA, IV.340, reinforcing bevor, English, *c.*1510

Leeds, RA, IV.4, sallet or kettle hat, Italian, *c.*1450

Leeds, RA, IV.410, sallet, German, 1470-80

Leeds, RA, IV.411, jousting helm, German, *c.* 1480

Leeds, RA, IV.424, sallet, Italian, late fifteenth century

Leeds, RA, IV.425, kettle hat, Flemish, 1480-1500

Leeds, RA, IV.426, barbuta, Italian, *c.*1440

Leeds, RA, IV.427, sallet, German, 1480-90

Leeds, RA, IV.428, sallet, German, 1480-90

Leeds, RA, IV.429, sallet, German, 1450-60

Leeds, RA, IV.430, armet, Italian, *c.*1435

Leeds, RA, IV.434, visor, German, 1480-90

Leeds, RA, IV.435, sallet visor, German, 1480-90

Leeds, RA, IV.436, sallet visor, Italian, *c.*1470

Leeds, RA, IV.437, visor, Italian, 1500-10

Leeds, RA, IV.438, sallet visor, Italian, *c.*1515

Leeds, RA, IV.439, visor, Italian, *c.*1515

Leeds, RA, IV.441, bevor, Western European, *c.*1500

Leeds, RA, IV.453, sallet, Italian, *c.*1490

Leeds, RA, IV.467, basinet, German, *c.* 1370

Leeds, RA, IV.468, armet, German, *c*. 1500

Leeds, RA, IV.470, basinet, Italian, 1380-1400

Leeds, RA, IV.481, sallet, Italian, *c.*1440

Leeds, RA, IV.497, basinet, Italian, 1380-90

Leeds, RA, IV.498, armet, Italian, *c.*1450

Leeds, RA, IV.499, sallet, German, *c*. 1480

Leeds, RA, IV.5, sallet, Italian, 1440-50

Leeds, RA, IV.500, capacete, Spanish, *c.*1470

Leeds, RA, IV.502, tilting helmet, German, *c*. 1490

Leeds, RA, IV.532, kettle hat, Italian, *c.*1470

Leeds, RA, IV.537, war hat, Flemish, *c.* 1460

Leeds, RA, IV.579, visor, Flemish, *c.*1510

Leeds, RA, IV.580, skull reinforce, Italian or Flemish, *c.*1510

Leeds, RA, IV.593, helm, Flemish or Italian, *c.*1520

Leeds, RA, IV.6 , basinet, German or Italian, *c.* 1380

Leeds, RA, IV.600, great helm, English, mid-fourteenth century

Leeds, RA, IV.7, barbuta, Italian, *c.*1460

Leeds, RA, IV.741, sallet, Italian, *c.*1450

Leeds, RA, IV.748, sallet, Flemish, late fifteenth century

Leeds, RA, IV.855, visor, Italian, *c.*1380

Leeds, RA, VI.48, tilting chanfron, German, late fifteenth century

Leeds, RA, XVIII.830, armourer's stake, English, sixteenth century

Leeds, RA, XVIII.97, hammer, English, nineteenth century

Leeds, RA, XVIII.98, hammer, English, nineteenth century

London, Royal Armouries, II.90, kettle hat, Dutch, *c.* 1616

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