Iron Documents

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Interdisciplinary studies on the technology of late medieval European plate armour production between 1350 and 1500

Matthias Goll

Für Theo, den selbstlosen Sinnstifter…

This document has been handed to the Philosophical Faculty of the University of Heidelberg as the PhD-Thesis of Matthias Goll on July 11th 2013. The original title was:

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List of abbreviations

AMI	Askeri Müze, Istanbul, Turkey
BAM	Bayerisches Armeemuseum, Munich, Germany
BMA	Burgmuseum Altena, Altena, Germany
BNM	Bayerisches Nationalmuseum, Munich, Germany
CH	Churburg Armoury, Schluderns, Italy
DHM	Deutsches Historisches Museum, Berlin, Germany
DIA	Detroit Institute of Arts, Detroit, United States
DNM	Danish National Museum, Kopenhagen, Danmark
ESRF	European Synchrotron Radiation Facility, Grenoble, France
HJRK	Hofjagd- und Rüstkammer, Vienna, Austria
KIT	Karlsruhe Institute of Technology, Karlsruhe, Germany
MDA	Musée del'Armee, Paris, France
MET	Metropolitan Museum of Art, New York, United States
MLM	Museo Luigi Marzoli, Brescia, Italy
MNMB	Magyar Nemzeti Museum, Budapest, Hungary
MNMC	Museé Nacional du Moyen Age (Museé Cluny), Paris, France
RA	Royal Armouries, Leeds, GB
RAM	Réal Armeria, Madrid, Spain
SKD	Staatliche Kunstsammlungen, Dresden, Germany
SMM	Stadtmuseum München, Munich, Germany
SNZ	Schweizerisches Nationalmuseum, Zurich, Switzerland
WM	Wien Museum, Vienna, Austria

Abstract

The purpose of this study is to find out details on the production of late medieval European plate-armour for the field-use. Therefore, the author first collected thousands of extant objects in a database. With this stock of data he then was able to cluster and to structure the armour parts by various typological and technological aspects. To ease the access to the topic, the author defined an understandable and standardized terminology and typology for the different variations of armour parts.

The author tried to prime the reader on the topic of armour production by summarizing the history of plate armour under technological aspects. This was followed by a large scale observation, definition and comparison of various armour-features and their making. To complete the picture, the main crafts that supplied add-on parts for the armourer's products were shortly described. The author then entered the problematic topic of the authenticity question. After a short abstract on the history of armour preservation, metallurgical and art-based approaches to the problem of authenticity were introduced and new aspects on armour making as well as suggestions for future approaches were presented.

The examination of a huge number of extant plate armour pieces proofed to be a practical way to find new common structures in the late medieval armour production in central Europe. The development of a standardized data acquisition and its systematic organization enables large scale comparisons that bring new evidence for common features of extant armour pieces. Many drawings, made especially for this study on the basis of the collected data, combine the results of the detail observation in a concrete way. Numerous common or "standardized" features were revealed. Similar to schools of masonry, of painting or of goldsmithing also for the armourer's art the existence of certain hand or workshop circles can clearly be presumed.

For the first time, ridges, rivets and washers, applications, surface decorations, turned edges, marks, measurements, weights and different fastening techniques were classified and used to suggest reconstructions of the historical technology and its development. The explanation on how iron plate material might have been made in the Middle Ages by means of a water powered hammer is discussed for the first time. On the basis of written and depicting sources, but also by ongoing traditions, methods for the mass production of armour by the end of the considered period were described.

This study also shows that a lot of questions remain not finally solved. A final decision on an item to be genuine or reproduced can for the most cases not be made. Further research has to be carried out to enhance our knowledge on this delicate issue. The findings of this study do certainly deliver a stable basis for any future approach by any discipline to the topic of late medieval plate armour.

Preface

Before entering medias res: It is of course not common that a student of European art history comes to study the technology of late medieval plate armour. The reason for this decision is very much based in the author's private interest and hobby. His hometown, the city of Bretten, each year celebrates its rescue from a two week siege, laid upon the town walls in the summer of 1504. Friends of the local history come together and dress in reproduced late medieval costumes – travelling for one weekend into the past. Since 1999 the author is a member of one of these groups which try to resemble one of the Landsknecht units of the late Middle Ages. In 2002 he had enough of the omnipresent bad equipment-reproductions in the scene. He started to reconstruct the equipment of a late medieval mercenary according to contemporary sources: clothes, buckles, shoes, purses, weapons and finally also armour. On this course he learned to know Peter Müller, a young armourer who had yet made a few simple armour pieces. In 2003 the latter made reproductions of an extant helmet and a breastplate made to measure for the author. The two armour-freaks became friends and finally Peter Müller moved his workshop in the old stable behind the author's house. The two always had the greatest respect for the making of the segmented and articulated hand-protections of the last two decades of the 15th century. One afternoon a bet was set that the author would not be able to reproduce a hand-protection preserved in the Wallace Collection in London. The author tried and succeeded more or less satisfactorily.

From then on he had tasted blood and he wanted to know more about all the details observable at extant armour pieces. In 2004 Peter Müller started his armour workshop as his main business, after having graduated as a doctor of mechanical engineering. In his workshop the author learned a lot about armour making and financed a huge part of his studies with the making of armour, dress and accessories for private and public clients.

For all this work it was always necessary to research extant medieval examples, depictions, statues and other sources. Very often the necessary studies came to an abrupt end, as almost all the publications showed only one image of the item of interest. Details about the full shape and the construction were very hard to find. Literature was antiquated and thus rarely to be found in public libraries and often hard to pay on antique sales.

Deriving from the general interest in the past, the author went to study art history in Heidelberg in 2003. There he got the experience on how to scientifically research a historical topic, as a side effect the quality of the armour made in Peter Müller's workshop became permanently better and closer to the original. The will for the documentation of the gained experience was growing.

Finally, the author's Professor in art history, Matthias Untermann, in 2008 encouraged him to write his Magister-thesis on the topic of late medieval plate armour[1]. This turned out to be so much fun and a field for much more research so – after having graduated – the author decided to also write his PhD-thesis on this topic, now with a stronger focus on the technology of armour making.

On July 15th 2013 the present book was handed in to the Philosophical Faculty at the University of Heidelberg as a PhD thesis with the title "Interdisciplinary studies on the technology of late medieval European plate armour production between 1350 and 1500".

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1 For the published version of this thesis see: Goll (2009).

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1 Introduction

What comes to your mind when you think of plate armour?

You probably see knights in fierce fights on horseback; you probably think of the considerable weight that the fighters have to bear and how inflexible they were in their motions, how difficult it must have been to breath and you may remember some suits of armour that you once have seen in a museum.

Armour is much more than that. Armour is like clothing-fashion. It varied in style and construction throughout the ages, for different purpose and from region to region. Armourers were often in direct contact with the rulers of their times. Many of them were personally as much appreciated as their famous art-creating contemporaries that we still remember today.

However, since the time of its use, what still exists of armour became disarranged – both physically and documentarily. Armouries and suits or even single items got torn apart, parts got lost, formerly associated pieces got into different collections, a lot got repaired and missing parts or whole suits were reproduced. Since the late 18th century, collectors and researchers are trying to get things back in order. Archive material provides names and locations of many old master armourers and their families. Sometimes documents tell about the cost of armour, occasionally they tell us the names of customers. The master of an extant object might be identified if it bears an identified personal or a workshop's mark. If the city, where the quality of the armour was tested, stamped the plate with its symbol, the production might also have been located there. Also some owners marked their items with their symbol.

The morphological and the art-context genesis of armour has been researched and described sufficiently throughout the last 200 years. Only a few future additions and corrections are to be expected. Concerning the making of armour, nothing seems to have been written down in the late Middle Ages, at least nothing survived. This is probably one of the reasons why the technology of armour production still remains a virgin field of research. One of the few and still unrivaled publications on the topic is Charles Ffoulkes' "The armourer and his craft"[2], written in the early 20th century. Ffoulkes provided for a good overview on the subject, while he did not classify and describe the making of certain features found on extant armour. The discussion remains rather general and at several points it is of course not up to date anymore. Brian R. Price[3] wrote a code of practice for armour reproduction about a hundred years later. This book does not gain further academic insight on the topic, it is rather intended to guide modern reproducers in making armour. In the last 35 years Alan Williams[4] has carried out important research on the material quality of plate armour. In various other publications, discussions of the ancient techniques of surface-decoration have been included.[5]

Nevertheless, in none of the preceding scholarly preoccupations with the topic of armour, the genesis of technological aspects has been studied in details. So far, many features observable at extant armour still remain undiscussed – despite their big potential for answering open questions on the artifacts themselves and on the ancient and almost vanished craft of armour-making. Furthermore, studying such features is indispensable for approaches to a differentiation between genuine items and high quality reproductions.

2 Ffoulkes (1912).

3 Price et al. (2000).

4 Most of the results are found comprehensively in: Williams (2003).

5 E. g.: Thomas and Gamber (1976) p. 25-34.

The reason for this topic still remaining widely untouched might derive from a simple competence question: Which academic discipline is suited for researching this topic? Is it art history? Is it not archaeology that takes care of profane material cultures of the past?

Studies on armour do certainly need the systematics and the tools of both disciplines. Most extant items were preserved "above ground". They did not get lost or dumped and thus they were never covered by dirt and rubbish that could now help to support their dating. Anyway, some tools needed to research armour are actually those used by archaeologists. The armourers left some fingerprints of their skills and taste of their own times at the items – these can be classified like archaeologists classified significant features of ancient pottery.

On the other hand, armour was not only made to fulfill a protective function: it is also artwork – sculpture, plastic, clothing, defensive weapon and in some cases even medium for the communication of 2-dimensional images. Art history is certainly the discipline that traditionally interprets all these aspects. Where written documents are missing or incomplete, "experimental archaeology" can help to answer open question. This discipline is – even though for many projects nowadays respected – academically still not widely accepted. For the sake of the usually high costs of experimentally reconstructing ancient crafts, most of the academic research publications only theoretically reconstruct ancient technologies.

The discipline that would cover the necessary skills for the descriptive reconstruction of the making of historical artifacts does not exist as such. This "history of technologies" has so far always been written by interdisciplinary approaches to specific issues. The authors of preceding papers on historical technologies were often non-academic lays, engineers, historians, art historians or archaeologists. Different disciplines, like philology, delivered their part as well.

The starting point for discussing the history of plate-armour technology is located somewhere in this cloud of disciplines and approaches. This study presents an interdisciplinary research project of its own, starting with new ideas on how to get closer to the open questions on the technological exertion of a nearly forgotten art or craft.

The focus of this study is exclusively on the central European plate armour production, as for the considered period the links to armour of other cultural regions seem to be marginal. The skills of the medieval, renaissance and baroque European craftsmen producing armour for the entire body from large plates were absolutely unique. In the context of this study "central Europe" means first of all "northern Italy" and "the German speaking lands", while indeed western and southern European countries like England, France and Spain also had important production sites from the second half of the 15th century on. The products of these countries will also be considered and compared to the German and Italian items wherever possible.

The limitation of this study to the years from 1350 to 1500 is due to this period showing the first zenith of the art of armour making. Since the decline of the Roman Empire, of all armour it was only the helmets that were occasionally made of larger plates. The tendency to cover also the torso by larger plates can first be stated in the mid 14th and therefore only very few earlier pieces could serve for the intended comparisons of technological features.

The question on protective aspects of armour will not be discussed in this study. There are reams of factors and parameters that need to be considered whenever this aspect is examined. The field-testing of originals is out of question. Using modern reproductions would only make sense if the material of the tested arms and armour would be made by the ancient techniques. The testing of arms-penetration would then have to be repeated with different arms, forces, penetration angles and beddings of the armour parts. Results would still only count for the tested items. Contemporarily, there was arms and armour of good and bad

quality in use. The historical accounts of many armoured men killed in battle already tell what would be the outcome of such "experimental archaeology". When considering the number of armoured fighters that survived battles and even blows towards their body, it becomes clear that the range of answers on the question of protection-effect reaches from "absolutely unhurt" to "immediately dead". In between there are many different results to be expected, shifting to the one or the other end of the scale.

By the beginning of the 15th century, special armour pieces were made exclusively for sportive use in different types of tournaments. The study of this field of the plate armour production is of course a very interesting and also still neglected field. Nevertheless, including tournament armour into the focus of the present study would mean to compare additionally some thousands of extant objects and there was simply no time for such an undertaking. Also horse armour could not be studied in the course of this study. The master armourers of the two excluded armour-categories are often the same that also made man's armour for the use in the field. This leaves interesting questions open for future research, extending the range of this study on these two branches of the armourer's craft.

This research project intents to reveal details on the recurring features of field armour; wants to show how ideas were processed; wants to show that norm-like features already existed from the earliest days of armour-making and that there has always been an immense room for creativity and invention. Studying and classifying the features found on extant armour can help to differentiate very exactly between different masters, schools, regions and times. This study tries to show that there is only little knowledge on this topic existing so far and there are many further open questions that cannot all be answered within a research project like the present one.

In the course of this research, it was not possible to do any extensive archival work. The edited contemporary sources are very close-lipped on telling technological details. Medieval depictions of armourers at work are rare and they do not tell much about the technology. Working descriptions particularly on armour-making were not written down; specialist's knowledge was most likely exclusively handed down orally to the chosen younger generation of workers. This system was intended to protect the technological experience of the local armourer's guild from competing guilds of other cities or from unauthorized craftsmen. Nevertheless, five relevant groups of written sources can be determined: 1. Guild-regulations; 2. Orders; 3. Payments; 4. Legal disputes; 5. Accounts and stock-lists. A few hints came "coincidental" into contemporary sources of these classes. All the secrets that these sources do not give away, need to be revealed by considerations on the technological features displayed by extant armour-parts. For the understanding of the techniques that human beings developed – from the mining of the ores to the fighter dressed in armour – sources of later times, other crafts, as well as of specialist's and own experience have to be consulted.

From the early 19th century on, in parallel to the rising scientific interest in the European Middle Ages, the collector's demand for ancient armour was growing. As the supply of armour was limited, prices were rising and a flourishing modern industry, reproducing arms and armour, got established. Forgeries were offered on the market and some reproductions were sold to second or third hand as originals. Nowadays, it seems often impossible to distinguish between originals and reproductions in many collections all over the world. As this study is based on extant armour pieces, the question of authenticity is essential for any kind of discussion. Therefore, the concept was to purposely include identified reproductions and suspicious objects in this study. Comparing the details of both – reproduced and assumed genuine plate armour – offers a chance for finding new criteria for identifying questionable objects without applying expensive or even destructive natural-scientific testing methods.

The possibility for large-scale detail comparisons of objects of certain and questionable provenance, on the basis of the collected data, will hopefully bring some new light into this dark area of the research field.

It is still uncertain which semi-finished material the armourer used; from where he bought it in and which way it took from ore to sheet material. This is probably due to the necessity of doing such research with the help of several disciplines. To understand this field, knowledge of art-history, of archaeology, of history, of metalworking and of some natural sciences like metallurgy is necessary. Especially the ironwork in all its facets is a very wide and difficult field. It is also a young discipline, as iron for a long time was widely considered as a material irrelevant for artworks. Iron was produced in the Middle Ages all over the world with the exception of Australia, New Zealand and the American continents. It could be produced in many different ways; the raw materials needed could be found almost everywhere. Old material was often recycled and the trade of iron was widespread. All these facts make research on iron artifacts very complicated.

So far, particularly the processes of making plate and its subsequent forming into a piece of armour were hardly the subject of studies. Many extant examples of 16th century arsenal[6] armour are so similar to each other that they presumably were made in some kind of serial-production processes, probably already organized in division-of-labor working processes. The historical development of the mass production of plate and armour has not yet been examined so far. Plate armour was produced for different social classes: for the noble man, for the well situated citizen and for the simple foot soldier. The comparison of the dimensions of extant armour parts might reveal what armour was really made to measure and what was "one size fits all" mass-production. The research in art history was so far mostly focused on the expensive and richly decorated armour. The simple and undecorated items have been studied only rudimentary. Production centers for plate armour were established in several cities all over central, western and southern Europe. If armour pieces are not marked, the place of their production and the names of their makers remain unknown. It is well possible that a lot of the extant items were actually made at less popular sites.

Whenever no direct written document or mark allows the tracking of the provenances, the scholar can try to get further by examining the technological features. Therefore, it is at first necessary to observe and to describe the smallest details that occur at extant armour pieces and to make them comparable to features at other pieces. A collection of detailed object images and data, organized in a database can provide the basis for such comparisons. To simplify the evaluation of the data a standardized system of nomenclature and typology of the contained items needs to be developed.

Several observations on extant plate armour pieces can serve as criteria for comparisons. This is: the marks, materials, surface structures, decorations, edges, ridges, washers, rivets, applications and the different plate-joints. Also dimensions, plate-thicknesses and weights provide interesting data for comparisons. Such examinations might reveal unknown relationships between different objects and object-groups might be defined.

The large amount of extant European plate armour pieces of the time between 1350 and 1500 makes it difficult to examine all the technological aspects of armour making. Reams of contemporary artworks depict lost types and pieces of armour that could also be organized and compared the same way like extant pieces. It was not possible to go into details on

6 Arsenal in the context of this study means a facility where the war-material for the equipment of huge numbers of soldiers was stored. The stock could quickly be handed out to personnel or citizens in case of danger or warfare.

depictions of armour found in art. Nevertheless, where necessary, artworks will be described and used as references for the understanding of extant objects.

Preceding studies in the field usually only described one object or they compared a small number of objects. The common object-descriptions cannot serve as a direct basis for object-comparisons. They were never standardized, neither in language, nor in terminology or in their focus. Different writers paid different attention to the observable constructional details. Most of the former descriptions are rather stylistic classifications than descriptions of technological features.

High quality object images were the most important working material for the present study. Despite many publications include images, details can usually not be recognized. Only few books contain images from different angles, but almost never they show the interior of an object. The view of the latter is very important for the purpose of this study. First of all, because it shows constructional and technological details not visible from the main sides of the object. Second, the interior surface is also the only one left in the most untouched condition after the armourer's shaping-work had been finished. Hence, approximately 1300 objects were handled and photographed by the author with specially designed equipment. Each object was pictured in about 3 to 8 images, each showing the item from a different angle. Most of the items were measured, rubbings of marks were made and they were shortly surveyed. In some cases the items had to be taken off display and to be reinstalled after the examination. On some days, the author had worked on more than 20 items, which left not much time for closer examinations. The examination of details was done later at the office desk. Several collections could not be visited due to financial and time limitations. Most of the museums were very open for this kind of research model. Unfortunately, the curators of the RA, the HJRK, the RAM and the MNMB did not support the access to a larger number of their collectibles.

The suggestions of this study for new scientific approaches to the topic of late medieval armour production are not meant to be set in stone and they are for sure not generally unproblematic. There is a lot of room for discussion, which hopefully will develop this topic further in the future. The collected data and the system in which it is now organized may help to reveal new relationships between documents and extant item.

2 Terminology and typology of plate armour

The intention of this research is, to discuss problems on the technology of armour manufacture. The desired results should allow bringing progress to many unsolved research-questions in this field by replacing the lack of written sources on the technology by reading extant objects like technological documents. For this purpose, the author of this study has amassed images and object data of nearly 5000[7] single armour parts. This bulk of information only becomes sensible when it is organized in a uniform system that allows to filter the data with aim of comparing various aspects. The first step to such a system is a nomenclature and typology that is as unmistakable as possible. An internationally accepted and standardized nomenclature and typology of armour does not yet exist, as will be shown in the following. To ease the understanding of the topic, suggestions will be made on how the terminology of armour can be standardized in the most simple and clear way. The suggestions will be already applied in the subsequent chapters.

2.1 Present-day's terminology and typology

"Poleyn, chanfron, couter, rerebrace, tasset, cuish, greave, solleret, sabaton, (Engl.); Mäusel, Kniekachel, Diechling, Beintasche, Spangröl, Bart, Gesässreifen, Bauchreifen, (Germ.); mentonniere, cubitiere, cuissard, soleret, tassiette, (Fr.); baviera, cubitiera, falda, fiancale, ginocchiello, (It.); bufeta, faldar, escarcela, quijotes, (Span.) etc.[8]"

These terms have no meaning to a contemporary with any knowledge on European plate-armour. While it is of course common that each scientific discipline uses its own specific terminology, anyway the question might be asked if an international and simplified terminology would not immensely ease scientific exchange and general understanding of publications on the topic.

Several attempts were made to find a uniform terminology for arms and armour. In 1972 an ambitious dictionary, the "Glossarium armorum", was published in 10 languages.[9] Nevertheless, this work has never won much recognition and until today there is a lot of misunderstanding between the different languages, even within their own terminology. The author has made a concordance between the concerned terms in these volumes and the terms suggested in the present thesis [ref_tab_con].

European plate armour in the second half of the 15th century was produced in different regions. The most famous were: Northern Italy[10] (Brescia[11], Milan[12]); The German speaking

7 The author counts each body-part protection separately (e. g. an arm defense consisting of permanently connected plates for the upper arm, the elbow and the lower arm wound count as 3 parts. E. g. a single visor counts as one complete helmet). About 1300 of these objects were examined and photographed in high resolution by the author.

8 See for example: Anonymous (1930), pl. 2.

9 Gamber et al. (1972-1996).

10 Boccia and Coelho (1967); Boccia (1982).

11 Rossi (1972); Thomas (1977a).

12 Boeheim (1889); Thomas and Gamber (1977).

lands[13] (Innsbruck[14], Nuremberg[15], Landshut[16], Augsburg[17]). Obviously there was also armour produced in many other regions, but only little research has been carried out on them so far: e. g. Western France (Arbois[18]), Flanders[19] (Brussels, Liege), Spain[20] (Aragonia) and England (London, Greenwich[21]). The armourers of these different regions spoke distinct languages: French, English, German, Flemish, Spanish and Italian. They also used different terms to describe their products.

The words "armatura (Italian)", "armure (French)", "armour (English)" and "armadura (Spanish)" in different spelling clearly derive from the Latin word for a protective clothing of the body "arma, -orum, *m"*. They are frequently used in written sources of the said languages for describing armour in general. Sometimes this could also include the offensive weapons. In German it is more problematic. The modern German word "Rüstung" has no Latin roots and was not used in medieval sources.[22] The general contemporary term used for armour was "Harnisch" or "Harnasch" (in different spellings). This refers usually to plate armour only. While in English and French the historical term "maille" (in various spelling) was used for a body protection made of small interlinked rings, each riveted together at the overlapping ends, the German sources speak of "Panzer" (in different spelling), which is the modern German term for any type of armour.

The contemporary terminology for single armour parts was very flexible and changing throughout the times and the different European regions. Even the term for the job title of the armourer differed within time and region. Pierre Terjanian is mistaken when he says that the German documents of the 15th century commonly refer to the armourers as "Harnascher" in different spellings, and only from the mid-16th century they would frequently use the term "Plattner".[23] Already before 1342 the German sources use the term "platner" to define a certain profession.[24] The 14th and early 15th century sources in the archive of the city of Vienna exclusively use this term. They never use the word "Harnascher", despite they frequently use the word "Harnasch" for any kind of body protection:

Niclas Chöppl der Irrher schaft seinen harnasch, der zu seinem leib gehört hat, item ain panzir, ain Hauben, ain prustplech, ain par armgret, zwen hantschuch zu verkaufen.[25]

13 Thomas (1944); Reitzenstein (1942).

14 Tiroler Landesmuseum Ferdinandeum (1954); Thomas (1974); Egg (1992).

15 Boeheim (1895); Reitzenstein (1967); Thomas (1977c); Willers (1978).

16 Frauenhofer (2004); Kalcher (1895); Spitzlberger (1975); Spitzlberger (1985).

17 Boeheim (1891); Boeheim (1892); Boeheim (1893); Buff (1893); Reitzenstein (1955).

18 Ffoulkes (1912), p. 136-137; Thomas and Gamber (1976), p. 195.

19 Terjanian (2009).

20 Calvert (1907); Mann (1933).

21 Grancsay (1929); Williams and Reuck (1995).

22 The term „Rüstung" in the late Middle Ages and the early renaissance defined a type of crossbow, see: Sensfelder (2009). It further described all kinds of winches, which is probably the reason why the winch-spanned crossbows were also called „Rüstung". It is not clear why this term was later used to define armour. (Thanks to Jens Sensfelder for this information).

23 Terjanian (2001) p. 158.

24 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1895), Reg. 12675.

25 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1895), Reg. 13542.

Furthermore, the term "Harnaschmeister" often found in German sources might be misunderstood. It does not mean "armourer", but it defines a person professionally responsible for publicly or privately owned armour.

A few definitions might have had a familiar sound to people's ears throughout all times, but most of the terms the armourers of old and their clients once used had got lost after the full body-armour had gone out of use in the course of the 17th century. When in the 19th century members of nearly all European societies became interested in the history and the collecting of ancient armour, it became necessary to find substitutes for the lost terms once used to define and describe the different armour parts and their segments. For this purpose those who occupied themselves with armour started to look for references on armour in ancient documents. The terms used in these sources never refer to any illustration. Therefore, it was necessary to compare extant armour pieces to contemporary depictions of armour and to try to match them to the terms found in ancient documents.

In some cases it was of course obvious which class of armour a certain term meant, especially if the sources used terms that were descriptive and/or still known – for example in German: Handschuh, Helm, Beinling, Brust etc. (each in different spelling). For many abstract words found in the sources the identification with an extant or depicted armour part was more difficult: e. g. Diechling (Ger.), poleyn (Engl.) etc.

In many cases authors of the 19th century just guessed what might have been the old term for a certain type of armour-part. Where no old definition could be found, new ones were created. For example for the description of different groups of helmets the terms "Schwarze Schaller" or "Geschlossener Helm" were created. In some cases these modern "inventions" were descriptive and therefore they really eased the identification to certain extend: e. g. the attribute "hour-glass" to describe a certain group of hand-protections [ref_arm_1266]. All these factors led to a complicated terminology, being a mix of ancient and modern definitions. This is still the situation today – a regrettable and unnecessary obstacle for interdisciplinary and international research approaches. In the following some "sources of confusion" will be exemplified in detail.

An inventory of all "mobile" objects present in the castle of Runkelstein in 1493 serves as an illustrative example on how difficult – or yet impossible – it is to connect a historical term to a certain type of object[26]:[27]

26 See also the various essays (e. g. Janitz, Schuppert, Wilckens) on the problem of medieval terminology and typology in: Appelt (1988).

27 For the English translation the author of this paper has chosen the terms commonly used in English literature.

In der harnaschkamer, genannt Neythart.	In the armoury, called Neythart.
Hundert und zwo wälsch tschaleren.	102 welsch (Italian?) sallets (helmets).
Zwelf teutsch tschaleren.	12 German sallets (helmets).
Fünff eisenhuet nach der alten welt.	5 kettle-hats (helmets) after the old world (?).
Fünf schifftung und pärt.	5 “Schiftungen” (reinforces?) and neck-protections.
Siben englisch stechhelm mit kappen.	7 English jousting-helmets with caps (linings).
Zwelf englisch stechhelm an kappen.	12 English jousting-helmets without caps (linings).
Zwen helm zu cröndlstechen.	2 helmets for the joust with Krönigen.
Zwen waffenhelm.	2 weapon-helmets (?).
Acht swarz wälsch tschalern.	8 black welsch (Italian?) sallets (helmets).
Vier stechküris.	4 jousting-armours (breast- and maybe also back-plates).
Drei krebs.	3 breastplates (maybe together with backplates)
Drei prüst.	3 breastplates
Ain halbs rüggl.	Half a backplate.
Zwai roßgstiernen.	2 shaffrons (horse head-protections).
Newnzehen par armrör.	19 pairs of vambraces (upper or lower arm-protections).
Aindliff achseln und spaneröl.	11 spaudlers (shoulder protections) and Spangröls (upper arm-protections adjacent to the shoulders).
Vier par clain achseln.	4 pairs of small spaudlers (shoulders).
Zwen stechhelm an gestirn oder hauben zu dem tracken.	2 jousting-helmets without the forehead or the caps for the “tracken” (?).
Vier swebscheiben.	4 besagews (discs protecting the armpits).

Vierzehn par ganze paingewandt.	14 pairs of complete leg-dress (leg-armour).
Drew par schinpain.	3 pairs of shin (protections for the front of the lower leg).
Zwai par schuechgewandt.	2 pairs of shoe-dress (foot-armour).
Sechsthalb par handtschuech.	6 ½ pairs of gloves (hand-protections).
Ain drüml zu ainem gliger.	1 “drüml” (piece?) for a horse armour.
Sechs stückl zu armrör.	6 pieces additionally to the vambraces (elbow protections?).
Ain untertail zu ainem kuris.	One lower part of a Küris (breast-and backplate?)
Fünff kniepückl.	5 knee-cops.
Siben pantzer, an pruech.	7 ring-armour shirts without pants.
Ain goller.	1 collar.
Ain schurzfleck.	1 apron-piece.
Zwo hundskappen.	2 hound-caps.
Ain krägl.	1 collar.
Ain kappen unter ain helmlin.	1 cap under a helmet.
Ain pantzererbl.	1 ring-armour sleeve.
Zwai par lidern armrör.	2 pairs of leather-vambraces (protection for the upper or the lower arm).
[…][28]	[…]

28 Transcribed from: Statthaltereiarchiv Innsbruck, Miscellanea 92 by: Schönherr (1900), p.79-680.

This translation makes clear that the actual appearance of the mentioned item cannot be reconstructed. Furthermore, some historical terms might easily be confused, like the German term "Hundsgugel" which describes a late 14th century helmet[29] enclosing cheeks and neck, with a pointed visor attached. Some sources (for example the inventory quoted above) use a similar term: "Hundskappe"[30], but in inventories this is frequently listed within the ring-armour items and is therefore certainly not made of plate.

The German word "Schaller" (in different spelling) used for a helmet with a flaring nape-guard appears frequently already by 1425[31]. In England the term "sallet" was used until the late 16th century – a time when no helmet comparable to the one piece "sallet" of the second half of the 15th century existed.[32] That also the medieval writers were not so sure about how to name a certain helmet is evident at another document, which says:

1478 Februar 11. Sigmundn Kraft bezalt ain eisenhut oder säler, ...[33]

Two popular examples of 19th century terminology might be mentioned: The type-variant "black sallet" or in German the "Schwarze Schaller", sometimes also called "Jagdschaller" (hunting sallet). The adjective "black" is attached as some of these helmets were left unpolished and rough from the hammer. Another example is a head-protection made of one plate which covers the skull, the cheeks and the neck. In the 19th century German literature, it was given the modern name "Beckenhaube", while in French and English literature the ancient terms "bacinet" (in different spelling) was used.

The problem of a confusing terminology in modern literature exists for long. Already by the year 1911 Charles Ffoulkes calls the attention to some examples:

29 For example in the Limburger Chronik in 1389 the term "hundeskogeln" is used to describe what must be a helmet, as the other body armour – breastplates, leg armour – is also mentioned and such an equipment was certainly not missing a helmet. In this source it also interesting to see that this type of helmet was obviously not only reserved to knights but also other men-at-arms like citizens and foot-soldiers, see: Post (1936), p. 179.

30 See for example: Schönherr (1900), p.79-680.

31 An inventory of 1425 mentions two „tschelern" or „tschaelaern", another one of 1426 three „tscheleden", see: Jahrbuch der Kunsthistorischen Sammlungen in Wien (1899), Reg. 17568 and 17573. When these words are pronounced in German they remind rather on the Italian "Celata" than on the German word "Schale" (bowl), often suggested to be the root for the definition of this type of helmet.

32 Blair refers to French, English and Spanish 16th century sources where the term denotes an open-face helmet with a fall at the forehead and a short flaring nape-guard, see: Blair (1972), p. 136.

33 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1900), Reg. 18319.

There are several Venetian salades in good condition, with the T-shaped opening for eyes and nose, a return to the form in favour in ancient Greece [ref_arm_2013]. The term 'barbute' is often given to these helmets, or to the large bascinet with projecting cheek-plates. As a matter of fact, we are still uncertain as to the meaning of the word, except that it was a headpiece with some sort of chin protection; for Olivier de la Marche distinctly speaks of la bavière de sa barbute. […] The word barbute was also used for a man-at-arms, as we learn from Du Cange. With regard to the word bavière, it is interesting to note that Buchon has transcribed the words bachinet à bavière as bachinet à bannière in his edition of St. Remy's description of Agincourt, which shows how careless he was as to the description of armour.[34]

Historiography in English language sometimes refers to these helmets using the term "barbute" and sometimes "sallet in the venetian style" or "Venetian sallet".

Several years after Laking Hans Müller-Hickler in 1933 complained:

Die Bezeichnung „Topf-" [ref_arm_1471] oder „Kübelhelm" [ref_arm_1470] kennt das 14. Jahrh. nicht, sie entstand in einer Zeit dilettantischer Behandlung der Waffenkunde, die von Romantik geleitet, Namen erfand, statt die alten mit gutem Recht benutzten Bezeichnungen zu gebrauchen. Etwas ähnliches [sic!] erleben wir auch jetzt wieder. Statt der schon im 16. Jahrhundert gebrauchten so charakteristischen Benennung „Rüstung," werden gewaltsam ellenlange Namen ausgeheckt, die kein Mensch versteht, der Laie, der doch auch Interesse an der Geschichte des Vaterlandes hat, erst recht nicht. Die Franzosen und Engländer sind konsequenter und behalten „armure und armour" bei. Die Alten nannten den Hauptschutz „Helm" (hialm)!, Griemhelm (Beow. 335), Helm, Helmfahs (Bieterolf.), Helmhuot. (Nibelungenlied).[35]

Müller-Hickler is presumably right when he says that the old terms were generalizing and that the modern ones are "violent" definition-attempts. Furthermore he antedates the primary concern of the present study: Making access to the topic easy for everyone.

Not all the problems with the terminology of armour can be discussed here, but these few examples might have shown how complicated research and understanding of the topic already in a national frame actually is – not to mention the existing obstacles for successful international research-cooperation.

2.2 Suggestions for standardized definitions[36]

With the fall of the iron curtain the eastern European collections of arms and armour got easier accessible for scholars from all around the world. Also archaeology throughout the last 2 decades got a new push and has unearthed a lot of armour pieces. Very often armour known from central Europe has been revealed, for example in the Baltic States, the former territories of the Teutonic knights [ref_arm_5103] [ref_arm_3963] [ref_arm_879] [ref_arm_1733]. More and more scholars with different mother tongues got involved, still

34 Ffoulkes (1911), p. 383.

35 Müller-Hickler (1932-34), p. 179.

36 For keeping the reference titles as short as possible, in the following the single items are quoted by an ID-number only.

not having a clear international terminology at hand. The first step towards an improvement of the situation would be an agreement on one common language. It is unquestioned that English is the new international "lingua franca", at least in most of the world's regions where people have access to education. Therefore, this language was chosen to determine the objects of interest for this study.

In most industrial and economical branches standards have long been recognized as a necessary tool for a global business-exchange. In the art sector in different disciplines several attempts had been made to establish nomenclature standards, but none can be considered as internationally accepted. This leads to the result that research often ends at national borders and ancient cross-border connections may not be recognized.

It therefore seemed reasonable for this study to first drop all the historically grown terms and then to find an entirely new logic-based terminology instead. The preceding terminology was not structured and therefore a classification-system of the different types of armour had to be developed. Nevertheless, there are intersections with the preceding terminology.

The structuring of plate-armour by means of the human anatomy was the first organizational-step. It was found that a first differentiation in the six main groups: head, neck, arms, hands, torso and leg was reasonable, as armour for each of these body-parts defines an independent defense that can always be worn separately. Subsequently, the more complicated body parts had to be divided in sub-groups: the torso in hip, the appending upper-leg and in front and back; the arm into shoulder, armpit, upper- and lower arm and into elbow; the leg into upper- and lower leg, knee and foot. Of each of these main- and sub-groups several types do exist. The intention was to find a definition being the lowest common denominator for describing each of them. The author was therefore visually comparing thousands of objects. Nearly all formal design-variations were purposely left aside and the considerations concentrated on the common ground from a constructional point of view. Illustrated definitions of each revealed group were developed. It seemed logical for their definition to keep the name of the type and to add roman-numbers. The shoulders and the elbows can have detachable reinforcement-plates that define a sub-class of these arm-protections. These sub-definitions were indispensable as most of the armour parts from before 1500 are single pieces, not attributable to an extant suit or its parts. The single extant reinforces therefore needed to be described by a separate type. The defined body-part types either consist of a single plate or they can be constructed from several adjoining plates. On many extant items some of the adjoining plates are missing. Therefore, but also to make closer literal description possible it is necessary to define also such sub-segments. Many items are only fragments and it is not always clear of which type they once were. In most of these cases the identity can be reconstructed via comparisons to complete examples. These segments of one type will be defined in the text by understandable descriptive terms like "flap", "nape-guard" or "lame".

2.2.1 Textile (not in the focus of this study)

Armour made from padded fabric only will be described as "textile-armour".

2.2.2 Leather (not in the focus of this study)

Armour can be made from thick and hardened leather, sometimes reinforced with metal bars or rivets. Such items will be described as "leather-armour".

2.2.3 Ring-armour (not in the focus of this study)

In the following all armour made of interlinked wire-rings is called „ring-armour".

2.2.4 Segmented (not in the focus of this study)

In this study, all items made from several segments held together via leather or fabric only are not considered as "plate-armour". These items belong to an own armour class described as "segmented-armour". Wherever items are discussed in the following, they are described by the terms: head-segmented, torso-front-segmented, torso-back-segmented, torso-front-and-back-segmented, arm-segmented, hand-segmented and leg-segmented. No further sub-types were defined.

It can be anticipated that segmented- and ring-armour was used for the protection of each part of the body before 1350, throughout the considered period and after 1500 – in parallel to the use of plate-armour,[37] but ring-armour will not be included in the following considerations.

2.2.5 Plate

2.2.5.1 Arm-protections

2.2.5.1.1 Armpit [ref_ill_typ_arm_pit]

This is a single-piece defense for the armpit only that is attached to a shoulder of type-I [ref_arm_181] or –II [ref_arm_5116]. Such defenses appear from 1400 on. The round versions in modern literature were called "Schwebscheibe" (Ger.) and "besagew" (Engl.).

It is difficult to tell where extant plate discs once had been mounted. A very early depiction of discs laced to the shoulders and at the elbows of a ring-armour shirt is found at [ref_ill_art_5167]. According to other contemporary depictions they appear also mounted to horse head-, pelvis- [ref_ill_art_5191], hand- [ref_ill_art_5252] [ref_ill_art_5370] [ref_ill_art_5377], elbow- [ref_ill_art_5245], knee- [ref_ill_art_5235], torso back- [ref_ill_art_5226] [ref_ill_art_5227] and head- [ref_ill_art_5277] protections, all throughout Europe and all throughout the 14th and 15th century. It is therefore not clear to which body part – or possibly horse head – a single disc once belonged.

2.2.5.1.2 Shoulder

2.2.5.1.2.1 Type-I [ref_ill_typ_arm_sho_I]

This defines a small shoulder-defense covering the shoulder joint [ref_arm_881] and – by some articulated lames – it protects parts of the upper arm [ref_arm_326] [ref_arm_425]. It was in use from about 1400 until the 1530ies and was historically probably called "*Achsel*"[38] (Ger.) and modern "Schulter" (Ger.) or "spaudler" (Engl.).

2.2.5.1.2.2 Type-II [ref_ill_typ_arm_sho_II]

This type describes a huge shoulder defense with "wings" at the front- and the backside that overlap parts of the torso [ref_arm_611]. It was in use from about 1410 on until 1630. Historically it was probably called "*Achsel*"[39] (Ger.) and modern "Schulter" (Ger.) or "pauldron" (Engl.).

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37 A protection made of small segment fastened to a textile or leather cover for the protection of the neck never existed.

38 See e. g.: Statthaltereiarchiv Innsbruck, Miscellanea 92, edited in: Schönherr (1900), p.79-680.

39 See e. g.: Statthaltereiarchiv Innsbruck, Miscellanea 92, edited in: Schönherr (1900), p.79-680.

2.2.5.1.2.3 Reinforce [ref_ill_typ_arm_sho_IIr]

This is a single detachable reinforce plate for the front of a right or a left type-II shoulder [ref_arm_742]. It was in use from the 1420ies on until the late 15th century.

2.2.5.1.3 Upper arm

Protections for the upper arm in modern literature were usually called “Oberarmröhre” (Ger.) or “upper vambrace” (Engl.).

2.2.5.1.3.1 Type-I [ref_ill_typ_arm_upp_I_ger] [ref_ill_typ_arm_upp_I_ita]

This defense is enclosing the upper arm only by half. While the Italian versions cover the rear side [ref_arm_811], the German examples cover the outer side of the upper arm [ref_arm_249]. These defenses were probably in use from the late 13th until the early 17th century.

2.2.5.1.3.2 Type-II [ref_ill_typ_arm_upp_II_ita]

This defense is enclosing the arm more than by half, but it is not completely embracing. It has normally no hinged flap [ref_arm_884]. These types were in use from 1420 until 1500.

2.2.5.1.3.3 Type-III [ref_ill_typ_arm_upp_III]

This defense is enclosing the arm completely. It might consist of a single tube [ref_arm_511] or it might be constructed of two halves hinged together [ref_ill_art_5335] (descr. 1). Such upper arm defenses were in use from the 1490ies on until the 1630ies.

2.2.5.1.4 Elbow

Elbow protections in modern literature are usually called “Ellenbogenkachel” (Ger.) or “elbow-cop” (Engl.).

2.2.5.1.4.1 Type-I [ref_ill_typ_arm_elb_I]

This is a defense that encloses only the point of the elbow [ref_arm_1021]. It is not clear if this type of elbow defense existed as such. The examples attributed to this group might just have lost the shell-like extension and would therefore be rather of type-II.

2.2.5.1.4.2 Type-II [ref_ill_typ_arm_elb_II]

This defense encloses the point of the elbow and the side where it bends by a shell-like extension, but it is not completely closed. The German [ref_arm_8] [ref_arm_9] and the Spanish versions [ref_arm_12] do differ in their shape from the Italian models [ref_arm_1001] [ref_arm_938]. In Italy such defenses were used from the late 14th century on and in Germany and Spain they developed in the 1450ies.

2.2.5.1.4.3 Reinforce [ref_ill_typ_arm_elb_IIr]

This is a single detachable reinforce for a left elbow of type-II [ref_arm_888]. It was probably developed in the 1430ies and used only in combination with armour of Italian style and construction – until the end of the 15th century.

2.2.5.1.4.4 Type-III [ref_ill_typ_arm_elb_III]

This is a defense made of one or several articulated plates that enclose the elbow completely. In the 15th century it was only combined with tournament armour. Renè d'Anjou's book on the Saumur Tournament includes the earliest depiction of such an elbow-defense [ref_ill_art_5392] (1470ies).[40] This type was in use until the mid-16th century.

2.2.5.1.5 Lower arm[41]

Lower arm-protections in modern literature are called "Unterarmröhre" (Ger.) or "lower vambrace" (Engl.).

2.2.5.1.5.1 Type-I [ref_ill_typ_arm_low_I]

This defense is enclosing the lower arm at the back-of-the-hand side only by half [ref_arm_119]. It was in use probably from the late 13th until the early 16th century.

2.2.5.1.5.2 Type-III [ref_ill_typ_arm_low_III_ger] [ref_ill_typ_arm_low_III_ita]

This defense is enclosing the lower arm completely. It is made of two hinged halves. The position in which the two halves are connected to the elbow differs between the German [ref_arm_534] and the Italian [ref_arm_810] versions by 90^0 ca. This type was in use from the late 14th until the early 17th century.

A comprehensive overview of the aforesaid types can be found here [ref_tab_typ_arm].

2.2.5.2 Hand-protection

In historical sources all hand-protections were called "Handschuh" (Ger.; in different spelling) or "gauntlet" (Engl.; in different spelling). The following type-illustrations and descriptions do not include the finger-protections, as these varied widely just as the possibilities for their combination with different types of hand-protections. The fingers will be considered separately below.

2.2.5.2.1 Type-I [ref_ill_typ_han_I]

This type includes all hand-protections enclosing the wrist and made of one plate only. It was produced in different variations from the second half of the 14th until the mid-15th century [ref_arm_1252] [ref_arm_1157]. The earlier versions in modern literature were called "Stundenglashandschuh" (Ger.) and "hour-glass gauntlet" (Engl.). Younger models with plates protecting all fingers together were called "Hentzen" (Ger.) and "Mittons" (Engl.).

2.2.5.2.2 Type-II [ref_ill_typ_han_II]

This type includes all hand-protections enclosing the wrist and being made of two plates joined at the wrist. This type was made from about 1440 on [ref_arm_1152] and was in use until the early 16th century [ref_arm_1155]. It was called in modern literature "Hentzen" (Ger.) and "Mittons" (Engl.).

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40 Compare also the arm defenses acc. no. A79 in the HJRK.

41 Type-II was omitted as no examples are extant. The roman number "III" was kept for the entirely enclosing type, in analogy to the lower legs.

2.2.5.2.3 Type-III [ref_ill_typ_han_III]

This type is a more complex hand-protection made of several plates. Only the cuff in some cases encloses the lower arm completely. Between and underneath the cuff and the metacarpal plate there is a wrist plate attached [ref_arm_1066] [ref_arm_1082]. All variants allow the hand to be moved translational. This type was made from the 1460ies on until the end of the 15th century. In modern times it was called "Hentze" (Ger.), "Fingerhandschuh" (Ger.), "gauntlet" (Engl.) and "mitton-gauntlet" (Engl.).

2.2.5.2.4 Type-IV [ref_ill_typ_han_IV]

This type is basically similar to type-III, but it has no wrist-plate. The metacarpal plates are joined directly to the cuff [ref_arm_1190] [ref_arm_1191] [ref_arm_1199]. It was produced from the 1480ies until the mid-17th century.

A comprehensive overview of the aforesaid types can be found here [ref_tab_typ_han].

2.2.5.3 Head-protection[42]

The definitions of the single head-types are based on simple protective aspects that are characteristic for each group. Chronological[43], constructional and design details were not attended.

2.2.5.3.1 Type-I [ref_ill_typ_hea_I]

This group includes all helmets with an un-tapered skull that covers the upper head to the ear-level. The helmet can consist of one [ref_arm_1610] or more plates [ref_arm_1616], forming a rounded [ref_arm_1619], a flat-topped [ref_ill_art_5391] (no example existing) or a pointed skull [ref_arm_2093]. These helmets never have a flaring brim or nape-guard. Variations of this helmet existed before and after the considered period. For different variations abstract terms were used in modern literature: e. g. "Spangenhelm", "Bandhelm", "Nasalhelm", "Normannenhelm", "Hirnhaube", (all Ger.); "nasal-helmet", "norman-helmet", "skull-cap" (all Engl.).

2.2.5.3.2 Type-II [ref_ill_typ_hea_II]

This group includes helmets that cover the head and the face completely, while the plates nearly touch the shoulders. The shape is not tapered and no brim or nape-guard is angled outwards. All examples are made of several plates. The earlier variation came in fashion in the 12th century. The older, smaller models in modern literature are called "Topfhelm" (Ger.) or "helm" (Engl.) [ref_arm_1457] and the larger, younger versions were named "Kübelhelm" (Ger.) or "great helm" (Engl.) [ref_arm_1461]. A second, different group of the late 14th or early 15th century has a pivoting face-guard and at the right side an articulated cheek-guard attached [ref_arm_1458]. Due to its general technological similarities with the "helm" – the invariably full face-guard and the skull always being made of a separate plate – it was put in the group of type-II helmets. Also Ffoulkes described them as:

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42 In the following discussions both terms "helmet" and "head-defense/protection" will be used as they are both common in any modern English literature.

43 For illustrative explanations on the development of all medieval helmet types see the chart in: Nickel (1974), p. 118.

[…] specimens of the great bascinet with collar and visor, which is more of the helm order than helmet […][44]

This type of helmet never got a modern, specific name. As most of the extant examples were found together in the city of Chalcis, they can be described as the "Chalcis type-II"

2.2.5.3.3 Type-III [ref_ill_typ_hea_III]

This group includes all helmets that are basically like type-I, but with a circumferential, flaring brim [ref_arm_1345] [ref_arm_1346] [ref_arm_1347] [ref_arm_1348] [ref_arm_1349] [ref_arm_1351] [ref_arm_1352] [ref_arm_1353] [ref_arm_1354]. This type also existed before 1350 and continued to be made in different versions until the mid-17th century. Some extant examples of the mid-15th century can only be distinguished from some contemporary type-VII [ref_arm_1662] helmets when seen from top, rear or interior. They usually have vision slits and a rounded, not pointed nape-guard [ref_arm_1419]. Type-III helmets in modern literature is called "Eisenhut"[45] (Ger.; in different spelling) or "kettle-hat" (Engl.).

2.2.5.3.4 Type-IV [ref_ill_typ_hea_IV]

This type describes all helmets with either an open face [ref_arm_1518] or with a face-guard pivoting centrally at the forehead [ref_arm_1528] or at each side of the skull [ref_arm_1492]. The shape is not tapered and the skull is usually pointed. Many examples had a collar of ring-armour attached. The open-face models and sometimes the visored examples in the modern literature were called "Beckenhaube" (Ger.) or "basinet" (Fr.; Engl.; in different spelling). The visored versions in old sources are defined as "*Hundsgugel*"[46] (Ger.; in different spelling).

2.2.5.3.5 Type-V [ref_ill_typ_hea_V]

This type describes all helmets with a tapered skull and a rounded nape-guard angling outwards. The variations can have an open face [ref_arm_1982] or a face-guard pivoting centrally at the forehead [ref_arm_2082] or at each side of the skull [ref_arm_2159] [ref_arm_2086] [ref_arm_4492]. In some cases these helmets can only be distinguished from type-VII helmets when a view from the top, the rear or the interior is at hand. The examples where the nape-guard is rounded and does not form an elongated point are attributed to group V [ref_arm_2040]. Helmets of this group in modern literature were called: "Barbuta" (Ger.; Engl.; Fr.; It.), "barbute" (Engl.), "Venetian sallet" (Engl.) or "sallet in the Venetian style" (Engl.). Variations equipped with a visor and a ring-armour collar are called "Hundsgugel" (Ger.) or "basinet" (Engl.; Fr.). A visored variation [ref_arm_1787] around 1500 developed into the so called "closed helmet", where the chin was protected by a separate plate that pivoted around the same rivets like the visor [ref_arm_1936].

44 Ffoulkes (1911), p. 383.

45 This is also the historical term, see: Strauch (1986), p.185.

46 Post (1936), p. 179.

2.2.5.3.6 Type-VI [ref_ill_typ_hea_VI]

This type includes all helmets that entirely enclose the head and are tapered around the neck so tight that the parts protecting the face need to be articulated.[47] All[48] examples have a pivoting face-guard. The articulation system of the lower face-guards varied in later times. At some examples of the 15th and early 16th century a small disc was attached at the neck. This type of helmet was made from the early 15th century on and continued to exist in numerous variations until the first half of the 17th century. In modern terms different variations were called: "armet" (Fr.) [ref_arm_1973] and "bicoque" (Fr.) [ref_arm_1929] – at both the cheek-plates are joined by a lock at the chin, they are articulated by hinges at the side of the skull. The "armets" often had a ring-armour collar attached and a small disc riveted onto a stick at the nape. Variations made from the early 16th century on in the 19th century were called "geschlossener Helm" (Ger.) or "closed-helmet" (Engl.). Here the lower face-guards were not separated at the front and pivoted together with the upper face-guard at the side of the skull. A very early example is [ref_arm_1936][49].

2.2.5.3.7 Type-VII [ref_ill_typ_hea_VII]

This group contains all helmets with an open face [ref_arm_1721], sometimes with a face-guard either made in one piece with the skull [ref_arm_1864] or pivoting at each side of the skull [ref_arm_1727] [ref_arm_1735] [ref_arm_1869]. The shape is usually tapered and has an elongated, pointed and flaring nape-guard. In some cases these helmets can only be distinguished from type-V helmets when a view from the top, the rear or the interior is at hand. The examples where the nape-guard forms an elongated point are attributed to type-VII [ref_arm_2156]. This type of helmet was produced from 1440 on and continued to be used for tournament only from the early to the mid-16th century. In modern literature they were called "Schaller" (Ger.; in different spelling), "Rennhut" (Ger.; for tournament), "celata" (Ital.), "sallet" (Engl.) and "salade" (Fr.). This type of helmet shortly before 1500 developed into a "closed helmet" by the attachment of a neck-protection that pivoted together with the visor [ref_arm_1810].

2.2.5.3.8 Type-VIII [ref_ill_typ_hea_VIII]

This group contains huge helmets that cover entirely the head and parts of the upper torso. Depending on their use they have a fixed [ref_arm_1644] or a screwed [ref_arm_1646] face-protection or a visor pivoting at the sides of the skull [ref_arm_1626] [ref_arm_1650]. Most of these helmets were meant for tournament use only. They needed to be fastened to the torso-protection. In modern terminology the different variations were called: "Stechhelm", "Kolbenturnierhelm", "Große Beckenhaube", "Jousting-helmet" (all Ger.); "frog-mouthed jousting-helmet", "helmet for the foot-combat", "Great Basinet" (all Engl.).

A comprehensive overview of the aforesaid types can be found here [ref_tab_typ_hea].

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47 For a comprehensive discussion on the development of this helmet-type see: Trapp (1926).

48 With the exception of [ref_arm_4487], where the lost face-guard once was probably attached by staple and pin, see also: Trapp (1926), p. 28.

49 This helmet is attributed to the type-V helmets, due to the tapered skull and the rounded, flaring nape-guard. It is recommendable to create a further helmet type for all "closed helmets" (type-IX?) for use in studies of armour made after 1500.

2.2.5.4 Leg-protection

2.2.5.4.1 Upper Leg

Upper leg-protections had no specific name in modern literature so far. The combination of an upper leg with a knee defense is usually called “Diechling” (Ger.) or “cuisse” (Engl.; Fr.).

2.2.5.4.1.1 Type-I [ref_ill_typ_leg_upp_I]

This defense is enclosing the upper leg only by half. This is the earlier type of upper leg-protection and was probably not produced after 1400 anymore [ref_arm_2910].

2.2.5.4.1.2 Type-II [ref_ill_typ_leg_upp_II]

This defense is enclosing the upper leg more than by half. The front is covered by one plate and the small toe side of the rear is covered by a hinged flap [ref_arm_2366]. From 1400 on until the mid-16th century this was the most common upper leg defense.

2.2.5.4.1.3 Type-III [ref_ill_typ_leg_upp_III]

This defense is enclosing the upper leg completely. The front is covered by one plate and the rear is covered by a hinged flap. In the 15th century this system was probably not used for the upper leg. It is known from a few costly suits of the early 16th century only[50].

2.2.5.4.2 Knee

Knee defenses in modern literature are called “Kniekachel” (Ger.) or “knee-cop” (Engl.).

2.2.5.4.2.1 Type-I [ref_ill_typ_leg_kne_I]

This defense is enclosing the knee only by half. This is the oldest knee defense, it got out of use by the end of the 14th century [ref_arm_4650].

2.2.5.4.2.2 Type-II [ref_ill_typ_leg_kne_II]

This defense is enclosing the knee more than by half with a shell-like extension at the small toe side [ref_arm_2264]. It was developed in the second half of the 14th century and was used until the mid-17th century.

2.2.5.4.2.3 Type-III

This defense consists of several articulated lames that enclose the knee completely. It is only known from costly suits of the early 16th century[51].

2.2.5.4.3 Lower leg

Lower leg defenses in modern literature are called “Beinröhre” (Ger.) or “greave” (Engl.).

2.2.5.4.3.1 Type-I [ref_ill_typ_leg_low_I]

This defense is enclosing the lower leg only by half. Such a protection is not found at field armour from the mid-14th century on anymore and no example is extant.

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50 See Henry VIII.’s foot-combat armour acc. no. II.6 in the RA.

51 See Henry VIII.’s foot-combat armour acc. no. II.6 in the RA.

2.2.5.4.3.2 Type-II [ref_ill_typ_leg_low_II]

This defense is enclosing the lower leg more than by half. The front is covered by one plate and the small toe side of the rear is covered by a hinged flap. It is found on a few armour-suits of the last third of the 15th century [ref_arm_2828] only and continued to be used until the mid-16th century.

2.2.5.4.3.3 Type-III [ref_ill_typ_leg_low_III]

This defense is enclosing the lower leg completely. The front is covered by one plate and the rear is covered by a hinged flap. This is the most common lower leg defense [ref_arm_2310]. It was made from the mid-14th century on and was in use until the late 16th century. This is the only armour part that frequently was designed so neutral that it usually cannot be attributed to either the northern or the southern alpine taste or construction.

2.2.5.4.4 Foot

Foot protections in modern literature are called “Schuh” (Ger.) or “solleret”/”sabaton” (Engl.; Fr.).

2.2.5.4.4.1 Type-I [ref_ill_typ_leg_foot_I]

At this type only one single plate covers the toes. It is usually connected to the lower leg via ring-armour [ref_arm_2781]. This type was probably in use from the 1440ies until the 1520ies.

2.2.5.4.4.2 Type-II [ref_ill_typ_leg_foot_II]

At this type several articulated plates cover the foot till the knuckles [ref_arm_2255]. This was probably the most common foot protection from the late 14th century on until the mid-16th century.

2.2.5.4.4.3 Type-III [ref_ill_typ_leg_foot_III]

Several articulated plates cover all the foot and the heel [ref_arm_2257].

A comprehensive overview of the aforesaid types can be found here [ref_tab_typ_leg].

2.2.5.5 Neck-protection

2.2.5.5.1 Type-I [ref_ill_typ_nec_I]

This type describes a protection for the frontal parts of the neck, used together with helmets that do not cover the chin and the throat (type-VII). It protects the chin, the throat and the frontal upper parts of the torso, where the torso-defense leaves the wearer unprotected. This type consists of one plate only, closely fitted to the chin and the upper chest. Only at the upper end one or more articulated lames might be attached [ref_arm_3173]. Such protections developed in the second half of the 15th century and were not used after 1500 anymore. This was historically and in modern literature called a “Bart”[52] (Ger.; in different spelling) or modern “bevor” (Engl.).

52 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1883), Reg. 48.

2.2.5.5.2 Type-II [ref_ill_typ_nec_II]

This type is basically the same as type-I, but it consists of at least two plates. One is protecting the chin and the second one the upper chest. They are fixed together at the throat-level. At the upper end one or more articulated lames might be attached [ref_arm_3034]. It was worn in combination with helmets of type-III, -VI [ref_arm_3044] or -VII.

2.2.5.5.3 Type-III [ref_ill_typ_nec_III]

This type describes a full collar-plate, protecting the front and the back of the upper torso, the shoulders and the throat but not the chin. Each, the front and the back-side, consists of at least two plates [ref_arm_3152]. This type was in use since the 1430ies and remained in use until the end of the 16th century. In old and modern literature this was called "Kragen" (Ger.), "Harnischkragen" (Ger.) and "collar" (Engl.).

A comprehensive overview of the aforesaid types can be found here [ref_tab_typ_nec].

2.2.5.6 Torso front and back-protection

2.2.5.6.1 Type-I [ref_ill_typ_tfr_I] [ref_ill_typ_tba_I]

At this type the thorax and the abdomen are covered by one plate [ref_arm_3734] or by several vertical plates [ref_arm_3811] which are not angling outwards at the waistline. Some examples might have had pelvis-lames attached, similar to [ref_arm_3698]. Type-I breastplates were only used from the mid-14th century until 1410 ca. Type-I backplates did not develop in parallel to the breastplates. There are type-I backplates existing, but they date from the end of the 15th century and never any pelvis-lames are attached [ref_arm_3417]. This type had no specific name before. It might be described as "einteilige/r Brust/Rücken" (Ger.) or "single-piece back-/breastplate" (Engl.).

2.2.5.6.2 Type-II [ref_ill_typ_tfr_II] [ref_ill_typ_tba_II]

At this type the thorax and the abdomen are covered by one plate angling outwards at the waistline to join the pelvis-lames. Plates of this type were in use from the 1480ies [ref_arm_3522] [ref_arm_3371] until the mid-17th century. This type had no specific name before. It would have been described as "einteilige/r Brust/Rücken mit Gesäßreifen" (Ger.) or "single-piece back-/breastplate with fold".

2.2.5.6.3 Type-III [ref_ill_typ_tfr_III] [ref_ill_typ_tba_III]

The thorax and the abdomen are covered by separate plates. The abdomen-plate can consist of several plates [ref_arm_3334] and lies underneath the thorax-plate. It is angling outwards at waistline to join the pelvis-lames [ref_arm_3429] [ref_arm_3264]. This type was in use from the 1450ies on until the mid-16th century. It had no specific name so far.

2.2.5.6.4 Type-IV [ref_ill_typ_tfr_IV] [ref_ill_typ_tba_IV]

The thorax and the abdomen are covered by separate plates. The abdomen-plate lies upon thorax-plate – made of a single plate or several lames – and is angling outwards at the waistline to join the pelvis-lames [ref_arm_3627] [ref_arm_3412] [ref_arm_3374]. Breastplates of this type were made from about 1400 until the mid-16th century. Backplates were not produced after 1500 anymore. This type was called "geschiftete/r Brust/Rücken".

2.2.5.6.5 Torso upper leg-protection [ref_ill_typ_tfr_leg]

This is a protection for the left or the right upper leg, attached to the pelvis-lames of a torso-front-protection of type-II, -III or -IV. From about 1440 on until the early 16th century they were made of a single plate [ref_arm_3796]. From the late 1480ies on they could be made of several articulated lames [ref_arm_3574]. This system from the mid-16th century on developed into long upper leg-protections with knee defenses attached – until the end of the century it had completely replaced the separate leg-protection. In modern literature these protections are called "Beintaschen" (Ger.) or "tassets" (Engl.).

2.2.5.6.6 Hip protection [ref_ill_typ_tor_hip]

This is a small plate, buckled to the pelvis-lames of the front- and the backplate to protect the hip. This is found at armour made between 1440 and 1500 [ref_arm_3926].

A comprehensive overview of the aforesaid types can be found here [ref_tab_typ_tor].

The structuring of all types proved to be the right way to keep an overview on all extant items and to keep descriptions in the text unmistakably and short. Only with the help of this clear structure all the collected pictures and data of thousands of objects could be organized in a digital database. The system is designed to allow range-extensions to armour pieces outside the focus of this study, e.g. of later periods or also to tournament armour. The author has tried to visualize the suggested definitions and the focus of this study in a clear structured diagram [ref_ill_dia_typ]. To provide a better overview, a concordance of number and belonging armour-type is found here [ref_tab_ID-type][53]. In chapter [A brief history of plate armour from a technological point of view] closer descriptions are given on the periods in which the certain types were used.

It is of course an interesting question, how many objects of each type are extant. The author extracted a small statistic from his database [ref_tab_numb]. As the extant pairs of limb and hand protections count twice, they seem to be extant in large numbers. Considering this, it is interesting to note that it is the helmets of type-V and -VII and the breastplates of type-II and -IV which are extant in the largest numbers. Nearly all single parts of the quoted suits are included in the counts on the single armour-types. Many of the suits are composite, incomplete or reproduced.

The terminology used here was developed by the observation of extant examples only. According to many pictorial sources, several more types of each category might have existed but have not survived. This terminology is just a suggestion and should undergo further practical testing and discussion in the future.

53 This file contains many more items than quoted in the text. It is the offline-version of the database. The reader is free to e. g. compare further items not quoted in the text.

3 A brief history of plate armour from a technological point of view

The stylistic genesis of European plate armour is described sufficiently in publications like Wendelin Boeheim's "Handbuch der Waffenkunde"[54], Ortwin Gamber's "Harnischstudien"[55] or Claude Blair's "European Armour"[56] – to name the most recommendable works only. The following comments try to extend these works by attempts of recreating what might have been the armourer's considerations when he changed the construction of a certain established armour part. The regard is limited to the major constructional changes that emerged throughout the considered period. The discussion begins with types made in the times when segmented armour changed over to larger plates. It will end with the introduction of the mass production and the decoration of armour in the so called "Maximilian" style. Occasionally it will be noted wherever a certain construction was still produced unaltered in later times. Contemporary artworks often show armour that does not fit into the type-scheme developed for this study. The discussion of the probability that certain items really existed and how they might have been constructed is a wide field for future studies. The remarks will be split into sub-chapters, named after the concerned body part.

The long established textile-, leather- segmented- and ring-armour had protective disadvantages in comparison to plate armour, but such armour could be lighter and more flexible while it left less "dangerous" chinks. Furthermore, the craftsmen making such armour needed less specialized skills, less tools etc. For example grinding and polishing was only necessary for segmented-armour plates placed exteriorly to a fabric, leather or undergarment. It was not easy for the armourers to meet the positive properties of the established armour types with the inflexible, large iron or steel[57] plates. Due to these natural limitations, armour making throughout the considered decades was rather a permanent experimenting and changing of aspects of fashion, protection and wearing-comfort. As a result, the developments of the single plate-armour types do not necessarily come together with protective improvements. Many presumably "older" types of plate armour have always been made and used in parallel to "new" inventions. This makes it necessary to describe the different combination-systems of complete limb[58] and torso[59] protections, as they can vary in different times and regions.

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54 Boeheim (2000), of course old, but still very useful for a general overview.

55 Gamber (1953) and Gamber (1955).

56 Blair (1972).

57 The definition of iron and steel is problematic. Modern metallurgy uses the term "steel" for any kind of forgeable iron-alloy with a carbon content up to 2% (iron material with more than 2% C is called "cast iron" and this is too brittle to be forged), see: Bargel (2012), p. 141. The term "steel" historically only defined iron-based material that could be hardened as its carbon content was about 0,4 % ca. Iron based material with a carbon content below 0,4 % ca. can barely be hardened and was historically called "iron" – the cheaper material of lower quality. Without the examination of the mechanical properties, the material-quality of a certain item remains uncertain. Some armour was hardened or made of hardenable material and other armour was made of not hardenable iron. Nevertheless, preceding humanities-based studies sometimes erroneously use the terms "steel" and "iron" without considering the historical meaning and without having metallurgical tested the material. In the following, plate-armour material is purposely described as "iron or steel" whenever the material-quality is not known. Whenever the terms are used separately, they intend to describe the concerned material-quality.

58 This is for the arm: shoulder, upper arm, elbow and lower arm; for the leg: upper leg, knee, lower leg and foot.

59 This is different possible wearing-combinations of torso front and -back types.

3.1 Arm-protection

The making of plate-protections for the limbs was probably the most challenging task for the armourer. It is therefore very surprising to see that – according to contemporary artworks and with the exception of the helmet – the first medieval armour to consist of larger plates was made for the arms and the legs [ref_ill_art_5343] (descr. 1). While it is already difficult enough to entirely protect the leg in a comfortable way by plates, this is even more complicated with the arms. While the knee allows no axial turning for the lower leg, the elbow and the two-boned lower arm can twist, to allow a turning of the wrist to nearly 360 degrees. The elbow can be bent to about 160 degrees. The shoulder allows a circular motion of the whole arm. Due to these facts, it is a difficult task to cover the arms with adjoining protections and to still allow an armoured man to fight with a weapon. These demands make clear that solutions had to be found for arranging protecting plates in a way so the movement of the elbow and the lower arm would not be limited.

The long-used ring- or textile-armour sleeve did not restrain the arm's mobility, but already in the high middle-ages this protection type was considered to be insufficient against penetrations and blows from different kinds of weapons. When in the late 13th century the armourers tried to improve the protection-systems, they started to fasten segments of plate or leather onto or in between the ring- (e. g. the knee [ref_arm_4650]), the textile- or the segmented-armour.

In the following, early arm-defenses will be shortly described. Subsequently, the development of the different plate-types will be discussed at examples of the different arm-protection systems.

3.1.1 Shoulder

Until the second half of the 14th century the shoulder was only[60] covered by ring- [ref_ill_art_5189] or segmented-armour. Such different, not standardized arm-defense variations of the 14th century did not restrain the arm's flexibility, but chinks – again only protected by ring-armour – were left between the plates. The oldest medieval shoulder defenses to survive are small plate-segments attached to segmented torso-front-and-back-protections [ref_arm_3904] [ref_arm_3906] [ref_arm_3912]. At [ref_arm_3910] one small articulated plate is attached at each side of the shoulders. They cannot be considered as real shoulder defenses, as they only cover the collarbone and only very insufficiently the shoulder joint.

In the second half of the 14th century the armourers developed shoulders of type-I. One of the oldest depictions of independent shoulder protections of type-I is found at [ref_ill_art_5289] (descr. 2). The oldest surviving example of a small type-I shoulder often found at contemporary artworks of the German speaking lands between 1420 and 1450 [ref_ill_art_5176] [ref_ill_art_5198] is probably [ref_arm_326] – still made of very small plates. Larger examples of type-I, probably also of the first half of the 15th century are [ref_arm_204] [ref_arm_220] [ref_arm_330] [ref_arm_427] [ref_arm_881] [ref_arm_5017] [ref_arm_5090].

To temper with the insufficient protection of the shoulder-joints, in the early 15th century [ref_arm_565] the Italian armourers developed large shoulder defenses consisting of several lames (type-II). To the left shoulder a disc [ref_ill_art_5270] (a late example) or at the front

60 From about 1270 to 1350 it was common – merely in France – to fix small „shields" so called "ailettes" (Fr./Engl.) or "Achselschilde" (Ger.) to each shoulder [ref_ill_art_5189]. As it is not clear which purpose these applications served and as a protective aspect can be doubted (see for example: Nickel (2002)), they are also here not considered as part of the defense.

of each shoulder until the end of the century a close fitting reinforcement could be attached [ref_arm_742] [ref_arm_744]. Until the late 16th century the shoulder defenses of type-II were unsymmetrical. At the right side it was necessary to leave a cutout in the armpit-region of the frontal wing to allow the lance to be pinched under the arm [ref_arm_5058]. When by the end of the 16th century the lance was not used in battle anymore the shoulders were frequently made symmetrical.

3.1.2 Armpit

Different shapes of armpit protections can appear at one particular pair of shoulders [ref_ill_art_5253]. According to illustrations also protections for the rear side of the armpits existed [ref_ill_art_5188] [ref_ill_art_5203]. At the effigy of Konrad of Weinsberg 1430 ca. [ref_ill_art_5223] (descr. 1) and at the cenotaph of Johann of Freiburg [ref_ill_art_5238] (descr. 1) the armpits are strikingly similar in shape and ridge decoration to the only extant example [ref_arm_880]. In the second half of the 15th century they are merely used in the German speaking countries and they are frequently round [ref_ill_art_5366] (descr. 2).

3.1.3 Upper arm

Possibly from the 12th century on, nearly enclosing plates of thick, hardened[61] leather were tied to the upper (the only existing example is [ref_arm_954], compare [ref_ill_art_5167]) and the lower arm [ref_ill_art_5249] (descr. 1). In the 14th century, sometimes they could be reinforced by applied metal bars [ref_ill_art_5157]. A rather late example is found depicted on [ref_ill_art_5244]. Already by 1365 in Germany type-III upper arm defenses were in use[62]. Probably from the 1430ies on the upper arms of the Italian system were nearly completely enclosed by one metal-plate (type-II). Towards the torso the plate was cut out at the lower edge to allow the arms to be put closely to the arm-cutouts of the breastplate [ref_arm_3933].

3.1.4 Elbow

Elbow protections in the shape of discs appear in English artworks from 1260 on.[63] Probably also leather was molded into a shape similar to a shell and fastened to the point of the elbow. The elbow could not be protected by a closely embracing plate, as this would blockade the bending of the elbow. To temper this problem, the elbow plate was enlarged with a leaf-shaped extension [ref_arm_362] (type-II). To improve the protection, the shell-like extensions of the elbow became much larger [ref_arm_52]. On the left arm – when fighting with lances on horseback the most exposed body part – a second, larger and thicker elbow plate could be optionally attached (type-II reinforce) [ref_arm_635]. At the right side the upper half of the shell-like elbow extension could be covered by a permanently fixed small reinforcement plate [ref_arm_702]. North of the Alps in the second half of the 15th century the elbow protection was usually designed as an independent shell-like plate (type-II) [ref_arm_20].

3.1.5 Lower arm

A pair of extant lower-arm defenses made of leather has recently been excavated [ref_arm_5103] [ref_arm_5104] and another, single piece was found in Dordrecht

61 For a reconstruction on how armour could be hardened and a historic overview of its use as armour see: Beabey and Richardson (1997).

62 See the effigy of Burkhard von Seckendorf (died. 1365) in the Heilig Geist Kirche, Gunzenhausen, Germany. Thanks to Christopher Retsch for this information.

63 Blair (1972).

[ref_arm_5121]. Though no images or artifacts are at hand, the first defenses to be made of iron or steel plate were most likely encircling the arms only by half (type-I) – due to the inflexibility of the material. Probably the oldest existing protections of type-III lower arms are preserved in the DNM [ref_arm_1027] [ref_arm_1029]. In 2011, they were mistakenly shown on display as upper and lower arm-protections of type-I, but most likely the parts were once attached to each other via hinges or leather so they would form a "tube" entirely embracing the lower arm. The slightly bent and pointed elbow-extension of these examples can be seen similarly at contemporary effigies of the mid-14th century [ref_ill_art_5344]. Instead, the armourer made a tube of two halves for the protection of the entire lower arm (type-III). This was close fitting to allow a wide motion-range of the contemporary hand-protection-cuff [ref_arm_980]. From the 1430ies on, the cuffs of a new variation of type-I hand-protections [ref_arm_1294] – now open at the pulse-side – allowed enough motion-space for the wrist and did not depend on a lean lower arm defense anymore [ref_arm_1277]. Therefore, in the years to follow the lower arms could be modeled shorter in length, wider in circumference and they were less tapered towards the wrist [ref_arm_846].

3.1.6 Systems

By the last quarter of the 14th century, it was probably the Italian armourers that tried to keep the chinks at the older systems made of single plates (e. g. [ref_ill_art_5249] (descr. 2)) closed by fixing them together in a way that would still allow certain mobility. The simplest solution would basically be a groove, consisting of three plates: one for the upper arm, one for the elbow and one for the lower arm. The arm-plates would lie inside the elbow-plate and they could be bent like the human elbow. As the elbow-plate would have to be placed invariably exactly at the elbow-point, the iron half-pipes of the upper and the lower arm could only protect the rear side of the arm. Such a hypothetical arm-protection [ref_ill_sys_arm_hyp] – leaving the attacked side of the body exposed – made no sense and was therefore probably never produced.

Probably to temper with these problems, already by the last third of the 14th century the armourers protected the lower arm by defenses of type-III and elbows of type-II. Nevertheless, at Italian armour the upper arm until the 1430ies was still of type-I, which left the front-side to be protected by ring-armour only. To avoid chinks between the elbow and the plates – opening when the elbow was bent – the armourers placed small articulated lames in between them. By sliding rivets[64] they made the lower arm pivotable. All parts now were held together by articulated rivet-joints. Due to the first appearance of this arrangement at arm defenses most likely made in northern Italy, this might be called the "Italian system" [ref_ill_sys_arm_ita_auI_aeII_alIII] (see for example the arms of the suit [ref_arm_4098]).

In the 1420ies the armourers replaced type-I by type-II upper arms. Furthermore, they added large shoulder defenses of type-II. While all other parts of the Italian system were permanently connected to each other, the shoulder defenses were always separate and usually of type-II. This system of complete arm defense – with variations in design only – including the revolving lower arms – was produced in the Italian workshops unaltered until the early 16th century. From the late 15th century on it was also produced in Flanders – but there the lower arms were not pivotable and no reinforcements were attached anymore. Until about 1500 basically the same system of full arm-protection was used – though not exclusively – throughout all Europe on the rather costly armour [ref_ill_sys_arm_ita_asII_auII_aeII_alIII] [ref_arm_4143]. From about 1510 on, also at field armour the elbows could optionally be made of type-III. In the early 16th century an upper arm defense of type-III was added and

64 For details see chapter [Turning via sliding rivets [ref_ill_joi_turningviaslidingrivets]].

this constellation (upper arm III, elbow II or III and lower arm III) was the one to supersede all other costly armour systems from the mid-16th century on.

The majority of all plate arm defenses depicted in European artworks of the first half of the 15th century seem to be of the Italian system [ref_ill_sys_arm_ita_auI_aeII_alIII]. For example, a pair of such arm-protections is depicted hanging below a helmet of type-III on the right wing of the Albrechtsaltar, made in Austria about 1437 [ref_ill_art_5372] (descr. 1). A group of fighters is standing around the figure of Jean d'Arc. All protagonists in the scene are armoured and each wears rather small protections covering the point of the shoulders (type-I) and parts of the upper arm (type-I). To protect the underside of the shoulder, small plates are placed at the front of the armpit. All these features are found exclusively at armour made north of the Alps. It is likely that many of them wear arm-protections of this system underneath the ring-armour sleeves. Many other depictions support the assumption that north of the Alps the small shoulder defenses were typically worn upon a ring-armour sleeve, which covered the upper arm of an Italian-system [ref_ill_art_5176] [ref_ill_art_5238] (descr. 2).

Nevertheless, in parallel to these "Italian" systems, in northern alpine Europe the separate arm defenses of the 14th century (e. g. [ref_ill_art_5249] (descr. 2)) were developed further without becoming permanently connected. From the first half of the 15th century no examples that could tell about the tradition of the older system do survive, but artworks show that it was obviously in use. For example the men to the left and to the right of the lady in the aforesaid altarpiece [ref_ill_art_5372] (descr. 2) obviously wear separate elbow protections upon a ring-armour shirt.

The lower arms were either of type-I [ref_ill_art_5195] but more commonly completely closed (type-III). As the elbow was connected to the upper and the lower arm only by the ring-armour underneath or a band of leather, the lower arm could easily be turned. A complicated revolving system as found on the Italian systems was not necessary. A disadvantage was the chinks between the plates. The complete arm-defense system consisting of parts not permanently joined at the elbow might be called the "German System" – as it never appeared in Italy but frequently in the German speaking lands (but also in other western and northern European regions). In the second half of the 15th century this system experienced some alterations. In the 1460ies the type-I shoulder defense at costly armour was usually permanently fixed to an upper arm defense of type-I with armpit protections attached [ref_ill_sys_arm_ger_asI_apit_auI_aeII_alIII]. From the 1470ies on also the larger type-II shoulders could be added, either separate from a type-III upper arm defense [ref_ill_sys_arm_ger_asII_auIII_aeII_alIII] (see for example the arms of the suit [ref_arm_3257]) or permanently connected to an upper arm of type-II [ref_ill_sys_arm_ger_asII_auII_aeII_alIII] (see for example the arms of the suit [ref_arm_3243]).

The 15th century knew also another arm defense system which did not survive in any example: The so called "jack-chains". This was usually only consisting of one or two narrow plate straps at the upper and at the lower arm with a simple plate at the elbow [ref_ill_art_5166] [ref_ill_art_5202] [ref_ill_art_5282] [ref_ill_art_5304] [ref_ill_art_5309] (descr. 1).

3.2 Hand-protection

Only few scholars had focused their research particularly on hand-protections.[65] A separate hand-protection did not exist before the late 12th century. The first defenses were made of

65 Cosson (1884), Mann (1942), Goll (2009).

ring-armour, in some cases probably connected to the sleeves of a ring-armour shirt [ref_ill_art_5390] [ref_ill_art_5374] (descr. 1). From the second half of the 13th century to such protections plate-discs were occasionally fastened to the back of the hand [ref_ill_art_5377]. The beginnings of segmented armour for the protection of the hand remain obscure. It has to be noted that at all late medieval segmented- and plate-hand-protections the inner side of the hand was never protected by plates. Excavated examples show that smaller plate segments were riveted into an exterior fabric cover. The oldest finds date from the mid-14th century and all are slightly different in their construction.[66] It is therefore difficult to tell if certain types had already been developed. Contemporary artworks indicate that in the first half of the 14th century some different variations were made in a similar way from larger segments [ref_ill_art_5234]. Nevertheless, according to extant examples, segmented hand-protections were made rather individually. Several excavated examples are merely constructed from small segments with a large plate covering the back of the hand. While some of these plates were left plane [ref_arm_1281] [ref_arm_1340], at others the natural shape of the back of the hand was imitated by embossing [ref_arm_1341] [ref_arm_1336] [ref_arm_1337].

The first type of plate hand-protection that clearly defines a group of similar objects is called "hour-glass hand-protection" – the name derives from its characteristic shape. The intention of the armourer was probably to produce a light hand-protection with as little gaps between the plates as possible. The cuff was widely flaring out so the wrist could move freely [ref_arm_1306] [ref_arm_1307] [ref_arm_4859]. This variation from 1420 on was superseded by another type-I hand-protection, where the cuff reached further up the lower arm at the back-of-the-hand side [ref_arm_1296]. At the pulse-side these hand-protections were closed by only a thin plate-bridge. This construction allowed for a natural angling of the wrist. In the German speaking lands the hand-protections of type-I from the 1430ies to the 1440ies were rather large and usually had only the extended metacarpal plate to protect parts of the fingers [ref_ill_art_5257] [ref_arm_1291] [ref_arm_1310]. An illustrative transitional type-I variation is depicted on [ref_ill_art_5223] (descr. 2). In Italy the type-I hand-protection with some alterations – a much longer, pointed cuff and articulated finger protections – remained in use until the end of the 15th century [ref_arm_1157].

In parallel from the 1420ies on – exclusively in Italy – hand-protections of type-II were made [ref_arm_1037] [ref_arm_1148] [ref_arm_1150]. This type was still very inflexible at the wrist, just like all Italian hand-protections. When the hand was angled, at all models a dangerous gap opened between the cuff and the lower arm – a problem never satisfactorily solved by the Italian armourers. After 1500 these hand-protections were not produced anymore.

By the mid-15th century in the German speaking lands hand-protections of smaller segments were produced again. Unlike the 14th century segmented-armour examples now the plates were overlapping and joined directly to each other, allowing for a translational motion of the entire hand while the plates were still close fitting. Probably the main intention of turning back to smaller segments was to safely connect the hand-protection to the lower arm. An early example of such a hand-protection, possibly of type-III, is seen on [ref_ill_art_5332]. Already at this model the most important feature that made these hand-protections superior to the Italian models is evident: The cuffs of all extant examples of the second half of the 15th century could be fastened directly to the lower arm. No dangerous gaps opened while at the same time the hand could move freely [ref_arm_1061] [ref_arm_1126] [ref_arm_1082].

66 For a discussion of several segmented hand-protections found in Wisby see: Thordeman (1940).

Variations of type-III hand-protections were still occasionally made until the 1580ies (e. g. for the Armour M99 of the SKD).

In the 80ies of the 15th century the armourers found that for a free motion of the hand the wrist-plate of type-III hand-protections was obsolete. Now the metacarpal plates were directly joined to the cuff (type-IV) [ref_arm_1228] [ref_arm_1272]. The Italian, Spanish or Flemish models were still rather stiff at the wrist, the cuff was still very wide and not fastened to the lower arm [ref_arm_1185] [ref_arm_1222]. A suit of field armour from the 16th until the mid-17th century was usually equipped with type-IV hand-protections. The entirely closed cuffs of some examples from the 1480ies on reached to the elbow and thus they served as a full lower arm-protection of type-III [ref_arm_1250] [ref_arm_1244] [ref_arm_1199].

3.2.1 Finger and thumb protection

The definition of different systems for the protections of the fingers is a very difficult task. Most of the extant late medieval hand-protections have lost the original finger parts. Hand-protections of the same type could be equipped with different types of finger and thumb protections. After articulated finger-lames had been developed from the 14th century on, many systems had probably been used in parallel throughout the second half of the 15th century. On many extant hand-protections the finger parts are lost, thus it often cannot be determined how the fingers of an extant hand-protection were constructed. As many systems do exist and descriptions would be too confusing, the definition of the differences is reduced to illustrations. These illustrations describe the common systems – some further construction variations certainly existed.

In the following the finger protection systems will be split into three large groups: The systems where each finger is protected separately (fingered hand-protections), the systems where at least two fingers are covered by one plate (mitten hand-protection) and systems that combined both characteristics.

3.2.1.1 Fingered hand-protections

At the oldest extant segment-hand-protection each of the fingers was protected by small overlapping scales (type-a) [ref_ill_sys_fin_a] [ref_arm_1341]. This system was also used in later times [ref_arm_1080] [ref_arm_1074] (at both items probably later completions). In the second half of the 14th century each finger could be protected by small, directly adjoined plates basically also arranged like type-a [ref_arm_1343]. In the mid-14th century single plates for the finger-bones and the finger-joints were made for the hand-protection [ref_arm_1340][67]. Of a unique system are the fingers at [ref_arm_1150] and [ref_arm_1165], where segments are riveted interiorly and the plates for the points of the fingers exteriorly to a lining cover. From the 1450ies on in the German speaking lands the knuckles at the roots of the fingers were usually protected by a separate single lame that lay upon the other plates, a feature found on hand-protections with variations in design until the mid-17th century. The construction of the remaining plates for the protection of the fingers varied widely. Fingers could be protected separately but by different systems:

- Type-i [ref_ill_sys_fin_i] [ref_arm_1118]
- Type-h [ref_ill_sys_fin_h] [ref_arm_1071]
- Type-j [ref_ill_sys_fin_j] [ref_arm_4904] [ref_arm_1059] [ref_arm_1090][68]
- Type-k [ref_ill_sys_fin_k] [ref_arm_1096]

67 As all organic parts are gone it is not clear how the single plates for the protections of the fingers were arranged.

68 This finger type is most likely genuine due to the old provenance of all quoted items.

3.2.1.2 Mitten hand-protections

From the early 15th century some hand-protections had the metacarpal plate extended a bit towards the points of the fingers (type-b) [ref_ill_sys_fin_b] [ref_arm_1308]. The fingers and the thumbs of some mitten hand-protections were often protected by ring-armour [ref_ill_art_5276]. The oldest extant examples still retaining the ring-armour parts are probably [ref_arm_1178]. From the 1440ies on the fingers of Italian hand-protections could be protected by one (type-e) [ref_ill_sys_fin_e] [ref_arm_1156] or two (type-f) [ref_ill_sys_fin_f] [ref_arm_1160] articulated lames covering all fingers together. From the mid-15th century on in the German speaking lands also at mitten hand-protections the knuckles at the roots of the fingers could be protected by a separate single lame that lay upon the other plates. Also here the fingers could be protected by one (type-l) [ref_ill_sys_fin_l] [ref_arm_1076] or optionally several lames (type-m) [ref_ill_sys_fin_m] [ref_arm_1135], but also hand-protections with pair-wise protected fingers were very common (type-n) [ref_ill_sys_fin_n] [ref_arm_1245] [ref_ill_art_5383] (descr. 2). Also Italian hand-protection models were occasionally equipped with such finger-lames [ref_ill_art_5194] (here type-II). Finger protections split in pairs were used until the early 16th century [ref_ill_art_5171]. By the late 15th century some finger-lames were combined with ring-armour [ref_ill_art_5229]. Even a combination of lames and ring-armour fingers split in pairs still exists [ref_arm_1061].

3.2.1.3 Combined systems

In the first half of the 15th century the Italian armourers favored a finger system that combined an elongated metacarpal plate with directly attached small scales for the fingers (type-c) [ref_ill_sys_fin_c] [ref_arm_1148][69].Optionally the first finger lame could also be articulated (type-d) [ref_ill_sys_fin_d].

3.3 Head-protection

Helmets are the first armour items to be made of one single larger plate. Already the late-republic roman legions used helmets made of a single iron plate, for example a certain type called after an important find-site “Weisenau-helmet”. The migration period knew only helmets riveted together from several plates, the so called “Spangenhelm” and the “Bandhelm”. From the 11th century on a helmet of type-I worked in one piece, usually equipped with a nasal-guard, was in use in Eastern and Western Europe.

The pivoting visor is probably an invention of the late 13th century. Claude Blair refers to the will of Odo de Roussillon (1298), where a *heaume a vissere* is mentioned.[70] Early illuminations of helmets with pivoting face-guards date about 1320: [ref_ill_art_5190] [ref_ill_art_5169] [ref_ill_art_5292] [ref_ill_art_5343] (descr. 2) – but the oldest extant helmets to be equipped with such a face-guard are made in the style of the last third of the 14th century [ref_arm_1495].

3.3.1 Type-I

Type-I helmets are the most simple types of all single-piece helmets. Generally two variations exist: one with a pointed and another one with a half-bowl shaped skull. A unique item in the SNZ [ref_arm_2093] is probably the best example to start the discussion of late medieval helmets of type-I. This example still has a pointed skull, but is already equipped with a detachable nasal-guard – a predecessor of later visor attachment systems (at type-IV

69 The fingers are entirely reproductions.

70 Blair (1972), p. 47.

and -V helmets) and a follower of earlier helmets with a fixed nasal-guard. Only two more type-I helmets of the considered period with pointed skulls are extant [ref_arm_1607] [ref_arm_1608], but they have only a small nasal-guard formed by two concave cutouts above each eye. Due to the burred lower edge it is well possible that these two helmets originally had a lower plate attached and would therefore rather count as helmets of type-V (compare [ref_arm_2167]).

The most common model has a simple half-bowl shaped skull [ref_arm_1622] [ref_arm_4265]. Many examples do exist but not all of them were examined closer for this study. They were probably produced from the 13th to the 17th century. Many are so simple there are not many features that allow an exact dating of specific items. Some variations, probably of the first half of the 15th century show slight cutouts above the ears [ref_arm_1621] [ref_arm_1624] [ref_arm_4468]. Another model, most likely from the same period shows a significant feature: the cutouts above the ears are angled outwards and the plate is also cut out above each eye [ref_arm_1618] [ref_arm_1619] [ref_arm_4625]. Hemispheric shaped helmets of type-I made of one piece remained in parallel use throughout all the plate-armour period until the mid-16th century, but in the 15th century the pointed-skull model was not produced anymore. The production of the half-bowl variation was probably easier. These models were also lighter and more close-fitting so a cap of ring-armour, a second helmet or a hat could be worn upon it. The main disadvantage of all type-I helmets was that they did not protect the lower parts of the head.

3.3.2 Type-II

Until the late 14th century the skulls of western European type-II helmets for the field use were still made of several segments fixed together by rivets [ref_arm_1443] [ref_arm_1456] [ref_arm_1457]. This type was the first helmet since the antique "Gladiator's helmets" to cover all the head, the face and to a limited extend also the neck by plates. Probably due to the difficulties of forging such deep helmets out of one plate, they were made from segments. From the late 14th century on type-II helmets developed into frog-mouthed helmets of type-VIII which were usually worn in the tournament only [ref_arm_1645].

Probably in the first half of the 15th century in the Aegean Region a last war-variant of type-II helmets with a pivotable face-guard and an articulated guard at the right cheek was developed [ref_arm_1445] [ref_arm_1458]. One disadvantage of these helmets was that due to their large dimensions they were uncomfortable for fighting on foot. Another factor that might have led to their disappearance off the battlefields about the mid-15th century was possibly their pointed silhouette being not fashionable anymore. The fighters were now looking for helmets with curvy, tapered skulls.

3.3.3 Type-III

Type-III helmets, variations are called "kettle hats", "capacete" or "morion", according to depictions in the 13th century were initially made from segments. A late example is shown on an Italian painting of the mid-14th century [ref_ill_art_5184]. In different Scandinavian countries several of such helmets, probably of the 14th century, survived [ref_arm_1422] [ref_arm_4380] [ref_arm_4579] [ref_arm_4174]. Also in Germany [ref_arm_1367] [ref_arm_1440], Italy [ref_arm_4345] and the Netherlands [ref_arm_4251] different segmented variations were excavated. By the end of the 14th century type-III helmets were usually made of one plate. Probably the earliest examples are variations with a small nose at the front of the brim [ref_arm_1362] [ref_arm_1401] [ref_arm_1414]. They were made with some alterations in design until the early 16th century [ref_arm_1398] [ref_ill_art_5149]. Another model used from the 1430ies [ref_arm_1347] [ref_arm_1368] [ref_arm_1441] until 1480 ca. [ref_arm_4264] is basically of the shape of a top-hat with a medial ridge or a point

at the top. In the first half of the 15th century, probably in Italy a unique model developed with a medial ridge passing from the frontal pointed brim to the rear point of the brim [ref_arm_1353]. At other variations the brim at the ears is rather steep and the skull is slightly tapered [ref_arm_1377]. This so called "Burgundian" type of kettle hat [ref_arm_1349] [ref_arm_1424] [ref_arm_4197] is actually not only shown in Burgundian artworks but also in artworks of other cultural regions, e. g. in Spain [ref_ill_art_5183]. The Spanish soldiers in the last third of the 15th century often wore a special variation called "capacete" [ref_arm_1413] [ref_arm_4184] [ref_arm_5102]. An absolute unique type-III model is [ref_arm_4464][71], while according to contemporary artworks [ref_ill_art_5347] such helmets really existed in the mid-15th century. The helmet [ref_arm_1380] of about 1500 is singular in its upward bending frontal brim. It is clear that the armourer tried to imitate a textile hat. Helmets of type-III are – unlike often suggested – not necessarily foot soldier's equipment only. Also some men-at-arms on horseback wear helmets of type-III [ref_ill_art_5255] (descr. 2) [ref_ill_art_5200]. They probably generally resemble the simple brimmed hat of the civilian clothing [ref_ill_art_5357]. The face and the vision were left uncovered, which made this helmet a perfect model for all fighters that needed to aim with ballistic weapons. Their defensive function is obvious – the head was protected merely from blows from above, the brim to a certain extend protected also the shoulders – and therefore different variations remained in use until the mid-17th century.[72]

3.3.4 Type-IV

In the first half of the 14th century the armourers tried to improve the protective functions of type-I helmets. First they left the plate a bit longer at the nape (type-IV). The lower edge continually moved more down [ref_arm_1518] [ref_arm_1541] until it covered the entire nape and the cheeks. To the lower edge – for the protection of the neck – now frequently a collar made of ring-armour was attached [ref_arm_1501]. At least from 1380 according to extant examples and depictions the skulls were pointed, resembling a contemporary hood. By the last quarter of the century an articulated detachable face-guard was frequently added [ref_arm_1494]. Examples for the detachable application of a nasal guard is depicted at many effigies: e. g. in Germany [ref_ill_art_5267] and in Italy [ref_ill_art_5284]. Only one example seems to survive [ref_arm_4424][73]. Probably in Italy a visor of a pointed shape with vision slits was developed. It was usually pivoting at each side of the skull. The central pivoting visor with vision slits – said to be of German origin – could also have an extensive snout, as the effigy [ref_ill_art_5258] suggests. The less pointed shape can be found very often at northern alpine contemporary effigies, e. g. [ref_ill_art_5271]. Due to the shape of their visor such helmets were called "houndskull-basinet". The visors were all detachable; probably to make this helmet a bit more comfortable when there was no threat to life or physical condition. While the versions with the centrally fastened face-guard seem to have gone out of fashion in the early 15th century, the models with the side-pivoting visors were in use until the 1440ies. A disadvantage of this helmet was probably that the visor could not be locked. A strike from an attacker into an upward direction could easily expose the wearer's face.

71 The vision slit at this helmet is functionless, it is too high. It might rather be the result of a blow from a sword or a staff weapon.

72 The British and the Canadian army used a steel-helmet of type-III (MKI and MKII) from 1915 to 1945.

73 A second one is attached to the type-I helmet [ref_arm_2093].

3.3.5 Type-V

In the first half of the 14th century the type-I helmets with a pointed skull developed into helmets of type-V by the addition of a flaring nape-guard. Two early examples with a short nape-guard do survive [ref_arm_2157] [ref_arm_1985]. They were probably made before 1350. If the visor pivot holes respectively the remains of a visor arm at these helmets are of the production time then these helmets might be the oldest surviving examples once equipped with a pivoting face-guard. Due to the similarity to these helmets the item [ref_arm_1620] might also have had a nape-guard that was cut off at later times. The helmet [ref_arm_4260] with its circumferential brim is absolutely unique. It shows features of a "Burgundian" helmet of type-III.

In the second half of the 14th century a new type-V helmet was developed. For the most part it was only a stylistic variation of the contemporary type-IV helmets. Technologically absolutely new was the skull to slightly flare out at the nape below a slight tapering. Many extant examples had a face-guard attached. This was invariably fastened at the forehead by a single, detachable hinge. Some variations had a half-bowl shaped skull [ref_arm_2023] (the genuine visor is missing), others a tapered point [ref_arm_2082]. Probably by the end of the 14th century helmets of the same shape were made with and without a ring-armour collar and a visor attached [ref_arm_1981][74] [ref_arm_1993].

In the first half of the 15th century also a less deep, lighter variation of type-V helmets was produced. Early examples might be depicted on a painting by Masaccio from about 1430 [ref_ill_art_5248]. They still look like simple skull caps of type-I, but small nape-guards are already visible. Extant examples of probably the same period are [ref_arm_1922] [ref_arm_1994] [ref_arm_2070] [ref_arm_4338] [ref_arm_4414]. Due to its brim slightly flaring out at the front the helmet [ref_arm_2176] is an absolutely unique variation of type-V. The helmet [ref_arm_1994] is very similar to the one worn by the soldier on the lower left side of [ref_ill_art_5242]. The extant example is of type-V, while the one in the painting seems to be of type-I, but both helmets have the embossing at the ears in common. Some models have a pivoting nasal guard [ref_arm_2079] [ref_arm_2085] [ref_arm_2131] [ref_arm_4513] that can also be found at contemporary depictions [ref_ill_art_5165] [ref_ill_art_5243] [ref_ill_art_5212] [ref_ill_art_5208].

3.3.6 Type-VI

Oswald Graf Trapp in 1926 published an article on the development of one group of type-VI helmets, the so called "armets".[75] This helmet is exclusively made for fighting on horseback. Although this is considered to be an Italian helmet-model, the earliest depiction is found in Germany [ref_ill_art_5336] – uncommonly with a pointed skull. It is not clear if it developed from a preceding type. An as yet unattended helmet possibly made in the early 15th century might be the oldest extant example of a type-VI helmet [ref_arm_2158]. It is kept un-restored in the storage of the MDA. The cheek-plates and the presumable face-guard are missing and it is heavily corroded. Nevertheless, the "tail" at the rear and the hinges are typical for 15th century type-VI helmets. Another unique example is [ref_arm_1929] – otherwise only known from artworks of the 1440ies.

The helmet that is now called "armet" probably developed in the 1420ies. At least from the 1440ies it is frequently equipped with a side-pivoting, pointed face-guard [ref_arm_1932]. The sight for the first time was provided by a slit between the upper edge of the visor and

74 The visor and the collar are lost.

75 Trapp (1926).

the lower edge of the forehead. All these models had a reinforce-plate riveted to the forehead and a ring-armour collar (none is extant) attached to the lower edge. Most of them had a disc riveted to a short horizontal shank at the lower edge of the nape [ref_arm_1938], but at extant item these discs usually got lost. Their purpose has often been discussed, without any final explanation. This type of helmet in different variations was produced until about 1520. It had the great advantage of fitting very closely, protecting all the head, including the chin and the upper parts of the neck. The pointed visor made attacking weapons slide off.

3.3.7 Type-VII

The type-VII helmet is the one to be divided into the most sub-groups. It is a type that was mainly used in the second half of the 15th century. Basically two open-face versions were in fashion in Italy: Both have an attached forehead reinforce, but one has the nape-guard made in one piece with the skull [ref_arm_2090] [ref_arm_2117], the other one has it made from one or more articulated lames [ref_arm_1777]. Similar to the helmet shown on the painting [ref_ill_art_5247] is the extant example [ref_arm_1830]. A special, richly decorated version – rare in extant examples – is painted by Botticelli in the early 1480ies [ref_ill_art_5375] (descr. 1) [ref_arm_1765] [ref_arm_1855] [ref_arm_1751].

Another Italian model had a sharply pointed nape-guard and a side-pivoting visor with an integrated forehead-reinforce [ref_arm_1672] [ref_arm_1807]. Alternatively the forehead-reinforce could be riveted directly to the skull and the visor – now protecting only below the eyes – had only low pivots [ref_arm_1688] [ref_arm_1706] [ref_arm_2094]. These helmets were meant only for foot-soldier's use, in Italy they were never added to costly armour suits.

In Germany the development of the type-VII helmet is probably based on a helmet of type-III that had a low brim with vision-slits. In the second half of the 15th century many type-VII helmets had a fixed face-guard with a slit for the vision. This variation remained in use for the tournament-variation "Rennen" until the second half of the 16th century. From the 1470ies also in Germany type-VII helmets got a pivoting visor, with [ref_arm_1704] or without [ref_arm_1733] an integrated forehead-reinforce. Usually the German helmets had a longer nape-guard that could be made of one or more articulated plates [ref_arm_1727] or one single fixed plate [ref_arm_1837].

The so called "black sallet" forms a rare group of extant helmets of type-VII [ref_arm_1702] [ref_arm_4254] [ref_arm_1886]. Even rarer are illuminations [ref_ill_art_5306] (descr. 1) [ref_ill_art_5337] [ref_ill_art_5334] [ref_ill_art_5383] (descr.1). It seems like this helmet was exclusively used in southern Germany in the late 15th and early 16th century. Typical for these helmets is that they were never polished, the show many pairs of small holes and the edge is usually not turned.

Type-VII helmets did not protect the chin and the neck. Therefore, the armourers often added a separate neck-protection. By the end of the 15th century the armourer's experimented with the attachment of the neck-protection to the visor pivots [ref_arm_1904] [ref_arm_1971] [ref_arm_1810]. These helmets later developed into the so called "closed helmet", a type used until the 17th century. According to contemporary depictions type-VII helmets with a pivoting visor and a long nape-guard were used with only few exceptions in combination with a horseman's suit of armour.

3.3.8 Type-VIII

The helmets defined as type-VIII are actually of several different types. All helmets needed to be fastened to the torso-protection and therefore they could only be used in combination with other body-armour parts. As all type-VIII helmets at least from 1450 on are used

exclusively in different tournament-types and never in battle, a further differentiation was spared for future studies.

The first group, the so called "Stechhelm" developed from type-II helmets. Until about 1450 – according to depictions in contemporary art – it could occasionally also be used in battle [ref_ill_art_5148] [ref_ill_art_5358]. The skull was usually riveted together from three plates: A very thick frontal plate in the shape of a lean bow for the protection of the face; a low skull; and a plate at the rear of the head. The face-guard was never articulated [ref_arm_1644].

Also the great basinet was not exclusively used in tournament [ref_ill_art_5173]. This helmet had the skull and the rear plate worked in one piece with the skull, one or two plates below the chin to protect the throat and a pivoting visor. The latter was shaped either hemispherical [ref_arm_1633] [ref_arm_1635] [ref_arm_1652] or frog-mouthed [ref_arm_1650] [ref_arm_1627]. A special variation consists of at least 4 plates, as the skull and the lower rear regions are made from separate plates. It has not been noted that all of these examples are actually type-IV helmets that – in the first half of the 15th century – were turned into type-VIII by basically replacing the ring-armour collar by plates of the same dimensions. At the lower edge of the skull-plate at all examples interiorly the holes for the pulleys that once held the ring-armour collar are still visible [ref_arm_1768] [ref_arm_1655] [ref_arm_1653].

A special version of the great bascinet with a bowl shaped skull remained in use for foot-combat tournaments (Kolbenturnier) until the early 16th century. The visor was screwed to the skull and forged from iron bars to form a grill [ref_arm_1646] or it was pivoting and made of a perforated hemispherical plate [ref_arm_1647].

3.3.9 A noteworthy, not preserved type

No example from before 1500 seems to survive of the so called "burgonet" or "Sturmhaube", despite depictions from the early 14th century on (e. g. [ref_ill_art_5250]) throughout the 15th century (e. g. [ref_ill_art_5242]) repeatedly show such a helmet. Its main characteristic is the "fall" above the eyes and the flaring napeguard. By the beginning of the 16th century it becomes a popular type and is extant in many examples. The only basically older examples are type-IV [ref_arm_1562] or type-VII helmets [ref_arm_1793] [ref_arm_5130] to which a "fall" was attached in the 15th, 16th or 17th century.

3.4 Leg-protection

The sufficient protection for the leg is similarly complicated to the protection of the arm. The wearer must not be restrained in walking – and kneeling! – when wearing full leg armour.

The oldest plate-like protections were probably made of leather, occasionally reinforced with iron or bone bars. No leather armour-part for the leg survived. As far as the author knows also no ring-or segmented-armour hose or stockings are extant, despite them being depicted in artworks.

3.4.1 Knee

After the helmet the knee protections from 1250 on are the first armour parts to consist of a single large plate.[76] The knight on the effigy [ref_ill_art_5254] wears knee protections of type-I. Only few type-I knee protections made of plate do survive [ref_arm_2280]

76 Blair (1972), p. 39.

[ref_arm_2281] [ref_arm_2282] [ref_arm_2283] [ref_arm_2284] [ref_arm_2285] [ref_arm_2286] [ref_arm_4650].

In parallel to the elbow-protections the armourer later sought to protect the rear side of the knee joint by a shell-like extension at the small toe-side (type-II). Transitional types are found at [ref_ill_art_5291] and the standing knight [ref_ill_art_5175]. Their parallel vertical ridges are similar to extant examples of type-I [ref_arm_2282] or [ref_arm_2280]. While Gottfried of Arnsberg at his effigy [ref_ill_art_5256] is still equipped with some old fashioned armour parts, like the reinforced leather lower arms, his knee protections are already of type-II, with the shell-like extensions at the small toe side. One very early extant example – possibly the oldest type-II knee defense – is probably [ref_arm_2266][77]. All extant knee protections of type-II have a medial ridge. Pointed knee protections seem to have existed according to contemporary artworks [ref_ill_art_5279], but no extant example is known.

3.4.2 Lower leg

Already about 1250 depictions show larger plates for the protection of the front of the lower leg.[78] In the second half of the 14th century the armour for the lower leg could still be made of leather [ref_ill_art_5249] (descr. 1), occasionally fastened onto ring-armour stockings [ref_ill_art_5280]. Also the lower legs at the brass [ref_ill_art_5254] were probably made of leather. No type-I lower-leg and only very few type-II protections exist [ref_arm_2539] [ref_arm_2828].

The far larger number of lower leg armour is of type-III. The oldest examples date from the second half of the 14th century [ref_arm_2291] [ref_arm_2325]. Despite the often repeated opinion that lower legs were never – also not later – decorated by ridges, contemporary artworks do often show embossed decorations [ref_ill_art_5285] or [ref_ill_art_5296] [ref_ill_art_5156]. Also some extant examples are known [ref_arm_2298] [ref_arm_2335] [ref_arm_2304]. Together with tapered helmet skulls lower leg-protections of type-III were the most elaborately worked larger plates in the 15th century. Without exception they resemble very closely the human anatomy. As the lower leg is unsymmetrical it is difficult to cover it with a close fitting plate. The lower legs were worked less elaborately in shape when from the 16th century on armour was produced in larger quantities.

3.4.3 Upper leg

The oldest extant upper leg defense of type-I dates from the mid-14th century [ref_arm_3023]. This was probably still riveted interiorly to fabric or leather. A few items from the beginning of the 15th century do survive [ref_arm_2909] [ref_arm_2922]. For lighter equipment [ref_arm_2926] and especially in Spain this type was still produced until the end of the 15th century [ref_arm_2932].

The type-I upper legs left the rear side of the leg without defense. Therefore, from the early 15th century on the Italian armourers attached a flap to the upper leg (type-II). As leg armour is merely meant for use on horseback, the side of the leg turned to the horse's body was not covered by plates. This type was in use on field armour until the end of the 16th century.

Type-III upper legs were only made for tournament armour in the early 16th century.

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77 Due to the similarity of the shell-like extension here is also a small chance that this is a late 14th century elbow protection of type-II with an upper arm defense. If this is the case then it is the only example with a medial ridge at the elbow.

78 Blair (1972), p. 39.

3.4.4 Systems

As the lower leg cannot twist like the lower arm it is possible to protect the upper leg, the knee and the lower leg by directly joined plates. From the second half of the 14th century on the knee was permanently connected to the upper leg, but the lower leg defense was always detachable. Systems consisting of a combination of different types were produced.

Until the mid-14th century armour systems for the knee, the upper and the lower leg was only covering the front side of the leg [ref_ill_sys_leg_luI_lkI_llI]. From then on until the early 15th century the leg was covered by an upper leg defense of type-I, by a knee defense of type-II and a lower leg defense of type-III [ref_ill_sys_leg_luI_lkII_llIII]. From then on the system – type-III lower leg, type-II knee and type-II upper leg – was the most common and was made from the early 15th century until the end of the 16th century in all Europe [ref_ill_sys_leg_luII_lkII_llIII]. In the second half of the 15th century in parallel to this also a system with all parts of made of type-II existed [ref_ill_sys_leg_luII_lkII_llII]. In the same period light defenses for foot soldiers of type-I upper legs and type-II knees were worn without lower legs of type-III [ref_ill_art_5309][79] (descr. 2). Knee protections could also be used singly, without being attached to an upper or lower leg-protection [ref_ill_art_5199].

3.4.5 Leg foot

It seems as if all foot-protections never covered the sole. As late as the 1430ies depictions show the somewhat old fashioned scale protected feet [ref_ill_art_5239] or [ref_ill_art_5342]. But already before 1350 foot protections made of larger lames were known [ref_ill_art_5286]. These developed into a system of joined articulated plates, protecting the upper side of the foot until the lower leg defense (type-II). In Italy in parallel the foot until the second half of the 15th century was often protected merely by ring-armour and a small plate at the toes (type-I). At the Earl of Warwick's effigy [ref_ill_art_5232] foot protections of type-III can be seen that cover all the foot including the heels with articulated plates.

3.5 Neck-protection

Until the first half of the 15th century the gap between the helmet and the torso-protection was insufficiently protected by ring-armour only. The development of the plate neck-protection is still obscure. Already by 1436 an inventory itemizes:

[…] item 27 stukh pertt [German, pl. Bärte] und vizier […][80]

The German word for the neck-protection is "Bart", meaning the same like "beard". Today this term describes a protection for the chin and the throat. A very early depiction of such a defense north of the Alps is found in [ref_ill_art_5153] (descr. 2). Probably one of the oldest extant examples is [ref_arm_3097]. Extant type-I neck-protection all date from 1480 to 1500 only [ref_arm_3173] [ref_arm_3197]. Their main advantage over type-II was that the weak seam of the upper and the lower part was less likely to open when hit by any kind of weapon.

In contemporary depictions often also a defense which covers only the lower part of the neck can be seen. It is surprising to see that only two examples from before the year 1500 are extant [ref_arm_3072] [ref_arm_3152]. On some illustrations it becomes clear that already by the second quarter of the 15th century the throat and the nape could be covered by plates while the chin is left unprotected (type-III). This is indicated for example at the effigy

[79] The man in the painting wears plate straps fastened to the outer side of his lower legs - similar to the „jack-chains" arm defenses.

80 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1883), Reg. 48.

[ref_ill_art_5219] (descr. 1), where on the right side of the deceased's neck-protection a hinge is visible, connecting the rear and the front plates. Also on Italian armour a neck-protection of type-III could be worn [ref_ill_art_5335] (descr. 2). Of this type of neck defense only one example still exists [ref_arm_3092]

Neck-protections could be worn with their lower plate optionally upon or underneath the breastplate [ref_ill_art_5218] (descr. 1). They were usually meant to be combined with helmets of type-III [ref_arm_3133] [ref_arm_3165], -VI [ref_arm_3081] and -VII. Different versions of type-II and –III neck-protections were made until the end of the 16th century.

3.6 Torso-protection

Claude Blair quotes a written document of 1171 that might tell of torso-protections consisting of smaller plate segments.[81] This is also the earliest document of plate armour he could find. The tracking of the development of torso-protections is difficult, as until the late 14th century the plates were usually covered by a surcoat. What such an arrangement could have looked like can be seen on a stained glass window of about 1370: Two armoured man wear torso-protections with vertical lames – probably riveted upon an undergarment [ref_ill_art_5159]. Several segmented torso-protections still exist. Before the year 1400 they consisted of a front-protection that was permanently connected to a back-protection [ref_arm_3924] [ref_arm_3923]; [ref_arm_3886] [ref_arm_3885]. Torso protections being a combination of textiles and small, interiorly placed plate segments were used until the mid-16th century. Such an armoured jacket is usually called "brigandine".

3.6.1 Torso front

The oldest extant breastplates are of type-I [ref_arm_3734] [ref_arm_3814] [ref_arm_3963] [ref_arm_4018] [ref_arm_4071] [ref_arm_4077], they all date around the year 1400 probably. It is not clear when and where the first single piece example was made, but it was most likely in the second half of the 14th century. The earliest of them had been covered by fabric, which emphasizes their relation to former segment-armour protections. Via the cover-material the back-plates were possibly directly attached to the front-plate [ref_ill_art_5289] (descr. 1). As the lower edge was not angled, a blow would probably drive the edge into the wearer's abdomen. At some plates of type-I therefore about 1410 the lower edge was turned exteriorly to reveal a less sharp radius [ref_arm_3810]. Such plates, as well as plates with decorative plate straps, were not covered exteriorly by fabric anymore and possibly had no directly attached pelvis protection. Nevertheless, the different vertical segments of the breastplate [ref_arm_3811] – still similar to the segmented-armour system with an exterior cover – are connected interiorly via a leather-lining. Two breastplates – once exteriorly covered by fabric – still retain one or more pelvis-lames in their original position [ref_arm_3698] [ref_arm_3507]. In both cases they are placed exteriorly at the lower edge of the breastplate. This region was a weak point. Attacking weapons would easily slide to the direction of the waist and penetrate in between the pelvis-lames and the upper breastplate. To improve their fitting, the armourer gave the most upper pelvis-lame a concave section [ref_arm_3698]. In the early 15th century – when the plates were already all placed exteriorly – the Italian armourers extended the upper edge of the first pelvis-lame to double parts of the upper breastplate (type-IV) [ref_arm_3607]. The type-I breastplate was from then on not produced anymore. Within the next years to come, on Italian armour the upper edge of the doubling lower pelvis-lame – now it should be rather called "abdomen-plate" – extended permanently further up the thorax-plate [ref_arm_3797], until about 1490 in Italy it covered all the upper breastplate with the exception of the turned edges of the thorax-plate below

81 Blair (1972), p. 37.

[ref_arm_3609]. According to extant examples it seems as if the German armourers did not start to make breastplates of type-IV before the 1470ies. In Italy and Germany the total weight of type-IV breastplates was often reduced by cutting the lower edge of the thorax-plate so the abdomen-plate would only overlap at a narrow seam-region. Type-IV breastplates were produced until the mid-16th century.

Probably in parallel to the development of type-IV breastplates in Italy, in the German speaking lands an as yet insufficiently attended breastplate-type was developed. Presumably also with the intention of protection improvement at the gap between the waist and the upper breastplate the armourers placed the most upper pelvis-lame interiorly at the lower edge of the type-I thorax-plate (type-III). This lame – now also better called "abdomen-plate" could also consist of several lames [ref_ill_art_5372] (descr. 3) [ref_ill_art_5341] (descr. 1) [ref_ill_art_5216] [ref_ill_art_5230] [ref_ill_art_5193] [ref_arm_3440] [ref_arm_4024]. The oldest extant plate that once probably had such a narrow abdomen-plate attached interiorly is possibly [ref_arm_3428]. It is the only surviving model of a box shaped type-III breastplate found in large numbers in northern European artworks from about 1420 to 1450.[82] That the so called "Kastenbrust" was often of type-III is documented on many contemporary artworks [ref_ill_art_5241]. Several examples with only moderately box-shaped silhouettes dating from the 1440ies [ref_arm_3621] to the 1450ies do exist [ref_arm_3438] [ref_arm_3623] [ref_arm_4043]. Many examples have several pelvis-lames attached, forming a wide skirt of plates. The sword is often stuck through a hole in the pelvis-lames [ref_ill_art_5223] (descr. 3) – a feature that is known similarly already in the 12th century [ref_ill_art_5310], where the sword was stuck through a hole in the ring-armour shirt. According to depictions the skirt of the "Kastenbrust" could also be made of scales [ref_ill_art_5268] (descr. 1).

In a late medieval fencing book the fighters wear breastplates of type-III [ref_ill_art_5226]. The thorax-plate seems to be split in two, hinged to the backplate at the sides and fastened in the center by buckles. Even though no extant plate of this system is known, it is similarly depicted at several different artworks, e. g. [ref_ill_art_5193] or [ref_ill_art_5341] (descr. 2). A related breastplate – here it is unclear if the central plate strap covers the gap of the centrally split plate – is shown on [ref_ill_art_5209]. Type-III breastplates seem to have been used merely in northern alpine Europe until the mid-16th century.

A very simple type of breastplate is probably the youngest development. Only from about 1480 on breastplates of type-II appear in contemporary artworks [ref_ill_art_5354] (descr. 2) and the earliest extant examples do usually date from about 1480 on [ref_arm_3458] [ref_arm_3447]. They have major advantages in comparison to all other types: As the part above the pelvis consists of one plate only, they are easy to make. The thorax and the abdomen-plate do not have to get adjusted to each other; they are light as they have no overlaps. There are no steps from overlapping plates on the surface, no weapon would get stuck there. This type of breastplate was made for Cavalry until the 19th century and is therefore the armour part with the longest tradition.

3.6.1.1 Front of hip

Already in the 1430ies the armourers in Italy and in the German Speaking lands attached single plates at the lower edge of the breastplate pelvis-lames – one for each upper leg. They were meant to protect the gaps between the upper leg defense and the breastplate. Early square examples are depicted at the Gent altarpiece [ref_ill_art_5262] and at a stained glass window in the Münster of Bern of 1447. Here they have already the shape of coat-of-arms,

82 It is possible that the badly damaged item [ref_arm_5127] also was similarly box-shaped.

a shape they will keep for the next 40 years [ref_ill_art_5153] (descr. 1). From the late 1480ies on the one-piece "torso upper leg-protections" were split into several horizontal lames, being extensions of the pelvis-lames for the protection of each upper leg. Early examples might be [ref_ill_art_5368] and [ref_arm_3652][83]. In the 16th century they reached further down the upper leg until about 1550 they reached the knee. When between 1550 and 1630 a knee-defense of type-II was joined to the torso-upper leg-protections, they entirely replaced the separate knee and upper leg defense.

3.6.2 Torso back

Backplates are rarely illustrated in contemporary artworks. The earliest depiction the author could find of an armoured man shown from his back is the statue of St. Mauritius in the Dome of Magdeburg [ref_ill_art_5374] (descr. 2). This statue is very difficult to date, as comparable objects are not at hand. Usually it is said to date from the second half of the 13th century. Anyway, it is also possible that it was made in the first half of the 14th century, as other depictions of segmented back-protections in artworks of Italian make from the second quarter of the 14th century suggest. In the painting [ref_ill_art_5185] the back parts are shown colored in violet and as rivet heads are visible it is likely that the back armour consisted of small plate segments covered and held together by fabric, probably similar to the extant example [ref_arm_3909]. Two "wings" are visible under the arm cutouts, fastened centrally by two horizontally buckled leather straps. Each is also buckled upwards towards the nape cutout of a central plate underneath. The latter may have consisted of one or several single plates. The backplates at the statue of St. Mauritius on the first look seem been riveted exteriorly on leather or fabric, as the visible horizontal lines and the horizontal rows of rivets suggest. The horizontal lines do rather remark a belt or a plate-lame that was permanently fixed to the armour and that surrounded the entire waist. Extant examples do suggest that the horizontal rows of rivets can actually interiorly hold vertically arranged lames. Similar to the backplates found in Wisby the plates of St. Mauritius could have been arranged [ref_arm_3891].

It is particularly difficult to reconstruct the genesis of plate armour protections for the back as only very few early examples do survive. The most precise rendition of an early back-protection, still consisting of very small segmented plates inside a fabric or leather material is found at the statue of St. George from Prague [ref_ill_art_5290] (descr. 1). In the upper central area the silhouettes of hour-glass shaped plate is visible. One plate of exactly the same shape [ref_arm_3384] and a similar, but larger plate [ref_arm_4800] are extant. However, it seems like the development of a plate-protection for the back had fallen behind the development of breastplates. Until the end of the 14th century backplates were most likely still made of smaller plate segments riveted inside a fabric cover. One special type seems to have consisted of one trapeze-shaped central plate together with some smaller segments that covered the sides of the lower back. The latter segments are not preserved in large numbers, some separate items might still exist in collections but have not yet be identified as parts of a back-protection. On the other hand the larger central plates are extant in several examples [ref_arm_3379] [ref_arm_3380] [ref_arm_3382] [ref_arm_3383] [ref_arm_3385] [ref_arm_4767] [ref_arm_4773] [ref_arm_4780] [ref_arm_4789] [ref_arm_4792] [ref_arm_4796].

83 The torso-upper leg lames were detached for some unknown reason and found by the author in a box separately from the breastplate. They are shown mounted at an old image [ref_ill_art_5396]. According to another old photography [ref_ill_art_5395] similar torso-upper leg-protections are still missing at the breastplate [ref_arm_3668]. They are most likely still in the museum storage and will probably be found soon when the recently moved stock will be unpacked.

In parallel to the breastplates of type-IV from 1400 on in Italy backplates of type-IV were made. The oldest example of about 1410 is preserved in the armoury at the Castle of Churburg. While this remained merely an Italian backplate-construction, also few later examples decorated in the northern alpine taste are preserved. The backplates [ref_arm_3374] and [ref_arm_3406] are plane examples made in Innsbruck about 1490. The closely related backplates [ref_arm_3327] and [ref_arm_3387] were probably made in the German speaking lands, but the items [ref_arm_3404] [ref_arm_3410] and [ref_arm_3412] according to the types of their marks were made in northern Italy.

The backplate of type-III was probably developed in the German speaking lands – it is found neither in Italian artworks nor at Italian suits of armour. The oldest examples to survive are probably [ref_arm_3303] and [ref_arm_3269]. Only slightly later, maybe dating from the 1460ies is [ref_arm_3315]. At this example, the wide ridges in parallel to the arm-cutouts remind on the design of older northern alpine backplates. At these – similar to the segmented types seen on artworks – the plate was still split vertically in the center [ref_ill_art_5172] and obviously hinged to the breastplate [ref_ill_art_5275]. Later backplates often have a separate plate riveted at the nape cutout [ref_arm_3345]. This feature might remind either on the central trapeze-shaped plate of older backplates or on the way the undergarment was visible at German backplates of the 1450ies [ref_ill_art_5275]. For the northern alpine market also the Italian armourers produced back-protections of type-III, but as [ref_arm_3296] is the only extant example such variations were probably less common. Backplates of type-III were obviously still produced by the early 16th century, as the example at the painting [ref_ill_art_5151] shows.

15th century backplates of type-II are very rare; the earliest examples date from the last two decades of the 15th century. It is very likely that both, front and back-protections of type-II, were developed more or less about the same time. The earliest extant Italian examples are plane [ref_arm_3365]. In the German speaking lands they were decorated only moderately by few ridges [ref_arm_3311] [ref_arm_3368]. Until the 19th century backplates of type-II were made for the cavalry.

On the contrary to all aforesaid backplates, those of type-I were not made in parallel to the corresponding breastplate type. Type-I backplates appear for the first time in the 1490ies [ref_arm_3417]. Nevertheless, some connection to older segmented backplates might exist, as all extant type-I examples are made of a central, trapeze-shaped plate with a smaller plate attached at each side. There are also some contemporary backplates of type-III [ref_arm_3334] and –IV [ref_arm_3390] [ref_arm_3374] where the upper plates are constructed in exactly the same manner. Actually the upper plate of the very early backplate of type-IV also consists of one central plate with two permanently fixed prolongations at each side [ref_arm_3391].

3.6.3 Concerning torso front and back together

3.6.3.1 Side of hip

To Italian [ref_ill_art_5182], but also to German armour [ref_ill_art_5228] small plates can be attached to the side of the hips. At the sides of the pelvis-lames at extant armour it is usually not visible how the lost hip protections once were attached. Artworks help to understand that they were attached with two straps, one riveted to the pelvis-lames of the breastplate and one riveted to the pelvis-lames of the backplate [ref_ill_art_5182]. Not many examples are extant and by style they are probably all of Italian make [ref_arm_3872] [ref_arm_3925] [ref_arm_3926] [ref_arm_5136] [ref_arm_3871].

3.6.4 Systems

A breastplate could be worn without a backplate, but not vice versa. Breast and backplates were worn together in different combinations. The Italian type-IV system is probably the oldest full torso-protection [ref_ill_sys_tor_ita_tfIV_tbIV]. Here the front- and the backplate are usually hinged together under the left arm [ref_ill_art_5231] (descr. 2) and closed by buckles at the right side [ref_ill_art_5233] (descr. 2). The thorax-plates are separate from the abdomen-plates – a horizontal split. All other systems are split vertically in an independent front- and backplate. From the mid-15th century on in northern alpine Europe front and back-protections of type-III were worn together [ref_ill_sys_tor_ger_tfIII_tbIII]. Exclusively in these regions from the 1470ies on backplates of type-III were combined with breastplates of type-IV [ref_ill_sys_tor_ger_tfIV_tbIII] – until about 1490 the most common system in the German speaking lands. Probably from the 1480ies on – until the 19th century – type-II torso-protections were combined [ref_ill_sys_tor_ger_tfII_tbII]. Judging by protective aspects none of the system is superior to the other.

4 Summarizing technological features

The armourers did not leave any written document on how they were working and what they intended to achieve with the construction of certain product-features. Today, such products are valued rather for their beauty and uniqueness than for the sophisticated technology that created them so many centuries ago. This is an unfortunate truth, as in the extant examples themselves there is still a lot to be read about the "engineers" the armourers of old were. It is the visible details that have to be studied and interpreted to find answers on many open questions on the topic. Already in 1921 Bashford Dean, the founder of the arms and armour department at the metropolitan Museum of Art in New York, wrote:

> *For, truth to tell, no one can really know armour who has not studied it with microscopic care, examining its spring-latches, linings, straps, hinges, rivets, plume holder, and […] its buckles.*[84]

The technological features named by Dean had never been examined and described satisfactorily, despite them providing a vast field of comparable factors. It is the aim of this study to establish a stable basis for comparisons that could possibly help to tell the genuine armour apart from the reproduced. Therefore, it is necessary to classify all the features found on extant plate armour.

Why did not already 19th and 20th century collectors and scholars simply compare and publish the largest possible number of objects for substantiating the findings of their studies? A good part of the objects known now was also known then!

The answer is simple: When reconsidering why comparisons remained limited to a small choice of extant examples only, the reasons can be reduced to one main factor: the cost of centrally assembling all the necessary data for comprehensive comparisons. Of course, it would be best for scholars to have all concerned artifacts – the objects themselves – on the table. As this; for various reasons; is not possible, a central assembling of data was – and still is – indispensable. For this purpose, journeys had to be made, items had to be photographed and to be developed; literature or documents had to be obtained. If the findings were meant to be published, manuscripts had to be typed, text layouts had to be made manually and books had to be printed. All this meant: The more items an author intended to compare the higher the research-costs would become; the more images were about to be included in a publication – inescapable for substantiating statements made in text on artifacts – the higher the printing costs would become. The necessary consideration of these cost-factors resulted in different compromises: editions were limited to few copies only; in the 19th and early 20th century many publications contained no images; instead of illustrations, long and detailed descriptions were inserted; some publications made use of drawings, while others of course were already illustrated by a limited number of black-and-white photographs. Until today the print of colored images is often avoided – due to the higher costs.[85]

The digital age by various technological innovations[86] makes it now possible to reduce the impact of the aforesaid factors on scientific knowledge-transfer. Digital photography makes the film-development dispensable. The internet provides for a countless number of free sources – be it images from museum databases, discussions and images in forums or access

84 Dean (1921), p. 60.

85 A comparatively recent example are the black and white images in: Eaves (2002).

86 But also e.g. the current comparatively low travelling costs.

to bibliographies and texts. The most important feature that the internet provides is the very low cost unlimited platform for scholarly publications of any kind. The printing cost of images becomes irrelevant for the author. Therefore, the goal of discussing topics on the basis of all-embracing, related data had become much closer at hand. If the 19th and 20th century scholars would have had such tools at hand, they would certainly have made extensive use of it. Description would have been reduced, due to the simple visual access to the artifacts. The scientific findings would have spread much wider, as the barrier of limited prints and high book-prices would be largely reduced. Of course, the haptics of a book cannot yet equivalently be replaced by a digital device. The printing of books on demand with the help of modern technology offers a further possibility that makes digital knowledge accessible the way people are used to – but with reduced cost for the scholarly author himself.

A digital and publicly accessible database could provide for an overview of many different aspects of armour, a project that should be administrated by scientists of the humanities. All kinds of approaches and disciplines occupied with historical armour could make use of the collected data – and in return could feedback potential new recognition to the database. For example the reconstruction of all provenance-stations is usually a difficult endeavor. Most of the objects went through different private collections and their provenance documentation is often interrupted. A central registration of provenance data would make this important information easily accessible and would help to avoid further losses. The acceptance of a standardized terminology as suggested above would help to avoid misunderstandings and would make international cooperation much easier. The classification of different technical features of armour would deliver a large amount of data for analogies. The reconstruction of the techniques necessary for the making of armour would provide a basis for further approaches of natural sciences to the reconstruction of the historical technologies and the authenticity question[87].

The author of this paper has developed a digital database-system that could fulfill the requirements of a central information-platform. For the moment it serves only as technical equipment for the research questions of this study and does not contain all desired object-data yet. Nevertheless, the structure of this database provides the possibility to collect and subsequently compare all traceable object-data. On nearly all of the ca. 5000 objects in the database the author noted at least the basic collection data and at least one image of each item is included. For many objects further data on technological and other details has already been added to the data-sheet.

Preceding studies focusing on armour usually ignored the doubtful pieces found within the sum of considered objects. This is not acceptable as this way an important and problematic aspect of the history of arms and armour got widely concealed. Only after both, originals and fakes, are overviewed, objective conclusions on doubtful objects can be drawn. Therefore, many reproduced items were included in the database.

The main column on which this study will be standing is the description and classification of any kind of detail to be found on extant armour, which could serve for comparisons to other objects. The lack of written sources makes such an approach necessary. There are actually a number of features on late medieval armour that provide information for analogies: turned edges, rivets, joints, ridge-embossing etc. In the course of this study it became clear that many of these technological features found on different extant items were so similar to each other that they could be summarized by one description. Some features are so common that they can almost be considered as “standards”. In many cases these “standards” allow

87 On the problem of authenticity see chapter [The problem of authenticity].

well-founded suggestions on how damaged or incomplete armour appeared in its original condition. The source for all classifications and suggestions is the real object. The aim is to develop an extendible catalogue that comprises facts for answers on different technological questions. It is not possible to quote all items showing one of the specific features discussed below. Therefore, only few examples are quoted as illustrative references.

4.1 Metalwork on the plates

4.1.1 The general forming of plate armour

From the 14th to the 16th century several depictions of armourers at work do exist [ref_ill_art_5373] [ref_ill_art_5329] [ref_ill_art_5214] [ref_ill_art_5301] (descr. 1) [ref_ill_art_5356] [ref_ill_art_5323] [ref_ill_art_5325]. Only one is really detailed in showing nearly completely all the tools and installations an armourer needed [ref_ill_art_5330] (descr. 1). It is not only the tools that need to be known when reconstructing the armourer's craft. The tools are actually all still used in similar shape and function for different kinds of crafts until today. What is much more difficult to be reconstructed is the techniques the armourers applied to reveal the final shapes of the items. The following chapter is a short assumption on how certain body-parts might have been made.

The part consuming the most time and energy is the three dimensional shaping of a helmet from a single plate. It requires sophisticated skills to deform a stiff, plane sheet-metal into the shape of a bowl. Probably due to these difficulties several helmet types – not only before 1350 – were made of segments riveted together. Not only the head, also other body regions were protected by laboriously shaped plates. Basically two methods can result in the same shape. Therefore, it cannot be said with certainty in which process an extant item has been produced.

The first method is merely working the plate from the inside of the bowl. The material is driven into a hemispherical shaped mold or stake by neighboring blows from a round-headed hammer. The plate needs to be turned permanently. This process – depending on the plate-thickness – does not necessarily require the heating of the plate. The following armour parts might have been made by this process in cold work – thicker material might have had to be worked hot:

- breastplates
- backplates
- lower arm defenses
- simple elbows [ref_arm_21]
- shoulders
- shallow visor [ref_arm_1483] [ref_arm_2172]
- separate forehead reinforces at type-V, [ref_arm_1946] [ref_arm_4492] -VI [ref_arm_1919] and -VII helmets [ref_arm_2090] [ref_arm_1777] [ref_arm_1706]
- shoulder reinforces

The second method works similar to the making of a silver cup [ref_ill_art_5311] – a technique that is still used by gold- and silversmiths today. At the beginning, the work can be eased by driving the plate into the shape of a shallow bowl by the aforesaid method. Then the bowl is placed with the interior side upon a stake and is hammered from the outside. The process is started at the widest diameter; the plate is turned while hammered. The hammer does not hit the plate exactly where it is in contact with the stake. It hits instead beneath to deform the plate by small negative ditches left by each blow of the hammer. With the repetition of this process the material towards the edges gets bulged and therefore maybe

slightly thicker. The bulging will only work when the metal is forged hot. Some shapes can be achieved only by this method:

- all single-piece helmet skulls
- pointed visors of type-IV [ref_arm_1567] and -VI helmets
- pointed and tapered type-II elbows [ref_arm_718]
- elbow reinforces [ref_arm_357]
- tapering at type-III, V or -VII helmet skulls
- tapering at the wrists of type-I hand-protections
- tapering at type-I necks
- tapering of knuckles at some type-III hand-protections [ref_arm_1063]
- knee protections
- lower leg defenses
- tapering of some pointed toe-plates [ref_arm_2698]

Several armour segments could be cut from a larger sheet and be bent into a simple groove. Only very little embossing-work was necessary for the making of the following parts:

- upper legs
- upper arms
- most upper lame(s) of type-II necks
- type-II helmets (at least for the lower plates)
- the lower plates of two-piece type-V helmets [ref_arm_2146]
- the attached nape-guards at type-VII helmets
- the lower plates at some type-VIII helmets [ref_arm_1651]
- the finger-lames of some hand-protection models [ref_arm_1127]
- the metacarpal-plates of some hand-protection models [ref_arm_1205]

Usually simply bent and not embossed are the lames:

- of the pelvis
- of the (torso) upper-legs
- of the torso-hip
- between the abdomen and the thorax-plate [ref_arm_3586]
- between the elbow and the upper/lower arm (Italian system)
- at the upper and the lower edge of the shoulder
- between the knee and the upper/the lower leg
- of the foot
- of lower/upper arms
- of lower legs [ref_arm_2329]
- of type-II, -III and -IV hand-protection-cuffs

4.1.2 Turned or angled edges and riveted bars

Surprisingly the very important feature of plate-edge conditioning seems to have never been closely regarded by scholars of the subject so far. No attempt for a classification of turned edges can be found in the literature. For comparisons of different armour parts, such a classification can be of great importance.

The application of bars or turns to plate edges besides a decorative aspect can follow the subsequent intentions:

- To stabilize the plate: To illustrate the stabilizing effect of a profile, a good example is maybe that a plastic ruler can easier be broken than a plastic ball-pen made of even thinner material.

- To prevent the wearer from cuts caused by sharp plate edges: Certain movements of the body or strong blows of any kind can cause injuries.
- To prevent bullets, arrowheads as well as blows and strikes from staff-, or hafted weapons from sliding off the plate-surface into unprotected body-regions.

Three main groups of edge-conditioning can be distinguished:

1. A massive bar is riveted directly at- or close to an edge – in most cases found on Italian armour. From about 1350 to 1450 occasionally bars were riveted close to the throat- and arm cutouts of segmented- [ref_arm_3861] [ref_arm_3867] or plate armour torso-protections [ref_arm_3810] [ref_arm_3438] [ref_arm_3623][88] [ref_arm_3607] [ref_arm_3621] [ref_arm_3814]; to shoulder protections [ref_arm_724]; around the face-cutouts of type-V helmets [ref_arm_1978] [ref_arm_2034] [ref_arm_2043]; near the upper edge of upper legs [ref_arm_2909] [ref_arm_2851] or to lower arms [ref_arm_1] [ref_arm_47]. This was certainly done to prevent unprotected body-regions from being injured by strikes or shots sliding off the plate surface. On Italian armour of the 15th century, occasionally inscriptions or floral ornaments decorated the surface of such bars. They were applied by small dots, punched next to each other with the help of a pointed chisel (pointillier) [ref_arm_3878]. Other bars were decorated by simple filing [ref_arm_90] [ref_arm_3861].

The classification of the following two groups can be combined, as it was certainly the simple angling that later developed into the complete turning.

2. The edge is simply angled to 90^0 ca.

3. The edge is turned so it touches the plate-surface.

In the following, first the different turned or angled edges found at extant armour parts will be classified and their making as well as their chronological appearance will be described.

Already in the Bronze Age, the armourers turned the lower edge of so called "ridge helmets". These helmets consisted of two halves that were connected by an overlapping, over-turned edge at the comb [ref_ill_art_5303]. In all times, the plate edges of segmented armour were neither turned nor angled. It is generally not necessary to turn the edges to make plate armour work. Throughout all times while armour was produced, certain edges remained unturned – even at exposed spots. For example, the lower edges of late 15th century type-VII helmet-variations are often not turned [ref_arm_1796] [ref_arm_1859], even though they were produced in a time when turned edges were a long established feature of type-V and -VII helmets. A general finding is that most of the turned edges on extant armour parts are set horizontally, while most of the vertical edges are not turned.

An edge can best be turned or angled after the armour piece is readily shaped, as too much deformation of a turned edge will result in the partly destruction of its profile. The process of turning an edge always starts with angling the plate along a certain line outwards or inwards. An edge can be turned by different techniques, to reveal different sections that serve as the basis for the following classifications. The quoted videos show how such edges might have been made.

4.1.2.1 Type-a [ref_ill_edg_a]

This is the simplest conditioning of a plate-edge: It is simply angled outwards or inwards to about 90^0. This profile already stiffens the plate, but the edge is still left relatively sharp. It

88 The bars at the arm cutouts are missing, the otherwise functionless holes now filled with rivets witness their former existence.

is very easy to angle an edge this way. The only tools needed are a hammer and an edged stake.

In the first half of the 14th century the armourers started to slightly angle the edges of vision slits, as can be seen at the helmet [ref_arm_1443]. At earlier helmets these slits were reinforced by a second, doubling plate [ref_arm_1457]. But also outer edges were occasionally angled, e. g. at the helmet [ref_arm_1422], the lower arms [ref_arm_1027] [ref_arm_1029], the segmented torso front [ref_arm_3860] and the breastplate [ref_arm_3734]. Type-a edges are never decorated. After 1400, edges are not angled outwards anymore this way. In the second half of the 15th century, the edges of the shell-like extensions at knees [ref_arm_2405] or elbows [ref_arm_722] were angled inwards, sometimes in segments [ref_arm_127] [ref_arm_583] [ref_arm_3296] to reveal a faceted appearance.

4.1.2.2 Type-b [ref_ill_edg_b-inw] [ref_ill_edg_b-outw] [ref_vid_edg_b]

When a type-a edge is turned completely – by 180^0 – the edge gets blunt by the revealed radius. No edge threatens to cut the wearer anymore. The stiffening effect might be inferior to type-a edges. At extant armour parts, type-b ridges are found either turned interiorly or exteriorly. Also this type of turn is not difficult to be made. A type-a edge just needs to be hammered flat into the right direction. No decorated variation is known from 15th century armour.

The earliest extant examples showing an edge of type-b have the latter turned outwards, for example the lower arms [ref_arm_956] or the type-I hand-protections [ref_arm_1307]. This edge appears throughout all the 15th century and probably also later at different armour types of all production regions (interiorly [ref_arm_12] [ref_arm_4310] and exteriorly [ref_arm_888] [ref_arm_272]). Nevertheless, it is a rather rarely applied type.

4.1.2.3 Type-c [ref_ill_edg_c-inw] [ref_ill_edg_c-outw] [ref_vid_edg_c-inw] [ref_vid_edg_c-outw]

Type-c edges combine both advantages of the aforesaid types. The edge is stiffened by the angling of the plate and the edge is blunted, due to the either in- or exterior 180^0 –turning of the outer edge. The older versions are turned exteriorly: Already about 1410 the edges of the – most likely Italian – breastplate [ref_arm_3814] is turned this way. Edges of type-c are usually found at the throat- and arm cutouts of simple breastplates, probably made in the German speaking lands [ref_arm_3501] [ref_arm_3699] from 1470 on. From the late 15th century on also interiorly turned variations were applied to German foot-soldier breastplates [ref_arm_3527] – a feature common in the early 16th century. These edges were never decorated.

4.1.2.4 Type-d [ref_ill_edg_d-inw] [ref_ill_edg_d-outw] [ref_vid_edg_d]

This is the simplest edge-conditioning with a hollow profile-section. The edge is rolled either in- or exteriorly to reveal a pipe-like section. Sometimes the plate is rolled around a wire that remained inside the edge (turned interiorly [ref_arm_1754], turned exteriorly [ref_arm_1802]). An edge of type-d strongly resists any kind of bending and its wide radius makes absolutely sure that no sharp plate edges can harm the wearer. It is more complicated to roll an edge this way than to make one of the aforesaid edges. First the edge is angled with a wide radius on an edged stake and then carefully rolled in by slight beats from a hammer. Exteriorly turned type-d edges are found at all kinds of armour parts in all production regions from the last third of the 14th century on [ref_arm_810]. After 1500 this type seems to have gone out of fashion. Early examples of interiorly turned type-d edges are [ref_arm_1461] [ref_arm_1148] [ref_arm_1711]. In the late 15th century, the armourers started to file a roped-

decoration into the turned edges [ref_arm_1063] [ref_arm_1128]. From the early 16th century on the roping was often embossed [ref_arm_1345].

4.1.2.5 Type-e [ref_ill_edg_e-inw] [ref_ill_edg_e-outw] [ref_vid_edg_e]

This edge is also of an in- or exteriorly rolled round profile-section like type-d, but it is angled to about 90^0 where the rolled in cut-edge touches the plate again. Also some items with edges of type-e occasionally have a wire inserted [ref_arm_1404]. The stiffening and the blunting effect is similar to type-d edges. This type of turned edge is a very common feature of type-III helmets, made in the mid-15th century in the German speaking lands (exteriorly [ref_arm_1402] [ref_arm_1400] [ref_arm_1420], interiorly [ref_arm_1346] [ref_arm_1360]). Interiorly turned edges of type-e are commonly found at the lower edge of forehead reinforces of type-VI helmets [ref_arm_1938] [ref_arm_1942], but also at shoulders [ref_arm_612], lower arms [ref_arm_365] and early 16th century throat-cutouts of foot-soldier breastplates [ref_arm_3551]. An interiorly turned edge of type-e can occasionally be decorated by embossing [ref_arm_2054] [ref_arm_1384].

4.1.2.6 Type-f [ref_ill_edg_f] [ref_vid_edg_f]

This edge is the most laborious of all types. It can only be worked hot. Edges of type-f are basically of a hollow, triangle section. The outer point of the triangle defines a ridge along the turned edge; the other angle is defined by a blunt radius. The ridge at the turn further stiffens the edge and the radius prevents the wearer from injuries. Only exteriorly turned versions are found at extant armour parts. In the German speaking lands, the section of the triangle is rather equal-sided. On armour of Italian style in section the side between the point and the cut plate-edge is usually shorter than the other two sides, which are more or less equal in length. While the proportions of the sides stay more or less the same, the dimensions of the cross section usually grow more narrow towards the end of the turned edge at throat-, nape and arm cutouts of torso front- and back-protections, at torso-upper leg-protections, shoulder reinforces and upper legs. Some helmets have a type-f edge applied [ref_arm_1394] to the lower edge and also the upper visor-edge at helmets of type-VI is sometimes turned this way [ref_arm_1908].

At the type-f edges of Italian armour often floral “pointillier” decorations or inscriptions can be found [ref_arm_732] [ref_arm_2873] [ref_arm_3880]. Also faceted embossing occasionally occurs [ref_arm_1735] [ref_arm_3637] [ref_arm_3688], sometimes in combination with filing [ref_arm_3723].

On breastplates attributed to workshops in Western Europe, like France, Spain or Flanders, the cutout for the throat might form a central small nose [ref_arm_3518] [ref_arm_3570] [ref_arm_3465]. Also at least one example made in the style of the German speaking lands exists [ref_arm_3703].

4.1.2.7 Type-g [ref_ill_edg_g] [ref_vid_edg_g]

This edge-type is found exclusively on armour made in the German speaking lands. It is basically similar to type-f, but in section the side of the triangle between the point and the cut plate edge is shaped concave. Such turned edges are found only on breastplates of the last quarter of the 15th century – probably all made in Augsburg [ref_arm_3668] [ref_arm_3614] [ref_arm_3695] [ref_arm_3757] [ref_arm_3601] [ref_arm_4049]. One breastplate has a small nose at the center of the turned edge at the throat cutout [ref_arm_3671]. For example [ref_arm_3613] is decorated by a roped-filing, the cut-edges of the breastplates [ref_arm_3615] and [ref_arm_3611] are decorated by an engraved or filed line and punched dots.

4.1.2.8 Type-h [ref_ill_edg_h] [ref_vid_edg_h]

The type-h edges are again not completely turned. The plate is first angled outwards to about 45^0 and then angled inwards again to about 45^0. The sides of the section maybe have a length of about 5-7 mm. This edge-conditioning mainly serves as a stiffening of the plate – the edges remain relatively sharp. It is found at German armour of the last quarter of the 15th century only. The upper edges of upper legs [ref_arm_2412], the edges of elbow-shells [ref_arm_283] and the upper edges of shoulders [ref_arm_282] for example can be designed this way. In several cases, this type of edge is applied to the lower edges of pelvis-lames [ref_arm_3479] [ref_arm_3284]. Often a line is engraved or filed along the first angle [ref_arm_3311]. At [ref_arm_3296] the edge where the thorax-plate overlaps the inserted nape-plate a "pointillier" decoration is applied. The upper edge at [ref_arm_2412] is embossed rope-like and filed.

4.1.2.9 Type-i [ref_ill_edg_i] [ref_vid_edg_i]

Edges of type-i are first angled outwards at about $60\text{-}70^0$, then back to the starting angle and inwards again by $60\text{-}70^0$. The section is that of a pan turned upside down. Such edges are often rope-like embossed and found from about 1490 at Italian helmets of type-VII [ref_arm_1855] [ref_arm_2035]; at one German backplate [ref_arm_3268] or at the upper edges of upper leg-protections of Italian production. Plain versions are very often applied to the upper edge of backplates where the inserted nape-plate overlaps [ref_arm_3310] [ref_arm_3267].

4.1.3 Embossing

The reinforcing or stiffening effect of ridges or corrugations is known since antiquity, when for example the Celts used this feature at the bosses of their shields or when the Greeks gave stability to the edges of helmets of the Illyrian type. Most of the extant late medieval armour parts show elongated embossing at the plates. From at least the mid-14th century on, the plates at the knees were decorated by ridges [ref_ill_art_5157] [ref_arm_2282]. It was long thought that these features were meant to stiffen the plate against arm penetration only. This might be only one of the reasons why they were applied to armour. The aspect of imitating the pleats of textile clothing is rather likely to have been the archetype for the first appearance of ridges – last but not least as textile- and armour-fashion always went hand in hand.[89] Generally, it can be noted that armour made in the German speaking lands is earlier decorated with elongated embossing than armour of Italian make. In the fifteenth century in both regions, relief-like embossing of symbols or images was very rarely executed. Unique examples are the breastplate [ref_arm_3721], with the embossing of a primitive face and the breastplate [ref_arm_3678], with the embossing of a heart.

Like turned edges, also ridges and corrugations can tell a lot about armour – groups of different objects related by their embossing might be assembled. Despite the significance of the information delivered by different embossing types, the only attempt to classify embossing seems to have been made by Bruno Thomas.[90] His drawings are for the most part only relevant for armour from about 1500 or later. He does not define the different medial-ridge types.

Two large blocks of embossing need to be distinguished:

89 For a discussion of the interrelationship between contemporary costume and armour see for example: Grancsay (1931) and Grancsay (1950).

90 Thomas (1977b), p. 626.

1. Raised (ridge) or recessed (corrugation) elongated embossing on the surface of merely decorative character.
2. Raised medial ridges that split an armour part medially into two (usually) symmetrical halves.

Both elongated embossing-types can be applied to a plate by different methods. Usually the general shape of the item is finished first. The simplest way is then to chisel the course of each edge of the later embossing to the interior surface of the plate. Placing the plate on a soft support, like lead or wood, – depending on the used force of the hammer-work – would already allow a slight embossing from the chisel punched into the plate. It is very likely that the workers used some kind of chisel-handle to ease this work, similar to the one seen in the painting [ref_ill_art_5361]. The plate is then placed on an edged stake and worked with the hammer from the exterior. The lines marked with the chisel will allow an exact placing of the plate on the stake. The hammer would always hit slightly beneath the highest spot of the stake, driving down the plate to reveal an embossing. It is not necessary to heat the plate for this work.

4.1.3.1 Surface ridges and corrugations

4.1.3.1.1 Type-a [ref_ill_rid_a]

This type of ridge is the simplest version. It is only raised and in profile it forms a "mountain pike" rising from a plane surface. Merely on armour made in the German speaking lands several of such ridges are applied in parallel lines [ref_arm_9] [ref_arm_1067] [ref_arm_2304] [ref_arm_3264]. Sometimes they are accompanied by parallel filed lines [ref_arm_3668]. The lines of these ridges are usually following the curve of the neighboring plate-edges. They appear at armour in the second half of the 15th century.

4.1.3.1.2 Type-b [ref_ill_rid_b]

This embossing is recessed from the plate surface. It forms a concave "valley" or groove on a plane surface. This is again a feature of the northern-alpine taste and also here several parallel corrugations can decorate the plate-surface – occasionally with accompanying filed lines [ref_arm_19]. In a few cases these embossing can cross others [ref_arm_1075]. These embossing occurs usually in curved lines following the neighboring plate-edge [ref_arm_364]. This feature was used only in the last quarter of the 15th century.

4.1.3.1.3 Type-c [ref_ill_rid_c]

The section of a ridge of type c forms a row of several steps, similar to a saw-blade. Always a bundle of steps decorates the surface. Each ridge is occasionally accompanied by parallel filed lines [ref_arm_304]. This embossing type is found exclusively at German armour from the 1470ies to 1500. All armour parts can be decorated by these ridges, for example breastplates [ref_arm_3632] and backplates [ref_arm_3319] or the cuffs of type-III or -IV hand-protections [ref_arm_1064] [ref_arm_1075].

4.1.3.1.4 Type-d [ref_ill_rid_d]

This type of ridge occurs for the first time about 1490 on armour made in the German speaking lands [ref_arm_1207]. Its main difference to the section of a ridge of type-a is the sharper angles at the two feet of the "mountain". These are further emphasized by accompanying parallel lines. Therefore, in each "valley" between two or more of such ridges two parallel filed lines are found while a type-a ridge is accompanied by no or one single line only. In the early 16th century these ridges – in German called "Riefel" – became the most common embossing-type for German [ref_arm_3473] [ref_arm_8] and Italian armour.

4.1.3.1.5 Type-e [ref_ill_rid_e]

Type-e embossing are made exactly the same way like ridges of type-a, but here the inside is turned out. Often at hand-protections the back of the hand is decorated with such corrugations [ref_arm_1336] [ref_arm_1305] [ref_arm_1066] [ref_arm_1088], but also the breastplate [ref_arm_3428] shows this feature. This type of ridge decorated armour from the 1430ies until the end of the century.

4.1.3.1.6 Type-f [ref_ill_rid_f]

The making of type-f is very similar to the making of type-b corrugations. Type-f embossing is found in few early cases at the elbows [ref_arm_955], the knees [ref_arm_2919], but in the German speaking lands between 1470 and 1510 merely at the back of the hand on certain variations of type-III [ref_arm_1061] [ref_arm_1096] or -IV [ref_arm_1245] [ref_arm_1274] hand-protections, at armpit protections [ref_arm_128] [ref_arm_129] or at the pelvis-lames of backplates [ref_arm_3311].

4.1.3.1.7 Type-g [ref_ill_rid_g]

The section of this ridge-type can be described as a “flat-topped mountain” or “elevated plain”. As it actually consists of two “steps”, its making is similar to the making of type-c ridges. Type-g ridges are found in the last quarter of the 15th century for example at upper legs [ref_arm_2406] – in a rope-like filed [ref_arm_246] or embossed variation at [ref_arm_2901] [ref_arm_3725].

4.1.3.1.8 Type-h [ref_ill_rid_h]

A ridge of type-h is a single step in the surface; its making is similar to the making of type-c ridges. At the upper legs [ref_arm_2410] [ref_arm_2809] type-h ridges form two bows, also in parallel to the arm cutouts at the backplate [ref_arm_3279] or the breastplate [ref_arm_3653]. This feature was used from the 1460ies to the 1480ies.

4.1.3.2 Medial ridges

Medial ridges are the first ridges to appear at late medieval plate armour. They are much more likely to have had a stiffening function than the surface embossing described above. But also here this cannot be the only reason for their application, as many objects from the beginning of the great period of plate armour until its end do not necessarily show central ridges at the top of the skulls [ref_arm_4343] [ref_arm_1702] [ref_arm_2086]. Early type-I hand-protections and also no Italian arm-protection – with the exception of the shoulders – had a medial ridge and only Italian breastplates made for export to northern Europe had such an embossing. No backplate (except of the pelvis-lames) ever had a medial ridge – due to the convex shape of the plate. After medial ridges had been applied to breastplates for years, by the end of the 15th century also in the German speaking lands this feature was often omitted [ref_arm_3425]. These items were for sure not considered as less protective. So here the design aspect was again also part of the armourer's intention when leaving or adding a medial ridge.

The making of a medial ridge is basically the same as the making of a surface embossing. Nevertheless, many types have a section different to the aforesaid ridges and corrugations. In the following the various types will be classified and described.

4.1.3.2.1 Type-a [ref_ill_med_a]

The section of a medial ridge of type-a reminds on a pointed arch or bow in the gothic architecture. This type of ridge is found at all kinds of helmets from the early 14th century to the early 16th century [ref_arm_1456] [ref_arm_1364] [ref_arm_1446] [ref_arm_1982] [ref_arm_1918]. Also many breastplates of the second half of the 15th century have a type-a ridge [ref_arm_3438] [ref_arm_3458] [ref_arm_4076]. All upper legs [ref_arm_2909], knees [ref_arm_2987], lower legs [ref_arm_2295] have a medial ridge of this type. Most of the neck defenses [ref_arm_3034], torso-leg-protections [ref_arm_3858], hand-protection-cuffs [ref_arm_1064] [ref_arm_1205] have such a ridge applied as well. In Germany all arm-protections can have a type-a medial ridge [ref_arm_312] [ref_arm_306] and also Spanish elbows share this feature [ref_arm_12].

4.1.3.2.2 Type-b [ref_ill_med_b]

This type of medial ridge is strongly embossed from the plate surface and shows concave sides. An early 15th century depiction of a very strong medial ridge of type-b is found at a breastplate depicted at an effigy in Wertheim [ref_ill_art_5272] (descr. 2). No similar breastplate of this date is preserved. From the 1430ies on, medial ridges of type-b are applied to all types of helmets [ref_arm_2030] [ref_arm_1382] [ref_arm_1348] [ref_arm_1721] [ref_arm_1945]; from the second half of the 15th century they become commonly attached to elbows [ref_arm_21], to Western European [ref_arm_3518] [ref_arm_3624], German [ref_arm_3593] [ref_arm_3497] and Italian breastplates (for export to northern Europe) [ref_arm_3649] together with their torso upper-legs [ref_arm_3817].

4.1.3.2.3 Type-c [ref_ill_med_c]

The section of this medial ridge looks like an "elevated plain". This type was applied to armour between 1480 ca. and 1510. It is rarely found at German breastplates [ref_arm_3658] and knees [ref_arm_2868]. At the hand-protections [ref_arm_1207] each knuckle at the finger-root has a type-c ridge with decorative filing applied. German helmets of type-VII often have a type-c medial ridge [ref_arm_1730] [ref_arm_1692], in some cases decorated with filed lines [ref_arm_1845]. German type-VII helmets often show some filed lines close to a small hole in the central skull/ridge [ref_arm_1800]. The purpose of these lines remains obscure. Helmets are the only Italian armour parts to have such a ridge applied

[ref_arm_1442] [ref_arm_1752]. Some type-VII helmets – said to be of French or Flemish production – have a medial ridge of type-c embossed as well [ref_arm_1718].

4.1.3.2.4 Type-d [ref_ill_med_d]

This type is a kind of combination between a type-a and a type-c medial ridge. The only extant example known to the author to have such a ridge is [ref_arm_1810].

4.1.3.2.5 Type-e [ref_ill_med_e]

A type-e ridge consists of two parallel type-b medial ridges. A plain version is found for example at the type-VII helmet [ref_arm_1690] or file-decorated variants at [ref_arm_1881] [ref_arm_1862]. The author knows this type only from helmets of type-VII.

4.1.3.2.6 Type-f [ref_ill_med_f]

This type consists of three parallel type-b ridges. This feature is found exclusively at a few type-VII helmets. The example [ref_arm_1899] is a reproduction – according to the showcase-label – made by the Atelier Ernst Schmidt in Munich. The marks do rather suggest that this helmet was made by Winkelmayer in Vienna[91]. The other items [ref_arm_1875] [ref_arm_4591] [ref_arm_4543] are most likely made in one workshop, as all are very similar to each other in shape and decoration. All three helmets share some common features, especially the many surface-ridges on the skull and the nape-guard. There is a high probability that all these helmets are reproductions. If this is true, type-f ridges might not have been known to armourer's in the late Middle Ages.

4.1.3.2.7 Type-g [ref_ill_med_g]

The type-g medial ridge is defined by two parallel, narrow type-c ridges. Examples are [ref_arm_4448] [ref_arm_4325]. Both have many similarities in the ridge decoration to the aforesaid type-VII helmets with a medial ridge of type-f. It is very likely that also these helmets are reproductions made by the aforesaid Vienna Master.

4.1.3.2.8 Type-h [ref_ill_med_h]

This is a combination of a type-a and a type-b medial ridge, found for example at [ref_arm_2035] [ref_arm_4452] (probably a reproduction) and [ref_arm_4589].

4.1.3.2.9 Type-i [ref_ill_med_i]

A type-i ridge consists of two piled type-c ridges. At least two type-VII helmets show this feature [ref_arm_1757] [ref_arm_1837].

4.1.3.2.10 Type-j [ref_ill_med_j]

This type of medial ridge has a convex section. It is found for example at breastplates, presumably made in the German speaking lands about 1490 [ref_arm_3580] [ref_arm_3789] and two Italian helmets of type-V [ref_arm_2024] (reproduction?) [ref_arm_2052]. The two type-IV helmets [ref_arm_1499] [ref_arm_1510] with this feature are most likely reproductions made by one workshop. Comparable examples never have a type-j ridge, it is also a feature usually found at items of younger date than the style-date of the aforesaid helmets. Furthermore, the skulls are not deep-drawn from one plate, but cone-like rolled from a plate with the edges connected at a seam, leading from the point to the brow.

91 See discussion below in chapter [New recognitions on marks] and [A suit in the BMA].

4.1.4 Not-embossed plate decoration

4.1.4.1 Edges

The not-turned plate edges of at some items are decorated either by applications directly cut into the plate. Four main technique-groups can be distinguished, but they often appear in combination at the same object:

1. The cut-edge is simply shaped by a series of convex or concave bows:

   The edges were probably roughly cut with the help of shears and then filed to the final shape. This feature is significant for armour made in the second half of the 15th century in the German speaking lands. The concave bows are usually found at the overlapping edges of lames, for example at shoulders [ref_arm_329], pelvis protections [ref_arm_3623], abdomen protections [ref_arm_3604] or at neck-protections [ref_arm_3059]. In fewer cases, also the abdomen-plates of Italian breastplates [ref_arm_3716] and torso-upper leg-protections [ref_arm_3817] are decorated by concave cutouts. The lame that connects the elbow to the lower arm on Italian armour from the mid-15th century on usually shows this feature [ref_arm_882], sometimes also one of the shoulder lames [ref_arm_715] and frequently the thorax-plates of back-plates [ref_arm_3404].

   Convex bows are often found for example at overlapping edges of torso-back pelvis-lames [ref_arm_3360], at the back of the hand [ref_arm_1061] or the ends of the visor-arms [ref_arm_1702], but also at the lower edge of the lowest lame [ref_arm_3302]. The concave and the convex cutouts at overlapping edges are found at armour until the first third of the 17th century.

2. The cut-edge is decorated by simple tooth-like filing:

   This work has been done with the help of a file, not much different to modern examples. On Italian armour of the second half of the 15th century, close to the points at the overlapping plate edges, often tooth-like filings are visible [ref_arm_861] [ref_arm_3817] [ref_arm_3410]. A few Italian breastplates show a simple, filed edge decoration at the upper edge of the abdomen-plate [ref_arm_3721]. In the German speaking lands, the overlapping edges of more costly armour in many cases are delicately decorated by filing [ref_arm_1064], often in combination with fretwork.

3. Close to the cut edge, the plate is pierced by ornamental fretwork:

   It was first necessary to drill or punch a hole through the plate and then to use a file to finish the details. This decoration technique is found only at costly armour parts made in the German speaking lands in the last third of the 15th century. Probably to avoid getting stuck in the delicate ornaments with clothes and flesh, usually only overlapping edges are decorated this way. The lower edges of some knees count here as overlapping edges as such leg armour decorated with fretwork was always worn in combination with lower leg defenses [ref_arm_4701]. Often the central point of a type-IV abdomen-plate was decorated with floral fretwork [ref_arm_3587], but nearly any kind of overlapping edge could be decorated this way. Probably the greatest masters of fretwork came from Augsburg, particularly the Helmschmied family cut beautiful ornaments into the plates [ref_arm_3300] [ref_arm_3695] [ref_arm_5094]. The fretwork often imitates plants that seem to grow out of the edge – similar to some masonry-ornaments found frequently at contemporary northern alpine architecture. In the German speaking lands, the floral decorations of plate edges were not produced anymore after 1500 ca. A late example might be the

backplate [ref_arm_3363]. Italian armourers did not make extensive use of elaborate fretwork-techniques.

4. A stripe of the surface along the edge is decorated either by filing, engraving, etching, gilding etc.:

   Ornamented bands, punched into the plate surface with the help of small chisels (pointillier), sometimes together with filed or engraved lines, are found on Italian armour from the second half of the 14th century [ref_arm_1251]. The Italian armourers decorated some costly armour this way until the late 15th century [ref_arm_3723]. It has not been noted so far that also on German armour surface decorations made in the pointillier-technique are to be found [ref_arm_3322] [ref_arm_3318]. On some German items of the last two decades of the 15th century each convex edge-bow is decorated with a small crescent-shaped stamp [ref_arm_1272] [ref_arm_3447]. The armourers of the Helmschmied family often in parallel to the edge filed a line into the surface, with a distance of approximately 3 mm. Then they filed small lines to the edge to reveal a tooth- or rope- like appearance [ref_arm_1207]. It is possible that at all extant examples this stripe once was gilded, as the remaining gold-coating at the shoulder [ref_arm_5098] suggests. Also the shoulders [ref_ill_art_5163] of about 1600 suggest that this feature really existed. In the early 16th century many costly suits of armour were decorated at the edges by a technique being a combination of blueing, gilding and etching. The oldest extant armour to have a blued stripe with gilded ornaments at the lower edge, is the type-VII helmet [ref_arm_1971], probably made in Augsburg in the 1490ies.

4.1.4.2 Surfaces

Surface conditions can tell details about the technology of the production, about the later use, maintenance and treatment of a certain object. Two different kinds of surfaces are found at each object: One at the interior, never ground and polished; the other one at the exterior, either left “rough” or entirely ground, polished and often even elaborately decorated. It has to be emphasized that a ground item does exteriorly usually not show remains of the forging like hammer scale, hammer-marks etc. The ground surfaces of genuine items are in most cases absolutely even.

Most of the surfaces of extant armour pieces cannot be considered as genuine. Iron based material is prone to corrosion. Repeated cleaning, in the time of use and conservation, had altered the original condition. Original coatings – interiorly and exteriorly – and shallow, recessed decorative drawings were often simply polished off throughout the ages. Today, a very close look is necessary to detect the remains of former decorations or coatings.

Not only the exterior, but also the interior surfaces deliver information on the object. In the following the significances of both will be described in detail.

4.1.4.2.1 Exterior surface

4.1.4.2.1.1 “Rough” and blackened

After all deformation work was finished, the surface of the armour plate was covered with hammer-marks and hammer scale[92]. Obviously, not all items were sold polished: 15th century

92 Hammer-scale is iron-oxide that is produced on every iron or steel surface when heated to a red hot temperature or above in a normal room-atmosphere (3 Fe + 2 O2 → Fe3O4).

sources do differ between “white” (i. e. polished) and “black” (i. e. rough from the hammer) armour. For example, a Viennese will from the year 1460 names:

> *[…] zwen eisenhuet, swarz und weiss […] doch nim ich meinem weib aus den pesten eisenhut […] sol meiner hausfraun pei dem haus beleiben*[93]

The “best” helmet was most likely the polished one. Only few existing items might have been sold “rough” from the hammer. Most likely their outer surface has at least got painted with oil and heated. The revealed black layer would prevent the item from corrosion and provide for a uniform color. A few helmets of the late 15th century were most likely never polished [ref_arm_1859]; some of them still retain colorful painting [ref_arm_1758] [ref_arm_1893]. Some formerly “black” items might have been made “white” by the cleaning throughout the ages [ref_arm_1796]. With the exception of helmets, no armour parts of the 15th century seem to have been sold “black”. From the early 16th century on it became more common to leave the surface “rough” and “black”. In the 17th century, most of the produced armour got blackened.

Today, it is very difficult to tell if a black surface is of the production time or maybe applied later. In many cases, what appears to be a blackened surface is actually a modern paint (maybe [ref_arm_2114]) or a rust-converter (e. g. tannin) applied directly onto the corrosion products (e. g. [ref_arm_2013] and all other items in Athens).

4.1.4.2.1.2 Polished

The largest number of objects had been ground and polished at all outer surfaces. Some might have been subsequently “blackened” by the aforesaid method. Some items were obviously first polished and then blackened [ref_arm_2348], but maybe at a later time in the 16th or 17th century [ref_arm_3333]. In Vienna, an early 16th century, unfinished suit of costume-armour is preserved [ref_ill_art_5382]. It still shows the stage of work when the forming was finished, but had still to be ground. It is noteworthy that the hammer-work is so fine that not much material would have to be ground off to reveal plane surfaces. By the mid-16th century, infantry armour of a certain style showed both, partly polished and partly rough/blackened surfaces (black and white armour) [ref_ill_art_5363] (descr. 2).

The sources – until the early 16th century – speak of “filing” when the finishing of armour parts is concerned.[94] The grinding of the plate can be done by different tools and techniques. Sandstone or files can serve this purpose. The sandstone could be cut into a huge wheel, which is either powered by a man, by a horse, a mule or by a water wheel. Probably some of the grinding work was achieved with large files. The finish in the 15th century was probably still made by hand on a polishing-bench [ref_ill_art_5313] [ref_ill_art_5326] [ref_ill_art_5316] [ref_ill_art_5318]. At least from the second half of the 15th century on also water power must have been used for finishing the products [ref_ill_art_5322]. The first mention of an armour polishing-mill found by the author derives from the year 1483, when a citizen of Innsbruck sells a polishing-mill and a smeltery in Mühlau, probably once build by the armourer Christian Spor.[95] With the help of water powered wheels and a gripper to hold the work-pieces in place – and the hot piece away from the fingers – the grinding might

93 See: Jahrbuch der Kunsthistorischen Sammlungen in Wien (1896), Reg. 15325. Translation by the author: […] two iron-hats, black and white […] but with the exception the best iron-hat for my wife […], it should stay for my housewife in the house […].

94 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1884), Reg. 1010: „[…] unz zum hertnen und ausfeilen 12 Krebsen […]“. Translation by the author: […] until the hardening and the filing 12 breastplates […].

95 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1900), Reg. 18749.

have been eased immensely [ref_ill_art_5340]. In the 16th and 17th century, for the mass production of armour professional polishing workshops and devices were developed [ref_ill_art_5339].

Works of art [ref_ill_art_5354] (descr. 1) and even surviving armour pieces indicate that armour generally could have been polished to chrome like appearance. When in the late 1970ies or early 1980ies the forehead reinforce of the helmet [ref_arm_1802] was detached for restoration, underneath a mirror-like polished genuine surface came to light.

4.1.4.2.1.3 Blueing

Blueing is probably a very old technique of surface-finishing. It is very simple to turn the silver-shiny color of the plate-surface into blue. The plate only needs to be heated all-over to 280-320 ^{0}C in a normal room-atmosphere reveal a shiny blue oxide layer on the surface. The most challenging part of this process is the uniform heating, which can be achieved by placing the object in a heated liquid or in heated sand. For a contrast-ornamentation of "white" and blue areas, this thin oxide-layer can be taken off by etching. The blue segments need to be covered by a special paint and the uncovered regions are treated with a weak acetic acid. The paint is subsequently wiped off the blue surface.[96] The oldest extant blue-etched armour is Friedrich III.'s horse armour of 1477 (HJRK A 69).[97] It is possible that many armour parts once were blued, but as the blue oxide-layer is very thin, it got polished off throughout the ages.

4.1.4.2.1.4 Gilding and silvering

Only polished surfaces can be gilded or silvered. Documentary evidence for the silvering and gilding of armour in the German speaking lands is found already by 1445. A list of payments for works ordered by Duke Albrecht VI. of Austria notes the following:

> *[…] dem platner 19 ducaten; daz silber auf der platen hat funf markh und drei gulden auf ain markh zu vergolden und zwen gulden von dem markch zu lon […]*[98]

It is unclear whether the armourer directly gilded the plate or just some applications, but the text suggests that at least the silver has been applied directly to the plate.

Another document of 1460 is similarly imprecise, but it is also telling that at least parts of plate-armour had been gilded:

> *So hab ich geben in presencia herrn Hilbranden Fuchs Micheln, goltschmid, zu dem harnasch gen Schottennland zu vergulden, geben 10 ducaten und 4 r. gulden.*[99]

Some armour of Emperor Friedrich III. or his son Maximilian was partly gilded:

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96 See: Thomas and Gamber (1976), p. 27.

97 Thomas and Gamber (1976), p. 104, pl. 32-33.

98 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1899), Reg. 17646. Translation by the author: […] 19 ducaten to the armourer; the silver on the plates cost five markh; and three gulden from one mark cost the gilding; and two gulden of the mark as salary […].

99 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1899), Reg. 17774. Translation by the author: For the gilding of the armour for Scotland I have paid 10 ducaten and 4 r. gulden in the presence of the goldsmith Fuchs Micheln.

1465 Juli 10. Hab ich auf gescheft meins gnedigen herrn, aber des jungen chaisers harnasch zu vergulden, per Hainrichen von Freyberg hofmaister geben 6 ducaten.[100]

No silvered armour part from before 1500 is known. The earliest gilded helmet is made of copper [ref_arm_1414]. An extraordinarily well preserved, etched decoration on a subsequently entirely gilded skull is found at the helmet [ref_arm_1855].

The technique of ornamental pattern-gilding on a blue surface has most likely been developed shortly before 1500. One of the earliest illustrations is an Italian painting from about the last decade of the 15th century [ref_ill_art_5186]. The helmet [ref_arm_1924] still retains some gilding where the surface is decorated by ornamental etching. The sides of the skull are not decorated, but they were probably blued to contrast the golden areas.

4.1.4.2.1.5 Etching

It was most likely the Italian armourers that first decorated their products with deep-etching. The oldest etched breastplate dates from the 1480ies [ref_arm_3736]. Only one etched pair of hand-protections, most likely made in the German speaking lands before 1500 exists [ref_arm_1136]. Most likely the etchings were applied secondarily in the 16th century, to match the hand-protections to other armour parts of a composite suit of armour.

4.1.4.2.1.6 Tinning

Exteriorly, only very rarely a tin coating is found on extant armour. The only items known to the author are [ref_arm_1399] and [ref_arm_1471]. Tin is a soft metal that can easily be polished or scratched off the plate-surface. It is also – even when polished – never as shiny as a polished steel plate. It is therefore very likely that the tin-coating of armour was merely intended to prevent the plate from corrosion. The technique of tinning iron is simple. The ground surface first needs to be etched to be free of corrosion products or other oxide layers. Then it is covered with an anti-oxidizing layer like animal-fat or natural-raisin and subsequently heated. A bar of tin is wiped over the surface and the melted tin will form a covering layer on the plate.

4.1.4.2.1.7 Painting

Some armour has been decoratively painted. The earliest example is a helmet of type-II [ref_arm_1481], but it is possible that the painting was applied in the 16th or 17th century. A helmet of type-VIII [ref_arm_1635] is painted with alternating dark and bright stripes. A few helmets of type-VII, made in the German speaking lands and left "rough" from the hammer, were also painted [ref_arm_1741] [ref_arm_1758] [ref_arm_1882] [ref_arm_1883] [ref_arm_1893]. The black and the white areas on the breastplate [ref_arm_3684] have been painted in the mid-16th century when the plate was still in use – to imitate the contemporary black-and-white armour.

4.1.4.2.1.8 Engraving, chiseling, filing

Surface ornamentations can be applied mechanically. More or less straight lines can easily be filed; more narrowly winding lines can be engraved with etcher's-needles. Repeated patterns or symbols can be stamped with especially shaped chisels [ref_arm_3197] [ref_arm_1245]. A drawing or an inscription could consist of hundreds of small dots applied

100 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1899), Reg. 17896. Translation by the author: 1465 Juli 10. On behalf of my Lord I have given 6 ducaten to the Hofmeister Hainrichen von Freyberg to have gilded the armour of the young emperor.

by a pointed chisel [ref_arm_621] [ref_arm_3062][101]. All these techniques are in use since antiquity and therefore they are also the oldest decorating-techniques found on extant armour pieces. In some complex drawings it is difficult to tell a chiseled line from an etched line. A closer look through a lens or a microscope might help. The edges of an etched line appear burred and the endings of an engraved line have the shape of a lean-bow. By the end of the 15th century, the costly German armour was often decorated with mechanically applied decorative lines and inscriptions [ref_arm_3363], until in the early 16th century the etching techniques replaced the older methods.

4.1.4.2.2 Inner surfaces

Interior surfaces of armour are regularly those that are facing the wearer's body. They resemble the most original surface of armour. No single piece of armour is ground interiorly. The outer surface must have looked similar before its grinding and polishing. Interiorly, hammer-marks are visible and often layers of hammer-scale. As these surfaces were often cleaned from corrosion, most of them cannot be considered as showing the state of the production time. Body sweat and condensing water increased a potential corrosion-risk of the interior surfaces. Despite this fact, surprisingly few items show an interior coating. Some armour was originally certainly tinned. For example the interior coating of the late 14th century breastplate [ref_arm_3698] cannot have been applied in later times, as the item still retains its original velvet-cover. Often the small plates of segmented torso-protections are tinned [ref_arm_3885]. The bright red or orange color found inside many extant armour parts [ref_arm_3638] [ref_arm_1352] [ref_arm_2039] are significant for the collection of Luigi Marzoli in Brescia – probably one of his restorers applied them in the 20th century. Possibly also modern is the paint at the leg armour [ref_arm_2843].

4.2 Joints and applications

After the armourer had finished the general shaping and polishing of the plates, the single armour parts needed to be joined together and to be fitted with fastening systems and applications. Most armour parts would not function anymore in the condition they are currently displayed or stored, as many of these features are lost today. For the understanding of the former function and appearance of a certain item, it is indispensable to classify all the data on joints, fastenings and non-constructive applications found on extant armour parts. No study has ever focused on such important aspects.

4.2.1 Rivets

A rivet is maybe best described as a metal wire with two mushroom-like widened ends. The main tasks of rivets can either be to connect two segments of any material inseparably together or to bring a decorative highlight to a surface of any kind of artifact. In some cases, rivets fulfill both tasks together.

Rivets are one of the oldest techniques for joining several metal pieces to become one artifact. Only the lacing of metal parts might be older. For example the hilts of 11th century

101 It is possible that the decorations on the suit [ref_arm_4143] to which this neck belongs are actually etched, as the lines are very irregular. If this is correct then this would be one of the earliest examples of armour-etching.

B.C. Celtic brass swords had already been riveted to the blade.[102] Hellenistic brass helmets often retain the rivets that once probably held some sort of lining.[103]

The historical term for "rivet" has been simply "nail"[104] or in German "Nagel"[105], probably as it had the same purpose like a nail: fixing parts together. While the heads of simple handmade nails were shaped roughly by a few blows of the hammer, the basic shape of the exterior rivet-heads is usually made by either some kind of die or by embossing. Just like nails, all armour-rivets are massive and have one "factory-head", formed before the rivet was attached to armour. The rivets were "closed" with the help of a hammer, when parts had to be joined together. Sometimes small plate-washers (see below) were first stuck over the shank to enlarge the surface of the revealed smaller mounting-head and to prevent the rivet from falling out.

On late medieval plate-armour, rivets are used for basically three different joining-techniques. The first fixes the parts directly together in an invariable position. The two other techniques leave limited articulation to the single plates: In one case by riveting the overlapping plates to fabric or leather; in the second case by riveting them directly together but – depending on the desired flexibility – either loosely enough to pivot or both to pivot and to slide (see below).

At each piece of plate armour rivets can be found. On items where all rivets are lost, the holes they left behind in the plate witness of their former existence. Rivets count to the wearing-parts of armour, at articulated joints they are exposed to even more wear than on fixed-joints. They easily got lost when the plates were stressed or corrosion reduced their diameter so they would slip through the holes. Shanks may also got cracked, due to material-defects. Maintenance work made it necessary to replace rivets. Broken plates needed to be taken off, old organic parts needed to be renewed – in times of use and in times of collection-keeping. The examination of the rivets is very important for an insight of item's restoration-history, but also for the determination of its authenticity. Certain features might tell if they were made by hand or by machines.

There is no evidence that rivets were formed by cutting techniques like filing or turning. Not only would this have been much too expensive, but also no traces of the necessary tools are visible at any presumably genuine rivet. Of course, these details might have got polished off, but for example the occasionally found eccentric position of shank and head contradicts the idea of their making by turning. Certainly, rivets were not cast, as rivets made of cast-iron would be too brittle when being hammered, not to mention the difficulties of casting such small iron objects before the techniques developed in the late 19th century. Furthermore, according to contemporary artworks, nails were usually forged [ref_ill_art_5327] and there is no reason why rivets should not have been produced by the same technique. Therefore, it

102 Kastner et al. (2007).

103 Museen der Stadt Landshut (2009). Here several examples of helmets with rows of rivets along the edges can be found. Abb. 33 or 63 show helmets of the 6th c. B.C. with such features.

104 See for example the 1544 billing of expenses of Henry VIII.'s Royal Armouries in: Ffoulkes (1912), p. 183.

105 See for example the words "Krebs-Nögl" and "Harnisch Nögel" in 17th century Zeughaus inventories and bills, in: Wettendorfer (1943-44), p. 75. In 1511 also the armourer to the court Konrad Seusenhofer speaks of "nagl", see: Jahrbuch der Kunsthistorischen Sammlungen in Wien (1884), Reg. 1028. That this term for rivets was also used in the 15th century is indicated by a document of 1499, where Maximilian I. permits the transportation of "eysen, stachl [steel] vnnd allerlay nagl" for his needs to Innsbruck, see: Böhmer and Wiesflecker (1990-1996), Reg. 13436. (http://regesten.regesta-imperii.de/index.php?uri=1499-06-19_4_0_14_3_2_640_13436). His "needs" are most likely concerning the armour workshops in Mühlau near Innsbruck and the nails are rivets for its mounts.

can be presumed that all old constructional rivets on armour were forged. The only exception found, might be the rivets with large floral heads for the interior attachment of the chin straps at the helmet [ref_arm_2028]. Most likely they were cast from copper alloy and gilded. This helmet was originally "white", i. e. polished. In the 16th or early 17th century, probably in Venice, it got covered by fabric (cover not extant) and several gilded decorations were attached. Also the nape-guard was extended by the attachment of a pointed plate. As the aforesaid rivets lay underneath the other copper alloy applications, the rivet heads were probably covered by the fabric. Therefore, they possibly derive from the time before the attachment of the cover.

Only rivets for the fixation of non-constructional applications were made entirely of copper alloy. At the hand-protection [ref_arm_1251] it becomes clear that the brass rivets are old, as the engraved and punched surface decoration of the attached copper alloy bands is not interrupted at the leveled rivet-heads. Also the narrow row of dome-headed rivets at the edge of the cuff is entirely made of copper alloy.

No scientific discussion of historical rivet-making seems to exist. It was also not possible to find a historical description of the manufacture of rivets. As a replacement, 19th comments on the making of nails may serve. It can be presumed that – also due to the identical historical terms – rivets and nails were made by the same workshops.

Different shapes of rivets occur on late medieval armour. Before entering the discussion of their making, the different types will be introduced.

4.2.1.1 Type-a [ref_ill_riv_a]

This rivet-type is found at armour parts of all types. It mainly[106] serves for fixing the interior leather on constructional lame-joints. The large, flat head prevents the leather from slipping over the rivet-head when stressed. The rivet-head is usually positioned interiorly so its flat appearance does not bother the wearer. On armour of Italian production, rivets of type-a sometimes also have their factory-heads exteriorly, e. g. for fixing leather straps or the holder plates of buckles. In these cases the rivet-heads are often decorated by simple chiseled or filed radial lines (e. g. [ref_arm_88]). Such rivets were reproduced for the restoration of the suit [ref_arm_5110] (e. g. [ref_arm_3880]). On armour probably coming from Maximillian I.'s armourer's workshop in Arbois rivets with ornamentally-stamped exterior heads have been used (e. g. [ref_arm_3855] [ref_arm_3823] [ref_arm_1973] [ref_arm_3570]). The same rivets are found at helmets of type-VI [ref_arm_1935] and type-VII [ref_arm_1744] [ref_arm_2088] [ref_arm_1751] [ref_arm_1754], all attributed to Italian making. Also for the attachment of the plate protecting the fingers at the item [ref_arm_1290], stamped rivets of type-a were used. It seems like decorated type-a rivets had been reproduced in modern times, as they hold the modern leather at the item [ref_arm_3287]. For an old repairing, two type-a rivets, one decorated by stamping and the other one by filing, were used with their head interiorly at the helmet [ref_arm_2148]. A very unique decoration – four stamped blossoms – is found at the rivets of the breastplate [ref_arm_3698].

4.2.1.2 Type-b [ref_ill_riv_b]

A type-b rivet has a hemispherical head, frequently placed exteriorly. This is the most common rivet-type and it is found at any type of armour and at any type of joint.

106 An exception is the pair of knees [ref_arm_2678] and [ref_arm_2846], where for sliding plate-to-plate joints type-a rivets are used. As this leg armour has obviously been extensively repaired, possibly the rivets are also not from the time of production. At the upper legs the upper lames are attached by rivets of type-b, as it is common for such joints.

Where constructional rivets should appear yellowish, a brass cap was brazed to the head of an iron rivet. Only expensive armour was equipped with such rivets and it would be too much to quote all the items that reveal such rivets. In many cases where the thin copper alloy plate is rubbed off, the tin-solder underneath is visible [ref_arm_1645]. As pars pro toto some examples with apparently genuine capped-rivets with varying head-diameters will be quoted: [ref_arm_1721] [ref_arm_1245] [ref_arm_1360] [ref_arm_1063] [ref_arm_2057] [ref_arm_3084]. The massive copper alloy rivets of type-b found on some objects are clearly modern [ref_arm_1747] [ref_arm_1062]. Their shank is thick in diameter and often also modern regular round washers are used at the joints [ref_arm_3322]. Especially reproduced suits of the late 19th and early 20th century contain such rivets [ref_arm_3213].

Also some types of iron type-b rivets are clearly modern: At some time in the early 20ieth century a large number of objects now in the MET were equipped with type-b rivets with decoratively stamped heads. Stuart Pyhrr quotes that it was Bashford Dean who assembled the different composite suits of armour for his private collection before they came to the MET.[107] To give the newly composed and completed "gothic" suits a somewhat uniform appearance for example at [ref_arm_4091] (for details see the single items [ref_arm_1682] [ref_arm_2337]) all rivets of type-b – apparently on Dean's order – were replaced by others, with either a stamped lion-head or a blossom. At the suit [ref_arm_3235] (for details see the single items [ref_arm_131] [ref_arm_1681]) only rivets with spiral-shaped heads were attached. The rivets at the helmet [ref_arm_1816] and at the chin/throat protection [ref_arm_3128] are probably also productions from this time.

Surprisingly, the same blossom-stamped rivet heads – Scalini calls them "a bozetta"[108] – found at some MET items are found at helmets in the MDA [ref_arm_2150], the MLM [ref_arm_2027] or the MNMC [ref_arm_1839]. While it is unlikely that they are genuine at the two latter helmets[109] – they hold new leather interiorly – at a number of Munich SMM breastplates they are most likely old [ref_arm_3655] [ref_arm_3656] [ref_arm_3657] [ref_arm_3661] [ref_arm_3663] [ref_arm_3664] [ref_arm_3665] [ref_arm_3666] [ref_arm_3667] [ref_arm_3699]. A further similar breastplate from the Munich Zeughaus with such a rivet is now in an anonymous collection [ref_arm_4079]. A drawing of one of the breastplates of about 1866 already shows a blossom-head rivet, although not very detailed and larger in scale.[110] At these breastplates, the rivets look more irregular than those on the said helmets and additionally around the base of the head they have a stylized ring of

107 Pyhrr (2006), here p. 109-111.

108 Scalini (1996), p. 67 (German text).

109 Also Rossi and Carpegna noted the similarities between the rivets on these helmets and suggested that they are modern, see: Rossi and Di Carpegna (1969), p. 39.

110 Wackernagel (1982a), p. 25, f).

pearls. Wackernagel – without a reference[111] – quotes that similar rivets were attached to armour attributed to Brescian workshops.[112] What he probably meant are two almost identical helmets of type-V [ref_arm_2113] [ref_arm_2124]. They actually reveal such rivets and are attributed to a Brescian maker. These helmets, together with [ref_arm_5109] can maybe help to proof Wackernagel's suggestion. Their rivets differ from Dean's restored objects by their obvious wear. At [ref_arm_2113], interiorly a part of the lining fabric remains – held by these rivets. It is therefore possible that in this case they originate from the time of use. The model for the reproduced rivets was possibly designed by the samples on one of these helmets. There is a helmet of type-VII [ref_arm_1819] in the MET, designed in the so called "Franco-Burgundian style", that is said to have been found in a river in France.[113] Also here, the blossom-headed rivets are found. The old images – presumably showing the pre-restoration condition – indicate that the rivets are genuine. Also a painting shows a helmet with a pointed skull and rivets with a blossom-shaped head [ref_ill_art_5243]. It is questionable if these designs were exclusively used in Brescia, as the manufacture of only the two first mentioned helmets can actually be located in this city. The extensive trade of such rivets that Scalini referred to (see above), supports the theory that they were not only processed in Brescian workshops.

The single lames of the hand-protection [ref_arm_1128] are also joined by rivets with blossom-shaped heads. They are slightly different from those mentioned above and might be original.

An absolutely unique version of type-b rivets is found at the suit [ref_arm_3256] (for details see the single items [ref_arm_866] [ref_arm_3926]). The very large and flat, gilded heads are clearly of decorative character, while they still have a constructional function. The damages at some of the heads show a smaller head of an iron rivet. Where the gold is rubbed off, at the large hemispherical heads a silver-shiny material is visible. Due to the defects where parts of the heads had broken off and where the surface is damaged by faults, it is likely that around the iron rivet-heads a material – both fragile and soft – is placed. This could well be a tin-lead alloy. Either these plates were cast around the iron rivet-heads or they were worked separately. The dot-and-line decorations are engraved and punched. The heads then were probably plated by gold foil.

111 As Wackernagel for the catalogue of the Munich Zeughaus worked together with Mario Scalini he probably got this hint from him. Scalini says that the "a bozzetta" rivets of the Munich breastplates "are not very different from certain original rivets on parts of armour that is certainly Italian and from more or less the same date." As a comparable example for an Italian breastplate with a similar rivet he names an example from the Santuario della Madonna delle Grazie di Curtatone near Mantua. It is not clear where this item is stored now and no image is included in Scalini's catalogue. Nevertheless, he is more careful than Wackernagel in drawing conclusions on a close relationship between the Churburg's Brescian breastplates and those in Munich when he quotes: "This fact [the Italian-style rivets] unfortunately, cannot be considered to have probative force on the Munich breastplates being of Brescian origin since the sources, especially the Datini archive of Prato, speak of a massive trade in these tiny products, which were evidently put on the market by Lombard workshops at extremely competitive prices, if it was thought worthwhile to transport rivets to Avignon. Tuscany and elsewhere. Apart from possible later interventions, intended to improve pieces for museum purposes, one has to note how these rivets appear also on German pieces, and that there are notable differences between the Churburg and the Munich breastplates.", for all quotes see: Scalini (1996), p. 71. The author of this paper was unable to find any other breastplate than those in Munich that has a similarly decorated central rivet.

112 Wackernagel (1982a), p. 115.

113 Pyhrr (2000), p. 9, cat. no. 7.

4.2.1.3 Type-c [ref_ill_riv_c]

Type-c rivets are the rarest of all types. Like type-b rivets, their main head is always exteriorly. The head is basically of the shape of a pointed cone. In few cases they serve as the pivot joints of visors on helmets of type-VII [ref_arm_1780] [ref_arm_1847] [ref_arm_1895] [ref_arm_2094]. In the same function, usually with a tapered profile, they are often used on helmets of type-IV with a side pivoting visor [ref_arm_1500] [ref_arm_1529] [ref_arm_1547] [ref_arm_1559] [ref_arm_1560] [ref_arm_1596] [ref_arm_1605]. While for many objects it cannot be said with certainty that these rivets are genuine, the archaeologically excavated and unaltered helmets [ref_arm_1520] [ref_arm_1543] proof that they were actually used for the visor-pivots of helmets of type-IV. Also at several of the apparently un-restored type-II helmets from Chalcis, the visors were attached by simple versions of this rivet [ref_arm_1445] [ref_arm_1449] [ref_arm_1450] [ref_arm_1451] [ref_arm_1453] [ref_arm_1454]. On two examples of type-III helmets, rivets of type-c are attached. In one case, they are of square section [ref_arm_1418], exceptionally long and pointed, gilded and towards the bottom two encircling lines are filed. Simple round examples are attached to the item [ref_arm_4434]. The type-VI helmet [ref_arm_1944] is equipped with pointed rivets of a square section (pyramid). Two helmets of type-V have their uncommon medial-ridge reinforce attached by pointed rivets [ref_arm_2075] [ref_arm_2107]. Two backplates [ref_arm_3340] [ref_arm_3264] and one breastplate [ref_arm_3426] are equipped with type-c rivets. These observations show that they were used in Spain, Italy and the German speaking lands.

4.2.1.4 Type-d [ref_ill_riv_d]

Rivets of type-d are probably the most elaborately worked types of all. They are technically based on type-a rivets, but the head is much larger and hemispherical embossed. All examples are made of one piece. Besides simple dome-shaped examples [ref_arm_1727], the head can be decorated by ornamental embossing. Some heads appear like blossoms [ref_arm_1718] [ref_arm_1840] [ref_arm_1858], while at others ridges are spirally winding around the head [ref_arm_1704] [ref_arm_1735] [ref_arm_1837] [ref_arm_1841] [ref_arm_1843] [ref_arm_1894] (probably not all are genuine at [ref_arm_1717] [ref_arm_1720]). This type of rivet has been used merely for the attachment of the lining and the chin-straps of type-VII-helmets. In only one case also a helmet of type-III is equipped with blossom shaped iron rivets of type-d [ref_arm_1383]. A second type-III helmet has similar rivets attached, but they are made of copper alloy [ref_arm_1398]. Unique are the dome-headed examples on [ref_arm_2094]: they are made of a tin or lead alloy. At the breastplate [ref_arm_3734], dome-shaped copper alloy applications that appear like rivet-heads are visible. They are actually separate caps that were sown to the fabric to cover the washers. The copper rivets underneath, together with an iron washer (lost through corrosion) held an exterior fabric cover in place.

4.2.1.5 Others

There are also other rivet-types found on armour that cannot clearly be attributed to one group. The most interesting is a certain rivet-model – the head basically resembling a blossom. It appears in similar variations at the visor-pivots of many type-VII helmets[114]. Due to their marks, some of these helmets are certainly reproductions [ref_arm_1857]

114 [ref_arm_1900] [ref_arm_1773] [ref_arm_1742] [ref_arm_1660] [ref_arm_1686] [ref_arm_1701] [ref_arm_1707] [ref_arm_1725] [ref_arm_1797] [ref_arm_1821] [ref_arm_1826] [ref_arm_1832] [ref_arm_1837] [ref_arm_1857] [ref_arm_1865] [ref_arm_1898] [ref_arm_1899] [ref_arm_4290] [ref_arm_4397].

[ref_arm_1899][115]. Others are so similar in the shape of the skull and other details that it is likely that all three were made in the same workshop [ref_arm_1900] [ref_arm_1773] [ref_arm_1742]. Most of the concerned helmets show pairs of holes at the level of the ears and at the top for the lacing of an interior lining. This feature seems to have been favored by many modern armourers, as many further reproductions suggest [ref_arm_4600] [ref_arm_4431] [ref_arm_4448]. The holes are rather common for tournament helmets [ref_arm_1732], but the design of the quoted type-VII head-pieces is typical for field use.

4.2.1.6 The making of rivets

The late medieval armourer would probably have been generally capable to make the required rivets by himself. As he was a specialized craftsman, his work-time was expensive and he would therefore certainly try to focus on his main work – designing the plates – rather than on mass-producing features like rivets. That there was a specialized craft-segment for the making of rivets is indicated by elaborately worked rivets of type-d, found at other contemporary ironworks, for example iron doors [ref_ill_art_5152]. An English 16th century source tells that rivets – just like all other semi-finished working material – were bought in by the armourer.[116]

Despite intense research, the author could not find any pre-industrial description of rivet-making.[117] Nevertheless, rivets were always mass-produced items. In 1828 a nail-smith of Stirling betted that he could make 17030 nails within two weeks; he finished even earlier. Normally he would finish 700 nails within a working day of 12 hours.[118] Their making is so simple that the medieval techniques cannot have differed much from the manufacture in later times. In the following, an early 20th century description of the hand-making of shoe-nails is quoted. The dimensions of shoe-nails are similar to armour-rivets and therefore the working-processes must be very similar.

115 See discussion below in chapter [New recognitions on marks] and [A suit in the BMA].

116 Ffoulkes (1912), here p.183.

117 This is especially surprising as the 19th century had a great demand for rivets in the construction of steam-boilers, steel-structure buildings, ships etc.

118 See: Anonymus (1828).

*Herstellung geschmiedeter Nägel. Man verwendet in der Hauptsache Flußeisen in Form von Rundeisen und gewalztem oder […] geschnittenem Vierkanteisen […]. Zur Bildung des Schafts, der Spitze und des Kopfs beim Schmieden von Hand dienen als Werkzeuge zur Herstellung kleiner und mittelgroßer Nägel der Amboß a, der Abschrot (Blockmeißel, Nagelschrot) b, das Nageleisen c auf dem Amboßstocke e und der Hammer d (Fig. 1–4). Das vierkantige Stabeisen wird im Schmiedefeuer auf Weißglut erhitzt, auf dem Amboß a Schaft und Spitze ausgeschmiedet und an der Stelle, welche den zu bildenden Kopf begrenzt, mittels der Schneide des Abschrotes b fast ganz abgehauen; schließlich wird der Schaft in das Loch des Nageleisens c gesteckt, die Stange durch eine leichte Wendung davon abgebrochen und der Kopf mit einigen Hammerschlägen fertiggemacht. Das Nageleisen c, welches im Auge der eisernen Stütze c1 durch Verkeilen befestigt wird, hat an der Lochstelle für Nägel mit hohlen Köpfen eine gewölbte Erhöhung (Krone); […] Durch einen Schlag mit dem Hammer von unten her wird der Nagel aus dem Loch herausgeschlagen. An Stelle der Kopfbildung aus freier Hand verwendet man besonders bei einfachen Kopfformen Gesenke (s.d.) die als Handgesenke aus einem kurzen Stück Flacheisen bestehen und an ihrem verstählten Ende die Form des zu schmiedenden Nagelkopfs tragen […] Jeder Nagel wird in einer Hitze fertiggemacht, bei kleineren Nägeln werden zwei Stück in derselben Hitze hergestellt. Ein Nagelschmied verfertigt täglich in 12 Stunden 2000–2500 Schuhnägel (etwa 1 kg) […][119]	Production of forged nails. Mainly mild-steel bars of round section or of either rolled or cut quadrangular section are used. For the hand forging of the shank, the point and the head of medium and small size nails the following tools are used: The anvil a, the cutting stake-chisel (Blockmeißel, Nagelschrot) b, the nail-iron c on the anvil-foundation e and the hammer d (fig. 1-4). The iron pole of quadrangular section is heated in the fire until white-hot, the shank and the point is forged on the anvil a, by hammering it onto the stake chisel b it is cut off almost completely, leaving enough material for the head; finally the shank is stuck in the hole of the nail-iron, the pole is broken off by a slight turn and the head is finished with a few strikes of the hammer. The nail-iron c, which is wedged to the eye of the iron support c1, has a flange (crown) around the hole for making rivets with hollow heads. By a blow of the hammer from below the nail is driven off the hole. Instead of the free-shaping of the head especially for simple head-shapes handheld dies, made from a flat bar of steel which has at its tempered end the [negative] shape of the rivet head attached […] Each nail is finished in one heat, of smaller rivets two items are forged in one heat. A nail-smith produces in a 12 hour day 2000-2500 shoe-nails (about 1 kg) […]

119 Lueger (1908), here p.570-571. Translated by the author.

The tools mentioned, do most likely not differ much from those used in the Middle Ages. A 19th century nail-maker at work is seen on the photograph [ref_ill_art_5380]. The tools are similar to those used for nail-making in the 15th century [ref_ill_art_5327].

Rivets must have been made by the nail-making process described above. The only difference is that the heads of type-b and -c rivets were not finished by the cross of the hammer, but by a punch-die of cone or dome shape. The heads of type-d rivets must have been finished by embossing. It would have been very difficult and time consuming to freely emboss the ridges on each single rivet-head with the chisel from the exterior. For this technique, the interior of the already dome-shaped head would probably have to be filled with some flexible, but resisting substance like lead or a special resin. It is more likely that the heads are actually made by a "punch-and-die" deep drawing technique. Maybe for this purpose, the nail-iron was designed with a "crown" around the shank-hole, as described above. Another possibility is that the rivet heads were hard-soldered to the shanks. To answer this question, a genuine rivet needs to be examined, e. g. by means of an endoscope. It was most likely not possible to fire-weld the shank to the pre-embossed head, as the thin materials would not keep the heat long enough and the hammering would damage the embossing.

The copper alloy caps on certain type-b rivets have to be shaped by deep drawing them from a thin plate, with the help of a punch and a die. Probably several domes were driven into the plate, before the single caps were separately cut off. Maybe the domes were also driven into a die so extensively that the single caps got sheared off the plate in the same turn. The iron rivet-head and the interior of the cap needed to be etched with an acetous liquid to clean off oxides from the surface. Without this procedure, it would have been almost impossible to braze the caps to the rivets by means of tin-solder.[120] The process of brazing the caps to the rivet-heads requires special skills, actually those of a goldsmith. Especially the gilding of the caps was problematic. Maybe this was done by fire-gilding the cap before it was brazed to the rivet. The other way round, the high temperature necessary for the fire gilding would destroy the tin-solder joint as it melts at lower temperatures.

4.2.1.7 Riveting

In practice, rivets come as a semi-finished item with one side already widened to form a pre-made head. The shank of the rivet is plugged through holes in the segments that need to be fastened together. The work-piece then is placed with the pre-made rivet-head on an anvil. To avoid damages to the pre-made head, a somewhat softer material like hard-wood or a bar of lead needs to be put in between the head and the anvil. Interior heads of type-a rivets can be placed directly on the anvil. For a sliding plate-to-plate joint or where leather is attached by means of a type-b, -c or -d rivet, interiorly a washer is placed under the rivet head before the riveting. This is not necessary for simple pivoting or fixed joints or where leather is riveted directly to the plate from the interior by rivets of type-a. In the latter cases, the hole in the plate was counter-bored from the outside. This allows the shank to splay enough to still hold, when the second head would be ground flush to conceal the rivet.

If necessary, the shank is cut to surmount the plate or washer only by a few millimeters, just sufficiently to form a secondary head large enough to hold the rivet safely in place. By means of a hammer with e. g. a bowl shaped peen, the end of the shank is carefully hammered flat while extending its diameter to all directions. Throughout the riveting a washer can be held down by means of a small fork-shaped plate, as can be seen on the workbench in the right

120 The author has made experiments with the production methods for such rivets, see: Goll (2009), p.02-103. The method used then was of a somewhat roundabout way. The technique of etching was not known to the author at that time.

lower corner of the image [ref_ill_art_5330] (descr. 2). To prevent the shank from bending, the worker has to take care not to hammer one side stronger than the other. With rivets of diameters maybe up to 10 mm, of course also depending on the toughness of the material, this work could usually be done without heating the rivet. As the shanks of rivets for armour pieces usually show diameters under 4 mm, they all had certainly been riveted cold.

4.2.1.8 Differing between "old" and "new" rivets

The detailed comprehension of the characteristic features of "old" (handmade) and "new" (machine-made) rivets[121] are important for the authenticity-testing of armour. The acceptance of a few points – which are not meant to be set in stone – certainly delivers some reliable facts for getting closer to the answer on the authenticity question.

Until the 19th century, no machines were used for the making of rivets or nails. Modern standardized machine-made rivets usually have a uniform appearance, whereas the handmade rivets are somewhat imperfect. What actually makes the determination difficult is the fact that nails – and therefore presumably also rivets – were still made by hand in the early 20ieth century in some workshops. Where rivets hold leather in a condition that is most likely not old, the rivets cannot be genuine. It is almost impossible to open and reuse a rivet, as the shank would afterwards be too short for re-riveting. The only possibility would be to lengthen the shanks by the welding or hard-soldering of a wire.

4.2.1.8.1 Type-a

It is often not easy to determine if the plain rivet heads of type-a are genuine. As they do not show many formal features, there is not much to compare to possibly modern examples. In modern building-supply stores, a certain type of nail, used mainly for the fixing of tar paper on house-roofs, is available. The same sort was also available in the 19th century. The modern nails are made of iron, coated with zinc against corrosion. When their shanks are cut to the desired length, they can be used as rivets of type-a. The old, handmade rivets might look more irregular and the edges of the heads are often burred. Except of the zinc coating, it is very difficult to differ between genuine and modern examples. The coating could easily be removed by acid or by heating the nails in a fire. Some restorers or armourers use the aforesaid nails as rivets today.

4.2.1.8.2 Type-b and -c

The sizes of machine-made rivets are standardized since the 19th century. Handmade rivets of type-b and -c vary slightly in their dimensions and in the shank-head symmetry[122]. The edges of the heads are often burred. The supply of standardized machine-made rivets with heads comparable in size to the handmade "old" rivets is limited. They usually have shanks of about 4 mm in diameter, whereas the "old" ones are below 3.5 mm in diameter. This means: Rivets with shanks of a thin diameter but a comparatively large head might be "old". Even where rivets are missing, the "empty" small-diameter holes can support such an assumption. Nevertheless, it is not difficult to alter machine-made rivets by reworking their heads. Even not-standardized dimensions could be produced by modern methods: To get to

121 The terms are chosen so carefully, as rivets might be "old", but not genuine, as they might have been replaced a long time after the item was produced, but still by substitutes made by the old techniques.

122 Compare the axonometric view of [ref_arm_1075], where at the right side a rivet is mounted so loosely that the shank and the diameter can be seen. Also note the different head-diameters of all the rivets at this item.

the desired shank-head diameter ratio of "old" models rivets could be produced by turning[123] or the dies of rivet-pressing machines could be designed in the required dimensions.

Massive copper alloy rivets that connect two iron parts are most likely modern replacements. According to all archaeological objects – probably for safety reasons – at constructive iron-to-iron joints always iron rivets were used.

Brazed copper heads on iron rivets are not always likely to be genuine, as they also appear e. g. at the reproduced suit [ref_arm_4141] (for detailed images of the rivets see [ref_arm_608]). David Starley quotes Robert Smith, who says that by the early 19th century brass capped rivets were still delivered in large numbers to the Armouries in the Tower of London for the repairing of ancient armour.[124] With the examination of the chemical components of rivet-caps by means of XRF-analysis, Starley developed a theory that could help to distinguish between "modern" and "old" rivets.[125]

4.2.1.8.3 Type-d

Awkwardly shaped genuine rivets are always hollow inside their ridge-decorated heads.[126] They are also made of one piece of iron.[127] As their making requires skills beyond the regular rivet-making it is very unlikely that rivets with these features are reproductions. A reproducer might have made the heads massive.

4.2.2 Washers

Washers are small, one-time pierced plates, put upon the shank of a rivet before staking. These plates can serve mainly two different purposes. They can extend the diameter of the shank flattened by staking or they can simply decorate an item.

A washer is often found at rivet-joints if the large "factory-head" of the rivet has an additional decorative character and is thus lying at the outside of an armour piece. The washer itself is then attached interiorly. Washers are only necessary where two segments are fastened together in a way that the rivets need to remain loose, to allow an independent motion of each of the fastened elements. Washers are consistently found where leather is riveted to a plate, to prevent the flexible leather from slipping off the rivet shank when under tension. For similar reason, washers might be used where ring-armour is attached to plate armour. In the following, three types of washers will be classified.

4.2.2.1 Type-a [ref_ill_was_a]

This is the simplest version of washers. They were most likely made by the piercing of a larger plate several times and the small washers were cut off in a square pattern – possibly with the help of large plate-shears. Such washers are rarely found on armour and they are used only interiorly. At the brim of the helmet [ref_arm_1360] they probably once helped to fix an interior lining.

123 The restorer Ian Ashdown in Onnens (CH) uses such rivets.

124 Starley (2006), p. 4.

125 The copper-zinc ratio of modern brass (8:3) differs from alloys produced before 1743 (7:3), when a new zinc-production method was introduced, see: Starley (2006), p. 3-5.

126 The aforesaid copper alloy examples at [ref_arm_1398] and [ref_arm_1692] might be massive casts, a closer examination in the course of this research was not possible.

127 Again with the exception of [ref_arm_1398] and [ref_arm_1692].

4.2.2.2 Type-b [ref_ill_was_b]

Washers of type-b are basically made the same way as type-a washers. The difference is that the corners of each square plate were cut off to reveal an octagonal pattern. This shape avoided injuries and prevented clothes from getting damaged. This is the most common washer-type, frequently used interiorly for the attachment of leather-parts [ref_arm_1272] or for sliding rivet-joints [ref_arm_613] in all production regions.

4.2.2.3 Type-c [ref_ill_was_c]

Round washers of type-c are found particularly on Italian armour, where leather is riveted to the interior. They usually have a slightly embossed section [ref_arm_3097]. Such washers were probably stamped from a larger plate, as it would be unprofitable to cut them with shears. At the presumably Spanish helmet [ref_arm_1418] type-c washers made of copper alloy hold the interior lining. In many cases, type-c washers are modern replacements of flat, standardized discs [ref_arm_3272] [ref_arm_2308], but also the embossed ancient versions seem to have been reproduced [ref_arm_9].

4.2.3 Non-detachable joints

Rivets were used for different types of plate-joints. In the 15th century the European armourers developed sophisticated articulated permanent fastening-systems. The most important types are classified and explained in the following paragraphs.

4.2.3.1 Fixed by rivet [ref_ill_joi_fixedbyrivet]

The simplest joining of two plates is riveting them tightly together, so they do not pivot around the rivet. The segments of type-II helmets for example were usually fixed permanently together by this technique [ref_arm_1471]. In the 15th century only in rare cases plates were stiffly fixed together by rivets. In this time, this technique was merely used for the attachment of hinges, leather-straps or decorative applications. Exceptions are maybe armpits. They could probably be riveted directly to the shoulder defense, as the details at the statue [ref_ill_art_5198] and the extant example [ref_arm_5116] (still attached to a shoulder defense) suggest. Also the torso- and the abdomen-plate of many breastplates were permanently fixed by such joints [ref_arm_3633].

4.2.3.2 Pivoting rivet [ref_ill_joi_pivotingrivet]

A joint that only needs to allow a plate to pivot works actually similar to a fixed rivet-joint. The difference is that the shank of the rivet is in diameter slightly smaller than the rivet-holes and the rivet is not hammered very tight. The most common examples are the pivoting-joint of face-guards merely at helmets of type-IV [ref_arm_1529], -VI [ref_arm_1944] and -VII [ref_arm_1704]. But also pelvis-lames, elbow lames, knee lames, foot lames, neck lames and the upper plates of backplates of type-III in most cases were joined by this technique. On armour this type of joint was presumably used for the first time in the mid-14th century, when the first helmets got an articulated face-guard and when the single parts of the limb-protections were joined together.

4.2.3.3 Riveted to leather [ref_ill_joi_rivetedtoleather]

Wherever single lames should be articulated, they could be connected by an interior leather strap. In most cases this system is combined with a pivoting or sliding rivet-joint, for example at: the lower lames of shoulders [ref_arm_262] [ref_arm_425], the upper lames of upper legs [ref_arm_2368] [ref_arm_2883]. At many pelvis-lames [ref_arm_3306] [ref_arm_3604] [ref_arm_3618] and at the lames of foot-protections [ref_arm_2245] [ref_arm_2254] a centrally attached leather strap prevented the lames from flipping over. In

some cases the pelvis-lames are connected exclusively by leather straps [ref_arm_3875]. The leather straps at joints are often lost or they were replaced in later times. Usually, functionless holes or remaining functionless rivets – both only visible interiorly – tell of their former existence. This technique is probably the technique to follow in its development directly onto the lacing of single segments. In the 14th century, the plates of torso-protections were usually still joined by an in- [ref_arm_3811] or exteriorly [ref_arm_3698] riveted leather or fabric. Towards the end of the century, the leather was attached interiorly and the former lining-like appearance was reduced to narrow stripes.

4.2.3.4 Sliding rivet [ref_ill_joi_slidingrivet]

Sliding rivets allow the lames to pivot and to slide. This system is frequently used at the joint of the single lames of type-III hand-protections [ref_arm_1063], at shoulder-lames [ref_arm_861], at the small toe side of knee lames [ref_arm_2471] and at upper leg lames [ref_arm_2412]. It is sometimes found at pelvis-lames of German breast- and backplates [ref_arm_3294]. Also the central joint at type-IV breastplates [ref_arm_3636] and the separate arm-cutouts at breastplates [ref_arm_3463] are often sliding. The slot is always filed into the plate placed underneath. The rivet is fastened loosely; interiorly a washer is necessary to prevent the rivet from falling out. This joint-type was probably developed in the early 15th century and used first for the knee protections on Italian armour. In the late 15th century, the German armourers attached a few plates for the protections of the hands directly to the lower arm defenses. These plates were fastened via a rivet sliding in a long slot. The slot was either filed into the main-plate [ref_arm_120] or it was filed into an interiorly attached stripe of plate [ref_arm_4926].

4.2.3.5 Sliding rivet with nose at edge [ref_ill_joi_slidingrivetwithnoseatedge]

There is a variation of the aforesaid system to be found at many items of the second half of the 15th century. Here the interior lame-edge forms a nose where the slot is piercing the plate. The intention was probably to save weight by the reduction of the plate-overlap [ref_arm_865].

4.2.3.6 Turning via sliding rivets [ref_ill_joi_turningviaslidingrivets]

A unique system for the articulation of armour plates is found exclusively at the joint between elbows of type-II and lower arms of type-III on Italian arm defenses. Here the outer plate of the lower arm at its upper end is pierced by two or three slots and connected to the lowest lame of the elbow by loosely fitted rivets, sliding in these slots [ref_arm_1] [ref_arm_810]. This joint-type allows the lower arm to be turned. It was developed already by the end of the 14th century and remained in use until the late 15th century.

4.2.3.7 Exteriorly attached hinge [ref_ill_joi_hingeexterior]

A hinge can be riveted exteriorly to the plate. In the 15th century, such hinges are usually small and the edges are decorated by filing. In some cases, on German armour they are made of copper alloy plate. They can connect the plates of type-III lower legs [ref_arm_2309], the flaps of type-II upper legs [ref_arm_2879], the breast- and the backplate [ref_arm_3876], the flap of the lower arms of type-III [ref_arm_365], the flaps on hand-protection-cuffs [ref_arm_1207], the thumbs [ref_arm_1272] or the cheek-pieces at helmets of type-II [ref_arm_1447].

4.2.3.8 Interiorly attached hinge [ref_ill_joi_hingeinterior]

Already in the 14th century, the armourers hid the hinges interiorly, probably to leave the exterior surface as even as possible. The flaps of type-III lower legs [ref_arm_2291] and

arms [ref_arm_986] were connected by this system, but also the flaps of hand-protections [ref_arm_1272], the cheek-plates of type-VI helmets [ref_arm_1919] [ref_arm_1929] and the single segments of some type-II backplates [ref_arm_3334].

4.2.3.9 Wedge [ref_ill_joi_wedge]

On helmets of type-IV [ref_arm_2121] and -V [ref_arm_2120] along the upper edge of the lost plate or leather strap for the attachment of the ring-armour collar small wedge-shaped rivets are attached. They were probably meant to lead blows of swords etc. away from the leather or they were meant to ease the over-slipping of a second helmet.

4.2.4 Detachable joints

Some of the single armour parts needed to be fastened in a removable manner, either to one another or to the wearer's body. The armourers developed different kinds of detachable joints. The most important and repeatedly found types are introduced in the following.

4.2.4.1 Bolt and eye [ref_ill_joi_boltandeye]

The abdomen- and the thorax-plate of breastplates [ref_arm_3621] [ref_arm_3624] [ref_arm_3678], the reinforces of shoulders [ref_arm_633] [ref_arm_663] and elbows [ref_arm_888] [ref_arm_5044] can be connected by a bolt-and-eye joint. This joint-type was first applied on armour in the first half of the 15th century.

4.2.4.2 Tube pulley [ref_ill_joi_tubepulley]

At type-IV helmets of the mid-14th century the ring-armour collar was attached via tube-shaped pulleys. Their making was very simple: the square head of a rivet – basically of type-a – was rolled to form a tube [ref_arm_1504] or the pulleys were made from a simply turned plate [ref_arm_1542] [ref_arm_1564], but also massive versions with the hole drilled exist [ref_arm_2121]. These pulleys were only attached to helmets before the end of the 14th century.

4.2.4.3 Square pulley [ref_ill_joi_squarepulley]

The ring-armour collar could be attached to the helmet-skull via pulleys with a square section [ref_arm_2112]. From the 1400's on these pulleys were not produced for this purpose anymore.

4.2.4.4 Bowl-pulley [ref_ill_joi_bowlpulley]

Bowl-pulleys made of iron or copper alloy are riveted to the lower edge of some helmets of type-IV [ref_arm_1520] [ref_arm_1562], -V [ref_arm_2082] or -VI [ref_arm_1933] for the attachment of a leather or plate strap [ref_arm_2183] carrying the ring-armour collar. The strap was fastened by a single wire or leather lace, led through each of the pulleys. After the mid-15th century, when ring-armour was not attached to armour anymore via pulleys, the bowl-pulleys were not produced anymore.

4.2.4.5 Drum-pulley [ref_ill_joi_drumpulley]

For the attachment of the ring-armour collar, until the early 15th century also drum-shaped pulleys were used [ref_arm_1655].

4.2.4.6 Central visor-hinge [ref_ill_joi_centralhinge]

The centrally pivoting face-guards of helmets of type-IV [ref_arm_1564] or -V [ref_arm_2023] [ref_arm_2082] were fastened to the skull by a detachable joint. The upper side of a hinge attached to the visor fitted onto a stud on the skull. An articulated turning bolt

grabbed over the hinge for its fastening. At the lower edge a small nose prevented this bolt from turning over. From the early 15th century on, this system was not produced anymore.

4.2.4.7 Hook-and-eye [ref_ill_joi_hookandeye]

This feature is rarely to be found on armour before 1500. Nevertheless, it seems to have been used, as the shoulder-reinforce [ref_arm_781] is equipped with a hook-and-eye system. Also the abdomen-plates at the type-III breastplates [ref_arm_3429] [ref_arm_3422] are interiorly connected via a hook-and-eye joint. In later times this joint-type became very common, for example for the attachment of upper leg-protections to the breastplate.

4.2.4.8 Turning locking-bolt [ref_ill_joi_turninglockingbolt]

A T- or r-shaped turning bolt is riveted to one plate and led through the connected plate and turned for fastening. Such a system is for example found for the attachment of the pelvis-lames to the backplate [ref_arm_3368], but it is more frequently applied at the connection between knees and lower leg-protections [ref_arm_2308] [ref_arm_2307].

4.2.4.9 Rectangular pulley [ref_ill_joi_rectangularpulley]

Lance-rests on Italian-style breastplates are often attached by such a system. In the case of [ref_arm_3570] the lance rest also fastens the reinforce to the breastplate. This joint-type was developed in the early 14th century in Italy.

4.2.4.10 Lacing-holes [ref_ill_joi_lacingholes]

The single parts of a suit of armour could be attached to each other or to the undergarment by means of laces. For this purpose pairs of holes were punched or drilled into the plate [ref_arm_611]. To prevent the laces from chafing, the radius of the plate-edges at the lacing-holes in some cases was enlarged by the attachment of riveted eyes [ref_arm_310] that are sometimes beautifully decorated [ref_arm_1797]. The lacing of the plate segments to an undergarment is probably the oldest type of all detachable fastenings.

4.2.4.11 Screw and thread [ref_ill_joi_screwandthread]

Screws are often used on German breastplates of type-IV to connect the abdomen- to the thorax-plate [ref_arm_3625] [ref_arm_4076]. Also artworks show this type of construction [ref_ill_art_5218] (descr. 2) [ref_ill_art_5219] (descr. 2). Usually the thread is cut directly into the thorax-plate. Also the face-guards of type-VII helmets of the “black sallet” group are sometimes fastened by a screw [ref_arm_1849] [ref_arm_1759]. Armour parts were probably not fastened by screws before the mid-15th century.

4.2.4.12 Spring-catch [ref_ill_joi_springcatch]

A very simple locking-system is a bolt, riveted close to the plate edge, sticking through a hole in the second plate. The spring-force is provided by the plate itself. This feature is used, from the mid-15th century on, for the closing of the cheek-pieces at helmets of type-VI. In the last third of the 15th century it was applied by the German armourers to lock the lower arm [ref_arm_546] and leg [ref_arm_2297] protections of type-III. Also foot protections can be connected to the lower leg by two spring-catches [ref_arm_2254] [ref_arm_2783].

4.2.4.13 Spring-lock mechanism I [ref_ill_joi_springlockmechanism I]

This sophisticated system is used exclusively in the last third of the 15th century for fastening a neck-protection to the breastplate [ref_arm_3064] [ref_arm_3066].

4.2.4.14 Spring-lock mechanism II [ref_ill_joi_springlockmechanism II]

The visor of German type-VII helmets of the last third of the 15th century is usually locked by such a mechanism. The wearer can press the push-button for lifting the face-guard [ref_arm_1704].

4.2.4.15 Strap staple [ref_ill_joi_strapstaple]

At the upper rear side of lower legs such a staple could be attached. The strap of the lowest lame at the knee protections was led through this staple to fasten both armour parts tightly together [ref_arm_2349].

4.2.4.16 Slot in plate for strap [ref_ill_joi_slotinplateforstrap]

At early armour for the lower arm [ref_arm_810] [ref_arm_956] [ref_arm_363] and leg [ref_arm_2309] [ref_arm_2325] [ref_arm_2291] sometimes a slot pierces the plates next to the buckle- or strap-joint. Either the strap end was stuck through this hole or the strap was riveted here interiorly and led through the hole to the outside. The flaps of some late 15th century hand-protections also show such slots [ref_arm_1207], probably the strap-ends were stuck through these holes. At the backplate [ref_arm_3417] the waist-straps were riveted interiorly and led through slots. An illustration of a fallen fighter [ref_ill_art_5249] (descr. 1) shows leather protections for the arms. They consist of one part only, do not close completely and are very similar to the extant examples [ref_arm_5103] [ref_arm_5104]. Here it also seems like the leather straps for the fastening had been stuck from the outside, prevented from slipping through the slots by a t-shaped ending. Therefore, it is very likely that the slots in the plate of later defenses derive from early leather-protections.

4.2.4.17 Detachable leather-strap [ref_ill_joi_detachablestrap]

One explanation why many objects retain no leather straps or buckles might be that the straps were attached by a buttonhole-like slit, clipped into a rivet of type-a [ref_vid_mushrivet]. This rivet has to be fixed to the plate with a small space between the head and the plate surface, looking like a growing mushroom. The extant leather straps connecting the elbow to the lower arm at [ref_arm_1564] and the rivets remaining at the shoulder-ends of the breastplate [ref_arm_3522] are designed this way. This system allows a quick and easy detachment of the single parts and for a simple replacement of fragile leather.

4.2.4.18 Strap and buckle [ref_ill_joi_strapandbuckle]

Armour needs to be fastened – either to the wearer's body or to other armour parts. Buckles – in the Middle Ages usually called "ringen"[128] – play an important but yet unattended role in the design and practical use of armour. While the armourer could easily have made them on his own, he could also have bought them in from a specialized craftsman, the so called "Rinckenschmied" [ref_ill_art_5321].

Until now scholars of armour did not pay much attention to this important part of fastening systems. Only one article focusing particularly on armour-buckles seems to exist.[129]

128 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1884), Reg. 1028. This document furthermore indicates that buckles for cheap foot soldier's armour were bought in and not made by the armourers. The word "rincken" of "rinken" is not used in modern German anymore. For the historical meaning see: http://www.woerterbuchnetz.de/DWB?lemma=rinke (16.03.2012).

129 Dean (1921). Dean is – as in most of his Bulletin-notes – very imprecise on where the buckles depicted in his text came from. As the same type of buckle was used for civilian equipment, sword-belts etc., without a context a buckle cannot be attributed to armour with certainty.

Probably the most comprehensive study of medieval belts in general was published by Ilse Fingerlin.[130] It can be anticipated that there are a lot of links between contemporary medieval belts and the straps on armour.

It is not easy to examine the buckle-fastening on extant armour. In most cases the buckles are lost. Those which survive are not necessarily genuine[131] – or at least they do not date from the production-time of the armour. Buckles belong to the wearing-parts of armour. As long as the item was used, they were exposed to abrasion. If they were riveted directly to leather straps, they got easily torn and lost. Another problem is that they can easily be copied. A piece of thicker plate and a file is enough for any metalworker to copy simple shaped examples. The cast buckles can easily be copied by making a mold of the original. Nevertheless, a few aspects on buckles on extant armour will be discussed below. A problem for a discussion was to find a reliable reference for definitely genuine examples. The collections of CH and the HJRK were considered good places to start from, as the concerned armour parts preserved in these collections are of the best provenances. Comparisons to contemporary artworks might be helpful. They sometimes illustrate straps and buckles at armour in details [ref_ill_art_5335] (descr. 3).

Buckles on armour are either made of copper alloys or of iron. Some of the copper alloy examples might have been gilded.[132] There are two basic types of buckles found on armour.[133] Until today these two types are still in use for different purposes – just the design may be different from the medieval ones. The first type consists of one frame only. The shape of this type varies from rounded (probably genuine at [ref_arm_1135] [ref_arm_1228] [ref_arm_1272] and square (probably genuine at the pair of lower arms [ref_arm_810] [ref_arm_986] and certainly genuine on [ref_arm_1341] [ref_arm_3898])[134] to rectangular or trapezoid (original maybe at [ref_arm_88] [ref_arm_2376] [ref_arm_3382]). Such examples will be called a “single-frame” buckle in further notes.

The second type consists of two frames, basically in the shape of an “8” [ref_ill_art_5352] [ref_arm_3796], which could be abstracted into a rectangular shape [ref_arm_3423] [ref_ill_art_5359]. Also variations resembling a combination of drop- and square shapes do exist [ref_arm_3795]. This type will be called the “double-frame” buckle. The term is similar to the contemporary one, as a French source of 1446 mentions “boucles doubles”[135] for the

130 Ilse Fingerlin tracks buckles with rolls actually down to the mid-13th century. The earlier examples do differ in their general shape from those found on plate-armour. See: Fingerlin (1971), p. 70-74.

131 For example the buckle on [ref_arm_4904] is most likely of the late 15th or early century, but it is certainly not attached in the original manner. The holding-plate is made too crude for the otherwise delicately worked hand-protection to which it is attached. The strongest evidence for a later application is the fact that the holder plate partly covers a second, empty hole in the armour-plate. Most likely it served for the interior attachment of a strap or for a hinge that joined a pulse-side flap to the cuff which is now lost. See also: Goll (2009), p. 36.

132 In the course of this study it was not possible to find visible remains of gold-plating, future research on the chemical-compositions of buckles might reveal new insight.

133 The references to buckles on extant armour given in brackets in the following discussion are chosen randomly. Certainly there are several more items with probably original buckles. Future research can extract all items with buckles for comparison.

134 This is a good example for the problems in mapping buckles on armour: The buckle on [ref_arm_810] is probably missing the roll. While the buckles seem to be “old”, it is not clear if they date from the time when the armour was made. They were obviously re-mounted, as the holding plates on each side are different.

135 Ffoulkes (1912), p.78.

fastening of body-armour. The double-frame buckles have a remarkable advantage over the single-frame type: The strap-end can be conducted through the second frame and thus it is less bothering than the free-moving end of a strap fastened by a single-frame buckle.

Both types can have a small roll or tube at one side, which would ease the opening of a tight strap and reduce its wear. A probably original single-frame example is found at the front of [ref_arm_3795] [ref_arm_3861] and a double frame is found at [ref_arm_3704]. That such buckles – still produced today – were definitely in by the second half of the fifteenth century can be seen on [ref_ill_art_5168].

How difficult it is to exactly date some models shows the obviously large timeframe in which the round-shaped double-frame buckles were used: In 2005, in Magdeburg together with several others a mold for such buckles from before 1284[136] was excavated. In 1961 on the "Vasa", a Swedish war-ship that sank in 1628, several of such buckles were discovered within numerous other finds. They are exhibited in the Vasa-Museum in Stockholm.

The holder-plates of the buckles were often decorated by filings at the edges, some also had chiseled or engraved patterns on the surface [ref_arm_1228] [ref_arm_1272]. Some simple brass buckles were made rather by filing than by casting [ref_arm_2294]. As iron could not be cast delicately enough before the 19th century, all the iron buckles must have been made by cutting or by forging [ref_arm_4926].

It seems like any contemporary type of buckle could serve for the fastening of armour. The only difference is maybe found between armour made in the German speaking lands, where rounded types are favored, and armour made in Italy, where the trapezoid shape seems to have been preferred.

Buckles found on armour can be found at other contemporary non-armour objects as well.[137] This becomes clear when some of Fingerlin's drawings of presumably belt or purse-buckles [ref_ill_art_5378] are compared to buckles on armour in art [ref_ill_art_5179]. Often metal-strapends can be seen [ref_ill_art_5290] (descr. 2). They did probably also not differ much from examples attached to non-armour objects.

On more expensive items, the buckles are expected to be decorated more elaborately. The most delicate armour parts of the considered period are certainly those made by Lorenz Helmschmied of Augsburg, most of which are preserved in the HJRK in Vienna. Unfortunately, the studies of the buckles on the items in this collection do not allow any reliable conclusions on contemporary designs. The fastenings on the suit [ref_arm_3257][138] had been restored so extensively that most of the buckles are reproductions[139]; they are not medieval in style, but rather renaissance or even baroque. At the pair of hand-protections [ref_arm_1208] [ref_arm_1246], the same buckles as on suit [ref_arm_3257] can be found. This pair of hand-protections has been attached to this suit at previous installations.[140] As

136 Berger (2006), p.5, plate A-48.

137 For the problems on the determination of the former use of single buckle finds see: Fingerlin (1971), p. 12-13, particularly on armour see p. 186-187.

138 It was not possible to study this suit in detail. Hopefully future research request for the study of such important details as buckles will be supported by the HJRK.

139 Thomas and Gamber say that all the straps and buckles are modern, see: Thomas and Gamber (1976), p. 106. Nevertheless the buckle at the elbow [ref_arm_533] could be contemporary with the suit. They are of the rounded single-frame type with a decorated holder-plate.

140 See the photography in: Thomas and Gamber (1976), pl. 40. After the publication of the 1976 catalogue the hand-protections were replaced by [ref_arm_1059] and [ref_arm_1124].

the considered buckles all look the same, it is well possible that in the 19th century they were cast from an original of the 16th or 17th century to reveal a uniform appearance of the armour parts assembled to one suit.[141] Even where smaller examples are expected, e. g. at the lower arms or at the shoulder, the same large rectangular double-frame buckles are attached.

4.2.4.19 Crests

Helmets of type-II were the first helmets to be surmounted by a heraldic application, a so called "crest". At these helmets, a three dimensional symbol was laced to the skull. A few examples still exist, for instance the painted leather crest on the type-II helmet [ref_arm_1488].

The center of the skull of nearly all type-V and -VII helmets is pieced by a hole. On Italian helmets of type-V it usually has the shape of a keyhole. Most likely these holes served for the mounting of a crest. Artworks show what they could have looked like [ref_ill_art_5187]. It is not clear how the joint actually worked. Only few contemporary crests for such helmets are extant[142], unfortunately the author was unable to examine any example in person.

To the type-VI helmet [ref_arm_1932] an iron "stick" is attributed, traditionally considered to be a base for a crest[143]. This item is most likely rather a 16th century tool for the interior cleaning of a gun-barrel. The thread at the one side was screwed to the cleaning-stick. The springs at the other end ensured a precise cleaning due to close fit to the interior surface of the barrel. A comparable object is preserved in the Zeughaus in Graz[144], there it is attributed to the aforesaid function. The Churburg item does also not really fit to the hole in the skull of the attributed helmet. Furthermore, the keyhole in the helmet's skull would not be necessary, a simple hole would be sufficient if the item was actually meant to hold a crest. The attachment of crests might have been simpler. It probably had a threat at its lower end and was fastened by turning into a nut at the interior of the skull. This nut maybe had a small nose that grabbed into the key-bit of the hole and thus no tool was needed to mount or dismount the crest.

4.2.5 Body-fastenings

One of the questions to be attended whenever armour is examined is on the way it was fastened to the wearer's body. This important approach has long been neglected by scholars of the subject. In 2002 Tobias Capwell wrote a detailed article on Italian "Arming-Doublets"[145]. He approaches this topic from the iconographical illumination of armour-fastenings, while the following considerations examine existing armour on the question of its former fastening.

Fastening-features on extant armour do not necessarily derive from the time when the armour left the workshop. In most cases it has to be assumed that attached organic material has been replaced throughout the lifetime of an armour-part. On many armour pieces, holes without any obvious purpose can be found. They were once filled by rivets which were holding organic parts or other applications. Many of the functionless holes can tell details about the intensions of the armourer and the way an armour part once worked.

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141 Before 1921 actually copies of buckles on Vienna armours were made, see: Dean (1921), p. 62. Unfortunately Dean does not specify which buckles were reproduced.

142 See for example the hydra-crest A2126 of the HJRK.

143 Trapp (1995), p. 55.

144 Brooker (2007), p. 325, together with the wheel lock gun RG73.

145 Capwell (2002).

Throughout all the early plate armour period, on contemporary artworks it can be observed that armour was optionally worn upon or underneath the clothing. Albrecht Dürer depicted one interesting possibility how armour could be combined with the textile clothing [ref_ill_art_5355]. A man-at-arms wears his breastplate and his hand-protections underneath a slit jacket, while his shoulder defenses and the elbows are fastened on top of the undergarment. In another of his works he shows a rider wearing his jacket upon the breastplate and the arm-defenses upon the jacket [ref_ill_art_5383]. The interaction between armour and clothing has not been the subject of any study yet. A few observations will be discussed in the following.

4.2.5.1 The body-fastening of breastplates

The waists of nearly all breastplates of the considered period are very narrow[146]. This has certainly not only been a matter of fashion aspects, but moreover this had a very practical task to fulfill. To keep the largest part of the weight away from his shoulders, with the help of a belt a tight fastening was set up at the waist of the wearer. The body region between the rips and the hip-bone is so soft that it can be tapered without causing unbearable pain, similar to the 19th century corselets in female fashion. By this "shell", the wearer got more space for motion at his chest, which eased the breathing.

With torso plates of the Italian system, the circumference is not as easily adjustable as at the plates of the German System. The hinges at the one side do not allow the backplate overlapping further with the breastplate. Only the buckled leather straps at the opposite side can be adjusted in stages in a narrow range. Much adjustment is not possible, as the system gets out of symmetry, resulting in the squeeze of the wearer's body at the buckled side. A little range is always necessary, as the body-measurements of the wearer could change, but also – depending e. g. on weather conditions – garments with different thicknesses could be worn underneath. As the abdomen-plate of the Italian system could not be unlimitedly tightened around the waist, for holding it in its position it needed to be buckled upwards to the thorax-plate. The wearer of a torso front and back-protection constructed in the Italian system had to carry more weight on his shoulders. The waist of these protections is usually not as tapered as at examples of the German system. The abdomen plates are "hanging" buckled to the thorax-plates. Probably to spread the weight on a larger surface, the front- and backplate on Italian armour nearly touch at the shoulders [ref_ill_art_5375].

The former fastening-system of single-worn breastplates can often not easily be reconstructed. No genuine back-straps survive at extant armour. The author has made himself some reproductions of armour. The back-straps of breastplates in these cases were riveted close to the plate edge underneath the arm-cutouts. To fix the plate to the body, these straps were crossed at the wearer's back and then attached to a buckle at each shoulder-end of the breastplate. In the course of this study it became clear that single breastplates of the second half of the 15th century cannot have been worn with such a strap system, as most extant examples do not show holes under the arm-cutouts for the riveting of the back-straps. This raised the question on how these breastplates were actually fixed to the wearer's body.

The detailed examination of several artworks is necessary to reconstruct how the original fastening might have worked. Illustrations of the backs of fighters are rare. In several cases no breastplate-fastening straps are visible at all [ref_ill_art_5150]. Other depictions are not detailed enough to allow the understanding of the back-strap system [ref_ill_art_5305]. In a few cases the straps seem to be actually riveted to the plate under the arm cutouts [ref_ill_art_5174]. Obviously different systems existed.

146 See chapter [Front].

The painting [ref_ill_art_5306] (descr. 2) delivers the best explanations on the question why usually no holes for the back-straps are visible at extant plates. In the painting, the battlefield is covered by fighters in combat, bodies and arms. Breastplates are lying scattered on the ground. The straps of the breastplates are forming an "X", clearly only attached to the shoulder-edges. What the system might have looked like when worn can be seen at [ref_ill_art_5345].

This system was most likely fastened at the frontal waist by a single buckle – easily accessible for the wearer himself [ref_vid_puttingonabreastplate]. The straps tend to slide upwards along the sides of the plate. Probably to avoid this effect, the plates of many breastplates of the second half of the 15th century were deeply cut out at the waist [ref_arm_3701] [ref_arm_3750] [ref_arm_3421] [ref_arm_3429]. It is also possible that they were meant to make the wear of a ring-armour shirt underneath more comfortable, while still forming a lean waist. These cutouts are already found at artworks of the 1470ies [ref_ill_art_5369] [ref_ill_art_5207] and they become common by the early 16th century [ref_ill_art_5177]. Probably due to this problem, also other, similar systems were developed. The buckle at [ref_ill_art_5246] was probably a bit difficult to reach, but the straps could not slide upwards as they were conducted through a ring at each side of the waist. Many similar type-II breastplates in the WM have a buckle attached directly to the plate at the left side of the waist [ref_arm_3528] [ref_arm_3529].

This system makes buckles at the shoulder-edges optional. The straps could also be riveted permanently to the plate or they might have been attached via a slit in the leather that was clipped to a "mushroom" rivet [ref_vid_mushrivet]. This could explain why so many simple front torso-protections do not have buckles attached to the shoulder-edges. Within time, leather becomes brittle. If the straps were buckled or clipped at the shoulders and not permanently riveted to the plate, they could be kept and maintained separately from the plates and given to the soldiers when they got prepared for combat. Especially for arsenal-armour this arrangement makes sense, as the permanent maintaining of hundreds of objects was a difficult and expensive task. Simplifications were certainly welcome.

Getting dressed in full armour was a long procedure that could not be achieved by the wearer himself. Several squires or servants were necessary to fasten all parts to their place [ref_ill_art_5364]. It was therefore very important to take care that, in case of emergency, the fighter could get rid of his armour by himself. A passage in Maximilian I.'s "Weiskunig" may serve as an illustrative proof for this necessity:

[…] Derer zu ainer zeit, Rit der Jung weiß kunig [Maximilian I.] in ainen großmechtigen streit, und als Er seinen ganntzn kiriß, und vechtharnasch anleget, da wolt sein wappenmaister, Ime das hauptharnasch, mit schraufen wol versorgen, damit die veindt Ime das nit aufschlagen mochten, Da fragt der kunig den wappenmaister, welches pesser were, den gewalt in seinder handt, oder in aines anndern hanndt, der wappenmaister gab anntwurt, welcher gewalt hat, der ist herr, da saget der kunig, Darumb so will Ich des harnasch geweltig sein, und mit der öffnung, des hauptharnasch, nit in deinen willen leben, wiewol du mir sölichs zu ainem gueten thuest, waist du aber nit, das aus unbetrachter oder unbesynndter guethaidt, vil laidt komen, Aus dem mag ain Jeder versteen, das dis kunig gewest ist, ein lerer unnd offenbarer, anndern kunigen, in der harnaschmaisterey und wappenmaisterey […][147]

Not only for the knightly riders, but also for foot-soldiers it was important that they were in control of their armour. If each of the defenders of a medieval city in case of alert would need a helping hand to buckle their breastplates at the shoulders, the war would permanently have been over before the first soldier left the arsenal. In danger it was possibly necessary to get rid of the armour in a short time and to escape quickly.

4.2.5.2 Breastplates and clothing

4.2.5.2.1 Type-III

Several contemporary depictions show breastplates worn without a pelvis protection [ref_ill_art_5236] [ref_ill_art_5255] (descr. 1) or together with a skirt of ring- [ref_ill_art_5273] or segment-armour [ref_ill_art_5272] (descr. 1). A wall painting, depicting St. George fighting the dragon [ref_ill_art_5274], shows that the ring-armour protection for the front of the pelvis is fastened completely independent from the breastplate by a leather strap around the knight's waist. These breastplates, according to the type-system defined above, would be considered as type-I.

Artworks made between the 1420ies and the 1450ies in the German speaking lands often show that breastplates at the shoulders were laced to the undergarment [ref_ill_art_5266] [ref_ill_art_5211] (descr. 1), but also a strap-system seems to have been used in the same period [ref_ill_art_5259]. While the shoulder fastening is easily understandable, it is usually less obvious how the plates were fastened to the waist. The development of an important feature of many extant type-III breastplates might be connected to this fastening question.

The abdomen-plate at some type-III breastplates is fastened to the thorax-plate by either one central rivet [ref_ill_art_5197], buckle [ref_ill_art_5215], hook-and-eye [ref_arm_3429]

147 Treitzsaurwein (1775), p. 97-98. Translation of the author: Once upon a time the young wise king [Maximillian I.] rode into a fierce fighting and as he put on all his armour and his fencing-armour, his armoury-master wanted to close his main-armour tightly with screws, so no one would open it by a strike. In this moment, the king asked his armoury-master what would be better: If someone had the control in his own hands or if someone else had the control. The master answered: The one who is in control, is the ruler. So the king said: That is why I want to be in control of the armour and I do not want to depend on you if I have to open my armour. I know that you want to do this for my own well, but you do not know that from your unconsidered or unconscious good will a lot of misery might emerge. By this, everyone might understand that this king was a teacher to other kings in concerns of arms and armour.

[ref_arm_3422] or bolt-and-eye joint [ref_arm_3621] [ref_arm_3624].[148] The armourer certainly had some intention when he applied these detachable joints. The simplest explanation might be that for transport the lower plates could be dismounted. Another assumption is that such breastplates might optionally have been worn without the abdomen- and the pelvis-plates or they could optionally be replaced by a skirt of ring-armour – for example for the ease of long rides or marches. As the extant examples show no holes for a fastening of the abdomen-plates to the waist, it is not sure that these breastplates could have been used this way. The only possibility is that a waist-belt was connected to the interior pulley at the lower edge of the thorax-plate.

A further explanation is that where no pelvis-lames are visible in depictions, the abdomen- and the pelvis-plates were worn invisible underneath the skirt of a jacket – for fashion reason only.[149] To join the abdomen-plate, the pulley or stud of the joint was then stuck through a hole or slit in this garment [ref_vid_wearingtf-III][150]. Only early examples with lacing holes at the shoulders could easily have been fastened this way. The extant later items with detachable abdomen-plates seem to have had back straps. The thorax-plate would have to be fastened to the body at the shoulders and therefore the back-straps and a waist-belt would necessarily be visible. No contemporary depiction shows such a construction. Therefore, it is not sure that the clothing-combination was the reason for the application of the detachable joint between the thorax and the abdomen-plate.

4.2.5.2.2 Type-IV

As said above, the abdomen-plate of type-IV breastplates may have developed by the extension of the adjacent first pelvis-lame. Its central point might imitate a feature of a contemporary craftsman's apron [ref_ill_art_5300] [ref_ill_art_5301] (descr. 2) [ref_ill_art_5302] [ref_ill_art_5365]. Just like an apron, also the abdomen- plates of breastplates were sometimes worn upon an undergarment, apparently without a thorax-plate. Single abdomen-plates worn upon a jacket [ref_ill_art_5294] or upon a ring-armour shirt [ref_ill_art_5287] are illustrated in several contemporary artworks, mainly of Burgundian origin. Also in other European regions, breastplates seem to have been worn this way [ref_ill_art_5281]. At the depiction [ref_ill_art_5338], only the abdomen-plate without any pelvis protection is visible. Generally, a color-contrast between the upper and the lower plate was obviously in fashion in the 15th century, as the thorax-plate could also be covered by leather or fabric [ref_ill_art_5164].

The question is how these single abdomen-plates seen on the aforesaid depictions were fastened to the body. It is of course possible that the waist-belt was sufficient, but the upper point of the plate would presumably not hold very close to the chest if it was not fastened. Furthermore, there is no obvious reason why a man at arms should have left his thorax exposed, while the rest of his body is sufficiently protected.

Some features on extant armour plates might help to explain how these breastplates could have been fastened. The upper parts of many plates of type-IV – especially at those probably

148 Also the plates [ref_arm_3437] [ref_arm_3434] might have once been detachable, as interiorly central functionless slots are visible. These slots might have served for a bolt and eye or hook and eye joint.

149 Also at early 16th century artworks often a breastplate seemingly worn without any pelvis protection is visible [ref_ill_art_5381]. Type-III breastplates were the most common type in the German speaking lands at that time. Nevertheless, the author does not know of the existence of a contemporary breastplate at which the abdomen- and the thorax-plate are connected via a detachable joint. In all cases they plates are permanently riveted together.

150 The breastplate seen in this video was made by Peter Müller in 2012 after the extant example [ref_arm_3624].

made in the German speaking lands – are held together by only one single screw. There is usually a thread cut into the thorax-plate. It seems as if the holes for the thread had been punched from the exterior by means of a pointed tool. The plate material would probably be too thin to contain a sufficient number of coils [ref_arm_3630]. The material displaced by the punching of the holes shapes a cone at the interior edge of the hole and thus more coils can be cut into the plate. The production of a screw and the fitting thread in the plate requires a lot of work and certain skills. This raises the question, why the armourer's did not simply rivet the pieces together.

Many of these screwed plates show up to three vertical positioning holes on the inside [ref_arm_3679]. This feature might have had the purpose of adjusting the length of the plate to wearers of different heights. Another possibility is that the plates should pivot around the central screw for the comfort of the wearer. There are actually extant breastplates where a central rivet is sliding and pivoting in a slit. At these examples – probably of Italian production – to the left and to the right of this joint an interior leather-joint is permanently applied to prevent the edges of the thorax- and the abdomen-plate from flipping over and blocking the motion of the wearer [ref_arm_3718] [ref_arm_3719] [ref_arm_3724]. At the German breastplates with only a single screw no such leather or the rivet holes can be found. A screw is not suitable for a pivoting joint. The permanent motion would result in a self-loosening of the screw. To avoid this effect the screw would have to get fixed by a locknut. This would mean that the interior nut could injure the wearer when the breastplate received a blow. The second problem is that without the interior leather straps mentioned above the plates could flip over at the edges, making it impossible for the wearer to move properly, which in battle could easily create a dangerous situation. The fact that many breastplates with a central screw-joint have a medial ridge at both the thorax- and the abdomen-plate [ref_arm_3751] [ref_arm_3593] makes it unlikely that the system was intended to increase the flexibility. Once the screw would have been tightened, due to these two ridges spanned into each other the plates would not pivot anymore. After all, if the intention was to make the plates pivoting a simple rivet would have been the easiest solution.

For the aforesaid reasons, it is very likely that the detachable connection of the breastplates is linked to the wearing-variations of type-IV breastplates seen on many contemporary artworks. It is possible that the wearer had put the plates on in the following order: First he held the thorax-plate to his body and closed his jacket upon it.[151] Onto this jacket, he now placed the abdomen- and the pelvis-plates and screwed them to the thorax-plates through a button hole or a slit in the fabric.[152] A belt at the waist would hold the plates tight to the body. Together with a close fitting jacket a fastening at the shoulders would probably not be necessary. It is also possible that the thorax-plate was separately fastened under the jacket by two straps, attached to the shoulders, crossed at the back and buckled at the front (see discussion and video above). If the breastplate was fastened in such a combination with the clothing, it would look as if only the abdomen- and the pelvis-plates were worn.

There might have been more types of breastplates that could have been worn in different combination with the clothing. A very special combination is seen on the statue [ref_ill_art_5293]. The figure seems to wear a textile skirt upon the pelvis-lames of his breastplate. It is also possible that this breastplate is of another type – a combination between

151 Some Italian front- and backplates have to be put on together as they are connected via hinges.

152 Torso-protections of the Italian system do not have to be fastened at the central point of the abdomen-plates, as the hinges and buckles at the sides fasten the plates together – the buckles usually attached to the upper points of the abdomen-plates therefore did not have to be fastened.

-III and -IV[153] – and the abdomen- and thorax-plates are worn upon, the pelvis-lames underneath the garment.

153 Tobias Capwell has realized such a type of breastplate for his reproduction of a full suit of armour. He probably took this idea from the effigy-statue of Richard de Beauchamp [ref_ill_art_5233] (descr. 1), at which the connection between the upper and the lower abdomen-plate suggests such a construction. As not a single breastplate of such a type exists, it is likely that the "gap" at the waist of the statue rather derives from a "seam" between the single segments of which the cast is mounted.

4.2.5.3 The fastening of other armour parts

4.2.5.3.1 Arm

4.2.5.3.1.1 Shoulder

Shoulder-defenses in the 15th century were usually fastened to the undergarment via laces close to the upper edge [ref_arm_282] [ref_arm_334] [ref_arm_611] [ref_arm_733]. The tapestry [ref_ill_art_5158] shows a wounded knight whose arm defenses had been taken off. The laces for their fastening are visible at the sleeves of his jacket. Around the year 1500, sometimes the shoulders were buckled, probably to the straps of the breastplate or to a neck-protection [ref_arm_266]. The lower lames of type-II [ref_arm_755] shoulders were usually buckled to the upper arm-defense, but they could also be connected permanently via pivoting and via sliding rivet-joints [ref_arm_605].[154] Type-I shoulders of the second half of the 15th century were usually permanently connected to the upper arm-protection. The upper lames of the shoulders were connected via pivoting [ref_arm_310] or sliding [ref_arm_569] rivet-joints. The lames between the shoulder and the upper arm had at the front side and in the center leather-joints and only at the rear sliding rivet-joints [ref_arm_304].

4.2.5.3.1.2 Upper arm

In the 14th century, the plate could be laced [ref_ill_art_5268] (descr. 2) to the undergarment, later it was buckled to the arm [ref_ill_art_5261] [ref_arm_277]. Upper arms on arm-defenses of the Italian system were permanently connected to the elbow via pivoting rivet-joints [ref_arm_1017]. At the upper end they had leather-straps riveted to the interior. Through this leather the upper arm was laced to the undergarment [ref_arm_3933]. In the center of the painting [ref_ill_art_5372], pairs of arm and leg-protections are hanging at the wall. At their upper ends the interiorly attached leather straps are clearly visible. Some contemporary artworks show the laces at the sleeves of undergarments for the fastening of the shoulders and the upper arm-protections [ref_ill_art_5288] [ref_ill_art_5308]. The German upper arm defenses were connected to the lower arm via interior leather-joints [ref_arm_249].

4.2.5.3.1.3 Elbow

Elbows of the Italian system were fastened by a strap and a buckle to the arm and also permanently connected to the upper and the lower arm via pivoting rivet-joints [ref_arm_143]. The lowest lame in between the elbow and the lower arm was turning via sliding rivets [ref_arm_809]. By the end of the 15th century, in Spain and Flanders the lowest lame was usually connected to the lower arm via simple pivoting rivet-joints [ref_arm_1012]. Elbows in German arm-defense systems were buckled to the arm and riveted [ref_arm_263] or laced [ref_ill_art_5260][155] to the leather-joint in between the upper and the lower arm.

4.2.5.3.1.4 Lower arm

Only lower arms of type-I needed to be fastened by a strap and a buckle [ref_arm_4926]. The encircling plates of type-III examples were closed by a strap and a buckle [ref_arm_723] [ref_arm_248] and the German, Flemish or Spanish models were sometimes closed by a

154 Also some type-I shoulder defenses could be buckled to the upper arm, but it is also possible that these items originally had been fastened via laces at the lower edge, as the pair of holes suggest [ref_arm_329].

155 Due to the detachable arrangement of the single parts of a German arm defense the genuine construction cannot be reconstructed with certainty. The laced variations of extant pieces are modern arrangements, the holes once might have held rivets [ref_arm_254].

spring-catch [ref_arm_365]. In both regions, the flaps were articulating via hinges. To the upper arm the German lower arm-defenses were connected via an interior leather-joint while the Italian examples were turning via a sliding rivet-joint.

4.2.5.3.2 Legs

4.2.5.3.2.1 Upper leg

At the upper edge, these defenses usually had a leather- or linen-strap riveted to the interior [ref_arm_2839] [ref_ill_art_5231] (descr. 1). This was probably laced upwards to a strong waist-belt. There are no depictions that could support this assumption. The knee-lames were usually connected at the big-toe side via pivoting rivets and at the small toe-side via sliding rivet-joints [ref_arm_2366]. The flaps of type-II upper legs were articulated by hinges.

4.2.5.3.2.2 Knee

Knee protections of type-II at the small toe side had sliding rivet-joints and at the big-toe-side pivoting rivet-joints for the connection to the upper and the lower lames. The main plate was fastened to the knee by a strap and a buckle. The lower legs were always connected via a detachable joint like a turning locking bolt together with a strap and a buckle [ref_arm_2413] [ref_arm_2840].

4.2.5.3.2.3 Lower Leg and foot

Italian lower leg defenses of type-III were fastened to the leg by straps and buckles [ref_arm_2308], their German pendants were closed by a spring-catch [ref_arm_2306]. The flaps were always articulated via hinges. The fastening of the foot-protection cannot sufficiently be reconstructed, as only few genuine systems are extant. In some cases, foot protections of type-II were connected by spring-locks [ref_arm_2240]. Type-III defenses had an articulated flap at the heel which was closed at the knuckle via a spring catch [ref_arm_2248]. At Italian armour, the defense was consisting of ring-armour which was directly connected to the lower leg-defense (reconstructed at [ref_arm_2295]). The foot-defenses could also be fastened to the shoe by laces [ref_ill_art_5283] [ref_arm_2956].

4.2.5.3.3 Neck

A neck-protection of type-I or -II [ref_arm_3062] [ref_arm_3044] is usually attached to the wearer's neck via a strap and a buckle. It is rather difficult to reconstruct if or how the lower plate was connected to the breastplate. Neck-defenses at costly armour can be attached to the breastplate via a sophisticated spring lock-mechanism [ref_arm_3066] [ref_arm_3064]. This joint-type made a strap at the neck unnecessary. Several examples show two holes close to the lower edge [ref_arm_3042], but usually breastplates do not have holes at the corresponding locations. Where more or less corresponding holes can be found, it is possible that these holes once fixed a lock-mechanism [ref_arm_3061]. In a few cases, the neck-protection was probably screwed to the breastplate [ref_arm_3034]. The fastening of the neck-protection to the breastplate via a buckle is only evident in artworks [ref_ill_art_5196] [ref_ill_art_5213] [ref_ill_art_5219] (descr. 3). The upper lames were always joined by pivoting rivets. They were prevented from pivoting downwards by a spring-catch at the right side [ref_arm_3099]. Lower plates were permanently riveted to the chin-plate [ref_arm_3090] or via pivoting rivet-joints [ref_arm_3065].

4.2.5.3.4 Head

The interior lining of a head defense plays an important role in the fastening of the helmet to the head. A padded lining already helped to keep the helmet in place. Nevertheless, it is necessary to fasten the helmet also to the chin or to the breastplate to prevent it from slipping off the head when blows stroke the helmet. Despite this assumption, the chin fastening of

early helmets cannot easily be reconstructed. Type-I, -II, – III, -IV, and early type-V helmets never show riveting holes for the interior attachment of a chin-strap. The only possibility is that the chin-straps were either fastened at other constructive rivets like those that held the lining-leather [ref_arm_1345] or they were directly attached to the lining. Type-VI helmets were most likely fastened only via the cheek-plates that also surrounded the chin. Helmets of type-VIII were usually fixed to the breastplate [ref_ill_art_5173] and in some cases also to the backplate [ref_arm_1650]. By the mid-15th century, nearly all helmets of type-III, -V and -VII showed two rivets or rivet-holes at each side below the lining rivets [ref_arm_1381]. Here certainly the chin-straps were attached, usually cut in a Y-shape [ref_ill_art_5346]. A few helmets still retain straps or their fragments from the time of use [ref_arm_1421] [ref_arm_1704] [ref_arm_1759] [ref_arm_1849] [ref_arm_2033] [ref_arm_1860] [ref_arm_1861].

At several helmets of type-III [ref_arm_1348] -V [ref_arm_1787] [ref_arm_2026] and -VII [ref_arm_1743] [ref_arm_1755] at the nape-protection a pair of functionless holes is visible. It is possible that these holes usually held an interior leather-strap [ref_arm_1847] or a staple [ref_arm_1711] [ref_arm_1713] [ref_arm_1732] for the hanging of the helmet to the wall or two the belt when on march. At least for type-III helmets another possible explanation is seen on contemporary illustrations. On the paintings [ref_ill_art_5189] and [ref_ill_art_5147], men-at-arms are wearing helmets of type-III that could be fixed to a buckle at the man's back-protection. The early segmented backplates [ref_arm_4789] [ref_arm_4767] [ref_arm_4792] have corresponding buckles attached at their upper end.

4.2.5.3.5 Hand

The plates for the protection of the hand were usually for one part fastened to the hand via a permanently attached lining-glove. The oldest type-I examples do not show any additional fastening via a strap and a buckle. A few simple type-I hand-protections of the first half of the 15th century were worn without a lining [ref_ill_art_5211] (descr. 2) and therefore fastening-straps became necessary. As the cuffs of type-III and -IV hand-protections in the second half of the century were articulated, a second strap became necessary for the fastening of the cuff. A brass effigy shows in details how a single Y-shaped leather strap could alternatively fasten both, the wrist and the cuff at the same time. The strap seems to use the same rivet as the articulated joint [ref_ill_art_5353]. At the hand-protections [ref_arm_1044] the strap is attached similarly. Type-III and -IV hand-protections only rarely had an entirely enclosing flap at the cuff. One example is [ref_arm_1060], where the flap is locked via a spring-catch. Several examples have a short flap only that is fastened via a strap and a buckle and articulated by one hinge, frequently attached to the thumb-side[156] [ref_arm_1075] [ref_arm_1081] [ref_arm_1245]. On some examples the two holes at the corresponding location of the cuff suggest that a flap-hinge had once been attached [ref_arm_1078] [ref_arm_1080] [ref_arm_1128] [ref_arm_1228] [ref_arm_4904]. There is one very special version of type-I hand-protection. This is the only example where the plate is not completely enclosing the wrist, but instead an articulated flap is attached at the pulse-side [ref_arm_1264].

156 Exceptions are [ref_arm_1060] and [ref_arm_1209] together with their counterparts. At the hand-protection [ref_arm_1209] it is possible that the right and the left cuff were accidently confused and erroneously mounted at the wrong hand-side. The items had obviously been restored and altered; the hinges for the flaps are missing.

4.2.6 Applications

4.2.6.1 Lining

The iron plate itself is inflexible and hard, an uncomfortable thing to be worn directly on the body. The armourers had to find solutions on how to make the wear more convenient and safer. Therefore, certain field armour parts of the considered period where necessary were equipped with an interior lining[157]. Without exception, all neck-protections – with the exception of those attached to helmets of type-VI – and of course all helmets were only usable with a padded lining. Leather gloves inside hand armour were most likely not padded. In the considered period, linings at protections for the limbs for the convenience of the wearer are not known and also torso-protections are usually not padded.

The traces that lost linings left at the objects – mainly empty holes – and the knowledge that the item once must have been padded are the basis for the reconstruction of the former attachment. If no traces of a lining – i. e. no holes – are visible, or where visible holes make no sense, the question might be asked if the object could function at all and could thus be a reproduction. In the following the different extant examples of linings are discussed.

4.2.6.1.1 Arms and legs

The only application that could be considered as some sort of lining for limb protections are leather straps riveted interiorly along the edges. They appear where the unturned plate edges would wear off the fighter's garments worn underneath, e. g. at the flaps of the upper legs [ref_arm_2839], where some fragments survive[158]. Here it also seems like the leather at the upper end of the main plate, through which the leg armour was laced to the undergarment, was also interiorly lined with linen-fabric. This should probably prevent the garment from wear by the rivets that hold the leather. The fabric also prevents the leather from getting stretched by the wearing-stresses. Also the interior upper edge of the lowest knee-lame was often equipped with a leather strap [ref_arm_2367] [ref_arm_2371]. Where plate-edges would permanently scratch the surface of other subjacent armour parts, such straps are attached. It seems like this technique was widely adopted in the 16th century. At the armour [ref_arm_5105] the shoulders and the torso-upper leg-protections have their edges lined with red velvet, probably attached in the late 16th century[159]. No elbow or knee defense with an interior leather strap at the edges of the shell like extension is known to the author. No other example seems to exist until by the very end of the 15th century the shoulders [ref_arm_528] seem to have leather straps at the inner sides of the wings, where they would scratch the breast- and the backplate. The early shoulder [ref_arm_881] still retains its lining being made of fabric and covering the entire interior surface. It is horizontally colored by green and white stripes and has no padding.

Limb-protections need to fit closely to the body so the wearer is free in his movements. This is probably the reason why such armour was never padded. It was probably considered sufficient to wear a thin but strong undergarment. These assumptions are supported by the fact that all extant limb protections before 1500 are very close fitting and lean in their design.

157 Horse-head-protections were usually also padded.

158 At the left counterpart [ref_arm_2370] the leather straps are modern replacements.

159 Thomas and Gamber (1976), p. 182.

4.2.6.1.2 Torso

Breast- and backplates in the late Middle Ages never were padded. Only at one early breastplate [ref_arm_3811] an interior large leather lining survives. It also holds the segments of this breastplate together. The breastplate [ref_arm_3428] might once have been equipped with a lining. Along the edges of each "valley" of the embossing a small hole can be seen. It is possible that they once held outer metal-bands in place (compare [ref_arm_3621]) or they even spanned an exterior cover into the "valleys", so the fabric or leather would follow the pattern of the embossing. One detail that supports the former attachment of an interior lining is a rivet remaining in one of the said holes under the left arm-cutout. Interiorly it still retains a small washer[160], which would only make sense if it held some organic part in place. As this breastplate has been altered and re-used in later times, these questions might never be answered sufficiently. One possible constellation is that the breastplate had been riveted to an undergarment, maybe itself reinforced interiorly like [ref_ill_art_5263]. There are breastplates of the late 15th [ref_arm_3426][161] or early 16th [ref_arm_3473] century with small holes along the edges. The purpose of these holes is uncertain. They could have served for the application of an interior lining or an exterior cover. Bullet-proof „Kürassier" breast- and backplates from 1600 on do often have an interior, usually padded lining.

Torso-upper leg-protections seem to have had no interior leather straps along the edges before 1480 ca. The earliest examples might be [ref_arm_3782] and [ref_arm_3837]. The holes or rivets along the edges lead to the assumption that the torso-upper leg-protections once held leather at the interior. At the lower edge of the examples [ref_arm_3574] and [ref_arm_5106] small rivet heads are visible, which probably still hold a leather strap interiorly. As the small iron rivet heads differ from the otherwise capped heads found elsewhere at the suit, it is possible that the leather bands had been attached secondarily.

4.2.6.1.3 Helmets

The head is one of the most exposed and thus most vulnerable parts of the fighter's body. Therefore, it needs special protection against blows of any kind. While the shell of a helmet should resist penetration in each situation, still the wearer's head could get injured by the shock transferred directly from the plate to the skull. A padded lining can reduce the force of such an impact. It also helps to keep the helmet in place in situations of fierce fighting or other fast movements like running or riding. This is especially important as a sliding of the helmet could block the wearer's sight. It is very unlikely that any war helmet had ever been worn without some kind of lining or padding. This does not necessarily have to be fixed to

160 When the author has seen and photographed the breastplate in 2007 it had a tin coating, which had unfortunately disappeared until February 2011. The washer is made of copper alloy. The tin coating could prevent from copper-oxides emerging easily by the exposure to body sweat, which would lead to a local destruction of the lining material.

161 Here all closed by rivets. Maybe this breastplate is composed from two other, younger ones of type-II. The said holes appear at simple breastplate for infantrymen (e. g. [ref_arm_3498]), but on no such a richly decorated comparable example. The pattern of the embossing reminds more on a backplate, with the several ridges at the abdomen-plate decorating the center of the pelvis-lames. It is also unusual that these ridges run over to the thorax-plate. This feature is often found on backplates, just like the appending [ref_arm_3264]. The latter does not show the small holes. For the breastplate neither an interior lining nor an exterior cover makes sense, as the thorax has an articulated joint to the abdomen-plate, which would be stiffened by such an application. If the breastplate was made of two simple ones of type-II, it is till unusual that the abdomen-plate lacks the cutouts at the sides of the waist, which is frequently found at Breastplates from 1500 ca.

the plate itself, but can also be designed as a separate padded cap. Helmets of type-I – probably used since the high Middle Ages [ref_ill_art_5180] and usually very difficult to date – after 1350 might still be worn with such a cap underneath.[162]

From 1350 on helmets were usually equipped with a fixed padded lining. Exceptions were probably helmets of type-II, which were large enough to be worn upon a helmet of type-IV or -V. These helmets did not necessarily need a lining, even though they might have had one to fix the outer helmet in a position that ensured a free sight. On a few 14th century sculptures, linings inside helmets of type-II are visible [ref_ill_art_5278] [ref_ill_art_5398]. Contemporary paintings show the interior of helmets of type-VII [ref_ill_art_5178] and of type-V [ref_ill_art_5192].

For the study of the former appearance and functionality of linings, items from the Armoury of the castle of Churburg are of great significance. From a total of about 29 linings or their fragments [ref_arm_1420] [ref_arm_1799] [ref_arm_2067] [ref_arm_2113] already 11 are in the Churburg collections, while 3 further examples (=14) were sold from there and are now in other collections.[163] The linings inside the helmets [ref_arm_1803] [ref_arm_1804] are replacements, attached in the last hundred years ca. Extant linings that most likely resemble the original or oldest arrangement are made of a row of several triangular gussets, fastened at the points with a cord to form a dome [ref_arm_1732] [ref_arm_1787] [ref_arm_1797] [ref_arm_1849] [ref_arm_1858] [ref_arm_1859] [ref_arm_1860] [ref_arm_1861] or they form a closed padded cap [ref_arm_1745] [ref_arm_1812] [ref_arm_1978] [ref_arm_2033] [ref_arm_2180]. At the type-VI helmet [ref_arm_1932] the lining is elaborately tailored to cover the complex-shaped interior while allowing for the cheek-pieces to get opened. This is the only lining of a type-VI helmet to survive. According to the few helmets still retaining an original lining, it usually has been made of plant-fiber fabric. For costly armour this (or the later replacement) could also be made of more comfortable material. At one type-III helmet a lining of green velvet is attached [ref_arm_1418]. In the case of [ref_arm_1495] it is made of wool.[164] The lining material is usually very fragile, at most extant armour pieces it had fallen to dust. Nevertheless, the comparison of empty holes or "useless" rivets with the lining-attachment of surviving examples sheds some light on the fastening of the lost organic parts.

Five different attachment-types of interior linings can be observed. The first is remarked by few pairs of larger holes at different locations on the skull, usually only found on helmets of type-II [ref_arm_1463], -VII [ref_arm_1732] [ref_arm_1797][165] and -VIII [ref_arm_1645]. Through these holes the lacing of a separate padded cap was passed and tied at the outside. By using different linings, such helmets could thus become adjusted to another head-size, e. g. for changing users of tournament armour. In the HJRK in Vienna several of such linings for tournament helmets are preserved. The author has examined two examples in a private collection [ref_arm_1637] [ref_arm_1638]. The helmets of type-II from before 1500 are so

162 This is the most likely for e. g. [ref_arm_2093] (which is probably made before 1350), as this helmet shows no holes for the attachment of an interior lining at the forehead. Simple skull caps nevertheless needed some application to fix the helmet to the head. This could have been achieved by leather straps attached to the lower edge above the ears or by lacing the helmet to the padded cap worn underneath, which itself was fastened under the chin.

163 It was a tradition of the Trapp family to maintain the collections, see: Scalini (1996), p. 17 (in German).

164 Trapp (1995), p.22-23.

165 Note that both helmets also have a permanent lining. This makes it difficult to understand what the pairs of holes were for.

rare and also usually in bad condition – most of them are archaeological finds – that it is difficult to reconstruct the former attachment of the lining. The pairs of holes found at the upper skull of such helmets did not necessarily serve the purpose of holding a lining. They could just as well have served for lacing the crest and the mantling[166]. There is only one example of type-IV [ref_arm_1515] that shows holes in the skull which might[167] have served for a detachable fixing of a lining.

A second type of lining was attached permanently. Many helmets from the earlier years of the considered époque – of type-I, -IV, -V, -VI and -VIII – have small narrow holes all around the lower edge and the face opening. These served for attaching the lining by a seam of linen thread. At least three examples with a lining stitched directly to holes in the plate do survive. At the helmet [ref_arm_1529] it is not clear whether the lining is genuine or a replacement. It is the only lining to survive that is made of leather. The copper alloy thread-eyes at the points where this lining could be adjusted in size are remarkable, but in the Middle Ages it was not uncommon to strengthen stressed holes this way. The two other examples of extant linings are in the Churburg Armoury [ref_arm_1495] [ref_arm_1559]. The lining of the latter is made of rough linen, padded with horse or cow hair[168].

The third type of lining is usually sewn to an interior leather strap. From the late 14th century on, helmets of all types do usually have a line of larger holes – wider apart from each other – circumferential around the narrowest circumference of the skull, right above the line of the ears. Often the holes still retain rivets which once held the interior lining. In most cases an encircling interior leather strap was or still is fixed. The lining itself was sewn to this band [ref_arm_1797].

The fourth is a special type of attachment, remarked by an iron plate strap riveted interiorly to the forehead. This forms a kind of bridge from the left to the right temple. Such straps are found on helmets of type-III [ref_arm_1404] [ref_arm_1408] as well as on type-VII [ref_arm_1743] [ref_arm_1797]. The lining was either riveted directly to this plate or it was stitched to a leather band riveted to it. It is not clear what the purpose of this construction was. No study of helmets seems to have noticed it at all. For some reason, this part of the lining was probably supposed to be taken off with ease – without opening all the common frontal rivets. By fixing the lining like this at helmets of type-VII with an upwards pivoting face-guard, no rivet head would block the visor. As this system also appears at helmets with a full, not articulated visor or at helmets of type-III, there might also be a different, yet unknown explanation.

All linings attached in one of the aforesaid ways could be replaced more or less easily. The armourer obviously intended to allow a comfortable exchange or repairing of worn out linings. Opening rivets for the detachment of the lining would have been time consuming and expensive, as the old rivets could not be used again. The leather strap was perforated at its lower edge by small holes, before it was riveted to the helmet. Sewing the fabric to the leather or plate strap was easily done with the help of a bend needle or a pig's bristle. No armourer's skills were necessary for this work.

The fifth lining-attachment requires the opening of all rivets for the replacement of the lining. In some cases, the linen-fabric of the lining had been riveted directly to the plate just above the ears [ref_arm_2113]. At the helmet [ref_arm_1710] this way of lining-attachment is most likely not the genuine arrangement. The helmet once had a visor with a forehead reinforce.

166 This is a small heraldic blanket in between the helmet and the crest.

167 In these holes also metal wedges similar to those on e. g. [ref_arm_2121] might have been fixed.

168 Trapp (1995), p. 29.

This is traceable by the pivot holes at the skull and the corrosion marks at the forehead which follow the lines of the integrated reinforce of the lost visor. The rivets of type-a, holding now the lining, are most likely not those of the helmet's production time, as two rivets of type-b survive at the right side of the skull. These probably once held the chin-strap. Interiorly the washers at these rivets still remain. It is very likely that all the rivets covered by the closed visor were indeed of type-a, whereas the visible ones originally were of type b, holding an interior lining leather-strap. At some unknown later time, the qualitatively very crudely worked and unpadded present-day lining was attached. Also the velvet lining of the helmet [ref_arm_1418] is probably not of the production time of the helmet. It is riveted directly to the edge of the brim. Above the ears, the helmet has circumferential rivets – probably these once held the genuine lining.

4.2.6.1.4 Hands

Hand-protections are easily fastened to the hand via a glove fixed to the plates. Hand-protections with single protected fingers will only work with such a lining. On many depictions an interior leather or fabric glove is shown, e. g. on [ref_ill_art_5224]. In the painting [ref_ill_art_5210] it is not clearly visible if the depicted hand-protections are equipped with a glove, but a red lining can clearly be seen in between the hand and the plate. Simpler or one-piece hand-protections might have been fastened with a strap and a buckle only. Also simple, fingerless gloves seem to have existed [ref_ill_art_5331]. The gloves were either made of plant-fiber fabric or of leather. In only a few cases these linings do survive. Also here the Churburg Armoury preserves the largest number of all existing examples [ref_arm_1096] [ref_arm_1142] [ref_arm_1150] [ref_arm_1165] [ref_arm_1167] [ref_arm_1258] [ref_arm_1259] [ref_arm_1301]. Also items of other collections still retain a lining, most likely from the times when the armour was in use [ref_arm_1061] [ref_arm_1202] [ref_arm_1296] [ref_arm_4904].

4.2.6.1.5 Neck

A neck-protection only makes sense if it is fitted with a padded lining. Without a thick padding, a frontal blow would make the plate hit the chin directly. Each genuine neck-protection of type-I and -II had a lining, but most of them are lost. Only the type-II neck-protections used exclusively together with visored helmets of type-VI [ref_arm_3065] needed no lining, as they were worn exteriorly on an entirely closed and padded helmet. The only two existing neck-linings from the time the armour was in use are found at [ref_arm_3059] and [ref_arm_3201]. Both are made of linen, padded with plant-fibers.[169] The lining was usually sewn to a leather strap which itself was riveted to the interior of the most upper edge. At neck-protections of type-II, the lining could additionally be sewn to a second leather strap, riveted to the lower edge of the chin plate. At the item [ref_arm_3157], rivets with rests of leather remain at this edge. Alternatively, at some objects the lining was possibly directly stitched to the plate, as the row of small holes at the upper lame suggests [ref_arm_3076]. Type-II neck-protections with a vision- or ventilation-slit at the upper lame never show holes for the attachment of a lining. A look at the interior makes clear that at these items the lining was sewn to a leather strap at the upper edge of the chin-plate [ref_arm_3133]. Also at some other necks with an articulated upper lame, but without a slit, the lining seems to have been fastened this way [ref_arm_3082] [ref_arm_3106]. The thorax-protecting plate of some neck-protections might have had a lining too, as the small holes along the edge of some plates suggest [ref_arm_3141] [ref_arm_3100].

169 For [ref_arm_3059] see: Trapp (1995), p. 73.

4.2.6.2 Exterior cover

Contemporary documents tell that already in the early 14th century helmets occasionally were covered by fabric.[170] A source of the first half of the fifteenth century speaks of a velvet covered breastplate and a helmet.[171] The miniature [ref_ill_art_5222] shows what a suit of fabric-covered armour of about 1440 might have looked like.

It is difficult to exteriorly cover armour decorated by ridges or other embossing. The fabric would have to be spanned into the "valleys" with the help of rivets or by means of a glue. There is a helmet of about 1510 in the BNM (acc. no. W4896) with a glued cover of red velvet. Probably also the cover of the helmet [ref_arm_1745] is glued and riveted, as it is still very close fitting and even fragments remained in place.

The oldest example of a fabric-covered armour-part is the breastplate [ref_arm_3698]. The red velvet is riveted to the plate by hundreds of rivets. A large number of other objects once has certainly been covered exteriorly, as fabric-remains [ref_arm_3734] rivets [ref_arm_1336] or the functionless rivet-holes suggest [ref_arm_1702] [ref_arm_1729]. Several helmets of type-V [ref_arm_2142] [ref_arm_2126] [ref_arm_4373] still retain a velvet cover, but these could have been applied at later times in the 16th or 17th century – judging by the renaissance- or baroque-style copper alloy applications at these helmets.

In the DIA there is a painting of Saint George in full armour from about 1430 [ref_ill_art_5162]. His breastplate is covered with white fabric or leather which is laced all around the edges by small bands that have metal points at their ends. Only the lance rest sticks through the cover. It is clear, that this cover was meant to be taken off easily.

4.2.6.3 Copper alloy applications

Already some of the earliest extant plate armour is decorated by ornamental copper alloy applications. In some cases, only functionless rivet holes testify of the former attachment of applications. In the following, the purpose, the origin, the genesis and the production techniques of such applications will be examined. Due to the presumable high price and the good quality of all objects decorated with copper alloy ornaments, it can be postulated that all of them are made for the well situated, probably knightly fighters and not for the simple infantrymen.

4.2.6.3.1 Purpose

Where straps are attached to the outer edges of armour, they enlarge the radius similarly to a turned edge, thus their function could have been to prevent injuries to the wearer by cuts from the plate edge. Copper alloy applications can furthermore simply intend to decorate the item, but some of them also transfer a message: e. g. the leopard at Edward of Woodstock's hand-protection [ref_arm_1303] refers to its owners coat of arms and to his virtues being the same like those of the animal: speed, strength, power, dignity etc.; the copper alloy fragments on [ref_arm_1265] have a verse of the bible inscribed.[172] Due to the still bluish appearance,

170 The document of 1322 forbids the armourers of London to cover their helmets with fabric, as the quality of the work should be easily visible, see: Ffoulkes (1912), p. 169-170.

171 A 1436 handover-inventory from Wiener-Neustadt amongst many other armour parts mentions: …item 15 gancz eisnein [i. e. iron] platten; item ain roten samadtein [i. e. velvet] platten und ain rot samadtein helmlin, from: Jahrbuch der Kunsthistorischen Sammlungen in Wien (1883), Reg. 48.

172 For the interpretation of the inscription see: Grönwald (2010), p. 187.

it is possible that the early items [ref_arm_1251] [ref_arm_1259] [ref_arm_1278][173] [ref_arm_1280][174] [ref_arm_1298] [ref_arm_1301] [ref_arm_1265][175] formerly had a blued surface that made a colorful contrast to the maybe gilded, but certainly polished copper alloy applications. The same effect can be presumed for objects of the second half of the 15th century which show decorative copper alloy applications and ridges or other embossing at their main plate. For example at the objects [ref_arm_2126] [ref_arm_2142] the extant fabric cover of red color was meant to contrast with the yellowish copper alloy ornaments. Nevertheless, in all the aforesaid cases it is not sure when the decorative straps had been attached to fabric-covered items. In summary, it can be established that the character of copper alloy applications is merely of a decorative nature, as they bring an unnecessarily additional weight to the armour while fulfilling no indispensable constructional or defensive task.

4.2.6.3.2 Genesis

It can be anticipated that yellowish applications are depicted in hundreds of contemporary artworks all throughout the considered period and everywhere in Europe [ref_ill_art_5211] (descr. 3) [ref_ill_art_5220] [ref_ill_art_5217] [ref_ill_art_5221]. The lack of decorative copper alloy straps on segment-armour pieces is noticeable. The earliest examples of copper alloy applications are found at plate armour from the 1360ies onwards. Maybe the most prominent substitute for the earliest costly decorated armour is the Churburg suit [ref_arm_4098], which is also the most complete extant ensemble of the time. The few other similarly ornamented plate armour items from before 1400 are all just as well attributed to northern Italian production. The largest group of items decorated with bands consists of helmets of type-IV, in use between 1390 and 1420. On the right hand-protection of pair [ref_arm_1263], [ref_arm_1303] at the small finger knuckle embossing a gilded cast copper alloy leopard is attached. It is likely that all eight finger knuckles once were highlighted by the same figure. These hand-protections are unique in being made entirely from gilded copper alloy plate.

Only few items with copper alloy applications of the years between 1420 and 1460 can be found. The only items of this period related to the aforesaid examples by the decoration technique are [ref_arm_117] and [ref_arm_879] – probably made in Italy in the sixties of the 15th century.[176] The remains of ornaments punched into the surface are found here at the iron bars at the lower edge – where normally a turned edge would be expected.

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173 At the pulse side of this hand-protection a part of the copper ally strap at the cuff had been replaced, probably in the time of use. The alloy appears a bit more reddish than at the other applications. The replacement is not decorated by engraving and the embossing resembles the fine quality of the other part only very insufficiently.

174 The roped copper alloy ring encircling the wrist of this right hand-protection is missing but can be reconstructed like the one at the left counterpart [ref_arm_1278].

175 Only two small detached segments survive, for the interpretation of the inscription see: Grönwald (2010), p. 187.

176 These items have not been examined in the collections and therefore conclusions are drawn here carefully. They had been excavated comparatively recently together with many other armour items at Cesis Castle. Even though displayed separately, the single parts of the lower arm [ref_arm_117] most likely belong together, as the remains of the hinges and the corresponding holes and decorative bands suggest. This together with the shoulder [ref_arm_879] is maybe what remains of an associated arm defense. The fact that the objects were found together and the ornamentation of the bands being the same at both items underline this assumption.

In the following years – again only according to extant[177] armour parts – the Italian armourers seem to have stopped the decoration of their products with copper alloy applications completely, with the exception of the aforesaid fabric covered helmets.

A rare mid-15th century helmet of type-III [ref_arm_1354] has fretwork decorated copper alloy bands attached to the brim. It is sandwiched between the plate and a roped band, the latter made of iron. This helmet is attributed to Burgundian origin, but as depictions are rare and – together with the similar objects [ref_arm_1397] [ref_arm_1424] [ref_arm_4197] – it bears no mark, this provenance remains a vague suggestion. A special group of type-III helmets, frequently attributed to Spanish production, often has a broad circumferential copper alloy band attached in the height of the ears. It is usually gilded and decorated by engraved acanthus-twines or inscriptions. These helmets are most likely made in the years between 1470 and 1500. No other Spanish armour-type is known to have been decorated by copper alloy straps.

From the 1470ies on, also the German armourers began to decorate their products with copper alloy ornaments. Armour made in the German speaking lands continued to be occasionally decorated by cast copper alloy applications until the late 15th century.[178] It seems like from then on the copper alloy ornaments were replaced by etched and gilded decorations directly applied to the iron or steel surface.

4.2.6.3.3 Techniques

In most cases, the applications are attached by means of iron or copper alloy rivets. Only the suit [ref_arm_3258] at the knees [ref_arm_2699] and at the breastplate [ref_arm_3615] has the bands fixed by screws. At [ref_arm_1354] they had been riveted and embraced by tin solder.

Only at the suit [ref_arm_3241] the copper alloy applications are plain, undecorated straps of plate. In all other cases, the decorations form either a pattern in relief or ornaments are embossed, engraved or punched into the surface. In the case of [ref_arm_1259] the engraved and punched decoration of the copper alloy straps extends also to the surface of the iron-plate.

All copper alloy applications to be found on extant plate armour are based on casting techniques. The difference between the techniques is that one allows the direct final shaping of the object[179], while the other one produces only the basic material that needs to be shaped and/or decorated by further treatment. In the latter case a billet is cast and subsequently

177 Contemporary artworks do not suggest that Italian armour after 1460 has not been decorated by applications. Andrea del Verrochio's equestrian statuette of Colleoni of 1496 at the Campo Santi Giovanni e Paolo in Venice shows relief-like decorated straps attached to almost all edges. On a painting of Titian [ref_ill_art_5397] a helmet of type-VII with a gilded and ornamentally engraved comb is shown. Also the edges and the rivet heads seem to be made of gilded or polished copper alloy. This helmet is almost identical to a second one, depicted on [ref_ill_art_5221]. The main difference is the black color and the visor, which is lacking at the helmet mentioned first. Also an effigy from about 1441, showing what is probably the English adaption of Italian armour, shows attached decorative straps [ref_ill_art_5265].

178 Famous examples with gilded or silvered applications are: RA, suit II.5 of Henry VIII., c. 1514; HJRK, suit A109 of Archduke Karl, later Emperor Karl V., c. 1514, both of the "Faltenrockharnisch"-type made in Augsburg by Konrad Seusenhofer; HJRK, "Blau-goldener Küriß" suit A578, c. 1557, anonymous master, probably Augsburg.

179 This is the lost wax technique. Even though there is a small possibility that they were filed from a block, due to the relief like appearance of the greatest symmetry, the production of the bands in a casting technique seems very likely.

forged into a strap of plate or into the desired profile [ref_ill_art_5314], which subsequently could be further treated by cold work. The straps produced by such a technique were most likely supplied by specialized craft-branches and in the armourer's workshop they got only adjusted and decorated. The necessary skills and tools were those of the armourer's everyday business. The bands were embossed by chiseling the patterns from the interior. A block of lead was placed in between the metal and the workbench or anvil. Subsequently the ornaments and inscriptions were engraved or chiseled and polished. Some works of Caspar Rieder of Innsbruck are decorated with copper alloy bands with open-work pattern, simply cut into a plate-strap [ref_arm_1096] [ref_arm_1142]. At other items of an anonymous master, fragments of fretwork-decorated bands do survive [ref_arm_1063] [ref_arm_1081]. Most likely these two hand-protections come from the same workshop. At least the same workshop made the copper alloy bands as the pattern is identical. Also the shape of these straps is simple enough to have been cut from a plate strap. The copper alloy bands decorated by fretwork are usually attached along turned plate-edges.

The cast ornaments have most likely not been made by the armourer himself. The technique demands a high degree of specialization. After the armourer had finished his product, he probably gave it to a goldsmith or another craftsman capable of casting copper alloys. This worker then designed the desired applications in wax and fitted them exactly to the curves of the armour part before they were cast by the lost-wax technique. The leopards at [ref_arm_1303] had most likely been cast by this method. Judging by the existing genuine items, it seems like mainly in Augsburg in the last 3rd of the 15th century applications were produced by this technique [ref_arm_3258]. All of these items are attributed to the workshop of either Lorenz or Jörg Helmschmied.

4.2.6.3.4 Reproduced ornaments on genuine armour

The suit [ref_arm_4141] has been ignored by scholars so far, as it was thought to be entirely a reproduction. The suit was probably made by Winkelmayer in Vienna[180] and it was bought by the BMA as a reproduction, but a closer look reveals that the helmet is actually a genuine example of the rare "black sallet" type-VII helmets [ref_arm_1702]. Some of the small holes at the lower edge – typical for this helmet-model – are now used for the fastening of copper alloy applications of the same type found at other parts of this suit. The edges of this helmet had never been turned and thus its simple appearance did – in the eye of the former restorer or reproducer – not fit to the knightly suit. Therefore, an un-knightly helmet had gained some dignity by the attachment of golden colored applications.

For the same reason, the plain copper alloy bands were attached to the helmet, armpit, neck, hand and knee protections of suit [ref_arm_3241]. James Mann suggested that the Nuremberg art dealer Pickert, who in 1861 had acquired the full panoply from the armoury at Hohenaschau castle in Bavaria, had arranged for the completion and decoration of the equestrian armour.[181] The hand-protections of this suit [ref_arm_1045] [ref_arm_1109] are reproductions.[182] Nevertheless, similar, undecorated bands are depicted in several contemporary artworks [ref_ill_art_5155].

Some of the copper alloy straps of suit [ref_arm_3236] are reproductions. Bashford Dean in his description of this suit states *"that six of the original latten bands are still present"*[183]

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[180] See discussion below in chapter [New recognitions on marks] and [A suit in the BMA].

181 Mann (1962), p. 13-14.

182 Mann (1962), p. 11 and Edge and Williams (2001), p. 235.

183 Dean (1925), p. 134.

and gives a drawing of four different types of decorations found on these bands. Unfortunately he does not say which of the current bands are replaced and which are genuine. Without a closer examination this remains impossible to tell. At the pair of hand-protections [ref_arm_1037] and [ref_arm_1163] – not belonging to the aforesaid suit – the bands were maybe also reproduced on Bashford Dean's instructions.

The suit [ref_arm_3244] seems to be composed of different items that once did not belong together. To cover this spot of bother, copper alloy bands were attached to the edges of the helmet, the neck, the breastplate, the front of the hips, the backplate, the elbows and the hands. The straps are ornamented by crude fretwork.

Even at the precious and certainly genuine armour in Vienna reproductions of bands attached. The applications at [ref_arm_1927] were attached in the 19th century to match the helmet to one of Helmschmied's suits.[184]

4.2.6.3.5 Lorenz Helmschmied's works in Vienna

Due to their elaborate craftsmanship and the influence they had on many reproductions, the decorative copper alloy attachments on the armour parts of Lorenz Helmschmied must be discussed here in detail. Most of the field armour parts attributed to his workshop typically have or had copper alloy straps riveted at chosen edges. They do either appear at overlapping, but also at outer plate edges.

It seems like only armour from the HJRK in Vienna bears both together, Lorenz Helmschmied's mark and the typical ornamented bands. Unmarked items in other collections are usually ascribed to his workshop whenever they bear bands similar to the Vienna examples or show other similarities to his works. Some items are indeed marked by him, but they lack the typical straps as they either got lost [ref_arm_3214] or had never been attached [ref_arm_3243] [ref_arm_3695] (no rivet-holes are visible).

Restorations of the 19th century certainly altered the genuine appearance of the Vienna items. The objects had to be cleaned and refurbished for display, probably before 1889, when Wendelin Boeheim opened the collections for public.[185] Parts of the applications had until then certainly been lost or detached, probably due to inappropriate handling throughout the centuries to which the copper alloy rivets did not resist. They might have been taken off for cleaning or for the recycling of the valuable material. The presumed restoration of the 19th century had to replace what still existed and to complete what was lost to finally achieve a uniform appearance of the reassembled suits.

Basically six types of bands, different in construction and design do appear on Helmschmied's products. All of these include a band of roped decoration, which varies in its design from object to object.

1. In the first case, under the roped strap a flat band with fretwork-like cutouts is sandwiched. This band forms rows of fleur-de-lys symbols, touching each other with the point of the side-leafs, leaving heart-shaped penetrations in the bands. At the base of each fleur-de-lys, a small gore is undercut into the surface. The profile of these decorations reminds on the 'gothic'

184 See: Thomas and Gamber (1976), p.97. It would be interesting to examine the lower edge of this helmet. If the present applications were not replacing other, similar attachments, the lower edge must presumably have been turned once before.

185 Thomas and Gamber (1976), p. 10. The restorations might have been carried out between the years around 1863, when plans for a public display were founded, and 1889 when the items came on display.

tracery of contemporary architecture.[186] The armour plate, the fleur-de-lys and the roped band are usually riveted together in the said order by means of single thin copper alloy rivets. The bands do follow exactly the curves of the plates. At the endings of the bands, where the plate edges are curved or pointed and where large rivet heads are placed upon the bands, the fleur-de-lys pattern changes to a wider and more decorated surface, or the pattern is changing to a more simple form. Here it also becomes clear that these and the decorations discussed below (2.) were most likely made by the same workshop: The bands on item [ref_arm_1246] are ending in a convex bow instead of the expected fleur-de-lys. At the pair of leg armour [ref_arm_2819] [ref_arm_2818] [ref_arm_2479] [ref_arm_2480] they are even ending in a row of four of such bows. As said above, even in the Vienna collection the authenticity of most of such extant bands is uncertain as very good copies have obviously been made for at least one of the Vienna objects [ref_arm_1927]. Underneath the ornamental bands at the pelvis-lames of the breastplate, lines filed into the surface of the iron plate can be seen through the cutouts [ref_arm_3615]. The same filing is found at the lowest pelvis edge of the backplate [ref_arm_3302]. These lines are maybe the remains of an embossed roping that at some date before 1584 were leveled by the hammer.[187] They are visible very strong and it does not seem like attempts were made to grind them off completely. If the plate once was embossed here, it is very unlikely that bands had been attached from the beginning, neither at the pelvis-lames of the breast- nor at the backplate. Besides this, at the latter no holes for the attachment of bands are visible, so the attachment at the pelvis-lame of the breastplate can be challenged as being original. It is therefore impossible to tell if other bands of the same type are genuine at all. Nevertheless, there is one example of decorated straps in another collection that can serve as a hub for what might be genuine and what might be restoration at the Vienna items [ref_arm_4904]. This hand-protection appears already in an inventory of the armoury of the Bürgercorps of Freiburg written down in 1845.[188] Its decorative bands had been taken off and refitted at some time, as the inappropriately large-headed iron rivet-joints suggest. These rivets also fix the interior leather glove to the plate. This fact makes it very likely that the alterations were carried out during the times when the hand-protection was still in use. Therefore, it is very unlikely that the bands are reproductions. As they exactly resemble the ornamented straps at certain Vienna items, they support the suggestion of the latter being genuine. Also the effigy of Jörg von Waldburg [ref_ill_art_5366] (descr. 1) can help to identify the genuine appearance of ornamented bands. The edges of his armour are decorated by stripes of fleur-de-lys and a roped band – resembling very closely those on the works of Lorenz Helmschmied.

2. The second type of sandwiched band is characterized by a row of directly adjoining convex bows. This decoration is much simpler in comparison to the fleur-de-lys bands. The bands are only decorated on the surface and no example shows any fretwork decoration. At the pair of elbows [ref_arm_35] [ref_arm_38] each bow is punched with a C-shaped mark. The identical bands at the two pairs of hand-protections [ref_arm_1209] [ref_arm_1247] and [ref_arm_1245] [ref_arm_1272] show a more detailed punched decoration of single lines, leaving a mark that looks similar to a wedge of a mandarin. No other objects decorated similarly could be found in the course of this study. It is noteworthy all examples are either

186 Tracery is occasionally also found at contemporary arms, like crossbow-winches (in Engl. Literature called “cranequins”) or sword-pommels.

187 At other items of Lorenz Helmschmied [ref_arm_3294] and [ref_arm_3695] a roping at the lowest lame has been leveled, too. At the backplate [ref_arm_3695] the pelvis has been prolonged by one additional lame. The second lowest lame shows interiorly the remains of the former roped embossing, once being the lowest border of the pelvis.

188 See: Goll (2009), p. 46.

found on hand or on arm-protections. No other body protection with such a decoration seems to survive, with the exception of the related bands mentioned here under 5. (again on hand-protections).

3. Due to their design variations, in the following the different roped bands will be described in detail. Basically they are all designed by sequences of wide, plane and twisted fields alternating with a fine line of stylized pearls. On at least two objects these bands appear solely, without the sandwiched band underneath [ref_arm_3613]. Thomas and Gamber are suggesting that these bands might have belonged to breastplate [ref_arm_3611], where they probably were taken off around 1495 for the attachment of adjacent torso leg-protections.[189] These straps could also derive from another, now lost breast- or backplate, or they are reproductions of the 19th century. It is also possible that they once had a second, fretwork decorated strap sandwiched underneath. The fine fretwork in the center of the lowest pelvis-lame supports this assumption – this would not match to an undecorated lower edge. The helmet [ref_arm_1971] at its lower edge is also decorated by a single roped band. The lower edge of this helmet had been decorated by gilded ornaments on a blued background.[190] The yellowish straps contrast nicely to the blue. As some of the overlapping plate edges, e. g. at the pivots of the nape-guard, are decorated by convex bows, maybe the copper alloy bands also once had a bow-decorated strap riveted underneath. A constellation similar to this is found at the pair of hand protections [ref_arm_1245] [ref_arm_1272]. The close relationship of the decoration of the aforesaid helmet and the latter objects suggest their affiliation to one suit or "Garnitur", but at least to the workshops of Lorenz or Jörg Helmschmied.

As said above, the design of the roping differs widely. The roped bands at the pairs of hand-protections [ref_arm_1209] [ref_arm_1247] and [ref_arm_1245] [ref_arm_1272] are worked in one piece with a row of convex bows. They are accompanied by a parallel narrow row of stylized pearls. The plane, tapered fields, e. g. of the roping at the pair of hand-protections [ref_arm_1059] [ref_arm_1124], are rather narrow with the row of pearls alternating in a rather steep angle. This is different e. g. at the pair [ref_arm_1208] [ref_arm_1246], where these fields are wider and the bordering pearl-bands in between are sloping less steep. As the bands are not tapered at their plane parts they look less plastic. Even though the fleur-de-lys strap underneath is very similar, the roped band at the helmet [ref_arm_1734] (not in Vienna) differs from all other objects decorated in this style. Here the very wide, also not tapered plane areas are interrupted by three narrow bands without a pearl-like decoration. This helmet has been excavated very recently and is therefore certainly no reproduction.

4. The straps at the hands [ref_arm_1244] [ref_arm_1207] appear like those described under 2., but the roping and the row of bows are worked in one piece. The bows are not decorated at the surface – only crude and asymmetrical filed lines are visible. The plane segments of the roping are very wide and the alternating fine twisted band is not decorated by stylized pearls.

5. The straps at the abdomen parts of the breast-and the backplate, at the knees and at the neck of the Vienna suit [ref_arm_3258] are different from the other fleur-de-lys straps found at items attributed to Lorenz Helmschmied. The roping is worked in one piece with the fleur-de-lys pattern. The roping itself is finer in diameter and the appearance is similar to two twisted wires. As no other breast-or backplate shows such copper alloy straps at the same location, the question of their authenticity has to be discussed. It is noticeable that at the four bands of the breastplate the two joints towards the center are screwed, while those at the

189 Thomas and Gamber (1976), p.100.

190 Thomas and Gamber (1976), p. 114-115.

sides are riveted. Also the straps at the lowest pelvis-lame are attached by screws, whereas the bands themselves are constructed as described under 1. At all other armour parts the decorative bands are attached by rivets.

6. At an elbow [ref_arm_35] single plate-bands (basically like 2.) with the rope decoration only engraved are attached. At the counterpart [ref_arm_38] a strap of convex bows is sandwiched underneath a separate roped band. It is not clear why the bands are constructed different from each other, while the elbows themselves seem to make a pair. One possible explanation is that at [ref_arm_35] the roped band had got lost and some restorer later filed the roping in the remaining band to match it with its counterpart.

4.2.6.3.5.1 Technique

The straps at the more costly armour had not been cut down to the desired length from a meter-wise produced band. The accuracy with which they fit to the curves of the edges can only be achieved by lost wax casting. This technique is very difficult as the shrinking of the cast metal has to be considered in the wax and so the dimensions of the latter have to be modeled slightly larger than they are finally needed. The wax straps had to be embedded in some sort of clay. The subsequent oven heating let the wax burn off, leaving a heat resistible negative of the wax. Then molten copper alloy was poured in the mold. While cooling down, the metal reduced its volume.[191]

The wax models might have been cast by a strap-shaped mold of wood or stone with the desired pattern incised. Also some kind of roller, pressing or cutting the desired pattern into wax plates is conceivable. Where the straps needed to curve, either the mold might have been designed accordingly or the warm wax was modeled according to the curves of the already finished plate armour. The wax straps were probably welded together by means of a hot iron, melting the joint. Interruptions in the decorations might have been cut from wax plates and attached the same way. Damages in the decoration could easily be corrected at the wax. Another advantage of this technique was that the basic molds were reusable for the decoration of other armour pieces and in case of the failure of the subsequent casting the work could be repeated quickly.

4.2.6.3.6 Ornaments on reproduced armour

The helmets [ref_arm_1857] [ref_arm_1899] together with the appending throat protections [ref_arm_5099] [ref_arm_3202] are reproductions, according to the marks[192] most likely made by Winkelmayer in Vienna in the late 19th century. The applications at the suits [ref_arm_3213] [ref_arm_3233] [ref_arm_3262] [ref_arm_4080] [ref_arm_4136] [ref_arm_4141] are certainly reproductions, as the entire suits are. With the exception of [ref_arm_3233], the bands at the mentioned objects are all trying to resemble applications on Vienna armours of Lorenz Helmschmied.

The suit [ref_arm_3209] of the former Klingbeil Collection is an entire reproduction, imitating the Churburg suit [ref_arm_4098] – with the exception of the lower left arm [ref_arm_5007]. Even the empty holes at the back of the hand were copied from the original.

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191 It is very likely that a goldsmith or a "Rotgießer" (craftsman specialized on casting copper alloys) made the applications, as their decoration is too complicated to be cut from a plate. Several goldsmithing products of the 15th century show similar ornaments. The drinking-horn of King Sigismund (Esztergom, Föszékedegyházi Kincstár, acc. no. 1964.18.1,2; see images in: Takács (2006), p. 370-371) is decorated by copper alloy fleur-de-lys bands identical to those on the Lorenz Helmschmied armours.

192 See discussion below in chapter [New recognitions on marks] and [A suit in the BMA].

4.2.6.3.7 Lost applications

Applications similar to those on the back of the hands on [ref_arm_1251] [ref_arm_1301] were most likely also once ornamenting [ref_arm_1259] [ref_arm_1301], to which the empty rivet holes testify.

Some entirely undecorated items seem to have been once decorated by copper alloy applications. The pair of hand-protections [ref_arm_1252] [ref_arm_1299] show small holes that maybe once held decorative stripes or other attachments in place. At each item in the area of the thumbs there is a large square hole which maybe also once held some sort of decoration.

In the Detroit Institute of Art there is a composite suit of armour [ref_arm_3214], which had its original parts most likely once decorated by cast copper alloy bands. According to the armourer's marks at the knees, the breast and the backplates are the work of the Augsburg master Lorenz Helmschmied. Also the upper legs (with the exception of the flaps) and the shoulders are certainly made by him. Only the breastplate shows no rivet holes that once held the presumed straps in place. Empty rivet holes are found at the edge of the backplate where the inserted plate at the nape cutout overlaps, around the shell-like extensions of the knees and at the upper and lower edges of the shoulders.[193] Most likely they resembled in their ornamentation one of the different decorative strap-types found on the Vienna armours of the same maker (e. g. [ref_arm_3257]).

The small holes, sometimes holding rivets, at the edges of the visors on the helmets [ref_arm_1540] [ref_arm_1548] [ref_arm_1566] [ref_arm_4258] maybe once served to fix ornamented copper alloy bands, maybe similar to those on [ref_arm_1495]. The lower edge of the helmet [ref_arm_1756] is not turned but pierced with small holes. Very likely they once held rivets for the fixation of ornamental bands. The lower legs [ref_arm_2291] [ref_arm_2296] [ref_arm_2325] [ref_arm_2958] have also small rivet holes on their lower edges. As the edges had not been turned, also here it is likely that copper alloy straps were attached, similarly to those at [ref_arm_2348].

The lowest lame of the pelvis on breastplate [ref_arm_3611][194] and of the backplate [ref_arm_3374] once was decorated by cast copper alloy bands. They might have looked like those on the pair of hand-protections [ref_arm_1096] [ref_arm_1142], as they are approximately contemporary and marked by the same master, Caspar Rieder of Innsbruck (Mühlau).

193 Some rivet holes on the lower edge of the right shoulder are still retaining some fragments of copper alloy rivets.

194 This breastplate has not been handled by the author, but Gamber (1957), p. 40, says that the lowest lame once had such applications. They got detached and the ridges at the lowest lame were leveled when around 1490 two torso-leg-protections were added.

4.3 Dimensions

4.3.1 Measurements

In 1474 the "Zeugmeister" of Lower Austria, Wilhelm Tenntsch (or Täntschen) accompanied the young Archduke Maximilian to Augsburg for having his body measured by the armourer Thoma.[195]

This and other sources tell that armour for wealthy men was made to measure. In 1488 Philipp I. son of the later Emperor Maximilian I. at the age of 10 had sent one of his pourpoint and a hose to his uncle, Archduke Sigismund, who wanted to order a suit of armour for his nephew.[196] The delivered armour is preserved in the HJRK in Vienna [ref_arm_3260], only the helmet – it was probably of type-VII – is missing.

Wherever no such documentation exists, it is not easy to answer if an extant item was made to measure. It is especially difficult to find final answers, as it is also possible that the armourers offered some of their products in different "standardized" sizes, similar to our modern "S, M, L etc.". The author has assembled measurements of hundreds of objects to approach this question. The comparison of dimensions is an exhaustive work. For the moment, the measurements of only three body-regions were evaluated: heads, torso-front and torso-back. Some types could not be measured at all in the course of this study or in small numbers only. Therefore, only the types of which a wider basis for comparison exists were considered in the following chapter. Future research should also differentiate between variation-groups of the same type.

4.3.1.1 Head

A very reliable measurement to be compared for a first overview is the width of the skull from ear to ear. The heights of some types can also be compared if the skulls of the concerned items are similar to each other in their shape. Nevertheless, the height does not tell if a helmet was made to measure. It has to be considered that helmets were always worn with a lining and therefore measurement-deviations from an average might have been less important – the size could be adjusted by a padding of the lining.

4.3.1.1.1 Type-III [ref_tab_dim_hea_III]

As the compared 79 helmets had different skull-shapes, the comparison of the height-measurements was omitted. The average width from ear to ear (inside) is about 18.5 cm. The max-min value of 6.0 cm shows that there is a wide range in the helmet-sizes and therefore many of them were possibly customized.

4.3.1.1.2 Type-IV [ref_tab_dim_hea_IV]

The ear to ear measurements of all 27 helmets do only vary in a range of 3.0 cm difference. It is therefore less likely that they were generally made to measure. On the other hand, the height differs by 8.0 cm. Most of the higher helmets have a pointed skull. It is interesting to note that many items with a skull-height below the average have either a hemispherical skull [ref_arm_1542] or they have a pointed skull with a pointed visor attached [ref_arm_1496]

195 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1899), Reg. 18210. Maximilian is called „the young Emperor". „Thoma" is probably identical to the armourer to the court of Archduke Sigismund, mentioned here: Jahrbuch der Kunsthistorischen Sammlungen in Wien (1899) Reg. 17972.

196 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1900), Reg. 19193.

[ref_arm_1519]. The two latter helmets have the unpractical downward-curving vision-slits in common.

4.3.1.1.3 Type-V [ref_tab_dim_hea_V]

Most of the 45 helmets were most likely not made to measure, as the difference between the widest and the shortest ear to ear measurement is only 2.5 cm. The average width of 18.3 cm is therefore certainly representative for this type of helmet. The heights vary by 10.0 cm which is due to the different groups to which the compared type-V helmets belong. The average height of 26.6 cm is probably representative for the classical "barbuta"-model.

4.3.1.1.4 Type-VII [ref_tab_dim_hea_VII]

Also at these 80 helmets the max-min value of 4.0 cm of all ear to ear measurements does not suggest that they were usually customized. The average width of 18.8 cm is certainly representative. The evaluation of the heights is particularly problematic as in the diagram the measurements of various models were compared.

4.3.1.2 Torso

The only measurement of torso-protections that could be reliably compared is the width under the arms. It would of course be interesting to compare the width of the waist as well, but the cutouts at the plates found at many torso-protections of the second half of the 15th century do not allow a reliable measurement.

4.3.1.2.1 Front

4.3.1.2.1.1 Type-II [ref_tab_dim_tfr_II]

The comparison of all measured plates implies that these breastplates might have been made to measure: the max-min value is 7.0 cm. The result looks different when only the 34 very similar simple type-II breastplates of the Vienna-Zeughaus are compared. It is very likely that they were not customized as the max-min value is only about 4.5 cm.

4.3.1.2.1.2 Type-III [ref_tab_dim_tfr_III]

Also the max-min value (6.5 cm) of type-III breastplates implies that many of them were made to measure. Items different in their appearance have been compared in this table and therefore further differentiations might reveal closer details if the more simple versions were possibly not customized.

4.3.1.2.1.3 Type-IV [ref_tab_dim_tfr_IV]

The dimensions of this type of breastplate vary the most. The max-min value is about 15.0 cm which suggests that they were usually made to measure this assumption is even more reliable as for this type the most data of a large number of objects is available.

4.3.1.2.2 Back

4.3.1.2.2.1 Type-III [ref_tab_dim_tba_III]

Backplates of type-III were usually worn together with a breastplate of type-IV. Therefore, it is not surprising that these backplates seem to have been also made to measure. The max-min value is 8.0 cm.

4.3.1.2.2.2 Type-IV [ref_tab_dim_tba_IV]

Type-IV backplates were worn together with a breastplate of type-IV. Usually these torso-protections were costly armour made for horsemen and therefore they were frequently customized. The max-min value of the few measured items is already about 9.5 cm.

The comparison of measurements is an exhaustive field of work and delivers only little information if not all dimensional aspects are compared. It would therefore be very interesting to compare three dimensional scans of armour parts. There is a chance that certain anonymous masters made several items with similar dimensions. It is therefore possible that groups of items coming from one workshop could be identified. The laser-based 3D scanning is not suitable for the imaging of bare iron-surfaces as reflections avoid the visual reconstruction of the item. It is theoretically possible to avoid problematic reflections by e. g. powdering the surface of the item with chalk etc. but due to conservational aspects this procedure is not recommendable. Any substance might harm the precious genuine examples, especially the organic parts. A very good, but costly alternative is the scanning by computed-tomography (3D X-raying).

4.3.2 Weight

One of the most erroneous legends about armour tells about its immense weight that made it impossible for the wearer to stand up again after having fallen to the ground or to mount his horse without the help of a crane.[197] Despite several publications naming the weight of single armour parts and in some cases also the weight of a complete suit, the image of the immobile "knight" is still widely spread. Such mysterious opinions are still repeated even by academics and "documentaries" in public media keep on amplifying a misunderstanding of the "knight's" armour.

The armourers of the late Middle Ages were specialized craftsmen that took great care of the balance between wearing comfort and protective aspects. The author has measured and compared the weights of a large number of extant objects. Not only the weight of a complete suit of armour should be of interest, but also armour parts for the simple soldier. These were never part of a suit and therefore the weight to bear was not very significant for the fighters anyway.

In the following, the aspects of weight of the single armour types of which enough comparable data could be collected will be discussed. Subsequently, some examples for weights of complete suits will be quoted.

Weights do usually not offer the possibility to tell the genuine armour from the reproduced. Also items that are most likely genuine can look very similar while they differ widely in their weight. Nevertheless, future studies of items belonging to one type-group can compare the weights in more details and maybe reveal chronological developments etc.

197 The myth that a knight has to mount his horse with the help of a crane is transported since Olivier's 1944 movie "Henry V.", see: http://www.youtube.com/watch?feature=player_detailpage&v=3jXFnQUU7yg (10.08.2012). Also the German "Sendung mit der Maus" in 1985 repeated this, see: http://www.youtube.com/watch?feature=player_detailpage&v=-y4j4QhU2nI (10.08.2012). In recent years for example Dirk Breiding of the MET tried to correct this wrong image, see: http://www.youtube.com/watch?v=NqC_squo6X4&feature=player_detailpage (10.08.2012).

4.3.2.1 Hand

It has to be attended that at most hand-protections the organic and often also the finger parts are missing. Therefore, the weights do not exactly represent the original mass.

4.3.2.1.1 Type-I “hourglass” [ref_tab_wei_han_I]

Only the earliest group of type-I hand-protections, the “hour-glass” variations are compared in this diagram. As all these hand-protections have similar dimensions, all of them lack their organic parts and the fingers, the weights are well comparable. The average weight of 0.28 kg is representative, as all 7 compared items do only slightly deviate in their weight from this mean. This is of course a very light armour part, even together with the finger-parts and the lining a pair of hand-protections of this group did certainly not weight more than 1.0 kg.

4.3.2.1.2 Type-II [ref_tab_wei_han_II]

Type-II hand-protections are a little bit heavier than the early type-I examples. The average weight of 7 examples is about 0.54 kg. This means that a complete pair might have weighed maybe 1.4 kg approximately.

4.3.2.1.3 Type-III [ref_tab_wei_han_III]

Even though this type of hand-protection usually consists of many segments and even though it flexibly covers all the hand and parts of the lower arm, the average weight of all 33 items is very low, compared to the types mentioned above. As the average weight is 0.45 kg a complete pair might have weighed not more than 1.4 kg.

4.3.2.1.4 Type-IV [ref_tab_wei_han_IV]

Only six hand-protections of type-IV could be compared, but also here the average of 0.42 kg shows that a pair was not heavier than 1.4 kg while the flexibility was as comfortable as of type-III hand-protections.

4.3.2.2 Head

4.3.2.2.1 Type-IV [ref_tab_wei_hea_IV]

The average weight of helmets of type-IV is about 2.33 kg, but the max-min value is already about 2.26 kg high. Therefore, it is clear that these helmets have a wide weight-range. Nevertheless, the weight of many examples does not deviate very much from the average. It has to be considered that this type of helmet frequently once had a ring-armour collar of significant additional weight attached.

4.3.2.2.2 Type-V [ref_tab_wei_hea_V]

The average weight of the 46 compared examples is about 2.4 kg. This is certainly representative for the classical “barbuta”. Many of them were actually a bit heavier while other type-V models seem to be rather lighter.

4.3.2.2.3 Type-VI [ref_tab_wei_hea_VI]

The weight of type-VI helmets was originally much more than the average of 3.52 kg as these helmets once had a ring-armour collar attached.

4.3.2.2.4 Type-VII [ref_tab_wei_hea_VII]

The average weight of 2.54 kg of this type of helmet is not representative yet and provides only a slight orientation. The max-min value of 3.63 kg shows that the single items differ in their weight widely from each other. This is due to the many different groups comprised in this table. Several items have e. g. no visor. For further conclusions, the data needs to be split into the single groups in further studies and more items of each group need to be compared.

4.3.2.2.5 Type-VIII [ref_tab_wei_hea_VIII]

This type comprises many different helmet models that could even be ascribed to types of their own. Therefore, also here the average weight of 5.82 kg cannot be representative, the max-min value is about 2.92 kg. Future studies need to differentiate the weight of different groups.

4.3.2.3 Neck

4.3.2.3.1 Type-I [ref_tab_wei_nec_I]

These neck-protections are more rarely than those of type-II and therefore also only little data was at hand. The average weight of 0.82 kg for 6 not complete examples is certainly representative. A complete example might have weighed about 1.0 kg.

4.3.2.3.2 Type-II [ref_tab_wei_nec_II]

The neck defenses of type-II weigh in average 0.75 kg and are therefore more or less of the same weight as those of type-I. For example the item [ref_arm_3034] (1.75 kg) weighs about 2.5 times the average. It is very likely that this example was meant for tournament only, as also the 3 vertical holes suggest. These holes served for the fastening of the neck-protection to the breastplate via screws, a feature typical for tournament armour.

4.3.2.4 Torso

4.3.2.4.1 Front

For all breastplates in future studies it would be interesting to further differentiate the data, e. g. to compare simple breastplates to those with holes for lance-rests.

4.3.2.4.1.1 Type-II [ref_tab_wei_tfr_II]

The 60 type-II breastplates weigh in average 1.99 kg. The max-min value of 1.86 kg shows that there is nevertheless a wide range in the weights.

4.3.2.4.1.2 Type-III [ref_tab_wei_tfr_III]

Probably due to their construction and the overlapping edges the 9 breastplates of type-III with an average weight of 2.80 kg seem to be generally heavier than those of type-II, but it is the item [ref_arm_3623] with 5.1 kg that lifts the average immensely.

4.3.2.4.1.3 Type-IV [ref_tab_wei_tfr_IV]

The max-min value of 4.86 kg shows that the average weight of 3.05 kg is not representative for all 49 items. The heaviest breastplate is of Italian make and weighs about 6.40 kg [ref_arm_3649].

4.3.2.4.2 Back

4.3.2.4.2.1 Type-III [ref_tab_wei_tba_III]

The average weight of 2.76 kg is representative for 25 backplates of type-III as the max-min value is at the rather low rate of 1.56 kg.

4.3.2.4.3 Limbs

The weights of the single armour parts for the limbs can often not be tested as they are permanently connected to other arm defenses. Therefore, only some examples of extant items connected in one of the systems described above[198] will be introduced.

4.3.2.4.3.1 Arm [ref_tab_wei_arm_ge] [ref_tab_wei_arm_it]

Five examples of the system [sys_asII_auI_aeII_alIII_ge] weigh between 1.48 and 2.03 kg (one arm). The Italian system [sys_asII_auII_aeII_alIII_it] is usually heavier: Six examples weigh between 2.73 and 4.10 kg.

4.3.2.4.3.2 Leg [ref_tab_wei_leg]

The five measured leg-systems [sys_luII_lkII_llIII] weigh between 1.97 and 2.49 kg (one leg).

4.3.2.4.4 Suit [ref_tab_wei_sui]

It is difficult to quote the total weight of a suit as no complete ensemble exists in its original composition. A mostly complete example – which was probably even worn in the current constellation – is the suit [ref_arm_4143]. According to the marks, the single parts were made by different masters. The total weight is 23.37 kg, but it has to be considered that the shoe-protections are missing (or they never existed). Another good example is the composite suit [ref_arm_4117] that also might have been worn in the current constellation (all parts formerly Churburg armoury). Some parts, like the torso upper-leg defenses, are missing and therefore the weight of 26.88 kg might have been a little bit higher. These two total weights show that the weight of a suit of armour was usually below 30.00 kg. The total weight to bear in battle was certainly slightly higher, as also ring-armour shirts or segments were worn together with the plate armour. The missing organic armour-parts had an additional weight. Nevertheless, the men inside these suits were all highly trained fighting specialists, similar to modern athletes. They spent a lot of their lifetime on running and riding with full armour. Today's soldiers do also usually not collapse when they have to march or to run with a back-pack of 20 kg or more, a helmet of 2-3 kg, possibly a bullet-proof vest and a heavy gun together with some cartridges. Unlike such modern fighting equipment, the weight of plate armour was spread all over the wearer's body. There is no doubt that it would have been a very embarrassing moment for a knight if he appeared to be too weak to mount his horse in full armour without support.

4.3.3 Plate-thickness

The topic of plate-thicknesses is another vast field of interest that demands a closer look. Claude Blair said that:

198 See chapter [Systems] and [Systems].

"Considerable care was taken in forging a fine-quality armour over such details as the thickness of the various parts. It will usually be found that, for obvious reasons, the parts at the front are thicker than those at the back while the helmet-skull is worked so that it is thicker in the more vulnerable places."[199]

This general held belief that armour was purposely designed thicker at the exposed areas was never tested in a comparative study. If Claude Blair had measured a series of items, he never published any document on that. No system for the measuring of plate-thicknesses of the different armour parts had ever been developed. The author of this paper has measured a large number of objects of all types in a repeatable manner, so a single spot measured on one item can easily be compared to the same spot at a similar object. The revealed data was evaluated to draw general conclusions on the making of armour. To get an impression on how the measuring was carried out, the author has made a short movie [ref_vid_meas]. The lowest locally measured value was finally documented.[200]

The measured armour types need to be divided into two groups. The first one comprises the torso-protections and the helmets. It was found that only examples of these types repeatedly showed immensely varying plate-thicknesses. The location where the plates had to be measured needed to be clearly defined. The average values of the single and of all items of one type were evaluated and visualized in 2-, respectively 3-dimensional diagrams. As the items of this block are those extant in the largest numbers, it is also this block that delivered the most data. For all other objects, such as limb-protections, hands, torso-upper leg-protections etc. the plate-thickness is usually more or less equally spread over the surface. Here only few spots were randomly measured, the maximum, the minimum, the difference (max-min) and an average value of one item was noted and also evaluated for all measured items of one type. The data is displayed in two dimensional diagrams. As the single parts of this block are rather rare– compared to the numbers of extant helmets and torso-protections – in some cases the measurements of only two or three objects had to serve as the basis for the evaluations. Future examinations should differ between the date, the production-place and the quality of the single items. The conclusions presented in this study are not final and further measuring is necessary to test the reliability of the results.

The quoted diagrams might help to identify problematic items. If the max-min value of all measures of one item is demonstratively low, a closer examination on the object in concern of its authenticity is recommendable. Equal plate thickness might mean that the plate was rolled by a modern technique. A good visualization of the varying plate-thickness of all examples of one type is provided by 3-dimensional diagrams. It is very likely that the different section-profiles found at different types are rather the result of the used embossing-technique than the idea of purposely reinforcing certain exposed areas.

199 Blair (1972), p. 189.

200 Armour has been polished throughout the years, but the few lost tenths of millimeters do not significantly alter general conclusions.

4.3.3.1 Group 1

4.3.3.1.1 Head[201]

The helmets were measured at four equally spread spots along a frontal, a central and a rear section. The quoted 3-D diagrams show in a simplified way the blank of the helmet-plate, looking from the frontal left side of the forehead.

4.3.3.1.1.1 Type-I [ref_tab_thi_hea_I]

Comparable data of only three helmets of type-I could be collected. Nevertheless, when looking at the diagrams it becomes clear that the average plate-thickness of all tested helmets is about 1 mm. As the average variation is only about 0.8 mm at a measured minimum of 0.7 mm and a maximum of 1.7 mm, it is reasonable to assume that hemispheric-shaped helmets of type-I were usually made of thinner plate and therefore rather light. This matches with the assumption that they had often been worn underneath a ring-armour cape or a hat. According to the few measured items, it seems as if the frontal and the rear section are generally thicker than the central section. As these helmets are rather thin at the center – the area where a blow is expected to hit the skull – it is possible that the thicker parts rather result of the embossing technique. Probably the helmets were worked merely from the exterior.

4.3.3.1.1.2 Type-II [ref_tab_thi_hea_II]

The rarity of helmets of the "great-helm" group and the bad condition of many items allowed for the measuring of only two examples. Both items are no archaeological finds and it is not sure if they were ever used as combat helmets in the 14th century. The average plate-thickness is about 1.5 mm. The single segments show a rather constant thickness.

4.3.3.1.1.3 Type-III [ref_tab_thi_hea_III]

The local measurements show clearly that these helmets were frequently thicker towards the center of the skull. The brim or the lower areas were thinner. This supports the idea that the armourer started from a smaller, thick plate-sheet. He first forged the edges of the plate thinner to reveal a larger plate and to reduce the weight at the less exposed areas. He then merely worked from the interior, which left the least worked areas in the center nearly at the starting-thickness.

4.3.3.1.1.4 Type-IV [ref_tab_thi_hea_IV]

The calculated average plate-thickness of 1.9 mm is certainly representative. These helmets were usually thinner at the cheeks and thicker towards the point of the skull, particularly at the rear. The embossing of the skull was probably similar to the making of helmets of type-III – merely worked from the interior. Only the point then needed to be worked from outside, which resulted in an increasing thickness, as the material was bulged here.

4.3.3.1.1.5 Type-V [ref_tab_thi_hea_V]

Helmets of type-V are clearly frequently thicker towards the crest. This suggests their making by the same techniques like helmets of type-III. It is likely that the crest area was purposely left thicker, as frequently enormous dimensions of up to 4.8 mm were measured,

201 Too little comparable data of type-VIII helmets was at hand and therefore the examination of these types have to remain subject to future studies.

while at the lower areas the thickness could be at about 1 mm only. The diagram shows clearly that the forehead was not worked thicker than the other areas around the crest.

4.3.3.1.1.6 Type-VI [ref_tab_thi_hea_VI]

Due to their construction it was difficult to measure helmets of type-VI. The forehead is usually reinforced with a second plate and therefore the plate-thickness could often not be measured in this area.[202] Furthermore, these helmets seem to consist of a mix of two kinds of plates. The cheek-plates were cut and embossed from readymade plate-sheet, thinner in comparison to the forged, thick skull.

4.3.3.1.1.7 Type-VII [ref_tab_thi_hea_VII]

Helmets of type-VII are in average of rather equal plate-thickness compared to helmets of type-III, -IV and -V. Type-VII helmets are even thinner towards the central crest. This might suggest that they were made in a different technique. The diagram suggests the working of the skulls from the interior with a second step: The tapered parts could either have been made by bulging a bowl at the narrow areas or by embossing the wider areas above the ears from the interior (see also below). The latter possibility is more likely as the diagram shows the thinner areas here. In this type-group the author has comprised a lot of helmets different in shape and production time and therefore the conclusions on the average measurements are not meant to be set in stone. A further differentiation of the question with a focus on the type-families might reveal different aspects.

4.3.3.1.2 Torso

The torso-plates were measured along four sections from the left side to the right: at the pelvis, at the abdomen, at the thorax and at the shoulder-points. The quoted 3-D diagrams allow a look onto the simplified blank from the wearer's perspective.

4.3.3.1.2.1 Front[203]

4.3.3.1.2.1.1 Type-II[204] [ref_tab_thi_tfr_II]

The average plate-thickness of 1.5 mm, the average maximum of 1.9 mm show that these plates were usually not very thick. Especially the many similar foot-soldier's breastplates of the WM, probably made in the early 16th century, are frequently thin, most of them in average between 1.1 to 1.7 mm. The average diagram of all items shows that the plates were slightly thicker towards the center, increasingly towards the lower abdomen. This suggests that the plates were cut in smaller dimensions than the readymade product and they were subsequently forged thinner towards the edges. This does not only reduce weight at the less exposed areas but it also eases the turning of the edges. The edges under the arms at the WM breastplates were frequently not finally cut or ground. Their burred appearance clearly shows that the final dimensions were finished by forging.

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202 The measurements given were taken from the skull only, at the edge of the doubling reinforce. The spots measured at the rear derive from the narrow "tail" worked in one piece with the skull, found in between the cheek-plates of each helmet of type-VI. The upper spots at the front were measured at the face-guard.

203 For comparisons of type-I breastplates not enough data was at hand.

204 The measurements of the pelvis-lames were omitted, as many important comparable items lacked these lames.

4.3.3.1.2.1.2 Type-III[205] [ref_tab_thi_tfr_III]

It is interesting to note that the 3-D diagram shows an increase of the plate-thickness towards the center of the thorax-plate. Also the abdomen-plate is thicker towards the center and thicker than the lower thorax-section. The single plates therefore were also cut smaller and subsequently forged thinner towards the edges. The pelvis-lames are not significantly thinner towards the sides of the body and were probably cut from a large plate.

4.3.3.1.2.1.3 Type-IV [ref_tab_thi_tfr_IV]

The pelvis-lames are frequently thinner than the other parts, but only slightly thicker at the center. As shown in the diagrams of the other breastplate-types, also here the upper plates are thicker towards the center. The average plate-thickness of the abdomen and the thorax-plate is nearly the same. They both were usually forged into the right dimensions from a smaller plate.

4.3.3.1.2.1.4 Upper-leg [ref_tab_thi_tfr_leg]

The upper-leg-protections adjacent to the pelvis-lames of breastplates are usually cut from plate sheet, as they do not show a decrease in the plate-thickness towards the edges. The average thickness of 1.2 mm is certainly representative, as the average max-min value of all measured objects is 0.5 mm only.

4.3.3.1.2.2 Torso back[206]

4.3.3.1.2.2.1 Type-III [ref_tab_thi_tba_III]

The average plate-thickness of 1.4 mm (all objects) shows that the backplates of type-III are usually thinner than the breastplates of type-IV, with which they are commonly combined. The quoted 3-D diagram illustrates that the upper plates are thicker towards the center, which suggests that they were probably cut from the sheet with smaller dimensions and forged thinner towards the edges. The thorax-plate is often thinner than the abdomen-plate. The pelvis-lames are in average thinner than the upper plates and as they are not significantly thicker towards the center, it is possible that they were cut from the plate-sheet and possibly only slightly forged.

4.3.3.1.2.2.2 Type-IV [ref_tab_thi_tba_IV]

Also here the equal thickness of the pelvis-lames suggests that they were cut from a readymade plate-sheet. The abdomen-plate is much thicker than the thorax-plate, but both were forged thinner towards the edges.

4.3.3.2 Group 2

4.3.3.2.1 Arm [ref_tab_thi_arm]

The diagrams show that the average plate-thickness of armpits (1.4 mm), elbow reinforces (1.3 mm) and shoulder reinforces (1.2 mm) is often a bit higher than the thickness of the remaining arm-protections (0.9 – 1.2 mm). The usually low max-min value indicates that the

205 As the abdomen-plate at type-III breastplates is usually very narrow and large parts of the abdomen are covered by the thorax-plate, the latter was measured in a further section.

206 For type-I and -II backplates too little data was at hand and therefore these types were not included in the plate-thickness examinations.

plates for the arms were not purposely forged thinner at certain areas and were therefore most likely cut from the sheet into more or less the final dimensions.

4.3.3.2.2 Leg [ref_tab_thi_leg]

Similarly to the arm-protections also the max-min values of the single leg-armour types were never forged thinner towards the edges. Therefore, also these parts were made from ready-cut plates. The knees (1.0 mm) and the upper legs (1.1 mm) were slightly thicker than the lower legs (0.9 mm) and the feet (0.7).

4.3.3.2.3 Hand [ref_tab_thi_han]

The plates of all hand-protections are never significantly thinner towards the edges. Therefore, they were most likely cut from a larger plate into nearly the final dimensions. The average max-min value is very low for hands of type-II, -III and –IV (0.4 – 0.5 mm). Only for the hand-protections of type-I this value is slightly higher (0.7 mm). It is interesting to note that the average plate-thicknesses of type-III and -IV hand-protections (0.8 – 0.9 mm) is lower than the average thickness of the usually older type-I and -II examples (1.2 mm).

4.3.3.2.4 Neck[207] [ref_tab_thi_nec]

The average plate-thickness of Neck-protections is 1.5 mm. The lowest and the most upper lame are usually thinner than the plate protecting the chin (not visible in the diagrams) and possibly cut from the plate. The max-min value of 1.1 mm (neck-I) resp. 1.4 mm (neck-II) derives merely from the chin-plate, which seems to have been usually forged from a smaller plate into the final dimensions.

4.4 The serial[208] production of armour

In the course of this studies, the in situ examination and the very good quality of the images taken personally of hundreds of items allowed for a quick and detailed comparison of similar items. For this purpose, the objects had to be clustered in groups. This work revealed that especially certain helmets – first thought to be of a unique variation of one type – actually belong to a larger group of other items. They are today just in an altered condition, lacking parts like face-guards, forehead-reinforces or attached nape-guards.[209]

To say it in short words: The clustering of extant examples suggested an unexpectedly limited type variety. This realization was surprising. The literature on the topic suggested a much wider diversity of different types and subgroups. This idea was additionally supported by observations in contemporary artworks, where a wide type variety can be found. While some of the depicted types might actually have got lost, others might just be misunderstood renderings of real existing models. Anyway, according to existing examples some considerations might be justified:

It can be presumed that the existing armour covers the largest part of formerly existing types. Now that even within this small leftover several nearly identical items can be found, it is possible that far fewer type-variations than expected actually existed in the late Middle Ages. This would also mean that already the 14th century armourers obviously produced or

207 No type-III neck-protections could be measured.

208 The term „mass-production“ would probably be too strong to describe any kind of medieval or renaissance manufacture. While of course large numbers of basically one item could be produced, the single products obviously still differed in various details as a lot of hand-craft was still needed to finish them.

209 See for example the discussion of the helmet [ref_arm_1710] in chapter [Helmets].

reproduced certain models in large numbers. The question is, if the manufacturing processes that created these items were maybe the beginnings of a serial-manufacturing.

Not much has been written on the serial- or mass production of armour. The main focus of a majority of the preceding studies on armour was on aspects of art and therefore merely on the costly and individually made examples. The production of the anonymous, simple and cheap armour parts were of lesser interest. Only one historian shortly discussed the sources on a possible serial-production of armour in the early 16th century.[210] The beginnings of the use of serial production methods still remain obscure.

According to the numbers of extant objects it can be estimated that the production score of plate armour until the 17th century has been permanently increasing. In the "Zeughäuser" (Engl. arsenals) of Graz, Solothurn, Zürich, Emden (descr. 1), Schwarzenburg, Munich and Vienna, 16th and 17th century armour is still represented in a number of almost identical items [ref_ill_art_5363].[211] Alone the numbers suggest that it was produced by some kind of serial-manufacture process. Certainly the increase of plate-sheet prices was one relevant factor. According to Alan Williams, the introduction of the presumably more efficient and thus cheaper indirect iron-production process was responsible for this development:

> *The most compelling evidence for the use of the Indirect Process is that the cost of armour fell to a remarkably low level in the 16th century […]. The cost of the cheapest armour becomes so low that the cost of the metal itself is significant. When the metal used in the cheapest serial-produced iron armour of the 16th & 17th centuries is examined, it is found that iron becomes commoner for arsenal armour, and its slag content increases. The metal used in the later 16th century for Italian arsenal armour was of lower carbon content than that used in the 15th century for infantry armour (but still steel rather than iron).*[212]

The quantitative capability of the iron or steel production had an influence on the development of a serial production of armour, but also other technological innovations surely have contributed their part as well. The following chapter discusses some early items that are related so closely to each other that they might have been made by some kind of serial-manufacturing processes.

In the German speaking lands in the 14th and 15th century most of the armour orders name individual items only. The first armour orders that sum up large numbers of one type date from the end of the 15th century. At the same time in northern Italy contemporary documents tell of armour ordered at once in large numbers. It was probably in this region where armourers were first capable of producing amounts of armour large enough to equip an army within a short time:

> *[…] Milan was able, after the battle of Macado in 1427, to furnish within a few days 4000 suits of armour for cavalry and 2000 for infantry.*[213]

It is unclear of what quality the delivered cavalry armour was. On the 2000 suits for the foot-soldiers certainly no great demands concerning their design and quality were made. They

210 Egg (1992).

211 A lot of additional objects that came into the antique market throughout the last 200 years are known to come from these collections as well.

212 Williams (2003), p. 889.

213 Gardner (1898), p. 14.

just had to fulfill their protective task. The armour was probably made by several independent workshops, each delivering some hundreds of items. One workshop executing a large armour-order was certainly not tempted to deliver the greatest variety of models. Just like today, large numbers can only be produced economically by means of standardized procedures. Variation is expensive, as new thoughts and skills have to be invested in its development. Therefore, – provided that the source for the aforesaid delivery is correct – already by the first half of the 15th century some kind of serial production might have existed in or around Milan. The question is: Can extant armour prove the assumptive existence of such a serial-production process in this time?

This question is not easy to answer, as the great times of the arsenal- or memorial-keeping of armour began in the German speaking lands at the very end of the 15th century and no older arsenals still exist in central Europe. No existing central European arsenal assembled in the late Middle Ages contains definitely serial-produced armour from before 1470. While it is possible that some guard-troops of the European nobility have been equipped uniformly, the preserved inventories of 15th century items in the great dynastic collections do not contain extant examples. The oldest relevant armoury would be that in the Castle of Churburg. While a considerable number of armour parts of the 15th century is kept there, the collections comprise only three similar helmets of the end of the 15th century [ref_arm_1859] [ref_arm_1860] [ref_arm_1861]. All other items are strictly different in their appearance.

In the German speaking lands some remains of 15th century city arsenals still exist (Munich, Vienna). In Italy no large number of similar items that clearly belonged to one Italian inventory assembled before 1470 is found. Some items of Italian make, now kept in different collections, possibly once belonged to one Italian armoury. Similar items, now kept together in one collection assembled in the last 200 years do often not come from the same ancient armoury-keeping. Due to the limited total numbers of concerned objects and the usually lost or doubtable provenances it is not possible to reconstruct a collection large enough to tell about the serial production of the contained items.

This is different with armour-hoards evidently found together. Three large finds of late medieval or early renaissance armouries are known, but they were all located in the central or eastern Mediterranean region.

- The armoury of the knights of St. John in the city of Rhodes fell in Turkish hands after the capture of the city. Large amounts of armour were forgotten and came to different collections throughout the last 100 years.[214]
- The second armoury consists of Turkish war-booty and was stored in different locations in the Ottoman Empire – most of it in the former Church of St. Irene in Istanbul – before it came to the modern Military Museum (AMI). A lot of the armour from St. Irene was brought to the US and Europe and is now found in different collections. The only closer study of the European armour from Istanbul was published by Stuart Pyhrr.[215] Hopefully one day it will be possible to examine, inventory, preserve and to publish the thousands of objects in the storage of the Askeri Müze (AMI). For the purpose of this study, the European armour on display in this museum has been examined, but much more is expected to be kept in the inaccessible museum-storage.

214 Walter Karcheski and Thom Richardson collected and published a lot of material on the Rhodes armour, see: Karcheski and Richardson (2003).

215 Pyhrr (1989).

- The third armoury was found in the Castle of Chalcis (or Chalkida) on the Island of Euboea. In 1840 approximately 300 armour parts were found in the ruins of the former castle.

For the question on authenticity the items remaining in Istanbul and Athens are of the greatest importance, as these collections are certainly not undercut by reproductions – no armour of other sources was added or bought in for centuries.

The find of Chalcis can be determined as the only arsenal-like conglomeration of early Italian armour from the period between 1350 and 1470. It was probably walled in by the Venetians before 1470 – just before the Castle of Chalcis was captured by the Turks – and has not been detected by the new rulers until the wall collapsed[216].[217] Unfortunately, parts of the find got dispersed to different collections. The database built for the purpose of this study can comprise only the basic data that could be found about the fate of the different items. The topic of the Chalcis finds is still waiting to be discussed scientifically as a whole. After a few un-detailed notes of a contemporary of the find[218], only three articles were published on the subject[219], while some of the helmets are discussed in articles with another subject[220]. Two of these articles or monographs are only available as manuscripts in the Royal Armouries Library in Leeds[221].[222]

The hoard comprised many European helmets or their fragments, most of them are stored in the National Historical Museum in Athens (63 items). Several unpublished parts of arm- and leg-protections together with some helmets are now in the MET (roughly estimated 200 single pieces).[223] In both collections also some segment- or brigantine armour parts are preserved. In Athens there are still parts of neck-protections [ref_arm_3071] [ref_arm_3079] [ref_arm_3080] and a single lower arm defense [ref_arm_88]. A superficial look at the limb protections of the Chalcis hoard in the MET reveals common features that suggest their making in a kind of serial-production process. As the objects were not examined in situ, approaches to the answer on this question are subject to future research.

Due to the evident relationship between many items from the aforesaid three "historical" arsenal finds of late medieval European armour, several types and models will be discussed in the context of their possible making in early serial-manufacture processes. The comparisons of the single items cannot go into every detail and will focus instead on the

216 See: Ffoulkes (1911), p. 381-382. In: Hefner-Alteneck (1854), p. 83, pl. 63 the note is found that the helmets were found in the castle's cistern. Imprecise drawings of few of the helmets are added.

217 The Island of Euböa together with the city of Chalcis from 1830 on had been part of the new founded Greek State. If the Turks would have found the armour it would possibly have been brought to the arsenal in Istanbul.

218 Buchon (1843), p. 134.

219 Blair (1983); Ffoulkes (1911) and Vassilatos (1934).

220 Scalini (1984), p. 3-5.

221 Norman (not dated) and Boccia (not dated).

222 All these texts study the helmets, but not the limb protections stored in the MET, mentioned below.

223 Bashford Dean, Curator of the Arms and Armour Department of the MET from 1906-1928, acquired them about 1920 for his private collection. After his death in 1928 the objects were bought by the MET. For more details on his collections and the Chalcis finds see: Grancsay and Kienbusch (1933). Without further research it is impossible to list all the parts that actually belonged to the Chalcis hoard, especially as many items got completed by new parts or joined with other original pieces. For example see the notes on the armour-suit [ref_arm_3236], which is merely composed from Chalcis pieces, in: Dean (1925).

relevant features. Most of the objects had been published with single descriptions and there is no need to repeat all information here. The object-data sheets provide for some further information on the single objects.

Many of the concerned helmets were personally handled by the author and therefore they can be analyzed in detail. As most of the Chalcis helmets are incomplete, it is likely that they were waiting for their repair already at the time they were walled in. A large part of the Venetian garrison of Chalcis was certainly using further armour in the conflict with the Turks and therefore the garrison's arsenal stock must have contained many more armour parts. What was found in 1840 is therefore probably only a small remain of what once existed – and as several of the helmets show close similarities, it is almost certain that even more helmets of the same model once were kept in the Chalcis armoury. Today, the Chalcis, the Rhodes, the Istanbul and comparable helmets from a few other places can be mapped into four large groups.

4.4.1 Type-V: "Chalcis barbuta"

21[224] helmets of type-V[225], most of them from Chalcis, are so similar to each other, that they might have been produced in large quantities in one workshop. They consist of two plates only, none has or had a visor attached and often the lower plates are lost. All helmets are crudely worked, no edge is turned. At the examples where the lower plate is missing the burred lower edge of the skull is visible.

However, there are actually features at these helmets that contradict their assumptive production by cheap serial-manufacture processes: The helmets are not all exactly the same. The skulls are pointed to a varying degree. Producing such a shape is also more difficult than making a simple hemispherical skull. The reason for the acceptance of this "more" of work is probably the intended advancing of the helmet's resistance against vertical blows from above – a pointed skull would hopefully make a blade or projectile slide off, instead of penetrating the helmet. In addition, the examples differ slightly in the shape of their cutouts above the eyes. While many have only one frontal medial ridge, some of the skulls show at each side additional vertical ridges from the point towards the ears [ref_arm_1989] [ref_arm_1991] [ref_arm_2022]. Furthermore, the arrangement of the holes for the lining-rivets is not the same at all the helmets. The helmet [ref_arm_2144] at the right side has a cheek-piece attached by a hinge. This could also be a modern restoration as the hinge is worked even too crudely for these helmets and it is attached by screws.

224 These are: [ref_arm_1462] [ref_arm_1984] [ref_arm_1988] [ref_arm_1989] [ref_arm_1990] [ref_arm_1991] [ref_arm_1992] [ref_arm_2011] [ref_arm_2022] [ref_arm_2059] [ref_arm_2063] [ref_arm_2072] [ref_arm_2103] [ref_arm_2127] [ref_arm_2144] [ref_arm_2146] (lower plate only) [ref_arm_2167] [ref_arm_4389] [ref_arm_4584] [ref_arm_4617] [ref_arm_5112].

225 Three helmets of the same type in other collections are today considered as a former part of the Chalcis arsenal: [ref_arm_4389] [ref_arm_4617] [ref_arm_2059]. Another helmet [ref_arm_2072] of this group for centuries has been kept in an arsenal of the Ottoman Empire. From these arsenals thousands of armour parts came to Europe in 1839-40, see: Pyhrr (1989), p. 87. As items similar to the Chalcis find actually existed and still exist in Istanbul (see the images in Pyhrr's article made by Bashford Dean), maybe from there came also some helmets now attributed to Chalcis. It is possible that the single lower plate [ref_arm_2146] actually belongs to one of the single skulls, which would reduce the total number of these helmets to 18. The lower plates at the items [ref_arm_4617] [ref_arm_2103] and [ref_arm_2059] are certainly modern replacements.

4.4.2 Type-II: “Chalcis closed helmet”

A fragmentary[226] group of 27[227] type-II helmets also raises the question on the possibility of them being produced in an early serial-manufacture process.[228] The skulls of these helmets are – similar to those of the type-V helmets discussed before – worked separately from the lower plate. The latter is a bit different: It usually flares out more at the nape and it is closed by an articulated flap at the right side of the chin, secured by a turning pin. Additionally, the face is protected by a visor with pivots at the sides of the skull. Only one of these helmets seems to be complete in an original condition [ref_arm_4408]. The further two complete examples [ref_arm_1458] and [ref_arm_1590] were intensively repaired and completed. Also all of these helmets differ slightly from each other: The cheek-pieces are of different size. The edges of the visors are of different shape, the vision is either made by a single or by two slits. The visor [ref_arm_1455] is made of two vertical plates – a very uncommon construction for a face-guard of the time. At the skull of [ref_arm_1452] a medial band forming a point at the center of the skull is attached. The skulls differ slightly in the shape of their points and the design of the cutouts at the forehead. Nevertheless, the technical system is the same with all the helmets and the general appearance is very similar (for the lost helmets of which only the visors remain this can only be presumed).

Two further, in shape similar skulls have to be discussed. They are maybe re-used older helmets of type-V. The relief [ref_ill_art_5399] (descr. 1) on the right side shows the rear of a helmet with an 8-time faceted pointed skull similar to [ref_arm_1985]. The lower edge of the latter is badly damaged, but at the rear of the helmet a nape-guard slightly flaring out is still visible. This feature is also observed at a similar example from the MDA [ref_arm_2157] which additionally shows some features now possibly lost at the Athens item. At the MDA skull some of the studs that once held the leather or plate strap for the attachment of a ring-armour collar are still in place. They once were fitted to the larger holes encircling the lower edge upon the line of small holes at the Chalcis example. The small holes served for the stitching of the interior lining. Exactly like at the MDA helmet also at [ref_arm_1985] there is a height-offset in the line of these small holes above the eyes. The frontal medial ridge at each is pierced by two holes of unknown purpose. At both helmets the side of the skull is pierced with holes for the visor-pivots. Next to a similar helmet on the right side of the aforesaid artwork [ref_ill_art_5399] (descr. 2) at the left side a helmet with an articulated face-guard is shown. Therefore, it is possible that the Athens and the Paris items originally were fitted with a visor. If this is correct then they are the earliest examples to survive. As the flaring nape-guard was not cut off for the easier attachment of a lower plate, the Athens helmet [ref_arm_1985] probably was never turned into a helmet of the type-II “closed helmet” group. This is probably different with the second similar helmet [ref_arm_1453]. It also shows a line of small lining holes along the lower edge. At the right side of the skull a fragment of the visor-arm is still fastened by its pivoting rivet. The lower edge – maybe once flaring out at the nape – looks like it has been cut off. The holes drilled next to the former

226 As the single visors in the MET probably via Dean all came from Chalcis it is possible that the formerly associated helmets are still extant in Athens.

227 Not all items are from Chalcis, but due to their similarity they belong to this group: [ref_arm_1445] [ref_arm_1446] [ref_arm_1447] [ref_arm_1448] [ref_arm_1449] [ref_arm_1450] [ref_arm_1451] [ref_arm_1452] [ref_arm_1453] [ref_arm_1454] [ref_arm_1455] [ref_arm_1458] [ref_arm_1473] [ref_arm_1474] [ref_arm_1475] [ref_arm_1476] [ref_arm_1477] [ref_arm_1478] [ref_arm_1479] [ref_arm_1480] [ref_arm_1483] [ref_arm_1487] [ref_arm_1588] [ref_arm_1590] [ref_arm_2147] [ref_arm_4408] [ref_arm_4460].

228 At least one is a converted or re-used older helmet [ref_arm_1453].

stud-holes probably once held rivets that fixed a lower plate. A further, similar helmet with a faceted skull and a trimmed lower edge is kept in the MET [ref_arm_1620], but it lacks the holes for a visor and the collar-studs. This could derive from misunderstood repairing, as the helmet would actually not work in the current condition. No holes suitable for an interior lining are visible. Therefore, it is also not clear if the helmet had secondary a lower plate attached. Nevertheless, as the lower edge had been trimmed very crudely this possibility is very likely.

The dating of all the discussed type-II helmets is discussed very controversially.[229] The capture of the city by the Turks in the year 1470 provides for a reliable terminus ante quem for the dating of all objects found. It is difficult to date these helmets, as almost no comparable depictions in art have been found yet. According to Paul Martin and Jean-Pierre Reverseau the items with the faceted skull would date about 1345.[230] That none of the helmets shows a turned edge either speaks for them being made before 1400, or again for their production in cheap serial-manufacture maybe also in later times.

Additional to their similarities, the fact that so many helmets were found together in Chalcis – and thus were probably once bought together – makes the production of each group in the surroundings of one workshop very likely. Where the helmets were actually made is unclear. Only one of the type-II examples bears 2 identical visible marks – a "P" or an "R" under a crown [ref_arm_1458]. Marks with letters under a crown are often found on Italian – more precise Lombardian – armour. Due to their marks many other items from Chalcis were actually made in the northern Italian region. Nevertheless the aforesaid helmets never appear in Italian or northern alpine artworks. As two of the few similar helmets that clearly not belonged to the Chalcis hoard[231] – [ref_arm_2072] and type-II [ref_arm_4460] – were both found in the eastern Mediterranean sea (Istanbul and Cyprus), it is well possible that Boccia is right in suggesting their production in the Aegean region[232].[233]

Even if for none of the helmet-variations a serial production can be attested with absolute certainty, the similarity of the helmets within the single groups are an evidence for a somehow uniform equipment of the late medieval soldiers – at least for those serving in southeastern Europe in catholic-christian stronghold-garrisons. Historical artifacts should not be met with modern standard-criteria. For the contemporaries the discussed helmets were identical, eventually there were no binding European norms existing.

4.4.2.1 The making of the two aforesaid groups

The skulls of both types are worked from very thick plate of about 3.0 mm in average, while the lower plates and the visors are made of thinner material, about 1.5 mm in average. The

229 The experts dated them very differently: Early 14th for the type-V helmets and late 14th century for the helmets of type-II (Vassilatos, p. 123-133, 136); Between the 30ies and the 60ies of the 15th century (Boccia, p. 7); 1370-90 (Scalini, p. 4); Ffoulkes summarizes the production-time range of the objects unspecified from the mid-14th century to 1470; certainly too early – about 1310 (Buchon).

230 Martin (1967), p. 60 and Reverseau (1982), p. 22.

231 One helmet [ref_arm_5112] is said to have been found in the Tiber by Giorgio Bini, see: Blair (1983), p. 14, note 14.

232 Boccia (not dated), p. 10-11. Boccia sees – e. g. in the pointed skulls - an oriental and byzantine influence.

233 All other comparable examples have either no reliable provenance or they are said to come from Chalcis. Therefore no such helmet can be clearly identified with its use in the western Mediterranean Sea or in central Europe.

rough exterior surfaces found at the not restored and even at the helmets "polished" in the last years, suggest that originally the plates were not ground and had a black appearance.

The system of making a low reaching helmet by attaching a simple nape and cheek protecting thin plate to a skull made of a thick plate is a cheap and quick way to produce a sufficient helmet. One worker can make in hot-work the rough shape of the skulls, one can finish the skulls cold, another one can prepare the lower plates and a fourth man can mount the parts. At the type-II helmets additionally the visors have to be produced. They are only slightly embossed and made of thin plate that could also be worked cold. To make the same helmet from one single plate is much more work and keeps one worker busy with hot-work for a long time. This is consuming more charcoal and more smith's hearths are needed to have several people making helmets at the same time.

4.4.3 Type-V "Chalcis basinet-barbuta"

A third group of 17[234] helmet-skulls, about half of them are from Chalcis or attributed to this find, will be discussed in the following paragraphs. The similarity of all helmets is their low reaching skull made from one plate, tapered below the ears and thus forming a flaring nape-guard. No plate-edge is turned and – with the exception of [ref_arm_4267] and [ref_arm_2128] (damaged) – all skulls have a central point. In shape nearly identical, some are equipped along the lower edge with studs or at least the holes are visible. Here a ring-armour collar was attached. A row of small holes for the lining-stitching is visible along the edge. Other helmets have only a row of holes for the lining rivets encircling the skull in the level of the ears [ref_arm_1986] [ref_arm_1993] [ref_arm_2000] [ref_arm_2008] [ref_arm_2095] [ref_arm_2097] [ref_arm_2129] and [ref_arm_2145]. At [ref_arm_2128] [ref_arm_2183] the studs still retain fragments of wire and a plate strap to which the ring-armour was linked. All helmets prepared for the attachment of ring-armour also show the holes or still the hooks and pins for the attachment of a central pivoting visor, of which no extant example can be attributed to this helmet-model. The latter variations – with the exception of [ref_arm_1981] and [ref_arm_4267] – have a medial ridge at the upper part of the skull. The helmets that never had a ring-armour collar do not seem to have had a visor too, as no features for its attachment are recognizable. Of this variation only [ref_arm_2159] has a medial ridge – anyway a unique variation of this group. While the general shape of the skull is nearly identical, this helmet has the lower edge turned, a medial ridge embossed at the upper skull, a small nose at the edge above the eyes visor with pivots at the side of the skull. These features cannot be found at any comparable helmet. It is possible that this is a transitional type from the Chalcis models to the classical "barbuta". This assumption is supported by a comparison of the visored helmet to the example of an early barbute [ref_arm_2156]. Both helmets have the same four holes of unknown purpose placed at the forehead of the skull and a similar t-shaped face-opening. The helmet [ref_arm_2008] is the only one that had a hinged small cheek-piece at the right side – now missing. Its skull is the only example faceted by 8 ridges.

All aforesaid helmets were either raised or deep-drawn from one plate-sheet. Maybe first a closed vessel was produced and then the face opening was cut. As especially the helmets without a ring-armour collar attachment still have a rough surface, it is possible that they were also not ground and polished. The absence of turned edges suggests an early date, probably between 1380 and 1420. Their making from one plate, the shape of the face cutout

234 These are: [ref_arm_1981] [ref_arm_1986] [ref_arm_1993] [ref_arm_2000] [ref_arm_2051] [ref_arm_2073] [ref_arm_2095] [ref_arm_2097] [ref_arm_2098] [ref_arm_2112] [ref_arm_2128] [ref_arm_2129] [ref_arm_2145] [ref_arm_4630] [ref_arm_5126] [ref_arm_2161] [ref_arm_4267].

and the elegant tapering is very similar to later Italian type-V helmets, the classic "barbuta", of which also some examples come from Chalcis.

The examples with a ring-armour collar attachment are probably the younger variations, as the only exponent with the features of both variations has no medial ridge [ref_arm_1981] – just like the helmets without a ring-armour collar. Therefore, it is possible that this helmet was first produced for the attachment of an interior lining only and was later fitted with studs for the fixation of a ring-armour collar. It is also possible that the helmet variations were made about the same time, but those equipped with ring-armour were reserved to wearers of a higher rank.

4.4.4 Type-VII "serial product"

A group of ca. 50 type-VII helmets probably provides the strongest evidence that already before 1470 Italian workshops had adopted some kind of serial-manufacture processes. Most of the simple models of the compared examples either come from Chalcis, Rhodes or Istanbul. All the concerned helmets are made of at least three plates: The hemispherical skull with a medial ridge[235], the lower edge left burred, a forehead reinforce riveted to the skull and an attached, flaring nape protection, slightly pivoting at two rivets at the ears – the latter plates both have an inward turned lower edge.

There are actually different variations of this helmet existing. The classical examples are very simple [ref_arm_1750] [ref_arm_1777]. The rivets can have decorative copper alloy caps attached [ref_arm_1721], the forehead reinforce sometimes has decorative concave cutouts at its upper edge [ref_arm_2010], the nape-guard consists occasionally of several lames [ref_arm_1887], at later items the skull can even be decorated by several ridges [ref_arm_1751] and the surface can be decorated by engraving and gilding [ref_arm_1855]. Therefore, some of the considered helmets were too costly to be produced in large quantities, but nevertheless, the system in which all the helmets were constructed support the following general assumptions on their making.

Particularly the often unfinished lower edge of the skull – covered by the aforesaid attached plates – brought up some questions on the making of these helmets. The forehead reinforce is not necessary, as the plate of the skull could simply have been left thicker – with a similar reinforcing effect. The nape-guard could have been worked in one piece with the skull as well. The answer is probably simple: The helmets were made in manufacture-processes using the division of labor. For the making of each part of the helmet a certain worker or group was responsible. Production costs could be reduced by the specialization of the workers to one process. Making a skull of only a simple hemispherical shape was easier than forming a helmet in one piece with a flaring nape-guard. Furthermore, the attachment of a reinforce-plate allowed for the use of thinner plate for the skull, which in turn reduced the time for the making of the latter. Thin plate was worked easier than thick plate. The number of necessary smith hearths in the workshops was reduced, as the workers made the attached plates in cold work. They also already turned the edges where necessary. Other workers ground and polished the single parts. Only little adjustment-work had to be carried out when the parts were mounted.

235 [ref_arm_1778] has no medial ridge. It was not possible to examine this helmet and therefore no conclusions can be drawn, but it has obviously been restored and was assembled from parts of different helmets, see also: Karcheski and Richardson (2003), p. 9. The author suggests that the skull is of later date, probably about 1500 and has some separately found genuine parts attached. All the skulls of the original helmets most likely had a central ridge. The medial ridge at the forehead reinforce of [ref_arm_1778] supports the assumption that it once belonged to such a skull.

An interesting publication brought up concrete ideas on how the most laborious parts – the skulls of helmets – could have been produced in series: The IWF-Göttingen published a video [ref_vid_buc] and an article[236] on the making of buckets in the Italian province of Brescia in the area of the village of Bienno. As late as the 1960ies in this area buckets for mason-work were made from one sheet of iron plate – with the help of waterpowered hammers! Until today, for museum-events[237] the hammers do still work. The area for more than 2000 years – until today – was famous for the making of all kind of metalworking, traditionally quality arms[238] and armour[239]. The working processes seen in the video are very simple to explain. Without restrictions, the same procedures could have been undertaken to produce the basic shape of a helmet and therefore the bucket-making will be discussed in detail.

Unlike the technique of raising a helmet, where most of the work is done from the later outside of the item, the buckets were made by a kind of deep-drawing process where the object is worked from its interior. The main advantage of the bucket-making technique was the forming of a huge number of objects at a time. In the video the men make seven buckets at one go. The handwork ratio throughout the process is still tough, but it is largely reduced by the help of the waterpowered hammer.

At first, from a store the plates are chosen and placed besides the smith's hearth. Several plates are inserted at a time in the hot oven. The anvil and the hammer head are prepared for the first forging process. The correct setup is controlled by a test-run of the hammer. The precise position of anvil and hammer is adjusted by moving the hammer backwards with the help of a heavy second hammer, swinging at a chain from the ceiling. Additionally the hammer is moved along its turning axle to remain centrally over the anvil. The first red hot plate is brought to the hammer with the help of tongs. The open bearings of the hammer are cooled by water, running through small channels to the necessary spots. The lifters operating the shaft of the hammer are permanently greased by a swap. The square plates are drawn out to reduce their thickness towards the edges, to enlarge their dimensions and to reveal a round shape. For the result of an equally dimensioned plate the worker is moving it very carefully with his grippers.

As the worker needs both hands for holding the work-piece, he regulates the start, beat-frequency and stop of the hammer via a handle operated by his left leg. The handle opens a water shutoff at the channel outside the mill, whose stream turns the mill-wheel. A stone serves as a weight for the closing of the shutoff. The worker thus only has to release the handle to slow down or to stop the hammer. For this work he is sitting at the left side of the anvil.

A second worker takes the drawn out plates to a waterpowered shear and cuts off the uneven edges. Subsequently the plates are sorted by size and by shape.

In a deep pit, a liquid, probably consisting of clay and charcoal, is mixed to which the plates are dipped before put in the oven. The liquid should prevent them from welding together when heated. Two plates at a time are drawn out red-hot under the hammer. This increases their diameter and makes the plates thinner, increasingly towards their outer edges. Working

236 Berbenni (1973).

237 For further information (in Italian language) see: http://www.comune.bienno.bs.it/Pages/Pagine_Generiche/?Id=48864 (24.01.2012).

238 The Beretta S.p.A. from 1526 until today has it's headquarter in the Val Trompia, a neighboring Valley of the Val d'Iseo where Bienno is located.

239 On the armourers of Brescia see: Rossi (1972).

two plates together makes work quicker as more volume keeps the heat for longer time and bumps or thicker parts are easier leveled out. After this process the plate edges are cut again. Seven of such plates are heated in the oven until red hot. A worker takes them off with tongs and lets them at once slide down from the support of the oven into a stone pit on the floor. The men blow their hammers a few times onto the plates to deform them so they stay together when forged. Then, with the help of the waterpowered hammer, the bundle is formed into the shape of a pan. For this process the workers had changed the peen of the hammer to an oblong mouth, rounded at the hitting end.

Each of these pans is dipped into the liquid described above, just as well as seven of the plates from the first go. The latter are then placed in the pan and pressed together by a simple wooden press. The rim of the pan is then beaten inwards to hold the plates together. The bottom of this "package" of plates is also treated with the liquid before it is placed in the oven. The liquid should probably prevent the pan from welding to the grill of the oven.

When completely red hot, the package is taken off the oven and slide again into the pit. Three men give it a rough hemispherical-shape by the blows of heavy hammers. The package got splayed from the heat and the hammering and needs to be tightened by a few hammer-blows.

Then the actual deep-drawing process starts. The package is worked under the hammer and permanently turned circular. The men make use of special grippers that reach over the upwards bending rim, throughout the process they are exchanged by larger examples. One man is operating the hammer and a second one handles the buckets. The worker begins from the largest circumference and slowly works towards the center. By the repetition of the circular beating the plates are shaped into deep bowls. When the desired depth is reached, the bundle is heated again and by means of a trapezoid plate beaten into the shape of a truncated pyramid. The "pan" or mold is taken off by hanging the buckets between a support and a hook and bending back the banked edges. Now, the seven buckets are separated. The sides of each are made even by a few beats of the big hammer, whose head had been exchanged to another of the required shape.

The revealed work-pieces – with the exception of the pyramidal shaping – resemble exactly a pre product of a helmet. If the technique of the waterpowered hammer was ever used in the described way for making helmets, it is very likely that its use ended in more or less the same stage. Further shaping and planishing needed to be made by hand probably. The helmet needed to be heated and worked from the outside. The techniques applied to get to the final shape of a helmet-skull are nevertheless the same like those of the bucket-making. It is probably even easier to shape a helmet of the group mentioned above, as the required dimensions are smaller, i. e. the bowl is less deep, and therefore a smaller plate can be used and the depth is reached much quicker. There was no need to cut or grind the lower edges of the skull, as they got covered anyway by the attached plates and by the interior leather strap for the lining.

Due to the limitations given by the trip hammer, a work piece for a helmet cannot be refined much closer to the final shape. This means that each helmet had to be finished singly by hand. The ridge had to be embossed and the surface had to be smoothed by a smaller hand hammer. All extant helmets of this type were most likely also ground and polished.

Other workers could make the nape-guard and the reinforce without a need for heating the plate. The required shaping could easily be done cold. Even the turning of the edges needs no heat, particularly as the plates of the concerned helmets with 1.0 mm average are very thin. The biggest problem in the making of these attachments was probably rather the deformation of the ready shaped plate through the tensions rising in the material when the edges were turned. It is also possible that first the edges were turned and then the plate was

brought in shape. Some nape-guards do obviously have a wire inserted in the turned edge [ref_arm_2015]. This allows a later adjustment of the turn without punching it flat. A hollow turn can either crease or become flat if the plate is shaped by hammer.

While the final evidence cannot be cited here, it is of course well possible that these techniques were once developed for the production of armour. Future research can focus on the history of the hammers of the region; maybe the shifting from armour- to bucket-making in the concerned region can be reconstructed by documentary evidence.

The open questions on the very important Chalcis finds – those in Athens are unique, unrestored, and belonging to one of the largest directly associated hoards ever found – serve as a demonstrative example that the knowledge on late medieval armour is far from being complete. Especially on the Chalcis finds a number of open questions demand further research.[240]

4.4.5 Central Europe

Extant early armour of Italian style is indeed often very similar. It is surprising that already by the end of the 14th century helmets of type-IV – the earliest type of armour to survive in larger quantities – often resemble each other very closely. Especially the model with the pointed skull is extant in several, almost identical examples [ref_arm_1495] [ref_arm_1543] [ref_arm_1494] [ref_arm_1509] [ref_arm_1529] [ref_arm_1562]. Though preserved in smaller numbers, several low-reaching type-IV models with a hemispherical skull are just as well similar to each other [ref_arm_1504] [ref_arm_1528] [ref_arm_1542] [ref_arm_1564]. Also some early helmets of type-III have very close similarities ([ref_arm_1348] [ref_arm_1352] [ref_arm_4572]) ([ref_arm_1374] [ref_arm_1400] [ref_arm_1404] [ref_arm_4316]) . These similarities suggest that most of the workshops of one region produced armour in a related style. As no total numbers, neither of production quantities nor of contemporary workshops, do exist, it is impossible to tell if a single workshop produced single models in the same style and in huge numbers.

In the second half of the 15th century, some ways of an serial-like production must have existed – in the south of the German speaking lands as well as in northern Italy and in Spain. Nevertheless, for the German speaking lands according to the remaining documents it seems like a delivery of 32 iron-hats made in Augsburg by three different masters in 1485[241] was one of the larger orders in the 15th century. Documents suggest that by 1490 patterns were sent to the armourers when armour was ordered.[242] Obviously the desire for a more uniform appearance of a group of soldier's was increasing.

One indicator for the production of armour in some kind of manufacture- or fabric-process can be found at the interior of some armour parts. Such objects are interiorly marked at a certain location along an edge by either a number of groove-like filings [ref_arm_322] or by punched dots [ref_arm_425]. While at some objects the marks are counting in numbers, at others the numbers of marks are the same at each segment of the item [ref_arm_757] [ref_arm_3752]. In the first case the marks are very likely only meant to help the armourer identifying the right mounting-order of the single pieces. Whenever markings counting only till 2 would have been found at armour for the limbs or the hands, it is possible that this was

240 This should focus on tracking down depictions of these items in contemporary artworks.

241 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1891), Reg. 8511.

242 July the 6th, Augsburg: The city council of Augsburg answers to a letter of Sigmund Gossenprot und Ludwig Hoser: …and [have found within a sealed letter by the Emperor, containing [… a draft and a pattern of a kettlehat, of which we should order a certain number…, from: Jahrbuch der Kunsthistorischen Sammlungen in Wien (1891), Reg. 8523, translated by the author.

meant to separate between the right and the left side of the body. As such marks are often found at non paired armour parts like breastplates and as they often count higher numbers, it is very likely that several almost identical objects were made at the same time in one workshop. Assuming that tens of items of one kind were made, it would be too time-consuming to add and later to count all the necessary marks to each segment. All segments of one item before mounting got the same number of marks. As the marks usually do not count to more than 6, it is also possible that the numbers describe the size of a serial produced armour part. It is also possible that different molds or patterns existed and the markings mapped the segments to one model.

A group of early items, probably produced in huge quantities, is a special variation of type-IV breastplates, preserved in the "Zeughaus" in Munich[243]. At least one plate – according to the catalogue description – is coming from the Zeughaus inventory but is now in anonymous private hands [ref_arm_4079]. They all are made of comparatively thin plate. The abdomen-plate has a medial ridge and its upper edge ends in a plain point. Usually the pelvis consists of three lames. All edges are only slightly de-burred by grinding and had not been cut after forging. Obviously the plates are of low quality, compared to other extant examples of type-IV. All plates have similar dimensions. In the Wackernagel's catalogue on the Zeughaus no detailed image[244] or description of the simple plates is published. Mario Scalini suggested that they are all of Munich production after an Italian model.[245] This is indeed possible, as several plates with Italian maker's marks – most of the from the Churburg armoury – are very similar, but usually of better quality and some of them are decorated by ridges. Two of the Munich plates indeed seem to resemble such decorated Italian models [ref_arm_3653] [ref_arm_3660]. Nevertheless, the construction of the Munich breastplates is different: The abdomen and the thorax-plates are permanently connected via 3 rivets, whereas the Italian Models have a central pivoting rivet and at each side an interior leather-joint.

Breastplates of type-IV are usually not very deep at the belly. The plates need to be shaped only slightly. The difficult parts are the turning of the edges and the outward angling of the abdomen-plate, where the pelvis is attached. Uncut edges are visible at the abdomen and the thorax-plates under the arm cutouts. It is likely that the pattern for the plates had been supplied smaller and was widened out into the desired dimensions. A second possibility is that they were already delivered in the right format from the plate-hammer. The burred edges do certainly not derive from the cold work of the armourer, the metal is splayed in a way that can only be achieved by working it hot. The thin plates used for the Munich breastplates did not have to be heated and could be hammered without much mechanical force into the final shape. For a metalworker it is always better to avoid the repeated heating of the material, as it is fuel consuming and the metal "burns off" within time. Additionally, the thin plates do not keep the heat for very long. While taking them red hot from the hearth or to the oven and placing them on an anvil or some other support, they already cool significantly. Even if they are still red hot when the first blows of the hammer hit the plate, within a few seconds the plate will cool down and cannot be forged anymore. It is also very difficult to heat the whole work-piece in the oven, as this leads to an all-over red hot temperature. When the plates are subsequently taken off for hammering, the already finished shapes from the preceding run

243 [ref_arm_3653] [ref_arm_3654] [ref_arm_3655] [ref_arm_3656] [ref_arm_3657] [ref_arm_3660] [ref_arm_3661] [ref_arm_3662] [ref_arm_3663] [ref_arm_3664] [ref_arm_3665] [ref_arm_3666] [ref_arm_3667] [ref_arm_3699].

244 On an image of the educational wall-display of the genealogy of breastplates also two simple plates are depicted, see: Wackernagel (1982a), p. 80, Abb. 16, breastplates 1, 3, 4.

245 After: Wackernagel (1982a), p. 26.

are easily deformed again by the following hammering. Also where the grippers hold the red hot plate it gets easily deformed.

The armourer or the plate-supplier probably forged the starting-slabs thinner and roughly into the necessary format. The control of the correct shaping would have been difficult for the armourer if the single plates were ordered ready-made from another workshop. Therefore, he might have given a pattern to the plate-hammer. As the lames for the pelvis are also left burred, it is obvious that the plates were not cut from a larger plate into their final shape. Compared to other breastplates, the turned edges are also of rather simple make. The lowest pelvis-lame has no turn at all. Such a breastplate was certainly finished within a short time. While it is of course difficult to estimate how long it actually took with the technical equipment of the time, it is certainly not wrong to say that one worker could finish such a plate within eight working hours.

Also in Munich another large group of breastplates of the considered period is stored[246]. They are of type-II, but all other features are similar to those of the Munich type-IV breastplates described above. All examples have a medial ridge – a feature not found on later type-II arsenal breastplates anymore. As contemporary depictions before 1480 ca. do usually not show breastplates of type-II, it is possible that the said ones were ordered for the Munich Zeughaus a little later than the type-IV examples, maybe in the 1480ies. For this type of breastplate already more deformation work is necessary. The plates are only slightly deep-drawn, but the deep-drawing of the plate requires more mechanical force than the making of breastplates of type-IV. On the other hand, no adjustment of the thorax and abdomen-plates for the mounting is necessary. Also here the toughest part is the angling of the lower edge and the turning of the edges. As the type-IV and -II plates of the Munich "Zeughaus" are all similar, it is likely that they were made in one workshop by some kind of early serial manufacture.

There are actually at least two sources that tell about the use of dies in the court-armoury at Innsbruck. One is found in Maximilian I.'s "Weiskunig", where his personal engagement in the technological development of his court-armoury at Innsbruck is described:

> *[…] weiter so hat der weiß kunig in der obgedachten platnerey wunderlich harnasch, fur sein kriegsfolckh, zu den kriegsharnasch, ain Newe kunst erdacht, das man in seiner platnerey, auf ain mal, dreissig vortertail [breastplates], desgleichen hindertail [backplates], aufgeformbt hat, dadurch in seiner platnerey, in ainem Jar, ain groß Anzal harnasch, fur die landsknecht, die zu fueß gefochtn und gestrittn haben, gemacht worden ist, wie wunderlich und kunstlich ist aber dieser kunig gewest.*[247]

246 [ref_arm_3491] [ref_arm_3492] [ref_arm_3493] [ref_arm_3494] [ref_arm_3495] [ref_arm_3496] [ref_arm_3497] [ref_arm_3501] [ref_arm_3502] [ref_arm_3503] [ref_arm_3504] [ref_arm_3505] [ref_arm_3506].

247 Treitzsaurwein (1775), p. 98. Translation by the author: "[… furthermore, the wise-king in his armoury developed a marvelous way for the making of combat-armour for his foot soldiers. In his armoury at one time thirty breastplates and also backplates were embossed. Hence, in his armoury in one year a large number of armour was made for the "Landsknechts" fighting on foot. This is how marvelous and artistic this king has been." This statement is somewhat imprecise. It is certainly impossible to deep-draw a pile of 30 breastplates in one "blow". Maybe the writer intended to say that 30 were stamped in one day, which is well possible (see discussion below).

The earliest note that clearly refers to techniques for the serial production of armour dates from the 5th of June 1504, just shortly after Maximilian had made Konrad Seusenhofer his court-armourer in Innsbruck (22nd of January). King Maximilian I. gives order to the „Salzmaier“ in Hall, Degen Fuchs, to have stampers and anvils made after the instructions of Konrad Seusenhofer.[248] It is possible that tests with stamping were not successful yet, as large numbers of breastplates (300) were actually still ordered from Mühlau in 1506.[249] One year later the sources refer again to the order of dies. In a document of January 1507 King Maximilian orders from his bullet-smith[250] in Absam, Jörg- Zangrer:

[…] zwei schabutten-ambos zu ruck und armschinen mit ihren kern und zugehorung machen, damit Conrad Seusenhofer, sein Hofplattner, alle Arbeit, die er zu machen Auftrag habe, ausstempfen könne.[251]

It took some months until Maximilian's order was realized. In June 1507, on the order of King Maximilian, the Raitkammer in Innsbruck had actually sent the son of Jörg Zangrer, Hans Zangrer, to the city of Eisenerz for making:

[…] einen Ambos zu einem modl zu harnaschblech.[252]

The "Schabotte" (Fr. chabotte)[253] mentioned above was probably the lower anvil, shaped like a negative mold of the breastplate, the "kern" is most likely the exactly corresponding core that is stamped into the "Schabotte" while the plate is placed in between [ref_ill_art_5379]. The molds might have been operated by a ram similar to [ref_ill_art_5170]. It is also possible that the core was lifted with the help of waterpower.

A document of 1511[254] proofes that in Innsbruck breastplates were actually deep-drawn. Here Seusenhofer accounts for the King's employees and their work in his court-armoury. This is certainly the most detailed source on the serial-production of breastplates. The text is difficult to understand as the syntax is interlaced, but a considerate reading reveals the basic facts that allow the understanding of the organization of the Innsbruck court-armoury.

The workers were split in groups. The first group made the subtle work. The second one produced exclusively the simple foot soldier's armour. Obviously some armourers had to work certain hours on the account of Emperor Maximillian I., but after work they were paid on Seusenhofer's account. The following paragraphs tell details about the numbers of simple breastplates produced in a certain time:

248 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1884), Reg. 738.

249 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1884), Reg. 784.

250 The order is probably given to the bullet-smith as he forges the canon-balls in dies and therefore he knows best about the necessary techniques.

251 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1884), Reg. 816. Translation by the author: "[… two die-anvils with their core and equipment for the making of backplates and arm defenses, so Conrad Seusenhofer, his armourer to the court, would be able to stamp out all the work that he has to finish."

252 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1883), Reg. 854. Translation by the author: "[… an anvil as a model for armour-plate."

253 For further explanations on the modern meaning of the word see: http://www.zeno.org/Lueger-1904/A/Schabotte?hl=schabotte (20.02.2011).

254 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1884), Reg. 1010.

[…] Die, so krebsen machen, darunder ainer armschin auf die fuessknecht machet, so dann ain ganze wochen ist, der ainer in kay. mt. zeit vntz zum hertnen vnd ausfeilen 12 krebsen, waz aber ir ainer in seiner weil kan machen auf gestempfter krebs, wurdt im von aim krebs verdingt zum hertnen 5 krewzer. Michel Lehenher, Hans Wagner, Caspar Schuestcr, Utz Gwerlich, Erhard Koch, Lienhard Salzpurger, feyler, Cristan Schuestcr, jünger. 7 personen.[255]

Egg[256] understood from this source that 6 workers – the named 7th man made arm-defenses – finished a total of 12 breastplates a week. This is certainly incorrect. These men were working on the cheap „rough" parts only. The average of 2 finished items a week is far too low for one specialized worker, especially if the rough shape of the breastplates was indeed formed with the help of dies. The armourer only had to finish the general shape, maybe to angle the lower edge, to turn the edges at neck-and arm-cutouts.

The most unclear word in the aforesaid paragraph is "untz". It is important, if it means "and", the named armourers themselves "filed *and* hardened" the plates. In older German dialects this word meant "bis" (Engl. until) and therefore it is very likely that in the concerned source it can be read as "until ready for" (filing and hardening). Here it is especially noteworthy that even the cheap footsoldiers's "stamped" breastplates later obviously got hardened.

If the interpretation is correct, in modern words the text would sound: "Within the group of the seven following workers, one makes arm defenses for the foot soldiers. Each of the other six workers finishes 12 breastplates – until ready for filing and hardening – within one week of his regular service to his Imperial Highness. For each further deep-drawn breastplate he finishes for hardening after his regular working-time, he is paid 5 Kreuzer.

A letter concerned with the same topic written later in the same year by Seusenhofer is even more precise:

255 Translation by the author (with interpretations of the unclear passages): "Those who make breastplates – one of them makes arm-defenses for the foot soldiers – whenever there is a full week make in the time of his imperial highness except of the hardening and the filing 12 breastplates. For whatever one of them worked on stamped breastplates except of the hardening in his own time he was paid for each breastplate 5 Kreuzer. […]"

256 Egg (1992), p. 317.

Vnd mit den raucharbaitern, so in meiner speys sein vnd die krebs vnd rugglein machn, halt ich die Ordnung, nemlichn, wann sie ordonari arbait gethan vnd feyerabnt haben, so mugen sy krebs machn, vnd wieuil sy krebs also nach dem veyerabent machn, so gib ich albeg yedem von ainem krebs zu Ion 5 k r . ; aber sy welln yetz etwas mer haben. Mit diser Ordnung mag kay. mt. fül krebs in geringer costn gemacht werden vnd dise raucharbaitcr machn ain wochen nach dem veyerabent, aine in die ander zu raitn, yezuzeitn mynder yezuzeiten mer angeuerlich 18 krebs vnd von ainem krebs zu Ion 5 kr. tuet in ainer suma anderhalben guldein rh.[257]

This text clearly says that in average the 6 workers after the regular working-time together finished 18 additional breastplates a week – hence 3 breastplates were made by one man. Together with the 12 breastplates made in his regular working time, one man made 15 and therefore all the workers together made a total of 90 breastplates a week.

It is very likely that specialized workers finished the breastplates mentioned above. In the accounts of Seusenhofer grinders and polisher are named together with their specializations:

Polierer vnnd Schleifer: Caspar Lusch selbander auf der subtil arbait, Hans Kessler auf den krebsen, Conz Teininger, schleifer vnd polierer, vnd ander arbait zuhelfer. Vier personen.

Also the pelvis-lames for the breastplates were obviously made by a specialized worker who furthermore had to pin down the breastplates on the anvil for stamping:

Balthis Vischer selbander, so die schossen [pelvis-protections] zun krebsen schmidt vnd die prust zum einschlagen aufpenst [probably: pin down] hat, aber kain wochenlon, sonder waz er teglichs vil oder mer verdient. Zwo person.[258]

This Balthasar Fischer is working independently from the court-armoury. He is paid only according to the daily work-quantity. Two people are working for him. They are forging the pelvis-lames and they are preparing the plates on the stamping anvil.

A little later in 1511 a second letter of Seusenhofer tells that a specialized worker was responsible for the stamping or deep-drawing itself:

257 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1884), Reg. 1028. Translation by the author (with interpretations): [… I have organized those busy with the "rough" work and paid by myself for the making of breast- and backplates as follows: Whenever they have finished their regular work and they have their free time they can make breastplates and no matter how many they make after work I pay them 5 Kr. For each. But now they want to have a little bit more. With this organization a lot of breastplates can be made for his imperial highness at low cost. These rough-workers make on a weekly bill after their regular work – sometimes more, sometimes less – enormous 18 breastplates and 5Kr. for each makes a sum of 1.5 gulden rh." (60 Kreuzer=1 Gulden rh.).]

258 Translation by the author: „Balthis Vischer who forges the pelvis-protections for the breastplates and who has pinned down the breastplates for stamping. He is not paid weekly but only for what he earns more or less a day. Two persons."

[…] Mer Conzen Teiniger, den ich zu aller noturft der platnerei prauch, mit krebs einstempfn, aufslagen vnd ander arbait, auch sleyfn, gib ich im ain wochen für speys vnd Ion 1 guldein rh.[259]

In summary, the breastplates were therefore certainly made by division of labor processes. One man pinned down the plate on the anvil. A second one operated the stamping process; a group of six workers made the fine hammer-work and turned the edges. Another worker made the pelvis-lames and a group of people were grinding and polishing the plates. It is nevertheless not clear who hardened and who mounted the pelvis-lames and the leather-straps. The weekly output of ca. 90 breastplates in the year 1511 can certainly be defined as "mass-production". It is surprising that the large breastplates orders addressed to the Innsbruck court-armoury are not continuing after Maximilian's death.[260]

Several type-II breastplates of the early 16th century are preserved in large numbers in the Vienna (45 items, e. g. [ref_arm_3421] [ref_arm_3527]) and the Munich Zeughaus (unknown number, e. g. [ref_arm_3499] [ref_arm_3500]). They all have no medial ridge and the turned edges can be of different types. At some objects, the arm cutouts are made of a separate, inserted plate [ref_arm_3552] [ref_arm_3551]. One variation with pairs of small holes drilled close to the edges exists in two versions: One is plane [ref_arm_3498] and the other one is decorated by a bundle of ridges [ref_arm_3473]. Two, in general similar items [ref_arm_3526] [ref_arm_3567], are actually of type-III.

All of these breastplates have cutouts at the tapering of the waist. They were either applied to hold the belt in place, to make the plate fit to different trunks or to facilitate the production. Many of them show no ridge decoration and the pelvis-lames are attached via the easy-to-make pivoting rivet-joint. The plate-thickness is usually below 2.00 mm. All these facts mark these breastplates as cheap equipment for simple soldiers. According to contemporary artworks, they were in fashion in the first two decades of the 16th century and therefore they could well have been made in the deep-drawing technique described by the aforesaid contemporary sources.

Maximilian I. throughout his reign had ordered huge quantities of breastplates. One of the earliest evident mass-order in 1495 addressed the Nuremberg armourer's to deliver 1000 breastplates. The city council answered in a letter to Maximilian on 12th of May that 300 items are in stock and that the other could not be delivered before the 7th of June. [261] This would mean that within about a month 700 breastplates could be produced or at least bought in. Such scores could certainly only be reached in a short time by serial-production methods like the division of labor. It is well possible that some of the extant Vienna breastplates were part of one of these mass-orders and later they came to the arsenal. Some of them even bear Nuremberg marks. Those that have no marks might have been made anywhere. It has already been suggested that the aforesaid type-II breastplates in Vienna were made about 1508, mainly for King Maximilian I. He wanted to have his troops equipped uniformly on his ride to his planned coronation as Roman Emperor in the Eternal City. The development of the stamping-technique is most likely connected to this event. Maximilian wanted to be

259 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1884), Reg. 1028. Translation by the author: "[… Furthermore Conz Teininger who I need for several works in the armoury, for the stamping and the hammering of the breastplates and for other work, also grinding. I pay him for expenses and salary 1 Gulden rh. a week."

260 Egg (1992), p. 318-321.

261 Böhmer and Wiesflecker (1990-1996), Reg. 3422 (http://regesten.regesta-imperii.de/index.php?uri=1495-05-12_3_0_14_1_0_3428_3422).

independent in his orders from the influential councils of the imperial towns and therefore he tried to establish the mass-production of armour in Innsbruck – his beloved city in his own hereditary lands. It seems like the output of the Innsbruck workshops was not sufficient, as Maximilian in 1508 still had to order 2000 breastplates from Nuremberg.[262]

It has not been scientifically examined so far if dies were actually used in the making of armour in other cities than Innsbruck and possibly also in later times. As the city councils of Nuremberg, Augsburg and Landshut had ordered to stamp the good quality items with the city's coat of arms, there is only little chance that the many unmarked breastplates of the Vienna Zeughaus were made in one of these cities. Only Innsbruck never had ordered the quality-stamping of armour produced in the city and therefore it is possible that the unmarked items were made in Innsbruck.

As also dies for the stamping of arm defenses are mentioned, the question can be asked, which extant items could be produced in this technique. A special type of extant arm defenses is made so simple that it was certainly made only for foot soldiers. The specialty of this armour is that the lower arm-protections have crude plates for the protection of the hand directly attached. They are fixed by one single rivet, sliding in a slot [ref_arm_5027] [ref_arm_4926]. The earliest depiction of such a defense is found in the Marienkirche in Reutlingen [ref_ill_art_5360]. Only the slot at the lower arm and a rivet head at its upper end are visible. It seems like the hand-lames could be slide interiorly when not in use. Generally, these defenses are not depicted very often. They were in use around 1500. Several of the elbow defenses bear the quality approval mark of Nuremberg [ref_arm_263] [ref_arm_275]. The mentioned objects and the sources for the serial-production technologies do of course mark the very end of the considered period. The preceding discussion of the topic of serial-or mass-production of armour shows that such processes were most likely developed long before the 16th century – but by far not all questions are answered.

262 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1884), Reg. 902.

5 Supplying crafts

To produce armour, different specialized supplying crafts or arts had to deliver their products to the armourer's workshop. Some of them, like the making of plates or the making of nails, were already described above in details. In the following chapter, some further supplying craft-branches not belonging to those of the armourer's specialization will be shortly summarized.

5.1 Wire drawing

Inside many turned edges a wire is inserted. The armourers rolled the plate around this wire to make sure that the edge would have a uniform, round appearance and would not accidently become flat by hammering. The armourer of course might have made this wire himself, but rather likely he obtained it from a specialized supplier.

The technique of drawing wire was known since antiquity. It is generally possible to forge a wire, but the thinner its diameter should be, and the longer its dimensions are the more difficult and time-demanding this work would become. Wire was needed for different purpose; a huge demand came from the ring-armour makers. As segments of such armour were often attached to exposed locations of plate armour, the production of wire is connected to armour making by even one further aspect.

The starting material for wire-drawing first had to be forged to a longer stripe with a diameter of at least 5 mm. Also the cutting of a plate into smaller stripes is possible. One end of these stripes had to be pointed to fit through a cone shaped hole in a draw plate that at the narrow side was 8-15% smaller than the diameter of the stripe. After sticking this end through the hole it was grabbed by a tong and the stripe was drawn with force through the hole. Different techniques for wire drawing can be adopted. The simplest one was operated by manpower. The worker was either standing on the drawplate, or the latter was fixed to a heavy wooden base and the worker is sitting on a swing [ref_ill_art_5324]. Also a winch with a crank handle could be used [ref_ill_art_5362] (descr. 1). These techniques were unsuitable for a mass production of wire, due to the need for immense manpower, especially in the beginning of the process which starts from diameters of maybe 4-5 mm. Such methods were rather suitable for the production of finer wires by drawing semi-finished products. The technology for the drawing of the latter got an important impulse by experiments carried out in Nuremberg around 1402 to 1415[263]. A local entrepreneur funded the systematical development of drawing wire by means of a waterpowered mill. Albrecht Dürer painted the famous wire-drawing "Sandmühle" in Nuremberg [ref_ill_art_5349]. The details of the new technique are for the 15th century obscure, but it is likely that it was basically the same like illustrated in Biringuccio's "pirotechnia" in 1540 [ref_ill_art_5362] (descr. 2). Here a water wheel operates a horizontal crankshaft. This is connected to a leather belt and a rope which ends in a ring put over the arms of a tong. A worker is sitting on a swing and controls the tongue with his hands. He grabs the wire which is lead through the draw plate in front of him exactly in the moment when he is the closest to the plate. The waterpowered shaft then by drawing backwards closes the chops of the tong holding the wire tight and pulling it through the draw plate. When in the most distant position to the draw plate the worker would release the wire and move forward with his swing again. This swinging process is repeated permanently.

263 See: http://www.nuernberginfos.de/muehlen-nuernberg/sandmuehle.html (23.12.2012).

5.2 Production of tools

Hammers, files, plate shears, anvils, stakes, saws, drills etc. had to be produced by specialized toolmakers. While hammers and stakes are probably the most simple of the mentioned tools and thus could have been made by the armourer himself, all other items required certain sophisticated skills. Plate shears had to be made of the best material, so they were able to cut up to 6 mm of steel plate. Anvils are often made of one heavy block of iron. They were usually not cast but forged, which required heavy hammers and supports for the handling of the work piece. The files necessary for finishing the fretwork on some armour needed to be made of very good quality.

Punch cutters needed to provide certain tools to the armourer's workshop. The mark-stamps needed to be cut into a steel chisel which subsequently was hardened and tempered. The symbols or letters have to be cut into the steel in reverse by means of small gravers and chisels. But also for decoration, rather simple punches were already used in the late 14th century. These might have been made by the armourers themselves, but most likely they were ordered from the same craftsman who supplied the punches for armourer's, city's or owner's marks, the so called "Stempfelgraber". These specialized workers were probably also making the punches for coins. The techniques for cutting iron were increasingly developing throughout the 15th and reached a height in the 16th century with the decoration of sword and rapier hilts.

5.3 Tailoring

For armour made to measure it was necessary to fit the lining to both, the armour and the wearer's body. The linings of cheaper mass produced and standardized armour were certainly made after standardized patterns. If a helmet was meant to be bolstered for comfort and against hits and blows, a specialist needed to pad a lining at the right spots. This also meant that it had to consist of two layers of fabric which could be stuffed with wool, hay, straw or horse hair. A stitching was in the end added to keep the filling in place. It is not clear if the sewing of the linings was carried out by the armourers. Possibly they worked together with tailors who fitted the armour with the necessary fabric parts [ref_ill_art_5319] [ref_ill_art_5320].

5.4 Etching

Decorative patterns can be drawn by corrosive liquids into the surface of iron or steel. This technique is very widespread in the 16th century and is employed not only for the decoration of arms and armour, but also for etching illustrations on printing plates. The "liber illuministarum" mentions several simple 15th century recipes on how to etch on steel[264]. For one technique the corrosive liquid is painted directly on the iron by a feather. For all other recipes the surface is covered with an acid resistant coating, while the locations where the ornaments should appear later were left blank. In these areas the corrosive liquid is applied by means of a brush, a sheet or a feather. The main difference to modern etching is that today usually all the surface is coated with a resistant paint and then this layer is taken off where the decoration should appear.

Into the surface of an artifact blued in the technique mentioned above a pattern can be drawn by etching off the blue layer with a weak acid. But ornaments can also be etched deep into the surface, with their dark color giving a strong contrast to the silver shiny polished surface. The strength of the corrosive liquid and the time of exposure are the factors which decide about the depth and clarity of the etching. A too strong liquid might go on reacting with the

264 Grancsay (1932), blue etching pp. 345-346, 668; for deep etching see pp. 668-669.

iron even though attempts had been made to wash it off and thus the contours of the etching might look fringy.

It is very likely that such techniques from the second half of the 15th century on were also used for decorating armour, as indeed a few objects of the time are decorated by blue- [ref_arm_1971] and others by deep-etching [ref_arm_3736].

5.5 Bellows

To reach the heat that is required in a smith's hearth, for example for hardening steel 723 C, it is necessary to bring air into the burning charcoal fire. For this purpose, since the high Middle Ages bellows were used. To achieve high and permanent temperatures it is very important to keep the air steadily floating in a regular stream. A single chamber bellow cannot provide this demand, as its work-cycle is interrupted by the refilling of the chamber. The solution was found in using two bellows. At production sites where metal was melted or where heavy iron billets were treated mechanically, water power could be used to permanently operate the bellows. In the armourers workshop they were needed only occasionally, for example for turning narrow curved edges or for raising helmets. Therefore, it was not necessary to use water power for the bellows. They were most likely operated by a handle, as can be seen at artwork [ref_ill_art_5330] (descr. 3).

5.6 Tanners

Tanning of animal skin was a specialized craft as well [ref_ill_art_5315] [ref_ill_art_5317]. Many different kinds of skins and fur were tanned for different purpose. For the making of armour, leather was important for the fastening of the single pieces. As it cannot be said with certainty that the remains of leather to be found on extant armour pieces are contemporary with the armour-production time, it remains questionable which kind of leather the armourers used. The bylaws of the armourers of Nuremberg required the use of buckskin for the gloves inside the hand-protections[265]. Also few remaining leather gloves are made of such material. It is usually tanned in the chamois method. This is the repeated kneading of the raw skin together with fish oil and its subsequent heating at about 40 ^{0}C. Often the grain side of the skin is grounded so injuries or other small imperfections would disappear.[266] The leather tanned by this method has a yellow color and is very soft. Also other animal skin like deer, sheep and goat skin is often tanned in the chamois method. It is still used today for cleaning window glass. The soft buckskin was favored for the expensive armour and for joints which need to allow a high flexibility. Cheaper armour was most likely equipped with cow-skin stripes.

5.7 Lace production

By the late 14th century small metal points at the ends of ribbons and cords do appear in the depictions of contemporary clothing. Also armour was often attached to the wearer's clothes or ring-armour shirt by means of such fastenings [ref_ill_art_5309] (descr. 3) [ref_ill_art_5308]. The laces were either made of plant- or wool-fibers or from leather cut into fine straps [ref_ill_art_5312]. The small points prevented the ends of the cords and ribbons from fanning out and helped to bring them through the holes in the fabric and the armour plate. These endings were rolled from small brass plates and then riveted, sewn or pressed to the fabric. The "Hausbuch der Mendelschen Zwölfbrüderstiftung" shows a specialized craftsman who made such laces [ref_ill_art_5328]. The armourer most likely did

265 Reitzenstein (1959), p.77.

266 See: http://www.lederpedia.de/lederherstellung/gerbung/saemischgerbung (23.12.2012).

not produce them by himself, even though he certainly possessed the necessary tools and skills for their making.

6 The problem of authenticity

Artworks are often high priced goods. Each craftsman or artist capable of reproducing nearly identical valuable originals can easily be tempted to make some good money by forging artifacts. This is not a modern problem only, plagiarism of successful goods is known throughout the ages. Well sellable plate-armour – possibly first designed by a favorite workshop – has possibly been copied already in the Middle Ages by competing workshops. But such products would nevertheless today be considered as genuine.

There is no indication that genuine armour had been reproduced for collection purpose before the early 1800's. From then on a growing demand for antique armour was responsible for the market-supply of forgeries, reproductions, completions and badly repaired items. The potential buyers of ancient armour usually asked for "beautiful" and complete pieces. Genuine items therefore often got heavily altered. Decorations like etching or gilding were added or – even worse – genuine decorations were polished off as they were only partly remaining or they were covered by corrosion products. While today alterations are often being recorded in a file, the 19th and even many 20th century restorers barely documented such interferences. Within the past 150 years, the repaired, completed and reproduced items have mixed with items of a more or less genuine condition.[267] Each curator of arms and armour collections assembled in the last 200 years, is aware of the authenticity-problem of the one or the other artwork in his museum. The responsible of the collections nowadays have the task to scientifically divide out all alterations and to reconstruct each item's history. This is necessary as the ignorance of these aspects might falsify the image of the medieval past. Therefore, whenever late medieval armour is examined, one obstacle on the way to reliable conclusions has to be attended: The often unanswered question on the authenticity of the concerned object or of some of its components.

The scholar will not find much help in the literature, as only little research concerned with this question has yet been carried out. Just a few articles dealt with the authenticity problem. Andrew Mowbray in 1967 said that the *"area of forgeries is practically a virgin field and will remain so until a major work on the subject – such as that planned by Stephen V. Grancsay – becomes available."*[268] Grancsay until his death in 1980 never published the announced work. Anyway, throughout the last 120 years a few "guidelines" got included in different general works on arms and armour. The most popular approaches will be introduced below. This paper does not want to be understood as the "major work" desired by Mowbray. Such a work can only be successful if it is executed in an interdisciplinary large scale research project. The present study wants to deliver all the information necessary to build a strong basis for further detailed studies on the subject.

It can be anticipated that, at the current stage of scholarly perception, it is not possible to answer satisfyingly the question on the authenticity of a certain item, whenever any unquestionable documentary evidence can be found. For most of the ancient armour pieces coming from the antique market no such documentation is at hand. A provenance of good sound could have been constructed easily and if it is bequeathed only verbally it remains very difficult to prove its validity.

Some preceding studies might imply that their results on questionable objects are final. Once the critical scholars goes deeper into the material itself, he will very soon get some doubts about bottom lines that appear to be set in stone. Of course, it is natural to wish for

267 As not all modern made armour was made to trick the buyer or spectator, but instead for decorative or scholarly purpose, in the following chapter such armour will be generally defined as: "reproduced".

268 Mowbray (1967), p. 15.

unambiguous answers, but masking all remaining doubts is not moving this important question any further.

For the understanding of the authenticity problem it is necessary to describe its historical causes. Therefore, some notes on the history of armour-preservation and the history of armour restoration and reproduction will be reconsidered. Subsequently, some of the major preceding approaches to the problem of authenticity with a focus on their limitations are discussed.

6.1 Notes on the history of armour preservation

The provenance is a very important factor when the authenticity of a certain item is questioned. Nevertheless, the present study can neither provide for a comprehensive history of the collecting of armour, nor can all the provenance data on each extant example be gathered. Such work would require extensive archival research, additional to the extensive object-studies already carried out by the author in the course of this study. The provenance-reconstruction of items coming from the antique market is often complicated and multifaceted. Therefore, it is still waiting to be discussed in a large scale study of its own.[269] Nevertheless, the knowledge of the different types of collections is inescapable for the understanding of the provenance-problem and subsequently of the problem of authenticity. Fortunately, of many objects all or at least some provenance-stations are published. Where the author had data at hand he added it to the object file.

Particularly when the authenticity of a certain item is discussed, an important question to be asked is on its provenance – or more precise: the reconstruction of the way a certain artifact was preserved until today. Undoubted documentary evidence on an item's existence before 1800 makes it unlikely for it to be a modern reproduction, as no reproduction activities before that time had ever been recorded. Reliable information can be provided by two different provenance-types: Objects that clearly came under earth before 1800 and objects that appear in – ideally illustrated – documents from before 1800.

Ideal conditions for the determination of an object as "genuine" are for example provided by a provenance from a well-documented and reliably executed excavation. Actually only a small part of the existing late medieval armour was excavated. The circumstances of the finding of many items that appear to be excavated are often not sufficiently documented. Such objects are found today in many collections, to which they usually came after 1800 either as a donation or by purchase. As unearthed objects are considered to be genuine, they were sought for by collectors. Therefore, some art dealers provided purposely corroded reproduced items.

For the preservation of the larger part of the existing stock some kind of collecting or conscious keeping has been the pre-condition. Several dynastic and private collections as well as armour preserved in churches provide undoubted genuine items, if documentary

269 An overview of 21 of the most important collections (with short descriptions) of European Armour and some additional private collections is found in: Boeheim (2000), p. 622-640. Boeheim's "Waffenkunde" was first published in 1890 and no update of his list of collections had been made. Many of them had undergone some major changes or they do not exist anymore. That already by the first third of the 20th century there was a great demand for an overview of the many important private sales of arms and armour of the 19th and early 20th century attests another, until today singular publication: Cripps-Day (1925). Similarly to this work all documented armour sales – be it private, of art dealers or of auctions houses – until today need to be recorded. The armour-database that was developed by the author provides the possibility to easily attribute such provenance data to each single object. Thus parts of the stock of now dispersed collections can be overviewed with ease.

evidence of the items from before 1800 exists. Many objects actually came from documented "old" collections into private hands.

Nevertheless, for the examination of archaeological items and such allegedly coming from "old" collections still caution has to be exercised as criminal minds might simply have invented a corresponding story.

Armour was usually preserved in one of five types of collections. The assembling of the armour in the first three groups had basically started in the days when the items were still in use. Such an inventory usually consists of objects once acquired for defense by a certain noble family or by an institution. The owner or his succession at some time gave up on the former designation of the objects and reduced their keeping to the purpose of commemorating the past. Like a racing driver that keeps the old fashioned cars of his former successes – and maybe another car of a competitor (in our case for example booty) – without ever driving them again. The fourth group describes collections that were assembled from the late 18th century on, after the collected items had long gone out of use. The fifth group is defined by a mix of dynastic and later assembled collections. Only few historical collections remained in their more or less original location but all of them suffered major losses, either by sales, by theft or by damages throughout violent conflicts. In the following each collection-type will be described in further details.

6.1.1 The dynastic collection

Dynastic collections are or were basically private collections of aristocratic families. They often contain costly armour attributed to the "heroes" of the past. The intention of collecting items for the remembrance of certain secular persons comes to a first height by the end of the 15th century. King Maximillian I. was one of the first rulers who consciously collected armour of important persons to keep the memory of their doings alive and to encourage their followers to act like these idols.[270] The mid-16th century saw the emergence of a number of museum-like institutions of arms, armour and other artworks. One of the oldest armouries to be preserved in Germany is probably August I.'s "Kunst- und Raritätenkammer" in Dresden, established in 1556. Until today this collection includes a large number of costly arms and armour, merely the Prince Elector's private armour from the 16th and 17th century.[271] The few pieces of the 15th century were acquired on the antique market since the last third of the 19th century, merely from the private Zschille collection. The Dresden collection was followed by the also still existing Real Armería in Madrid. Philipp II. from 1565 on collected the arms and armour of Emperor Charles V. and others of his ancestors. The collection contains relatively few field armour pieces of the 15th century.[272] The third collection in the group, and still the most impressive of all historic armour collections, was compiled by Archduke Ferdinand II. of Tirol (1529-1595). From 1565 on he gathered a huge amount of armour attributed to his ancestors and other "heroes" of the past and of his own times in the castle of Ambras, close to Innsbruck.[273] After his death, in 1601 (Latin edition) and 1603

270 Reitzenstein (1969) p. 70.

271 Bäumel (2004), Schöbel and Karpinski (1985) and Schöbel and Schaal (1985).

272 A 16th century illustrated catalogue of the armour was published in: Jahrbuch der Kunsthistorischen Sammlungen in Wien (1889), p. CCXLII-CCCXXIII and Jahrbuch der Kunsthistorischen Sammlungen in Wien (1890) p. CCCLIII-CCCC. A selection of collection-catalogues: Quintana Lacaci (1987) and Valencia Don Juan (1898).

273 Thomas and Gamber (1976), p.11.

(German edition) an illustrated catalogue of most of his suits of armour was published.[274] This early catalogue in its text never refers to the armour shown on the prints but instead to the doings of the depicted persons themselves. Thus the collection of Ambras cannot be seen like a museum that focuses its attention to the art of the object. It rather uses the latter to give a visual impression of the former owners of the armour. The desire of the collectors for attributing their object to famous historical persons can be felt in modern public museums until today. However, a great portion of the stock of Ferdinand's collection survives and was transferred to Vienna in 1806, where since 1888 it forms the largest part of the Hofjagd- und Rüstkammer inventory in Vienna[275]. The history of the collection at Schloss Ambras, including the suggestions for a reconstruction of the former installations, was published by Laurin Luchner in 1958.[276] Parts of the collection were brought back from Vienna to Ambras in 1980-81. This collection is not only of the highest importance because it is the largest one. It is also one of the few still existing collections containing the most costly genuine armour from the second half of the 15th century, often even identified with its former maker and its owner. Anyway, due to completions, repairing and restorations not all the details on the armour now in the Hofjagd- und Rüstkammer in Vienna can be considered as original.

Some further, smaller dynastic collections of the 16th and 17th century do still exist. For example the Armeria Reale of Karl Emanuel I. in Turin (with later additions) or the Fürstlich-Hohenzollern'sche Sammlungen in Sigmaringen.

A small but – concerning the original condition and the age of the items – very important collection is the armoury of the Churburg castle. The collection is based on the armoury of the Counts of Matsch, comprising private arms and armour from the late 14th century on. The successors of the Matsch family, the Trapp family enlarged the stock of armour of their predecessors by their own equipment. After the sale of several items about 1930 – fortunately most of them are now in international public collections – a lot of rare armour is still kept in the castle in southern Tirol. The artifacts are particularly precious as even the oldest parts of the late 14th century often retain original leather straps, linings and textile or leather gloves. Besides the doubtless importance of several nearly complete armour-suits of the 15th century, the many extant examples of simple soldier's armour is worth to be mentioned explicitly. This is also the main difference between other ancient dynastic armour collections and the Churburg armoury. For example the initiators of the collections in Madrid or Vienna were not interested in keeping the simple foot soldier's equipment.

Nevertheless, some further dynastic armouries with costly and foot soldier's armour still exist. Usually these collections are comparatively small and contain items from after 1500 only, like for example the collections of the Esterházy family in the castle of Forchtenstein. A unique and important collection that may be attributed to both, the group of dynastic and of arsenal collections is the armoury of the Grandmaster's Palace in Malta.[277]

6.1.2 The arsenal

Arsenals are usually of a public character and therefore they comprise merely cheaper armour for foot soldiers. At some time the responsible understood that the stored items could be of no use for combat anymore. At this point the collection was either liquidated or kept

274 Thomas (1981).

275 Thomas and Gamber (1976) pp. 11-12.

276 Luchner (1958).

277 Laking (1903) and Galea and Mintoff (1990).

as an appreciated relic of the glorious "freedom defenders" of old. The latter decision meant to accept the effort necessary for the maintenance of the collectibles.

Many "Zeughäuser"[278] or arsenals were established at the beginning of the 15th century. Garrisons or city-authorities kept their arms and ammunition in such stores. In Rhodes, Chalcis and Istanbul parts of arsenals comprising huge amounts of 15th century armour were preserved. In Vienna and Munich all the war-material was stored in different places, usually in the towers of the city walls. The earliest inventory of the Vienna and the Munich city arsenals, both from 1444 do not include armour, but the ballistic weapons with all their belongings and mainly material for the besieging of hostile fortified places. In Munich already by 1430 in parallel to these storages an city-arsenal in a building of its own existed, while in Vienna it took until about 1532-34, when the first Zeughaus at the Fleischmarkt behind St. Laurenz was built.[279] The arsenals of Munich and Vienna still retain a comparatively huge part of their inventory from the late 15th century and later. While in Munich there are several torso front-protections from the last third of the 15th century, in Vienna there are many torso front-protections for infantry from around 1500. Surprisingly in both collections there are only a small number of head pieces of the same period preserved. The earliest plate armour items in the Zeughaus of Vienna date from the 1450ies: a composite suit for a man [ref_arm_4090] and a nearly complete horse armour of Italian production (WM acc. no. 127.151-153 and 127.157-159). These early items are considered to have come later into the city-arsenal, probably as donations from a noble owner.[280] A composite suit of armour for the man (or its parts), on permanent loan to the Museum in the Goldenes Dachl in Innsbruck, was probably also given to the Zeughaus in a time after its use. The remaining parts of the 15th century in Vienna are breastplates of type-IV [ref_arm_3703] [ref_arm_3738] [ref_arm_3739] [ref_arm_3740] [ref_arm_3741] [ref_arm_3742] [ref_arm_3743] [ref_arm_3744] [ref_arm_3745], a backplate of type-II [ref_arm_3371] and helmets of type-VII [ref_arm_1894] [ref_arm_1895].[281]

All the still existing Zeughäuser had gained additional objects by donations or by purchase throughout the last 200 years. This means that also here the provenance of many objects is not absolutely certain. Heavy restorations, repairing and completions, for example at the objects in the Vienna Zeughaus, make the reconstruction of the genuine appearance of the single items very difficult.

Many historical "public" arsenals were dispersed over different collections throughout the last 200 years. For example most of the stock of the Bernauer Rüstkammer was sold in the 1930ies to the Museum für Deutsche Geschichte in Berlin, now the Deutsches Historisches Museum. Further arsenal stores containing no or only very little armour from before 1500 can be visited in Solothurn, Emden and Graz. Some stock of the former Zeughäuser of Zürich and Basel still exists, but is kept in storage not accessible for the public.

278 „Zeug" can be translated as „iron stuff".

279 For the history of the organization of the city defense and the role of the "Zeughäuser" see: Wackernagel (1982b) and Waissenberger (1977).

280 See: Gamber (1977), p. 40.

281 The catalogues of the Vienna Zeughaus do not tell closer details on their provenance. All these items are of finer quality and all different. Maybe they came later into the Zeughaus. The 1977 catalogue mentions for only two of them [ref_arm_3744] [ref_arm_1894] a possible provenance: They were maybe bought together with other parts from the private armoury of the rich Vienna citizen Jörg Strasser in 1504, see: Düriegl (1977), p. 76, cat. no. 49 and p. 84, cat. no. 115.

6.1.3 Armour preserved in churches

In the considered period nowhere in Europe men were buried dressed in their armour anymore. Where armour is or was found in churches, it was usually once deposited as a votive offering from a person saved from danger. Arms and armour was kept also close to the church-tombs as a long lasting memory of the deceased's heroic manners. Especially in England armour was often kept in churches[282], but also in Italy several important suits were preserved this way. About 1930 in the Santuario della Madonna delle Grazie a Curtatone near Mantua a number of armour suits – until then considered to be made of "papier-maché" – were recognized as being composed from genuine armour parts.[283] In Germany a late 15th century armour-suit was preserved in the church of Schwäbisch Gmünd[284]. All these examples are named in documents from before 1800, but all the named objects got altered by modern restorations.

6.1.4 The modern assembled collection

Throughout the last 200 years many private collections were entirely reassembled. In a few cases some nobles built their collections on the basis of small collections from ancient family possession. Also rich privateers started to collect arms and armour. The reasons that made nobles and privateers collecting armour need to be seen on the historical circumstances. At the Beginning of the 19th century the whole western world went through major political and social changes. The French Revolution had just overthrown what has been the state of the art since antiquity. In many countries the nobility had to give the government into the hands of non-aristocratic citizens. This development was about to take over to all the European countries throughout the 19th until the early 20th century. Of course, restoration politics after the Congress of Vienna postponed the establishment of democracies, but nevertheless the aristocrats were struggling to keep their social status – and their wealth. The industrial revolution from the 18th century on played an important role in these developments. Some citizens had become rich by founding production companies. With the establishment of a new wealthy, non-aristocratic social class a new and steadily growing interest for the patronage of arts aroused. Contemporary arts were encouraged by rich donors and antiquities became more and more valued.

Arms and armour – besides their designation for combat – always had a symbolic meaning. As leftovers of the times of knighthood they stood for a noble attitude, fairness, respect and strength. Some of the new wealthy and increasingly politically influential citizens as well as some wealthy aristocrats sought to legitimate their social status by assembling large collections of arms and armour – the most impressive status symbols of the past – just as the higher noble families had done since the 16th century.

In parallel to the social changes the Romanticism of the late 18th and early 19th century – first and foremost the novels like Horace Walpole's (1717-1797) "The castle of Otranto" or Sir Walter Scott's[285] (1771-1832) "Ivanhoe" – brought up a new interest for the times of chivalry. While Walpole in the third quarter of the 18th century had already revived these times in the architecture of his castle-like country house Strawberry Hill, Grave Franz I. of Erbach-Erbach started to collect antique arms and armour from the 1770ies on. For his armoury he also altered some rooms in his late-baroque castle to form one ample "gothic"

282 On armour in English churches see: Cripps-Day (1922)

283 Mann (1930) and Mann (1938).

284 See: Museen der Stadt Landshut (2009), p. 145.

285 In his historism castle „Abbotsford" also Sir Walter Scott had gathered some antique arms and armour.

hall. A large part of his collection still can be seen in Schloss Erbach. At the beginning of the 19th century an increasingly sensitive understanding for the medieval and renaissance times came up. About 1809 Franz Pforr (1788-1812) in his painting of the entry of Emperor Rudolf of Habsburg in Basel [ref_ill_art_5348] for example showed the stylistic ambient – including the armour – of the early 16th century in a surprisingly correct manner. The love for the details of the material culture of the past had awakened.

It was not long until the first happenings trying to reenact the age of chivalry were set up. Several jousts in the medieval or renaissance manner were held in Sweden already by the last third of the 18th century[286]. The first of such events to be remembered until today – due to the enormous efforts of its organization – is the "Eglinton Tournament" of 1839[287]. For this event the Earl of Eglinton, Sir Archibald Montgomery (1812-1861), convinced about forty nobles to acquire tournament armour and to train for one year for a real joust. The arms and armour was provided by the London art dealer Samuel Pratt, who sold original and reproduced items to the participants. Some of the equipment survives until today and is exhibited in a special showroom in the Royal Armouries in Leeds.

Since the time of its use huge quantities of medieval and renaissance armour was still kept in many castles and arsenal stores. From the beginning of the 19th century the private owners or the city communities often sold such stock to rich privateers to make some easy money or to gain space in their estate for various purposes.[288] Medieval European armour that survived for different reason in the Ottoman-ruled Aegean region was sold from the arsenals and was brought to Western Europe and North America. Huge amounts of armour from different sources came into the flourishing antique market. From such sources dealers like Samuel Pratt in London and later Victor Bachereau in Paris got their goods from.[289]

Probably the largest part of still existing armour from the 19th century on was sold to private collectors. Privately owned items were often sold or exchanged within the society of collectors. A market for antique arms and armour still exists today and therefore provenance-history is still a changing field that requires good documentation.[290] The estimated total number of extant armour pieces for field use from before 1500, including few identified reproductions, might reach at most 6000 objects. When comparing this to the number of 5000 16th and 17th century items preserved alone in the Landeszeughaus Graz, it becomes clear that for armour collectors the late medieval pieces throughout all the times of armour collecting were not easy to get and thus they were highly valued.

Some private collections of the 19th and 20ieth century shall be named. Some of them are now dispersed to different locations:

France: Arosa, Spitzer, W. H. Riggs, Napoleon III.

England: Wallace (still existing), Laking, Scott, Duc de Dino, Meyrick, De Cosson, Noel Paton.

Italy: Poldi Pezzoli, Stibbert, Luigi Marzoli (all three still existing).

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286 Anstruther (1963), pp. 246-247.

287 For a short note on the Eglinton Tournament see: Watts (1989).

288 The aforesaid Franz I. of Erbach-Erbach for example acquired items from the arsenals stores in Nuremberg, Amberg and Neumarkt.

289 On the history of the armour coming from Rhodes see: Karcheski and Richardson (2003).

290 In December 13th 2011 the Brussels auction house Pierre Bergé sold a part of the last great private collections in Germany (Klingbeil, Berlin).

Germany: Soeter, Hefner-Alteneck, Kuppelmayer, Zschille.

Austria: Wilczek, Till.

USA: Hearst, Dean, Severance.

Russia: Tsar Alexander I. (now Eremitage St. Petersburg).

Sweden: Hallwyl

6.1.5 Mixed collections

With the rapidly growing number of public historical museums in the second half of the 19th century many single arms and armour pieces were sold or donated to the newly assembled collections. Therefore, several museums not specialized on armour today contain the one or the other piece of armour.[291]

With the beginning of the 20ieth century museums started to buy a lot of armour from privateers with the intention of preserving it for the public. Some of these collections now contain a mix of dynastic, arsenal and modern assembled collections. For example the Royal Armouries in Leeds preserve the old armouries of the crown as well as additional items acquired throughout the past 200 years. The most precious purchase from private possession was probably the horse armour attributed to Duke Waldemar VI. of Anhalt-Zerbst, which came into the Tower Armouries in London in 1959 (now Royal Armouries in Leeds, acc. no. VI. 379). This is similar to the inventories of the Museé del'Armeé in Paris, the Livrustkammaren in Stockholm and the Kremlin Armouries in Moscow, that all acquired several collectibles from donations or by purchase throughout the 19th and the 20th century.

6.2 Notes on the history of armour reproduction and restoration

At least from the second third of the 19th century on[292] armour has been reproduced, like the items made for the Eglinton tournament of 1839 proof. The reasons why craftsmen started to reproduce antique armour are simple: A growing demand could not be satisfied by original items – especially early armour existed in only few examples.

It is inviting to imagine the distinction between genuine and reproduced armour as easy. In Europe for the most part the tradition of armour making has been interrupted for centuries. In the 19th century the industrial revolution had already generated so many new inventions in the sector of metal-work that scholars often suggested that the modern-made armour could easily be unmasked by detecting fingerprints of modern techniques. Until today it is generally ignored that the 19th century still saw good craftsmen, trained in ancient techniques like nail-forging, fire gilding etc. and even their working-material might still have been made by old techniques. Furthermore, at that time the collectibles in public museums were often not behind glass and in some cases they could even be accessed for taking measurements.[293] Therefore, it might be difficult to tell the products of some skilled modern workers apart from the genuine items. For these reasons, it is important to reconstruct the history of armour reproduction in a short sketch.

Two types of reproductions need to be generally distinguished. One was sold by the maker or a dealer as a reproduction and the other one was made to deceive a potential buyer. In the late 19th and early 20th century in different European countries several companies offered

291 E. g. the Victoria and Albert Museum, The Mittelmoselmuseum Traben-Trabach, The Museo San Lazzaro degli Armeni etc.

292 For example for the Eglinton Tournament of 1839.

293 Schedelmann (1963), p. 100-101.

"declared" reproductions. Unfortunately, the products were never clearly marked as reproductions.

Laking considers Italy to be the place where armour has been reproduced first. He says that poor quality work was made there already by the early 19th century. Furthermore – unfortunately without any reference – he mentions three families making reproductions and forgeries of arms and armour: The Diamante in Rome, the Gaggini in Milan and the San-Quirine in Venice. The suits they produced came into the market in the years between 1865 and 1880. He says that the Italians reproduced merely the *"flamboyant renaissance types"*, in contrary to the German colleagues who specialized on the *"Maximillian and so called gothic-types"*.[294] In France between 1860 and 1870 *"excellent and most deceptive armour and weapons"* were produced, *"forgeries that are interesting because they showed originality and were made with much care and thought."*[295] Laking adds to the list of reproducers also the names Leblanc-Granger and Charles Rouget who both made fantasy suits of armour for the Paris opera. Also in Paris, about 1875 a certain Mr. Klein made reproductions of suit for decoration but also a *"real master"* of the armourer's craft worked there: Antoine Vechte.[296] In London in the 1880ies an armourer called Francis was working.[297]

Some of these companies, like the Atelier of Ernst Schmidt in Munich, published catalogues of their offers.[298] Ernst Schmidt was probably not making armour himself. Most of his products were possibly made by the armourer Lorenz Kilian who died in 1919, but Schmidt had also other craftsmen working for him.[299] He even promoted his products by promising to use old production methods for their making[300], obviously already back then being aware that the originals were made of a material different from the modern. Another problem is that the images in his catalogue might also show original arms and armour parts which Schmidt apparently also sold.[301] Just like undoubted documentary evidence on an item's existence before 1800 can proof its authenticity, in some cases the catalogue image of a certain item might proof that it is a modern reproduction. Today it is very difficult to track down where all the Schmidt items went and where they are now. Anyway, the current locations of few items are known.[302] For educational purpose the Baden-Baden Karl Gimbel before 1904 had assembled a large collection consisting almost exclusively of

294 Laking (1920), p. 112.

295 Laking (1920), p. 112-113.

296 Schedelmann (1966), p.15.

297 Laking (1920), p. 120-121.

298 The catalogue of the Atelier Ernst Schmidt in Munich – probably first published about 1910 – has been commented and reprinted, see: Mowbray (1967). Mowbray on p. 161-168 also reprinted the catalogue of G. Pigeon of Paris.

299 Mowbray (1967), p. 7.

300 On one of the images there is to read: „Nachbildungen alter Waffen und Rüstungen aus Stahl u. Schmiedearbeit in alter Behandlung" (Engl.: Replicas of old arms and armour made of steel and smithery in old treatment. Transl. by author) Mowbray (1967), pl. 2, p. 19. The meaning of the sentence is not absolutely clear. The word "Stahl" or "steel" is often used for any kind of material which does not have to be carbon steel suitable for heat treatment. It also remains unclear if "alte Behandlung" or "old treatment" refers only to the smithery or also to the production of the material.

301 See: Mowbray (1967), p. 8-9.

302 Stephen V. Grancsay in his foreword on the reprint of Schmidt's catalogue describes several reproductions of 16th century style in private collections, see: Mowbray (1967), p. 10-11.

reproductions.[303] The suits [ref_arm_4115][304], [ref_arm_4131][305] of the Gimbel'sche Waffensammlung according to Mowbray came from Schmidt's Atelier. Maybe Gimbel had ordered also other suits from there, but they are not illustrated in Schmidt's catalogue. Most items from Gimbel – including the two aforesaid suits – later came to the Marksburg, where they are currently exhibited in the "Rittersaal". In the entrance hall of the Higgins armoury at Worcester a copy [ref_arm_3262] – said to come from Schmidt's Atelier – of the Vienna suit [ref_arm_3258] was exhibited.

According to Schedelmann[306], Schmidt had some competitors producing also good quality reproductions. He names "C. W. Fleischmann" and "Joseph Hugel"[307] in Munich, "M. R. Schmerha" in Vienna and a "mysterious" master Wessely. An armourer who is said to have sold his products as both, original and reproduction, was Leopold Winkelmayer in Vienna. It was easy for him to get very close to extant armour pieces, as in many museums of the 19th the artifacts were displayed without glass and often even without any barrier. Thus it was even possible to take measurements on the originals. Schedelmann says that Winkelmayer even used an armourer's mark and "too large" city marks. Unfortunately he does not give a reference for this assumption. Through the criminal-case on the Vienna art dealer Salomon Weininger the name of a further skilled 19th century armourer is known: Johann Böck of Vienna. Weininger had borrowed original pieces from public collections and had copies of them made by Böck. Weininger then gave back the reproductions until his deception was discovered.[308]

Laking has probably been the first to publish some notes on the mid-19th century production and trade of faked armour by two gentlemen, the London art Dealer Samuel Pratt and his armourer Thomas Grimshaw. This forger merely produced imaginary medieval helmets, but he also constructed whole fantasy suits of armour. His objects by their "style" seem to date from the 10th to the 14th century and many of them were described by Laking.[309]

In 1992 Karen Watts published an article that deals again with the duo Pratt and Grimshaw. She notes that at least 75 of Grimshaw's helmets were sold via Pratt to Robert Curzon, later the Baron Zouche. Grimshaw's forgeries seem to be rather easily identified as such. A scrapbook attributed to his own hand with sketches of many helmets is preserved in the Royal Armouries in Leeds. It seems like he mainly worked after depictions of armour in contemporary artworks and not after extant examples.[310]

Similar to the Grimshaw case – with a much wider impact on the total stock of merely ancient arms – were the early 20th century forging and selling activities of the duo Konrad and Kahlert. The first was a very skilled craftsman making excellent reproductions and the second was an art dealer who brought the forged items into the market. It was Hans Schedelmann who – by buying Konrad's bequest – had secured several correspondence-letters of the two that proved the ordering and production of forgeries. Schedelmann

303 Gimbel (1904)

304 See: Mowbray (1967), p. 101, pl. 61. It is not clear where the suits or its parts are today.

305 See: Mowbray (1967), p. 75, pl. 36.

306 Schedelmann (1963), p. 100-101.

307 Schedelmann reproduces an image of Hugel at work, see: Schedelmann (1964a), p. 51.

308 Hayward (1977), p. 78.

309 Laking (1920), p. 113-116.

310 Watts (1992).

published the first article on their activities ten years after Konrad's death in 1948.[311] It is not likely that Konrad made a lot of armour-reproductions. In 1924 he was asked by the Dresden museum officials about his opinion on a helmet offered for sale to the museum. He confessed that it was him who made it years ago, but that now he does not do such work anymore, as it is not profitable.[312] Unfortunately it is not known where this helmet is preserved now. No armour has clearly been identified with Konrad's hand; most of the objects attributed to him are staff-weapons. Nevertheless, his dealer Kahlert sold armour parts, e. g. the pair of hand-protections [ref_arm_1084] [ref_arm_1130], but not all Kahlert sales were forgeries as he also dealt with original items.

Not all reproductions of armour were forged from plate-sheet. Several companies also offered electro plated replicas of arms and armour. The Stolberg'sches Eisenwerk in Ilsenburg (near Wernigerode) and Karl (Carl) Haas in Vienna made electro-plated reproductions of armour in the late 19th century.[313]

To understand the basic differences to the conventional armour making techniques, it is necessary to describe the electro-plating[314] method in a few words. Electro plating is a technique already developed by the mid-19th century.[315] In an electro-chemical process iron elements solved in a liquid are joining at the surface of a conductive mold to form a stable layer. This layer becomes thicker with the continuation of the process. Once the desired thickness is reached the mold can be removed from the metal-artifact. The interior of an armour part produced by this technique would probably not show hammer-marks. If the item was not finished by forging the turned edges would be massive, maybe it would also be recognizable that rivets or applications are formed in one part with the plate. Nevertheless, it is a widely held belief that electro plated material was generally too brittle to be forged and that therefore edges or embossing could not be finished with the hammer. While certain electro-plating processes indeed produced only brittle material, in the 19th century the chemist Klein by red-heating the material revealed iron that could be forged and welded – just like wrought-iron.[316] Therefore, it is actually possible that items were reproduced by the electro-plating technique and were subsequently hammered to reveal a forged appearance.

The author has never seen an armour part of 15th century style, apparently made by electro-plating. This technique was most likely only used for reproducing more complicated shapes at richly embossed items of later periods. Due to the immense effort of the mold-making, the production of artifacts was probably only profitable when several items were produced from one mold.

For sure, many objects were made to trick the potential buyer, as a lot of money could be made by such sales. It is in the nature of the subject that forgers operated secretly and avoided to leave any documentary evidence on their activities. Only in few cases, by chance some evidence was found. The faker Grimshaw had left his private scrapbook including several drawings of the objects he faked or considered to fake.[317] Kahlert had kept many letters of the correspondence with his forger Konrad. In the yet unsolved cases it is difficult – if not

311 Schedelmann (1948).

312 Kroener (1988), p. 98.

313 Schedelmann (1964b), p. 116-117.

314 For the discussion of an electro plated armour-piece see chapter [An electro-plated helmet in Delft].

315 For a comprehensive overview see: Meißner and Doktor (2001).

316 Volger (1873), p. 366.

317 Watts (1992), p. 101.

impossible – to find further evidence for such activities. Even where it was found, until today it is often impossible to identify the produced objects with a documentary source, as usually no notes on the sales had been written down. Many reproduced articles were first sold directly from a dealer's atelier to private collectors and therefore no catalogues that could help to track down provenances exist. Many allegedly genuine armour pieces suddenly "popped up" from out of the blue. Most of the private collectors did not ask for documents as they believed in the provenance-story verbally communicated by the seller. To obscure their true provenance, many doubtful items went through so many stations that it was difficult for a buyer to investigate if they were "clean". Items were often re-sold by collectors and a buy from a collection of good reputation often washed away remaining doubts.

Many buyers of ancient armour wished to have a complete suit. In a few cases suits of armour were composed of genuine pieces. The larger number of museum suits is composed from genuine and reproduced parts, as not all missing pieces were available as originals. The reproductions that completed a suit were probably initially sold as copies. After the items had got handed over to new owners this information often deliberately or unwittingly got lost.

6.2.1 Modern alterations

The extant armour parts often had been neglected throughout the preceding centuries and many were in a bad condition. Parts were lost or they had got separated and needed to get fixed again. Rust had covered the surfaces and the organic parts had fallen to dust. As the conservation of the objects in their most original state is merely an invention of the times after World War II, earlier collectors and museums did often not care too much about the alteration of the objects. In the 19th and the first half of the 20th century many broken or heavily corroded armour pieces were brought back to "beauty".[318] In the 19th century material produced in pre-industrial techniques as well as craftsmen capable of working by the old techniques were still available. Today it is therefore difficult to tell when a repairing or completion was made.

Already by 1890 Wendelin Boeheim was of the opinion that fragmentary collectibles should not be completed. He suggested to better exhibit such objects with a good image showing a complete reconstruction. In his opinion the object had to remain unaltered as each completion would only further damage the original condition. To private collectors and dealers of arms and armour he gave the advice not to alter objects and to better buy a good cast replica from the *"Stolbergsches Eisenwerk in Ilsenburg"* or an electro-plated copy of *"Haas in Vienna"*.[319]

Unfortunately, until today original armour is extensively repaired or completed – armour in public and in private possession. At least, modern alterations or completions carried out by public collections get usually documented today. For example the right elbow [ref_arm_492] was made in 1956 by the armourer of the Tower Armouries Theodore Egli.[320] Nevertheless, some recent completions are very regrettable. Stephen V. Grancsay published an article on a poorly preserved helmet in his collection which apparently came from Rhodes. In close details, photographs and drawings he describes how the burred edges of the holes in the skull were cut straight and how 25 patches – cut from a genuine armour segment from Chalcis! – were embossed and subsequently welded into the holes.[321] It is certainly fair to ask, why

318 See for example: Potier Echelles (1901), p. 10.

319 Boeheim (2000), p. 584.

320 Edge and Williams (2001), p. 235, 239.

321 Grancsay (1952-53).

Grancsay did not simply order an entirely new reconstruction. An artifact so heavily altered cannot be considered as genuine anymore. Also some other restorers of the last century made use of modern welding techniques. For example parts of the brim at the helmet [ref_arm_1417] were reconstructed by welding patches to the old substance. Regrettable is the "repair" of the cutouts at the waist of the breastplate [ref_arm_3696]. The genuine structure was mistakenly filled by plate segments.

In the late 90ies of the last century Dieter Müller "filled" the corrosion craters on the plate-surfaces of a genuine suit in his collection by electro-plating.[322] This certainly also heavily altered the original condition, but at least the general shape of the plates was not changed by this restoration-method.

Heavy restorations and completions are still realized today. Not only private collectors alter original objects to give them a "nicer" appearance, but also some museums still do this. Each museum has its restoration department or at least it cooperates with a restorer. Several examples of recent restoration work can be quoted. Especially archaeological objects often got stabilized by artificial resin [ref_arm_1520] [ref_arm_3284]. The share of raisin at the helmet [ref_arm_1460] for example is certainly higher than the share of iron. For example the damaged paintings on the head piece of the Vienna helmet [ref_arm_1893] had recently been "completed". The reinforcement plate for the forehead of the helmet [ref_arm_1802] had been extended in the 1980ies. Small plates were riveted to the side ends of the plate. This is certainly an unnecessary "restoration" based on the complete misunderstanding of this helmet. In 2012 the detached visor of this helmet was found in the storage of the museum. Examinations by the author made clear that before its "restoration" – the detaching of the visor and the extension of the forehead reinforce – this helmet was in an absolutely genuine condition. Comparisons to similar helmets support this assumption and allow the reconstruction of the original appearance [ref_arm_1706] [ref_arm_1718] [ref_arm_1735].

Several items show repair that might have corrected a mistake that already occurred in the production process. For example the helmet [ref_arm_1702] on the top of the skull shows on several locations copper-colored soldering at cracks in the surface that could have occurred when the skull got embossed. Similar repair is visible interiorly at the helmet [ref_arm_1713]. The copper-colored solder is also found at presumable reproductions like [ref_arm_1510] and is therefore not necessarily late-medieval. Hard-solder has certainly been used in the late Middle Ages and can probably not easily be differed from modern repair. The most common stabilizing technique is the riveting of a patch of plate into or onto the problematic location. Hundreds of objects show such repair [ref_arm_1298] [ref_arm_1328] [ref_arm_1346] [ref_arm_2334] [ref_arm_3724]. Also here it often cannot be said with certainty at what time the patch was applied.

6.2.2 Historical recycling of armour parts

One important question on the existing stock of ancient armour is: Where is the rest? In the times when armour was used on all European battlefields millions of armour parts must have existed. The fate of most of them cannot be retraced. A large number might still remain undiscovered under the ruins of castles, the moats outside city walls and the ancient battlefields. The material of another large group was certainly reused for the making of non-armour items. A small number of items were preserved above ground. Within the stock of extant armour few parts are found that were obviously reused. Some older types were turned into a more fashionable model. In the following chapter a few examples of such alterations will be introduced.

322 Müller (1999).

6.2.2.1 Reusing the plate for non-armour items

In the 15th and 16th century doors in castles and churches often got reinforced by metal plates. One example was reinforced by breastplates that were hammered flat [ref_ill_art_5295]. Another breastplate of about 1580 was turned into a keyhole plate [ref_ill_art_5201]. A kettle hat has been recycled into a cooking kettle [ref_arm_1378]. An etched 16th century breastplate ended up as part of the base plate of a baroque lock [ref_ill_art_5307]. There are many more such examples to be found.

6.2.2.2 Giving armour a fashionable upgrade

Many armour parts were used for a long time, the shape and the decoration of some of them in later times got adapted to the latest fashion. At some time in the 16th or 17th century the central upwards pointing edge of the abdomen-plate at [ref_arm_3946] was cut off and the curved ridges at the abdomen and the thorax-plates were flattened by hammer to give the item a plain appearance in the taste of the time. The surface was simply blackened after these alterations had been carried out. The lines of the former ridges are still visible in- and exteriorly. The breastplate [ref_arm_3684] by the mid-16th century was painted by black-and-white stripes to imitate a contemporary "black-and-white" breastplate. The type-V helmet of the late 14th century [ref_arm_2058] by 1450 was turned into a more fashionable version of the same type. The studs that once held the ring-armour collar were taken off, the face-cutout was enlarged and the lower edge was turned. The face-guard was probably already missing and the helmet was used with an open face-cutout. The helmets [ref_arm_1653] [ref_arm_1655] [ref_arm_1658] [ref_arm_1768] are actually type-IV helmets of the late 14th century, in the first half of the 15th century they were turned into helmets of type-VIII by the application of large shoulder-covering plates at the lower edge. The type-IV helmet [ref_arm_1562] was stripped off his visor and a fall in the fashion of the mid 16th century was attached to the forehead. On the helmet [ref_arm_1754] the forehead reinforce is most likely a later addition. This helmet probably looked similar to [ref_arm_1752] and both of them had a face protection attached. At each side of the skull, above the ears there are two former holes visible, now closed by rivets.

All the aforesaid activities throughout the last 200 years have altered the history of genuine armour. For the reconstruction of the genuine picture it is therefore indispensable to try to scientifically divide out what has been added to the extant examples in the two past centuries.

6.3 Preceding preoccupations with the general topic of authenticity

6.3.1 Archaeologist's, art historian's and connoisseur's approaches

Throughout the last two hundred years, all persons who intended to buy armour or to examine it for scholarly purpose were interested in methods of authenticity-testing: dealers, private collectors and museum curators. The consulted experts usually had gathered their experience by the handling of hundreds of objects. Different information-classes had to be attended when the authenticity of a certain armour part was in question. The methods used for approaching the problem remind on those of forensic sciences. In the following some preceding, non-natural-scientific approaches will be introduced.

By the times many private collections were assembled, not much had yet been written about ancient armour and thus collectors had to do research about their collectibles by themselves. For the authenticity question of unique examples it was necessary to study the historical depictions of armour – to find out if such an object might have really existed.

Some of the early scholars publishing good quality articles on antique arms and armour – most of them British – were also collectors.[323] These men – even if some of them had never academically studied archaeology or art history – due to the quality of their work can be considered as academic scholars. Despite their experience, no collector published a word that would describe the factors that need to be considered when the authenticity of armour should be tested. By 1890 the custos of the Vienna Hofjagd- und Rüstkammer Wendelin Boeheim – himself being neither a collector nor an archaeologist or art historian – in his "Handbuch der Waffenkunde" was probably the first to dedicate a chapter to this problematic aspect of any kind of preoccupation with arms and armour.[324] Unfortunately his explanations are of a generalizing nature and they are not supported by any references to particularly concerned artifacts. He included no images of the features described. Nevertheless, Boeheim has been an experienced scholar. His suggestions are basically plausible and therefore the passages in his book dealing with armour will be summarized in the following paragraphs.

Boeheim argued that private collectors did often not have enough experience for not being tricked by criminal dealers. On the other hand many dealers – even though no academics – had become specialists in the classification of arms and armour, due to the many objects they handled throughout the years. As a simple primary indicator for the authenticity-testing of a certain item he set up the following formula concerning the price: If an offered item can currently not be produced for the named price it is most likely genuine. He justified his argument by the assumption that a potential forger intended to earn much more than he would by selling honest work-pieces. Only if a price was much higher than it would be for nowadays' work, the potential buyer has to be careful and to further test an item's authenticity. Boeheim then names several object-features that need to be examined: Does the general shape fit to the presumed date? This would be very important if the offered item allegedly can be attributed to certain historical happenings or persons. Do the decorations, inscriptions, coats-of-arms in design and techniques apply to the presumed date? He mentioned that even at genuine items the aforesaid features could have been applied in modern times to raise their value. Inscriptions and verses would reflect the expression-style of their own time. Boeheim presumed that here forgers would easily make mistakes in the application of aphorisms or mottoes, as they were usually no academic philologists or culture historians. Concerning the general shape Boeheim argued that the forger usually worked "accidentally" more regular than the old craftsman. The. Boeheim presumed that the making of plate-sheet by hammer-forging and the subsequent embossing of the plate must have left interior hammer-marks. Modern rolled plate-sheet would show elongated grooves crossing such hammer-marks. He considered the breastplate as the least profitable part to be forged, as it should not appear as being made of plate but rather forged from the billet. Forging a 16th century style helmet with its high medial ridge from one single plate-sheet would just as well be not profitable. Therefore, many suits of armour actually would consist of a genuine helmet and breastplate, completed by reproduced parts. These completions could easily be detected by a comparison of the colors of the iron. Even if all the features appeared correct, the rivets could unmask an item as a forgery. The old ones were made by hand and the modern ones are made by machines. He mentioned armour allegedly produced in Paris that – judging by a superficial look – appeared without blemish, but the helmets and breastplates were made of plate-sheet (he probably means "rolled" plate). No matter how expensive they were sold, if they would have been made in the old techniques and in the full thickness of the material it would be too unprofitable to produce them today. He also thought that the

323 E. g. Charles Alexander Baron de Cosson, James Gow Mann, Francis Henry Cripps-Day and Sir Guy Francis Laking.

324 Boeheim (2000), p. 572-581.

welding seam of helmet skulls made of two plates can be detected interiorly. If the testing of all features did still not unmask the item as a forgery, applications like velvet and leather would do. The connoisseur would recognize the color of old velvet and the modern alum-tanned leather appears different from the old leather. The rust on iron can be considered as a sign of age. The forgers would use this feature to trick the naive buyer who does not know that this is no indicator, as there are genuine iron artifacts that show no trace of rust. Boeheim allegedly knew that forgers used different methods to corrode their products. The "young" rust would be of bright red color and could be wiped off with the finger. Also damages – be them deriving from fighting or from falling to the ground – on armour were imitated by the forger to make his products less suspected. Where it may appear illogical that such damages could derive from a natural cause, e. g. if they were found in the cavities of the general shape, they had possibly been applied on purpose. To trick the potential buyer, the faker would often take an old armour part and make it more valuable by embossing and decorating it with "fresh" ornaments. These ornaments could easily be distinguished from the "old" as the modern worker was not capable of working by exactly the same technique and style. Especially etchings would not be of the same quality. Such alterations on old pieces, Boeheim said, fed several people in Paris, Nuremberg, Munich and Stuttgart. Poor quality work of this kind was made in Venice. [325]

Boeheim's arguments are based on a good deal of personal experience. Nevertheless, a reader who has never seen a piece comparable to one currently in question is left helpless with his guidelines. Also for the experienced, Boeheim's arguments do not remain without questions. His argument concerning the price is a doubtful factor. By the early 20th century in the foreword to his catalogue of reproductions Ernst Schmidt said:

> *"The purpose of this endeavor [making reproductions] is to enable the amateur of these familiar decorative objects to enjoy them at reasonable prices compared to the cost of originals."*[326]

This shows that the prices for reproductions or forgeries – at least about 1910 when the catalogue was published – were not necessarily high. When suggesting that the forgers of his days would easily make mistakes in the application of "aphorisms or mottoes" Boeheim forgets that the craftsmen of old might also have made mistakes and that some of them might even have been analphabets. Also the masters of old copied inscriptions from successful products, but they often altered, exchanged or omitted some letters by chance or in purpose.[327] Furthermore, there is no evidence that all 19th century craftsmen were working "more regular" than the ancient armourers. In both times high or little skilled workers might have made armour. While he is probably correct in saying that all old plate had been made by forging, it is an unproven assumption that all 19th century rolled plate showed grooves. This was certainly a matter of quality and a craftsman determined to sell his product as genuine could easily grind or polish such grooves off the starting material. It would also not be a problem at all to heat a rolled plate and to treat it with the hammer to reveal the "expected" hammer-marks. Furthermore, even in Boeheim's days plate sheet was probably locally still produced with a machine-hammer (see below). Another fact leaves doubts on Boeheim's assumption concerning the small hammer-marks: Hundreds of un-embossed hammer-made iron plates are found as reinforces on old doors [ref_ill_art_5389] or on old

325 Unfortunately no company names are quoted.

326 Mowbray (1967), p. 13.

327 Compare: Potier Echelles (1901), p. 28-29.

iron chests. None of them show small hammer-marks, as they were made by huge waterpowered hammers that drove the surface more or less plane. On the rivets Boeheim omits the definition of the differences between handmade and machine-made examples. Furthermore, by the end of the 19th century rivets were maybe locally still made by hand.[328] The leather and the fabric parts are also a weak indicator for the authenticity of an object only, as also on genuine items they had possibly been exchanged in younger times.

A few years after Boeheim, Baron Potier had published another essay on the methodology for detecting forgeries. His arguments were much the same like Boeheim's: the color and intensity of rust, hammer-marks, the traceable use of machines and the general ignorance of the old techniques.[329] It was Potier who uncovered that even Boeheim's judgment was not without blemish: Boeheim had described a late 15th century suit of armour[330] as genuine, while – according to Potier – it was made by the forger Winkelmayer of Vienna.[331]

The next scholar who published some notes on the problem of authenticity was Sir Guy Francis Laking. He was the first to illustrate his findings by main views of the concerned objects. Most of his arguments were of an intuitive nature and are not based on profound reasons. Some examples will be quoted: He described the items made by the mid-19th century forger Grimshaw as being made of the poorest craftsmanship and impossible to be actually used. At some pieces the *"peculiar markings left by the rollers"* on rolled plate were visible.

> *"The rivets were often not more than round-headed nails; the edges of the plate seem to have been cut with shears; while such attempts at decoration as are found might have been made by a savage from Central Africa."*[332]

It is not understandable why a dome-headed rivet should not look like a dome-headed nail. Laking also does not say why the ancient armourers should not have used shears for cutting the plate or what they should have used instead. Furthermore, in nearly all other points his argumentation remains as general as Boeheim's.

In 1914 the first exhibition to the problem of authenticity, showing exclusively reproductions and forgeries, was permanently installed in the armour galleries of the MET. At this time this was probably the only conscious display of such objects in the entire world. In 1932 Stephen V. Grancsay wrote a short article on this exhibition.[333] The intention of this installation was to offer *"the student a splendid opportunity to train his eye and to improve his taste, and this training is the more essential as greater trouble has been taken to deceive than to deceit. By pointing out defects in forgeries we emphasize the skill of the ancient armourer and thereby encourage an appreciation of authentic armour"*. Stephen V. Grancsay even offers: *"*

> *...when the student wishes to examine an object more closely, it will be removed from the case for his convenience."*

328 See chapter [The making of rivets].

329 Potier Echelles (1901), p. 13-15.

330 Boeheim (1897-99).

331 Potier Echelles (1918-20), p. 298-299.

332 With what else should the plate have been cut?

333 Grancsay (1932).

This attitude is a noble, but singular one. At some date this ensemble of forgeries has been taken off display.[334]

Grancsay in his article on this exhibition mentions much the same "features to look for" that Boeheim had promoted before him. He superficially classifies some armour parts as reproductions, allegedly as the form is too poor to be authentic. Later on he regrets that there is too little space in the article to *"describe the methods used by the members of the department in distinguishing genuine elements from restorations, obviously the most important part of a lesson in detecting forgeries. Each object presents a new problem, for the intriguing subject of forgeries is not an exact science."*[335] Anyway, there has been still enough space for Grancsay to debase a certain group of persons also preoccupied with the topic:

> *"There are two ways of testing authenticity – that of the connoisseur and that of the archaeologist[336]. The connoisseur deals with impressions and intuitions; the archaeologist proceeds by the examination and analysis of form, construction, decoration, metal and patination. Each object is studied from the craftsman's point of view; only in this way is it possible to understand the practical purpose of every rivet, buckle, perforation, and turning pin. Because of the many separate elements, sometimes over two hundred, comprising a suit of armour, it is clear that this study is mainly the field of archaeologists rather than that of the connoisseur. The details which make up the structure of armour are too numerous for it to be possible, except in obvious cases, to authenticate or condemn an object in a flash of intuition. The connoisseur's judgment is unconsciously affected by associating and comparing the object under examination with similar objects known to him. Thus the connoisseur might condemn a piece because in his experience he has not seen nothing like it, or because, having been restored in part or having additions made to it, it no longer measured up to his ideals.[337]"*

The "connoisseurs" for Grancsay are the many private collectors that – to his opinion – do not substitute their conclusions on the authenticity question with reasonable arguments and decide only by "gut feelings". Anyway, a suspicious form cannot be the only evidence for an item to be "faked". What if the scholar – Grancsay blames only the connoisseur – just has not seen a genuine object of the same form, as none is known or none has survived? However, he is right in demanding that especially art historians and archaeologists should study all the details of an object before judgments are delivered.

One further preceding discussion of the subject should be summarized. Certainly the most comprehensive study of the authenticity problem was published by Hans Schedelmann in 5 articles in the Zeitschrift für Waffen- und Kostümkunde.[338] Unfortunately, the references to

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334 The only current comparable exhibition is part of the Tournament Galleries in the Royal Armouries in Leeds, where armour made for the 1839 Eglinton Tournament is on display. The author visited the Royal Armouries in spring 2010 for research, but it was unfortunately impossible to see any of the Eglinton armour, as the rooms were closed for reconstruction work.

335 Grancsay (1932), p. 47.

336 Grancsay's limitation of authenticity testing to the scientific discipline of archaeology conceals the second discipline traditionally occupied with the topic: art history.

337 Grancsay (1932), p. 47.

338 Schedelmann (1963), (1964a), (1964b), (1965), (1966).

most of the information and images included are more than scanty. Schedelmann was the first to demand "a permanent consulting of comparable material" whenever authenticity is in question and he was the first to emphasize the significance of an item's provenance. He further suggests the establishing of a central register of known forgeries in one of the large museums of arms and armour. Schedelmann then enters a discussion of certain criterion that could tell about the authenticity of armour. While of course several suggestions are congruent with those of earlier writers on the subject, in a few cases his arguments are more detailed. Concerning the material he mentions that due to the old metallurgical processes the genuine material would delaminate. The observation of such a feature for Schedelmann is a clear proof of authenticity. But he has to admit that parts that do not show such signs can still be genuine. He is sure that a forger would never organize or reproduce old material as this would make his work unprofitable. Furthermore he warns to confuse simple material-cracks with such delaminations. Cracks would pass in a more or less 90 degree angle through the plate, while delaminations occur in parallel to the plate-surface. Concerning the techniques, Schedelmann – in parallel to Boeheim – assumes that the modern could never reach the skills of the old craftsmen and therefore poor proportions would easily unmask a forgery. The modern armourers would weld the helmet-skulls together from two plates. The roped turns would simply be made by turning them around a wire and then filing the roping.[339] He did obviously not know that also genuine roping was not always embossed [ref_arm_1128] and that hundreds of turned edges on extant armour have a wire inserted [ref_arm_1726] [ref_arm_2076]. Since his articles no comprehensive studies on the problem of authenticity of armour have been published.

An expertise worked out strictly by academic rules is distinguished by matter of fact and careful decisions. Experts should be able to put down into words why they decide for a specimen to be authentic or reproduced. The detail description of images and sculptures – respectively all manmade artifacts – is their every day job. Grancsay and none of his colleagues published satisfyingly enough reasonable arguments. How should a lay recognize if an expertise is well-founded, if the art historian – like the connoisseur – does not make his considerations transparent? If an academic is not capable of doing so the quality of his statement cannot be distinguished from that of Grancsay's connoisseur. Scholars should better honestly permit that for the largest part of the extant plate armour a permanent uncertainty in the judgment on an item's authenticity remains.

The authenticity testing of some specific items has been described by some of the scholars named above. A few chosen examples will be introduced and discussed later in this study. For the understanding of various possible approaches first the basics of the metallurgy of armour production need to be generally described.

339 Schedelmann (1963).

7 The metallurgy of armour production

In different times different iron-production techniques were developed and used, sometimes in parallel. In the following the differences between various modern and ancient techniques will be described. The entire technological background cannot be provided by this study. For a deeper understanding John Verhoeven's book "Steel metallurgy for the non-metallurgist"[340] can implicitly be regarded to all interested non-specialists. All knowledge necessary for the basic understanding of metallurgy can be found in this publication. The second and the third part of this chapter deal with the topic of plate-making and the different plate qualities used for making armour.

7.1 The production of iron and steel

Metallurgy is a vast and eclectic field. Various techniques for the production of iron-based material got developed throughout the last 3000 years. It is not possible to go into all details within the range of this study. An easy-to-understand overview of the history of iron and steel making is provided for example by Wolfgang Piersig.[341] More detailed descriptions are found in a mid-19th century publication of Frederick Overman.[342] A general description of the major production processes for the making of material that could be used for armour will be summarized in the following.

Armour can be made of basically two different kinds of material: wrought-iron or mild steel.

7.1.1 Wrought-iron production

The term wrought-iron describes all iron-based material that was refined with the help of mechanical force. Different methods for the refining were developed. Depending on the construction of ancient smelting-furnaces, two kinds of iron-based material could be revealed. One kind is the so called "cast-iron". This material contains about 4% carbon which makes the cooled material very brittle but keeps its melting point very low at about 1200 ^{0}C.

While "cast iron" is still produced industrially today, the following kind of material is not industrially used anymore. It is the product of a furnace operating at lower temperatures only and probably the oldest technique of iron making. The revealed material – called "bloom" – contains less carbon than the cast-iron (<4%). The iron never melted completely as the furnaces did not reach the necessary temperature of more than 1500^{0}C. The product is usually a heterogeneous sponge-like block of iron with locally higher carbon content [ref_ill_art_5384]. Inside the bloom hollow spaces and occasionally inclusions of charcoal and slag are to be found.

At least since the 14th century the central European metallurgists processed both – cast- and bloomery-iron – to reveal forgeable material of increased quality for various applications. Both materials cannot be used directly for the production of armour plate. They first need to be refined by different techniques. The old refining techniques required a certain amount of mechanical labor to reach a more or less homogeneous quality of the material – no matter if they started with the cast- or the bloomery-iron. In the following, first the refining of bloomery-iron and subsequently the refining of cast-iron will be summarized.

340 Verhoeven (2007).

341 Piersig (1988).

342 Overman (1851).

7.1.1.1 The refining of bloomery iron (direct process)

The author had the chance to film a specialist for the direct iron-making process at work [ref_vid_dir]. For the refining of bloomery-iron a bloom made in a Japanese furnace (Jap. Tatara) was first broken into pieces. These were subsequently white-heated in a smith's hearth. By hammer-forging the material was densified, some of the semi-liquid slag splashed out of the volume and included charcoal pieces burned off or got battered to dust [ref_ill_art_5385]. To further clean the material and to homogenize the chemical composition, the densified bloom was broken or cut into smaller segments. Several of such plate-like pieces were piled together [ref_ill_art_5386], white-heated and welded together by forging. To allow the pieces to join, it was necessary to dust the heated pack with a powdered welding flux like quartz sand or borax ($Na_2B_4O_7x10H_2O$). Repeated white-heating and forging further drove out remaining inclusions. After a certain refining stage, the volume was broken in two pieces that again were piled and forge-welded. Similar to the dispersing of bakery-ingredients for obtaining a homogeneous dough, the "ingredients" in the iron block would homogenize with the processing of the work. Furthermore, inside the white-hot material the elements can move (diffuse) to a certain extent. The chemical components in iron tend to spread equally throughout the volume. Depending on the amount of repeated heating and the time the volume was kept white- or red- hot the substance would become more and more homogeneous. It is likely that not all non-metallic inclusions could be removed by this process. Due to the laminar welding seams and the extension of inclusions and defects, the material is expected to show an interior layered or band structure [ref_ill_art_5387]. Charles describes the formation of this structure:

> *[…] the repeated piling and forging […] leads to surface oxidation and local enrichment in more noble elements such as nickel and copper, which becomes incorporated as extended solute bands in the final ferrite structure.*[343]

It is not clear how long this method was used in Europe, but it was certainly locally still exercised until the end of the 19th century. For example in Japan the traditional sword-smiths still produce their working-material by a direct refining process (Jap. Tamahagane).

7.1.1.2 The indirect process

The cast-iron was widely homogeneous, but could only be used for the casting of artifacts that required no flexibility. For reaching similar deformation-properties to refined bloomery-iron, the carbon content has to be reduced. Already by the 14th century metallurgists tried to convert cast-iron into forgeable iron or steel. In central Europe before the 19th century it was not possible to reach both necessary conditions at the same time: the oxidizing atmosphere inside the furnace together with the high temperatures to still keep the melt liquid while the carbon content was decreasing. The old cast-iron refining-techniques started with the smelting of cast-iron in special finery hearths (1200 ^{0}C ca.) that produced an oxidizing atmosphere on the surface of the melt. The charge needed to be moved by stirring or turning the melt from time to time to bring not yet de-carburized parts of the volume in contact with the oxygen. With the ongoing progress the melt slowly turned into a pasty mass. Parts of the slag occurring on the surface of the melt remained as inclusions within the volume. After the desired carbon content was reached, the revealed mass was taken off the furnace and forged under the hammer into billets. To drive out remaining impurities and to reveal certain billet-dimensions it was necessary to fold and forge-weld the material. One indirect process of iron

343 This layered Charles (1998), p. 497.

making, the so called "puddle-method" was industrially used from the second half of the 18th until the early 20th century.

7.1.2 Mild steel production

The modern methods reduce the carbon-content of cast-iron by directly blowing oxygen into the melt inside the blast-furnace. The furnaces reach the temperature to melt pure iron (1538^0C). To the revealed nearly pure liquid iron the corresponding elements necessary for desired material-properties are added. The technology for the mass-production of mild steel is comparatively young. In 1861 the so called "Bessemer-process" was first introduced in the German steel-production, but was widely used only from 1867 on.[344] The steel produced by this technique was still of a comparatively low quality, as it contained too much phosphorus. In the years to follow, until 1879, Thomas and Martin developed the Bessemer-process until nearly all phosphorus could be extracted from the melt. The introduction of this process marked the beginning of a totally new age in the production of iron and steel. Within the following forty years it would completely supersede the old wrought-iron-production techniques.[345] Today a number of sophisticated techniques exist; a very popular one is the Linz-Donawitz-method. Mild steel is an entirely homogeneous material. It can either be cast directly into profiles or into billets. No mechanical refining is necessary.

7.2 The making of plates

Armour plate cannot be cast. It needs to be forged or rolled from billets or bars, made by one of the techniques described above. In pre-industrial times, only wrought-iron had the required quality-characteristics – ductility and solidity in the correct ratio – to be used for the making of armour.

There are only two ways to obtain a plate-sheet suitable for making armour. A billet or a bar has to get white-heated and then to get deformed by means of either a hammer or of rolls. The technique of rolling iron-plate was – according to the current stage of research – not successfully implemented before the end of the 17th century.[346] Therefore, this technique was most likely not used for the making of late medieval armour-plate. The production of iron plate by a powered hammer has not been discussed scientifically so far. No details about the production of plate-sheet in the classical period of armour production were documented. Even though plate was produced and demanded ever since humans found out about the use of metals for their own well, the written sources remain silent about the details of its production. Especially the production of plate from iron based material requires special skills and experience of the worker. Unlike the same work on copper based alloys[347], iron plate-sheet can only be made from white-hot material – working it too cold would result in cracks in the material. Neither Agricola[348] nor Bringuccio[349] or any other pre-industrial writer on metallurgy described the making of plate. The oldest descriptions of making hammered plated date from the late 18th century; none of them has been edited and discussed in

344 Anonymous (1880), p. 79.

345 For a closer description of the development of the Thomas-Process see: Piersig (1989).

346 Lang et al. (1988), p. 390.

347 Alloy: metallic substance composed of two or more elements, as either a compound or a solution. The components of alloys are ordinarily themselves metals, though carbon, a nonmetal, is an essential constituent of steel, see: Anonymous. Definition of "alloy", Encyclopedia Britannica.

348 Agricola (1977).

349 Johannsen (1925).

connection to the making of armour. In the last 40 years few short articles were concerned with the topic of ancient plate-production[350] and only one of them described the techniques of making plates with the hammer according to 18th and 19th century sources[351]. Nearly all that the history of crafts, the art historys, the archaeology or archaeo-metallurgy published on the making of armour-plate is restrained to the level of guessing and thus it is not going to deep into the details of this particular technology. The assumption that the European black-smiths before the 14th century were not able to produce plate sheets large enough to make e.g. a breastplate, cannot be held. Already about the year 600 for the making of a bell in the German speaking lands steel (!) plate of 85 x 35 cm has been forged.[352] Such dimensions would easily serve for the making of a one-piece helmet or a breastplate. The basic technology for the making of large iron-plate was certainly known long before it was used for protecting other body parts than the head.

It is possible to produce plate without any help from machines, but the mechanical deformation of a larger billet into the dimensions of a thin plate requires a lot of manpower and it is very time-consuming. It is possible that technological enhancements of waterpowered hammers played an important role in the emergence of more and more plate armour in the second half of the 14th century. The use of waterpower was common in antiquity, but it had been declining through the early Middle Ages. Probably from the 11th century paddle-wheels were increasingly used to operate different supplies like grain mills, grinding mills, bellows, hammers and later also mills for black powder. One of the earliest depictions of a waterpowered machine is a saw depicted in Villard de Honnecourt's 13th century sketchbook [ref_ill_art_5299].

While not a single source mentions rolling-mills in the concerned period, the existence of hundreds of "Blechhämmer" (Ger.) (Engl. "plate hammer") in the German speaking lands is documented. For example in 1409 a "plechhammer" is mentioned in the possession of Conrad Eschenloer in Nuremberg[353] – by the end of the century a very important armour-production city. The hammers were all located in close vicinity to natural water flows. This indicates that they were operated by water-wheels. One of the oldest depictions of a waterpowered hammer dates from the last quarter of the 15th century [ref_ill_art_5300]. Many illustrations in metallurgical books of the 16th and 17th century also show such hammers [ref_ill_art_5297]. Different hammer-types existed for the production of various goods, but they cannot all be discussed this in the course of the present study. Until today, in Europe some waterpowered hammers are still operating for educational purposes.

One of the earliest detailed descriptions of the manufacture of plate metal is to be found in Carl J. B. Karsten's book "Handbuch der Eisenhüttenkunde", published 1816[354]. He gives a close instruction on the production of plate by both, hammering and by rolling. In the following his descriptions on the hammer forging will be translated and transcribed.

> *To bring the iron into the shape of plate – i. e. extending it both by its length and by its width at the same time – it has to be heated to white-*

350 Mutz (1981), Gut (1986), on the late 19th century techniques for rolling iron plates see: Anonymous (1987).

351 Anonymous (1983).

352 Mutz (1983).

353 Koch et al. (1939), Reg. 5820. (http://regesten.regesta-imperii.de/index.php?uri=1409-05-27_1_0_10_0_0_5827_5820).

354 Karsten (1816) pp. 601 ff.

heat and then to be forged by the beats of a hammer. Only in rare cases the plate can be finished in one heat. Usually the iron […] would get cold before the plate would be finished. Thus – to get to the desired dimensions – it is necessary to reheat the iron several times. The amount of pieces handled in one work shift is defined by the capacity of the facility for the heating of the iron, the power of the hammer, the dimensions of the work piece and the experience of the producer. […]

A good plate has to have the same thickness at each spot and it has to be free of buckles, wrinkles and delaminations[355]*, as these are not simply disfigurements but they could also become problematic for the further working of the plate. Furthermore a good plate has to withstand a repeated bending and should not be so brittle to crack throughout this testing. Hammering plate too cold will result in more brittleness of the iron which has to be reversed by tempering.*

The used iron should be soft and flexible [here he names sorts of iron that should not be used].

Even though the shape of the starting-material is not important, for the aim of making plate, the use of flat iron is more sensible than the use of a bar of square section. The dimensions are chosen according to the aspired width and thickness of the plate.

At the very first stage the iron bar is cut into its desired length, according to the desired length of the end-product. From such a piece in the end two plates will be revealed. This bar is called "Sturz". It is of almost the double length of one later plate, because the work will concentrate mainly on extending the width of the bar. The lesser the iron will be stretched into length the more beautiful and better the plate will become.

The cutting of the bars is achieved either by a hammer and a staked chisel or by machine-powered steel shears. For the first method the bars have to be heated white-hot, while for the latter method this is only necessary for thicker material.

The iron bars are subsequently either heated in a smith's hearth or in an annealing furnace. White-heating the iron in a hearth is an impractical and coal-consuming method and the quality of the plates decreases. The bars are placed on iron sticks lying across the hearth. They are covered with coal from all sides and they are slowly heated with the help of the blower.

When inserting the material into the furnace the heat should be increased rapidly to avoid the appearance of too much hammer-scale. The quantity of iron in the furnace at one time should not be higher than what can be handled within the time given. Keeping the material hot for

355 Karsten uses the old high German term „Schiefern" which derives from the word "Schiefer" engl. "schist" (geol.). This term is not used in modern German and can only be found in older dictionaries such as Rimer et al. (2009), under no. 1445 3). Karsten certainly means delaminations – a clear indicator that the working material usually consisted of layers.

too long will result in a higher loss of the substance by combustion and an unnecessarily high use of coal.

The method of producing plate under a hammer is old but still often used. Such a hammer usually weighs 200-250 kg. The lifting distance is usually 22 inches. The fin of the hammer measures 14 inches in length and ¾ inch in width. The surface of the anvil is shaped convex to allow a quicker spreading of the iron. The more slender the anvil is, the faster the work can be finished, but also more accuracy of the worker will be needed to get an even plate. Some hammers work with an anvil 4 inches wide; others use anvils of ¾ inch width. A more even and wider anvil will bring more plane sheet but the time required will be higher.

[The author of this study has made a short movie that shows – in a simplified manner – the processes described in the following [ref_vid_pla].]

The bars will be heated and then forged on one side to the double of their width. After heating them again also the other end will be treated the same way. Then the bar will we bend in its center and folded together by a hit of the hammer. Two workers are working together, one spreading the first, the other one the second end. The readily over-bent bars are now called "Urwellstürze" and this process-segment is called "urwellen". One "Urwellsturz" consists of two halves, while each will later become one plate.

The Urwellstürze will be heated again and forged at the side that is already spread to the double of the former width. After reheating, also the over-bent side will be spread. This work process is called "das Gleichen" or "das Stürzen" and the bars worked that way are called "Stürze" [again]. This work requires a lot of concentration as the material in the centre should not remain thicker than at the edges. The hammer has to hit the centre of the "Stürze" and drive the iron slowly to the side.

In the next stage several pieces are worked under the hammer at once and thus more heat is required. To avoid a forge welding of the two plates, the "Stürze" are plunged into a liquid called "Hahnenbrei" [Engl. "rooster-pulp"], made of water, clay, chalk and coal dust. Then several "Stürze" are put together to one "Pack" or "Zange" of the weight of about 50 kg or – depending on the desired dimensions of each final plate – six to twenty pieces all together. The entity of "Zangen" that are worked together in one shift is called "Zeche". Each "Zange" is heated and forged separately under the hammer. This is very hard work that requires a lot of experience. Thus always two workers are doing the job of constantly turning the pack, so the hammer does not hit the same spot for too many times. For the support of the worker and to keep the pack from falling off the anvil two right angled hooks are attached to each side of the anvil, the so called "Knecht" [Engl. "servant"], on which the pack can rest. To avoid that one side gets stretched more than the opposite side, the pack has to be turned – a job that also must not be neglected at the [aforesaid] processes of "Urwellen" and "Gleichen". The worker has to take care, not to cause too many buckles or dints in

the surface of the plate. Because the plates are becoming cold very quickly, the pack has to be reheated and forged three to four times. After each round the packs have to be opened to see if the "Stürze" got welded together. If this is the case, they need to get separated. Then the "Stürze" are put back together in a new order. This is necessary as the plates in the centre of the pack keep the heat longer and thus they are extended more than those at the outer side.

After the process has been repeated the third time, the plates should have reached the desired length. The pack is then opened and the single sheets are planed between a slow going "Pritsch- or Abrichthammer" and an anvil with a much larger surface. Afterwards the plates are finally planed with wooden hammers. The ready plates can be cut to their final dimensions – either by hand- or waterpowered scissors.

Even though this description is not contemporary with the ancient armour making, it provides a detailed insight on how plate was actually made in pre-industrial times. Several clearly hammered raw plate-sheets – the edges left burred – are nailed as reinforcement to exterior side of the wooden main-gates at the Castle in Mauterndorf/Austria [ref_ill_art_5389]. The plates delivered to a late medieval armourer's workshop must have looked very similar to these. A Viennese document from the beginning of the 15th century suggests that the armourers chose different plate-dimensions for different armour types. In 1425 the lock-smith Kristan von Melk owes to the armourer Maister Lasslaben:

[…] 20 guldein oder 20 paingwandstürz [raw-plates for leg-armour] und 20 hantschuchstürz [raw-plates for hand-protections] und 14 klain scheiben [small discs] […][356]

7.3 Plate quality

Armour needs to resist attacks by different types of weapons. The late medieval armourers had plate of different quality – and price – available that could fulfill this demand to a certain degree. Depending on the client's requirement, armour could be made from cheaper, not hardened iron-plate or from a tougher and maybe even heat-treated steel-plate. Pure iron is rather weak and thus it needs to be used in larger thicknesses to get protective properties similar to thinner steel plate. This comes together with an increase in weight. If armour should be both light and strong, there is the possibility to use steel instead of iron. Already in the late 13th century Jansen Enikel in his description of the biblical Goliath's appearance wrote:

356 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1895), Reg. 13651.

[…]
dar zuo hat er ein isenhuot,
der ist von stahel also guot,
daz uf ertrich dhein man
so vestes huotes ni gewan
[…][357]

This source does not say that the helmet was actually also heat-treated. It might have been made of un-hardened steel, which could indeed already show better penetration-resistance than iron plate. As the technique of hardening steel was known since antiquity, it is very unlikely that the armourers did not harden their products after they had already purposely and proudly made them from steel. Furthermore, the buyer would only be willing to pay the higher price for steel armour if he would get a product with protective properties superior to lower-cost iron-plate armour.

The historical sources do clearly differentiate between the two qualities.[358] For example an inventory of 1464 for lists

[…] 4 wälschi[359] *ställichi [steel] panzer, 4 eisneni [iron] banzer, […]*360

These notes show that the contemporaries were well aware of the material-qualities of different armour parts.

From contemporary documents some of the main supplying regions for certain armour-production cities can be identified. Nuremberg used iron from the Oberpfalz, the steel came exclusively from the Steyermark.[361] King Maximilian I. for his court-armoury in Innsbruck in the early 16th century ordered that iron and steel must only be supplied form the Steyermark. As a quality prove, the iron and steel from Leoben on order of Maximilian I. from 1501 on had to be marked with the cities coat of arms – an ostrich – as it was also (occasionally) done before.[362]

357 See: Strauch (1986), p.185. Free translation by the author: "Furthermore he has an iron-hat made of steel. No man on earth ever had such a strong hat."

358 E.g. see: Böhmer and Wiesflecker (1990-1996), Reg. 13436. (http://regesten.regesta-imperii.de/index.php?uri=1499-06-19_4_0_14_3_2_640_13436).

359 „Wälschi" probably means „Italian" or "French". The German language often uses the term „welsch" for European peoples that speak a Latin-based language.

360 Panzer could also mean ring-armour, from: Jahrbuch der Kunsthistorischen Sammlungen in Wien (1899), Reg. 17851.

361 See: Ress (1967), p. 827-829.

362 Böhmer and Wiesflecker (1990-1996), Reg. 11610. (http://regesten.regesta-imperii.de/index.php?uri=1501-03-02_1_0_14_3_1_2642_11610).

Nearly[363] all plate armour is made from plate-sheets of an iron-alloy. In the Middle Ages plate was not only used for making armour, but also for the reinforcement of doors or chests[364] etc. As only metallurgical examination[365] can show the quality of any material – i. e. if a certain item was made of steel or iron – in the following considerations the two terms will be summarized as "iron". Modern metallurgical terminology summarizes all industrial produced iron based material as "steel". It would be confusing to generally adopt this term to all historical iron-alloys as some objects were evidently made of rather soft iron that could not be hardened like steel. That steel occasionally has been used in the different armour production regions and for different armour qualities has been proofed in several metallurgical studies; most of them were carried out by Alan Williams[366]. Even some of the oldest medieval plate-armour items were found to be made of hardened steel. The material quality was certainly a matter of cost. The basic processes the armourer had to apply for the production of a certain armour part depended only insignificantly on the quality of the material used. Furthermore, the material quality does not answer the authenticity question, as steel and iron until the early 20th century was produced in methods similar to late medieval processes. The making of armour from steel-plate is probably not different from its making in iron. The armourer might have needed more force when he cold-hammered steel, as this material is usually tougher than iron, even when not hardened. The only relevant difference emerged when the shaping of the plates was finished. While armour made of softer iron simply needed to be ground, polished and mounted, the steel-armour needed some more laborious treatment. It was certainly best to grind it before it was hardened, as doing this work afterwards would be much more abrasive- and time-consuming. To avoid a deformation of the ready-shaped plates caused by the heat-treatment process it might be necessary to apply a temporary supportive construction. The item then needed to be heated all over to a red-hot temperature (above 723 ^{0}C – austenitizing temperature) and then to be cooled quicker than it would do when just left exposed to room temperature. Basically two ways of cooling can be applied: either by a rapid "plunging" of the item into a cold liquid, or by cooling it more slowly – e. g. in a warmed liquid, melted lead or heated sand. In the latter case the purpose is to achieve a delay in the cooling in comparison to a more rapid cooling to room-temperature. The steel treated in such a way is hard but very flexible as well. Steel that had been plunged red-hot into cold water becomes very brittle and hard. To avoid the steel product from breaking, the brittleness can be reduced by heating the steel again for a longer time at a constant temperature – depending on the desired mechanical

363 Few exceptions do exist: The pair of hand-protection [ref_arm_1263] [ref_arm_1303] and the helmet [ref_arm_1414] are entirely made of copper alloy plate. At the hand-protections [ref_arm_1060] and [ref_arm_1079] at each side one of the metacarpal lames is made of copper alloy plate. The finger-root plates at the hand-protection pairs [ref_arm_1059] and [ref_arm_1124], [ref_arm_1074] and [ref_arm_1125], [ref_arm_1142] and [ref_arm_1096] [ref_arm_1096], [ref_arm_1208] and [ref_arm_1246], [ref_arm_1207] and [ref_arm_1244], [ref_arm_1245] and [ref_arm_1272], [ref_arm_1209] and [ref_arm_1247] and at the single items [ref_arm_1063], [ref_arm_1066], [ref_arm_1071], [ref_arm_1250], [ref_arm_1129] and [ref_arm_4904] are made of copper alloy. Reproduced hand-protections with copper alloy finger-root plates are the pair [ref_arm_1045] and [ref_arm_1109] as well as the reproduction of the Freiburg-hand-protection made by the author [ref_arm_5111].

364 In 1496 Maximilian I. orders a payment to a locksmith for his work on a chest in Maximilian's private chamber made of iron and plate, see: Böhmer and Wiesflecker (1990-1996), Reg. 7659. (http://regesten.regesta-imperii.de/index.php?uri=1496-11-25_2_0_14_2_0_4009_7659).

365 This is the analysis of the crystal micro-structure of iron and the testing of its hardness.

366 Williams (2003).

properties and the chemical composition of the material – ranging between 150 and 600 ^{0}C (tempering).[367]

The tempering of plate armour was a difficult task. The larger the plate was, the more care the armourer had to take when he heat treated one of his products. The most important was, to avoid a deformation of the overall red hot object. The shape had to be finished before the heat treatment and no subsequent correction was possible. Stresses inside the material, deriving from the cold shaping process, got released when the item was heated. This, together with the force of the own weight could easily have led to a deformation of the work piece. But also a tong used for handling the hot object when plunging it into e.g. water might have resulted in a distortion. Correcting a distortion after hardening meant to first heat the steel for a longer time red hot and then to let it cool very slowly to soften it again. Then the form could be altered again and the heat treatment could subsequently be repeated. The best way to avoid the necessity of such time-consuming correction would have been the installation of a stabilizing framework inside the object – before it was hardened. The holes for the later attachment of different applications could have served to fix such a construction. It was anyway easier to drill or punch holes before the object was hardened. The supportive framework might have been attached by screws, by wire or by rivets.

7.3.1 Turning iron into steel: Case carburizing – case hardening

The so called case carburizing method can be employed if low-carbon iron should be turned into steel. This is the attempt to bring carbon into the surface of the material from outside. Case carburizing is actually based on the mechanism of atom migration – diffusion – within a metal. The main requirement for the migration of carbon into iron is the availability of a gas being a mix of carbon monoxide (CO) and carbon dioxide (CO_2). If the relative amount of CO is higher than that of CO_2 one carbon atom will dissolve from two CO molecules into the iron, leaving a CO_2 molecule that will float off. When charcoal, the common fuel for a smith's hearth in the Middle Ages, is burned, such a gas will form if not too much air is blown into the fire. To bring and keep carbon close to the iron which should be carburized it can be coated for example with a mixture of clay and charcoal dust and subsequently be heated in the charcoal fire. The basic process is already described by the 12th century Benedictine munch Theophilus.[368] It was especially adopted for the production of tools or blades which needed to have a flexible core but also a high hardness at edges and surfaces. The "liber illuministarum" mentions the rubbing of the iron with organic material and its following heating in the fire. The text does not mention the necessary coating of clay and the necessary reaction time.[369] To make the carbon diffusing from the coating into the iron, the work-piece inside such a carbon-rich packing needed to be kept for several hours at a temperature of about 870 to 950 ^{0}C. The difficulty is, to heat the item hot enough for allowing a rather quick diffusion of carbon into the iron while keeping at the same time the CO ratio high in the gas in contact with the iron. If the ratio of CO_2 is higher, the iron might become decarburized or even oxidized. But reaching higher temperatures in a simple smith's hearth with an airflow controlled by bellows means automatically to blow more CO_2 into the open fire. Only a closed oven chamber, where the air float for the fire is kept outside can provide a stability of the required conditions. The longer an item is kept under these premises the more carbon will diffuse into the iron. It is difficult to estimate the temperature at which the

367 For further and more detailed explanations on the heat-treating of steel see: Verhoeven (2007).

368 Brepohl (1987), p. 59.

369 Bartl (2005), p. 663-664.

diffusion begins and how deep the carbon will migrate in which time. Verhoeven gives the following equation for the calculation of the diffusion-depth[370]:

$$Time\ (s) = dxd/6xD$$

(d= depth of carburization; D= diffusion coefficient, given in Verhoeven tablet 7.4) [371]

After the carburization, i.e. turning part of the iron into steel, it can be hardened like any other steel (see description above).

Another method for hardening the surface of steel is nitration. Here the steel has to be kept for a certain time in a 600 C hot nitrate bath. The "liber illuministarum" only describes the process of quenching the hot iron into nitrate rich substances such as earthworms, or liquids containing hair, horn, claws, or excrement. As, according to the described recipe, the material was kept for only a short time in these substances, nitrate could not move into the surface of the iron. The technique is not described precisely enough to assume the employment of the modern nitrating method for the late Middle Ages. What could have happened to a steel plunged into the said substances was probably a mix of surface carburizing and nitrating of the steel.[372]

Only few armour pieces were suggested to have been hardened only on the surface region by one of the methods described. It was Alan Williams who suggested that some specific parts had got purposely case carburized and quenched.[373]

7.4 Metallurgical testing

Aside from the examination of features visible with the naked eye or retraceable by documentary research also metallurgical testing-methods have the potential to reveal further data on iron artifacts. The four main questions that could potentially be answered by such methods are on the place, the date, the production technique and the quality of the material.

7.4.1 Quality testing methods

Modern metallurgy[374] usually tests two quality-characteristics of a sample-material: the hardness and the crystalline-microstructure.

The hardness can be tested by different methods. For the relatively thin armour plates only such testing methods are useable that press a body of certain hardness with a known force into the sample's surface. The indented body leaves a mark at the artifact, its dimensions allow the calculation of a characteristic figure[375] expressing the material's hardness. The damage the indentation leaves can be limited to the size of a grain of sand and no part of the sample needs to be detached. The revealed data expresses in comparable numbers the durability of the material against any kind of penetration. Whenever an armour part is found to be hard, it is likely that the armourer used steel instead of iron and he probably purposely heat treated his product. The hardness-testing method cannot tell anything about the

370 Verhoeven (2007), p. 65.

371 The summary on diffusion is extracted from p. 63-70 in Verhoeven (2007).

372 Bartl (2005), p. 664-665.

373 Williams (2003), p. 731 and here chapter [A type-II helmet in the Royal Armouries].

374 In the following text the term „metallurgy" means and comprises the different common methods for testing iron material, e. g. metallography and hardness testing.

375 For preceding studies on armour usually the unit VPH was used.

provenance or date of an item, as the same factors can be found equally at modern or ancient material as well.

Further information on the quality of the sample-material and the possible methods used to improve its hardness can be gained by the examination of the crystalline-microstructure. This structure is made visible by a microscopic image. The specialized method for this imaging method is called "metallography". As the surface of iron artifacts is usually coated by corrosion-products, a small section of the sample needs to be polished. If this is done at the cut-edge of a plate, the sample does usually not have to be detached from the artifact. This sampling method is usually preferred over the grinding and polishing of the outer surface of an artifact. After the polishing, the different chemical components need to be virtually emphasized with the help of acid. Under a reflected-light microscope now the crystalline-microstructure becomes visible. The image shows a map-like arrangement of fields that can be classified by shape, size and color. The different elements present describe their own characteristic field and color. A specialist now can estimate for example the amount of carbon present at the examined location. If non-metallic inclusions like charcoal or slag are present, they can be seen as elongated dark lines or as dots. By the arrangement of the crystals (phases) the metallurgist further can tell if the hardness of the material was increased by heat treatment and he can make suggestions on the method used to achieve such properties. This method cannot tell about the provenance of the artifact, but it can suggest – if slag inclusions are present or if layers deriving from mechanical refining processes are visible – that the material was made by a wrought-iron production-technique. If no or only small inclusions and no layered structure are visible, the material might be modern mild-steel.

An analysis of the chemical components might help to narrow down the date an iron or steel artifact has been produced. If for example manganese is present in significant amounts, according to Craddock it is very likely that the material was made not before the early 19th century. On the other hand, iron with no amounts of manganese can be of any date. Also alloys of iron and other metals – with the exception of nickel – are very unlikely to pre-date the mid-19th century. Craddock says that the approach of defining all material containing no sulphur to be rather older than the 18th century – the time when melting furnaces started to be operated with coal as fuel – is not suitable for the detection of forgeries. Already from the mid-18th century on the sulphur content decreased, as higher furnace operating temperatures allowed for a reduction of this element off the melt. Therefore, also 19th or 20th century reproductions might contain no or only little sulphur.[376]

Different element-quantity testing methods exist. The optical-emission-spectrometry analyzes the light emitted from an electric-arc activated between the sample and a copper or silver electrode.[377] Each element present in the sample emits light of a characteristic wavelength. The intensity of the radiation tells about the present quantity. This testing method leaves a burned spot of about 1 cm in diameter on the surface of the artifact.

A non-destructive possibility for the determination of the chemical components of a sample is provided by different X-ray analysis systems. The X-ray fluorescence sends X-ray beams into the sample, these beams are absorbed by the material, re-emitted and recognized by a detector. Each present element shows a specific emission-spectrum. By this method the presence and the ratios of the contained elements can be verified. The problem of the

376 Craddock (2009), p. 154-156.

377 For precise measurements this can also happen in an argon-atmosphere and with the help of a wolfram-electrode. The chambers of devices are often too small for armour parts. Therefore a sample would have to be detached from the artifact.

examination of iron with these systems is that a very important element – carbon – cannot be detected; only elements with an atomic number higher than 8 can be identified. Another problem is that only to a depth of ca. 0.1 mm the present elements can be detected. As the pre-industrial iron material is expected to be rather heterogeneous in its chemical components, the XRF-results do not tell anything about the situation deeper in the volume.

An analysis of the quantity of elements present in a sample-material tells about its quality and the production process. It is also a logical consequence to ask if the results can maybe tell where the material came from. To answer this question it would be necessary to test the chemical characteristics of iron-ores sampled from a large number of different mining-sites. The characteristics could be compared to the chemical composition of iron-artifacts, with the possible result that the source of the material could be identified. If the mining-site was evidently closed at a certain time, even a "terminus ante quem" for the production of the iron-sample could be presumed. Nevertheless, it would still be problematic to clearly identify a mining site. Unlike most other metals or alloys, iron could be produced almost everywhere in the world. Iron ore can often easily be mined. The fuel necessary for the operation of a melting furnace is charcoal, which can be made from any kind of wood. The only material needed for the building of a furnace is clay and stone. Thus, throughout all the last 3000 years iron has been produced all over Europe. Furthermore, the possible addition of scrap-metal – produced from different ore – in the refining process could have influenced the chemical composition. It is also possible that from one sort of ore different alloys and iron-qualities were produced – with a result of different chemical characteristics. In the considered period the quality of the iron did probably depend much more on the refining technique than on the available natural resources. Furthermore, the location of an armourer's workshop could still have been far away from the ore mining-site and the smelting furnace.

Until today no chemical fingerprint of certain iron ore mines could be discovered. Maybe future research can help to map iron artifacts to the sources of the ore. The analysis of iron slag might help to approach this topic. Some slag-analysis projects with the aim of provenancing and characterizing ancient iron artifacts have been carried out in the past.[378] The results do not yet help to attest the authenticity of iron artifacts, as no project centralizing the data exists yet.

Another nondestructive testing method is provided by a scanning-electron-microscope (SEM). A beam of electrons makes the atoms on the sample's surface sending back signals that provide information on the scanned object's topography, chemical composition, and other properties such as electrical conductivity. This method delivers information on the surface's sample only. The artifact has to be examined in a vacuum and therefore for examining armour the testing chamber has to be rather large. The author does not know about any SEM-testing of armour. The results of such examinations could help to identify the sources of the material and the refining technique if a large scale study producing immense quantities of comparable data would be carried out.

A natural-scientific method used for the dating of iron-based artifacts is the quantitative analysis of C14 isotopes present in the sample material. This age-testing method – called the "radiocarbon dating" method – is not reasonable for iron artifacts. First of all, it inevitably damages the tested object. In any case a flake of considerable size[379] – depending on the amount of carbon in the material – has to be detached to reveal at least about 1 mg of carbon. The results are often unclear, due to impurities containing C14 isotopes – e. g. oils or coatings

378 Buchwald and Wivel (1998); Pigott (1989); Rose et al. (1990); Williams (1991).

379 According to: Sperl (2001), p. 8, up to 1 cm3 of sample material would be necessary.

– that got secondarily added into pores or cracks in the sample. Also admixed scrap-metal or welding fluxes like limestone would lead to falsified results. According to Cook et. al. probably due to this reason the European armour examined in a vast study on the age of iron objects could not be dated by the radiocarbon-method.[380] Unpublished attempts have been made to date armour by C14-testing of attached organic parts like leather or simply dirt from in between the plates. The results tell about the age of these substances only, not about the plates themselves. To make an item authentic, for example old wood – e. g. easy to be obtained from a torn-down house – could serve for mixing an ancient C14-cocktail. If a criminal mind intended to fake an artifact, such a cocktail could be daubed on armour-leather or into narrow gaps between the plates from where later a sample would be taken.[381]

7.4.2 X-ray based imaging methods

In a few cases X-ray imaging methods delivered reliable information for the determination of an artifact as genuine or reproduced. This is especially the case for artifacts of complex material systems, like swords or hafted weapons. At genuine examples often different alloys had been fire-welded to reveal certain mechanical properties or decorative elements. These features of genuine items are difficult to be reproduced by a forger. The authenticity testing of swords with the help of non-destructive, 2- or 3D-imaging X-ray methods is therefore often successful, as the different components of genuine items can clearly be visualized.[382]

It is more difficult to examine armour by X-ray methods. The material does usually not consist of different alloys welded together. Simple 2D X-ray imaging (radiography) does not tell a lot about an item. It can only be helpful to detect modern welding seams or camouflaged repairing. Micro computed-tomography[383] offers the possibility to non-destructively reconstruct 3D views of the interior structure of a sample material. The main difference to common X-ray examination (radiography) is that a rotation of either the sample or the X-ray source during the scan delivers information from all three dimensions. To say it in easy words: The spectator of a reconstructed scan can virtually "fly" through the scanned substance. What such images are sought to show, are structures within the sample's volume (inclusions, cavities etc.). The main difference to other testing methods like microscope-examination is that the sample does not have to be dissected, i. e. damaged. Basically the method works as follows: X-ray beams are sent through the substance. Differences in the density of the examined substance passed by these beams do locally differently absorb the X-rays. The detector of the scanning device recognizes the smallest intensity-deviations. A computer correlates these deviations and processes an image.

Due to the permanent increase of computer-processing-capabilities throughout the last twenty years, the testing of metals with the help of micro computed-tomography had been immensely processed. The resolution of the scans revealed from industrially used CT's already reaches down to ~5 µm. In the conventional method the X-rays cross the sample's rotating axis in a 90^0 degree angle. This technique is ideal for scanning more or less cylindrical samples, where the thickness and therefore the absorption is more or less equal in all scanning-directions. The results of such scans cannot detect very small and local

380 Cook et al. (2003), p. 22.

381 On a larger study on the methodology of radiocarbon dating of a larger number of iron artifacts and the limitations of the method, see: Cook et al. (2003).

382 See for example the essays on the examination of swords: Wessel (1995) or Wessel (1995). For various possibilities of artifact-examination provided by micro-computed-tomography see: Kastner et al. (2007).

383 For easy-to-understand explanations on the basics of computed-tomography see: Avinash C. Kak (2001).

density-variations. Probably due to the sample size-limitations of most of the micro computer-tomographs, none of the usually large armour parts has yet been tested by this method. The images could help to tell by which method the material was made. Such information could possibly be used to narrow down the time-frame in which a tested artifact had presumably been made. The biggest advantage is, that a tested artifact would not get damaged. In chapter [Ideas for new approaches] the author describes another promising X-ray based imaging method that had previously not been used to approach the question on authenticity.

7.4.3 The authenticity testing of armour

The occurrence of inclusions in the plate-material has been suggested as the strongest factor in classifying objects as originals or reproductions. Whenever metallography-testing could detect no inclusions, the material was considered to be modern mild-steel and therefore the item was a modern reproduction.

The main problem with such metallurgical explanations is the erroneous assumption that the old wrought-iron techniques were not used anymore in the days when reproductions were made. Furthermore, it is possible that the metallurgists of old also produced high quality steel – at least locally nearly heterogeneous and free of impurities – by the wrought-iron production methods.

When the authenticity of a certain object is questioned, the metallurgists should first try to determine the method used for the making of the working material. Until today, no research on the possible differentiation between the different wrought-iron refining techniques had been carried out.

The basic questions on this concern have also not been answered yet: Are there necessarily inclusions in iron-plate made from wrought-iron? It is possible that ancient armour plate was made from a relatively pure, large bloom without the necessity of being forge-welded? This possibility has already been suggested by a finding of Charles.[384] He says that *"bloomery iron can be very clean, being produced at lower temperatures in the solid state, so that silicon is not reduced into the metal phase from silicates in the charge."*[385] This means that possibly no or only little slag inclusions would be contained. A find of a bloom near Trondheim/Norway, C14 dated to the time range between the years 390-545, delivers additional support for this assumption. The bloom was at its outer regions almost free of carbon, but interiorly it was relatively homogeneous with a carbon content of about 0.7%. It contained only few larger hollow spaces, but almost no slag inclusions.[386] Furthermore, it is also possible that a folding and forge-welding process together with the long-term keeping of the material at a white-hot temperature could have led to a complete or nearly complete disappearance of the layered structure of mechanically refined iron – at least it is possible that such structures cannot be detected by metallography-imaging. In conclusion this would mean that armour made from such plate would not show no or only few defect structures – but it would still be genuine.

On the other hand, some other simple facts suggest that not all armour plate that shows impurities must be genuine: Wrought-iron – more precise "puddle-iron" made by the indirect process – was produced well into the 20th century. For example in Donawitz in Austria, the

384 See: Charles (1998), p. 500.

385 See: Charles (1998), p. 498.

386 Espelund (1996), p. 53.

last puddle-hearth stopped working in 1917.[387] To give some numbers on the quantity of puddle-iron produced in the times when the making of armour reproduction was at its height: The most important device for making wrought-iron was still the puddle-hearth. In the year 1878 1533 of them produced 24.723.029 cwt of wrought-iron.[388] Actually the production-quantity of wrought-iron by the same year was still more than twice as high as that of mild steel.[389] These facts show that wrought-iron (puddle-iron) was the commonly used material in the times when presumably the most armour reproductions were made.

It was also suggested that the chemical composition of "modern", coal smelted iron-based material, would contain sulfur, which in turn was expected to be absent in charcoal-smelted "old" metal. It has been suggested that from the 18th century on iron has regularly been smelted by coal-charges. This is a mistaken assumption as well, as many 19th century sources still mention the use of charcoal as fuel for the blast furnaces. In 1878 in Germany 178 charcoal operated fineries were producing 446.670 cwt of wrought-iron from scrap-metal[390].

Additionally, the often quoted assumption that forgeries of armour would necessarily have to be made of rolled plate becomes questionable when late 19th century sources still speak of thick wrought-iron armour-plate for ships, being produced with the help of machine-hammers in England. The preferred material was recycled scrap iron. The hammered material was considered to be superior to the rolled, as the forge-welding seams were much stronger. The result was that rolled plate showed delaminations at crack-lines while the hammered would appear absolutely homogeneous![391]

A description on the making of sheet-iron shows that by the mid-19th century in England, plate was rolled optionally from directly produced iron or from puddle-iron. The directly produced "charcoal iron" was considered to produce sheets of better quality:

> *The making of sheet iron is a branch full of intricacies and difficulties; but once thoroughly understood, it is very simple and agreeable. The main difficulty we encounter depends upon the quality of iron from which it is made. Charcoal iron generally works well; but some kinds of puddled iron do not make good sheet iron. […] Sheet iron was made in ancient times by means of forge hammers; it was flattened down by broad-faced hammers on large anvils. This method is still practiced in the eastern parts of Europe. At the present day, and in our own country, sheet iron is rolled. It is made partly from charcoal blooms, and in some places from puddled iron.*
>
> *a. In all cases where thin sheet iron is to be made, the iron must first be converted into flat mill bars. Charcoal blooms, as well as puddled iron, undergo the same treatment, with this difference, however, that good charcoal blooms do not require a welding heat.*
>
> *Puddled iron is to be piled, and a pack of rough bars welded and rolled down into flat mill bars. These bars are from four to six inches wide, varying in thickness, according to the number of sheets to be made from*

387 Köstler (2006), p. 137.

388 Anonymous (1880), p. 87.

389 See: Anonymous (1880), p. 80, tab.

390 E. g. Anonymous (1880), p. 87.

391 Oppermann (1863), here p. 433-435.

them. Heavy sheet iron and boiler-plate are to be made from mill bars, if we want a good article. Sheet iron is principally made from charcoal blooms shingled down into slabs; sometimes from puddled rough bars, piled, welded, and shingled by the T hammer into slabs. By neither method is good boilerplate made; a second reheating is, in all cases, to be resorted to, if we want the best article the material is capable of producing. In the manufacture of sheet iron, our main attention must be concentrated upon the quality of the iron, and the power at our service. All other matters are of subordinate importance, and have little bearing upon the success of our operations. Clean, white, fibrous iron, and a surplus of power, are the most essential elements in making good and cheap sheet iron.[392]

7.4.3.1 Preceding approaches

In the following some specific approaches to the problem of authenticity of armour will be introduced and critically discussed. It can be anticipated that no reliable non-destructive method, neither for differing between original and reproduced iron-based plate nor for any direct dating or provenancing, had been found yet.

Only one metallurgist carried out analysis on a huge number of armour parts: Alan R. Williams. He was frequently testing the material quality only – by hardness tests and by metallography-imaging. From the data revealed, Williams drew conclusions on the material's manufacture processes. His knowledge and the amount of items tested by him are absolutely unrivaled. Nevertheless his approaches are not unproblematic. The basic problems concerning the metallurgical recognitions in Williams' studies were described by Robert D. Smith:

Williams draws conclusions from the analysis of one tiny area on a piece of armour and then takes this as indicative of both the whole piece of armour and, occasionally, for a whole suit or garniture of armour. Here we have an example of technological synecdoche: the implied assumption is that the results obtained from that one piece are characteristic of the whole. In an attempt to address this issue Williams does offer examples of some armours for which he has been able to analyze several pieces, in which all the various elements are made from broadly similar materials and have broadly similar heat treatments and from this he concludes that the analysis from a small sample is indicative of all armour production. Whether this is true writ large, though, cannot be proved. Medieval and early modern materials in general, and iron and steels in particular, are notoriously heterogeneous. Indeed, detailed work by this reviewer […] has shown that the surface hardness of a single breastplate can vary very widely over its entire surface.[393]

The author of this paper by own experience supports Smith's statement concerning the varying hardness of one item. Even at the comparatively small surface of a certain hand-protection-cuff the measured hardness was found to vary widely.[394] Williams frequently

392 Overman (1851), p. 365-366.

393 Smith (2004).

394 Five locations were tested in a line of 100 mm in total, from the left to the right edge of the cuff. The lowest value was 225 and the highest 363 HV, see: Goll (2009), p. 87.

considers the varying carbon content of a presumably heterogeneous material to be responsible for the varying hardness. The author of this study suggests that it is rather the varying heat treatment while the armour was forged, the natural cooling or possibly the tempering method that resulted in different hardness-properties at different locations. Williams never proved his theory despite it would have been an easy task to test the carbon content at the location of the hardness indentation – particularly at the samples of old armour plate he destructively heat-treated to subsequently test their hardness.[395] Furthermore, there is no suit of armour existing today which supposedly left the armourer's workshop in the current composition. Nearly all suits had been repaired and/or completed in the times of their use and after. It is also not sure that the armourers, when making a complete suit, used only iron of one smelt – and the properties of iron-based material might be different from smelt to smelt. Alan Williams frequently ignored these facts and drew conclusions on the whole armour by examining only one spot or part. It is not very meaningful if the results of metallurgical testing differ from part to part. Each part of a suit had different purpose and could therefore also be designed from plates of different thicknesses and/or with different mechanical properties. Research on the topic is also not established far enough to tell if not also costly armour could have been assembled contemporarily from different workshops. If time was too short for the making of a suit made-to-measure, the combatant certainly did not go into battle without armour. It is therefore generally questionable to define parts of a suit of armour as not originally belonging, on the basis of differences in their metallurgy.[396]

Only one of Williams' numerous articles seems to deal with the problem of authenticity. The title "To what extent can forgeries be detected by metallurgical analysis?" promises to shed some light on the question of authenticity by metallurgical testing.[397] Its content totally fails to answer any question on the topic. It is just a collection of his common metallography-analysis, telling about the mechanical properties of seven helmets. Williams does not mention any other expected difference between modern and "old" iron or steel than that samples which contain slag inclusions must be genuine.

The most lamentable omission of all metallurgical approaches in Williams' works is that no attention is paid to the metallurgy of reproductions. In various collections there are hundreds of items that are considered to be reproductions, available for testing. These could provide a good basis to start from. The authenticity of the tested specimen in Williams works is usually not questioned and therefore the revealed data might be falsified by the coincidental and unrecognized testing of modern material, like puddle-iron. As long as this question is not comprehensively answered, also the general conclusions on ancient material-properties stand on a weak basis.

Another scientist, David Starley, carried out some authenticity-testing on questionable objects of the Royal Armouries in Leeds. He tested microstructure and hardness, and like Williams he revealed information on few spots only. Additionally the items were X-rayed to detect hidden modern welding seams etc. For example the helmet [ref_arm_5107][398] was found to be genuine as the skull was made of one piece of not hardened iron-plate that shows

395 See: Williams (2003), p. 898-902.

396 In the article on the Wallace collection suit A21 Williams suggest that a "tilting socket" once associated with the suit was not belonging to the ensemble, as the metallurgy was "unlike any other piece [of the suit", see: Edge and Williams (2001), p. 239.

397 Williams (1979).

398 Starley (2004).

inclusions and significant corrosion penetration. The question why the same properties should not be found at a helmet made in the 19th century remained unanswered.

The aforesaid approaches had not significantly forwarded the topic "authenticity questions on plate armour". In the following, some suggestions for different approaches will be discussed.

8 Suggestions for new approaches to the mapping of plate armour

As said above, many different factors influence the mapping of armour to a production site, a producer's name and the production time. The reasons for such a mapping should be split into two categories: suggestions and facts. The facts derive from the observation, classification and comparison of technical and stylistic details. They could be provided by methods used by humanities and by natural scientific disciplines. A single fact is usually not enough to allow a final mapping. The conclusion on certain facts should be of a suggestive character.

The more armour pieces the scholar had in his hands the more he will become aware of what might be genuine and what is doubtful. Nevertheless, this "feeling" should not influence a final judgment. It is better to leave the expertise open than to condemn an object to be a fake or a reproduction, even though doubts might remain. Wherever this advice is not regarded, the suspected armour parts were left neglected and without conservation in the shelves. This happened for example to some items of the Collezione Odeschalchi, now in the Palazzo Venezia in Rome. The author of this paper was told by the restorer of the collections that some 25 years ago a scholar of arms and armour[399] was asked to go through the storage rooms and to sort out what he considered to be reproduced – and so he did. The reasons for this specialist's decisions have not been documented. The objects rejected by his judgment are ever since lying unpublished, dusty and rusted in a shelf. Many of these items are most likely genuine [ref_arm_2828], just some are for sure completed [ref_arm_3714] (only thorax-plate genuine?) or otherwise altered.

Many specialists are too quickly at hand with their final judgment. But what if the objects defined as reproductions are indeed original? It is very dangerous to give statements of which the specialist cannot be a hundred percent sure. Actually this makes possible that historical facts get altered. The approach of sorting out and neglecting armour parts is even more questionable when considering that a good reproduction is an artwork of its own right and a document of the history of armour-production itself. Even if the purpose of its production was to deceive a potential buyer, it does not make the artwork itself a bad thing. The skills necessary to make an exquisite copy of a historical model are the same the ancient armourers must have possessed. The only difference is that the simple copying requires no creativity.

Nevertheless, the existence of fakes and reproductions is a fact that belongs inseparably to the history of armour production. Can it be good to let the "bad fakes" rust unattended in the storage? Would it not be fair to show them to the interested museum visitor, so he can also understand the difference between a copy and an original?

That for at least the past 200 years armour was reproduced, shows that it is of timeless fascination for many and it shows the importance it has for the material-culture of Europe. The 300 years of flourishing armour production in Europe between 1350 and 1650 play a significant role in the development of European crafts and thus for the conditions that led to the industrial revolution. The roughly 150 years between 1650 and 1800, when armour production was reduced to simple torso front-protections and helmets, are responsible for the huge loss of knowledge about its traditions.

The visitor of a museum or the reader of a book wants to see or learn about objects of art. If these objects are armour parts, then he would also love to see the reproductions, as long as the book or the showcase label defines them as such. He also would not mind if he found many question marks behind any statement. Even more, such an approach shows the

399 This person is now the curator of arms and armour in a famous south western Swiss historical museum.

interested lay that there are still a lot of unanswered questions on the topic. This is the best justification for the necessity of further research.

In the following, suggestions will be made how certain details can help to map extant armour to different aspects.

8.1 Dating reference

To allow a determined dating of objects of art, it is important to define stable basing points. Comparatively few armour pieces were excavated; many more were always kept above ground. Thus, not much reliable archaeological data for dating plate armour is at hand. Extant plate armour was so far mainly dated by stylistic criteria. These criteria were developed by comparisons to depictions of armour in artworks. Already by the early 19th century it became clear for the students of the topic that most of the late medieval and renaissance artworks were detailed reproductions of contemporary real existing objects. The technical features of armour shown on sculptures, drawings, engravings, miniatures and paintings would usually function, if transferred to a three dimensional object. Rivets are at the right spots, lames are shown in the correct positions, just as they are found on extant armour pieces. Even superficial comparisons proofed that many artworks are most likely eye witness reports of what contemporarily was in fashion or in use, but at least what was still known.

In the late medieval period, not many of the concerned artworks carry an exact date attached by the producer. In some cases art historians were able to date objects with definite or highly probably accuracy. These are the most important basing points for delivering reliable dates to extant plate armour. Examples found in more or less reliably dated artworks still have to be examined on four aspects before they are taken for dating extant armour. The questions to be asked are:

- Is the artwork contemporary, maybe a reproduction or heavily altered by restoration?
- Does the artwork maybe show fantastic items which did contemporarily probably not exist?
- Is the armour shown of the latest fashion of the moment the work was finished?
- Was the armour already old fashioned in the moment the artwork was produced?

Especially effigies which show the full armoured deceased are important for dating armour. This field has nevertheless not been studied sufficiently enough to deliver satisfactory answers. On such sculptures it usually seems very likely that the sculptor used an existing suit of armour as a model. Monuments like the one of grave Otto IV. of Henneberg (†1502) in the city church in Römhild, probably cast by Peter Vischer the elder (*1460; †1529), suggest this assumption, as it is embossed at all sides and the helmet can even be detached like its real iron model.[400]

Commemorative or tomb stones and brasses often have the date inscribed when the deceased had passed away. Taking this date uncritically for dating the depicted armour is not advisable. This date is not connected to the completion of the artist's work. Effigies were often made in the lifetime of a person[401], and thus they could only show what contemporarily existed. If the purchaser had a long life after the finishing of his stone or cast, the date of death would not fit to the fabrication of the shown armour. In some cases the monuments were finished

400 Bauer and Demmler (1941).

401 This is for example the case with both monumental brasses in the city church of Römhild, see Bauer and Demmler (1941), p. 2-3.

long after the death of the commemorated person. This happened especially if the one passed away unexpected or the momentary financial or political situation did not allow an immediate realization of the project. In such a case it would be questionable if the sculptor still used contemporary armour as model for his work.

Also problematic is the determination of the armour as the one the deceased used when he passed away or is it of the times when he had his most success. If he died of old age it is unlikely that he still owned up to date armour, so he was probably depicted in his old equipment. In some cases, extant written documents like bills or orders helped to narrow the exact production date of an effigy or monument.

Nevertheless, the date of the production of an effigy is usually to be estimated within a period of at most plus or minus 20 years around the death of the depicted. This means that the production date of the armour would also lie within this period.

Generally the possibility for an exact dating of armour should not be overestimated. Given that the deceased was actually shown in his own armour, it still does not mean at all that it was produced shortly before his death. Not all nobles could afford to be permanently equipped with armour of the latest fashion. Armour was not simply thrown away just because it was old and it cannot be stated with certainty that the sculptor even used armour as model which did actually not even belong to the depicted. Of course, it is unlikely that medieval social norms would accept an exaggeration of the actual status of the deceased. Anyway, benefactors generally wanted to be depicted with their best and most up to date wear, and modesty was certainly out of place at contemporary commemorative artworks. This could have led to some conscious shifting of the facts on the contemporary appearance.

According to contemporary depictions, fashion was actually rapidly changing throughout the 15th century. The fashionable stylistic features an armourer proposed to his client when discussing an order might have been already antiquated weeks, months or even years later, when he delivered his products. The style of complete suits changed very quickly from the beginning of the 15th century, especially in the regions north of the Alps. Mainly the ridge – in all facets – was used to design the plate surfaces. The Italian producers were rather modest with the application and the experimenting of new decorative features.

The easily visible changing of fashion now helps modern scholars to date armour. Stylistic details had been observed and brought into a chronological order. It is therefore possible to date most of the extant armour pieces within a range of 20 years at most. These methods are usually unquestionable so far, but it is usually not possible to exactly date armour to the year or even the month of its production. The development of the different types of turned edges, ridges, embossing, plate decorations, surface finishes, shaping techniques, plate-thicknesses, rivets, washers, fastening systems applications and marks have not been classified yet and thus they had not been ordered chronologically before. The attempt proposed above of defining a utility time of certain features might help to closer date extant items.

8.2 Mapping with the help of marks

The question on the name and the life of artists or craftsmen is probably one of the most central ones for any research on historical artworks. In parallel to all medieval art, the contemporary armour is not consequently signed by symbols, letters or signatures that could allow the identification of the maker's name. Even though the earliest pieces occasionally already bear stamped marks, until the end of the great period of armour in the mid-17th century the marking of the plates did not become common at all. Even objects of the highest quality were not consequently marked. Some marks might have disappeared from polishing, but certainly the largest part of extant objects was not marked. Even where objects were marked, the symbols often cannot be identified, either because they are nearly vanished or

because the meaning cannot be understood. Sometimes the names of armourers found in written documents can be attributed to certain pieces, if their seal on the documents or their coat of arms etc. is known and can be found stamped into a certain armour piece.

The topic of the interpretation of marks and the possibilities of identifying the master, the former owner, the production region or city is a vast field. The identification of marks is very important for any approach to the understanding of the armourer's art, but it requires intense archival research. In the last 150 years research brought to light the names of many armourers throughout Europe. For the 15th century, the names of the armourers appearing in historical documents of the cities of Milan, Brescia, Augsburg, Nuremberg, Landshut and Innsbruck were published. The only monograph on the topic was published in 1959[402]. This book is of little use for the scholar, as none of the included illustrations of marks is referring to any extant object. In the library of the Royal Armouries in Leeds there are several cartons full of hand written record cards describing marks on all kinds of extant arms and armour all over the world. This records were collected by Charles Alexander Baron de Cosson (*1846; †1929) in the 19th and early 20th century and is known as the "de Cosson Index". They also contain manuscript-like information that was sought to be published as a dictionary for arms and armour, which was never realized. Several handbooks[403] or collection-catalogues[404] include lists of a choice of marks. Until today it is such single publications that need to be studied when questions on marks arise. Many marks were already identified or at least suggestions on their identification were published. The identification of marks on Italian armour is merely due to Lionello G. Boccia, on German armour it is merely due to Wendelin Boeheim and Bruno Thomas. The 3 volume-publication "Der neue Støckel" by Eugene Heer comprises 6.500 marks of gunsmiths and crossbow makes marks but no armourer's marks. It is also important to compare the marks published by Heer with armourer's marks as marks of different craft-branches often show similarities to each other. Future studies may help finding new relationships between different specialized crafts.[405] The author estimates that the larger amount of the existing marks still has to be identified.

One important question is, where all the armour went that was evidently produced in the less famous production centers. Contemporary documents of cities all over Europe proof the existence of armourer's workshops not only in Innsbruck, Augsburg, Nuremberg and Landshut. In the 15th century armourers were working for example in Munich, Regensburg, Stuttgart, Pforzheim etc. For example the city of Freiburg im Breisgau was probably also a production center for armour production. The "Zeugwart" for Lower Austria, Wilhelm Tentsch, bought armour there from a "harnascher" in 1478.[406] Not a single object of the 15th century has yet been identified with one of the said cities. Pierre Terjanian, in his essay on a high quality helmet made most likely by a Basel armourer, showed that there is still new information to be found on the armourers of the less popular centers[407]. Certainly documents

402 Gyngell (1959).

403 E. g. Boeheim (2000), p. 633-680; Nickel (1974), p. 281-311.

404 E. g. Thomas and Gamber (1976); Di Carpegna (1969).

405 For more on the similarities of master-marks on products of different craft-branches see: Goll and Sensfelder (2011).

406 Jahrbuch der Kunsthistorischen Sammlungen in Wien (1900), Reg. 18351. It is not clearly defined which „Freiburg" is meant. Certainly it was either the one in Üechtland or in the Breisgau, as all other places called "Freiburg" were too small at that time. Freiburg in Üechtland had specialized crafts in the 15th century and in 1477 had become a "freie Reichsstadt". Future archival research maybe can reveal the possible armour production in these cities.

407 Terjanian (2001).

of other central and western European countries survived and have simply not been viewed yet. It is possible that in the future anonymous objects might be identified with their master. Private seals of armourers are still extant but they have not yet been found on any item – for example the seal of the Vienna master Kristan [ref_ill_art_5371].

Within the range of this study it was not possible to focus on the aforesaid aspects comprehensively. To ease further studies of marks, some suggestions for their classification will be introduced in the following.

A computer-aided comparison of data on marks entered into a database could allow revealing numerous kinds of interrelations between different objects – up to now an arduous Sisyphean labor. Marks can be classified by several aspects. The first aspects are concerning the intention of the marking:

Producer identification:

The mark is the personal sign of the armourer and serves like his signature or in modern words: it is his brand. It can consist of whole names ("Innocens" for Pier Innocenzo da Faerno [ref_arm_2215]) abbreviations ("casp" for Caspar Rieder [ref_arm_3374]) or initials stamped in different fonts. Also symbols that refer self-explanatory to the name of the maker were used (e. g. a wheel for the name Ger. "Wagner" Engl. "wagon-maker"). Such symbols are merely used in the German speaking lands. For example the Augsburg armourers of the Helmschmied family occasionally signed their works with a jousting helmet with a cross at the crest (e.g. [ref_arm_3401]). Initials on Italian armour are often surmounted by either a cross with the lower branch split in two halves [ref_arm_781] [ref_arm_3097] ("GIS" for Giovanni da Salimbeni?), by a crown [ref_arm_1353] or by an abbreviation line with a central bump [ref_arm_2119]. The crown upon a letter also occurs on northern alpine armour [ref_arm_1724]. A group of its own is formed by symbols consisting of several single chiseled lines, found exclusively on armour made in Spain [ref_arm_3153]. Some variations were maybe applied with a single stamp [ref_arm_24]. These marks are considered to be workshop's marks. A unique workshop identification is the stamping of some items with the word "Arbois", the name of the French city where Italian armourers had established a workshop by the end of the 15th century [ref_arm_3570].

Quality control:

The mark is attached to good quality items after an inspection on behalf of an administrative authority, usually the city-council or the armourer's guild. Such a mark can either show the city's symbol (Augsburg: pine-cone [ref_arm_282], Landshut: hat [ref_arm_1890]) or the coat of arms (Nuremberg [ref_arm_3421], late 15th century). It is also only these three cities that are known to have implemented this quality-approval by means of a mark. The Italian cities made no use of it.

Also interior approval-marks are found. The mark is stamped to the interior of an item to prevent it from being ground of. It was probably attached after a first quality inspection before the item was ground and polished. It is possible that from the early 16th century on these marks were attached by the workers of a waterpowered hammer who delivered semi-finished plates in the right dimensions to the armourer's workshops. Such interior marks are rarely found at armour before 1500. The only earlier items the author could find are [ref_arm_3867] [ref_arm_3698].[408] In the early 16th century, some breastplates were

408 Also a small fragment of segmented armour – found in the castle of Otepää (destroyed 1396) – is stamped with a cross in a ring. This mark might be one of the earliest found on armour, but it is not clear which side of the fragment was the in- and which the exterior, see: Rachewiltz (2004), p. 108, pl. 3.

stamped interiorly [ref_arm_3423] [ref_arm_3568] (at both items not clearly identifiable: a letter in a ring of pearls, N?)

Owner identification:

Items stored in the Imperial Ottoman arsenals were often marked with an Arabic symbol (e. g. [ref_arm_1064] [ref_arm_1063]) engraved or chiseled into the plate. Some central European arsenals marked their items with a stamp: Venice, [ref_arm_2132] (said to show a winged lion); Zeughaus of the Habsburg family, a "Bindenschild" [ref_arm_3527], early 16th century; Matsch family, coat-of-arms [ref_arm_1495]. Also modern owner's marks are found at several items. For example in Bruxelles the Museé d'Antiquites [ref_arm_3350] and in Paris the Museè d'Arte [ref_arm_3199] in the 19th century had stamped several items with the full name of the museum. Also many items in the Stadtmuseum Munich have a lead seal riveted into a hole, stamped interiorly with the monk – the city's symbol – and the letters KBLWM (probably Königlich Bayerische Landwehr München)[409].

A single mark can be classified by aspects concerning its depiction. There is a great variety of symbols and letters stamped into the plates. Actually there are no restrictions:

Letters (in capitals or in lower cases, in Antigua or in Gothic Print), sometimes with abbreviation lines [ref_arm_1978], sometimes spelling whole words.

Crosses [ref_arm_1512], split crosses [ref_arm_2048], crowns [ref_arm_612], helmets [ref_arm_1743], fleur-de-lys [ref_arm_1348] etc.

Coat-of-arms-like arrangements: [ref_arm_1521] [ref_arm_1929] [ref_arm_1724] [ref_arm_880].

Various stylized objects are found at armour made in Italy and the German speaking countries, e.g.: fleur-de-lys [ref_arm_1348] [ref_arm_1710]; cow's head [ref_arm_2081] [ref_arm_1712] Armour); blossom [ref_arm_1769] [ref_arm_2148], animal [ref_arm_3430] etc.

Each symbol can further be defined as recessed or embossed.

The position of the mark at the object should be considered, as the armourers seem to have preferred to mark their objects at more or less the same position.

Nearly all classes can occur combined on one object, especially as occasionally several marks can be stamped into one item. On Italian armour commonly a group of marks is found, often three marks form a triangle.

To ease the comparison of marks, the author additionally suggests developing a supportive method for the identification of marks in the future. The marks could be rubbed on a thin paper directly from the objects. The rubbings are scanned together with a size-reference (e. g. a transparent scale-paper). These scans stored in a database can be used for computer aided comparisons to reveal marks with similar dimensions. The author of this paper has already collected hundreds of mark-rubbings that could serve as the basis for such a mark-database.

8.3 New recognitions on marks

The author wants to draw the attention to a unique type of mark that has not been described so far: The round lead seals attached to 19 15th century[410] items (e. g. [ref_arm_3656]) of the Munich "Zeughaus". Wackernagel made only a short note of them in his 1982 catalogue,

409 See chapter [New recognitions on marks].

410 Many later items in the collection also bear this seal mark.

while he described another monk-mark found stamped directly into the armour plate.[411] The lead marks are important, as they are the only marks of this type found on extant armour of the concerned period.[412] The lead seal is always fixed in a hole drilled into the plate. In some cases, it seems like older holes of other purpose were used, as a second "empty" hole of a possible former pair is visible close to the seal [ref_arm_1801]. Maybe it was tried to use existing holes to keep the genuine object untouched. The symbol is always stamped interiorly, probably to prevent the soft lead from damage. Nevertheless, at many objects the stamping is badly spoilt, but it can be seen still very clearly for example at [ref_arm_2412]. The symbol resembles in its center a monk looking to his right, dressed in a wide, caped coat. To his feet the seal is encircled by the letters KBLWM. The letters might stand for "Königlich Bayerisches Landwehr Museum" or alternative for "Königlich Bayerische Landwehr München". From 1865-1869[413] the Zeughaus items were maintained by a citizen militia, the "Königlich Bayerische Landwehr".[414] The monk is the traditional symbol for the city of Munich and a monk with wide sleeves also covers the museum guide of 1866 [ref_ill_art_5393].[415] The marked objects of the inventory were possibly those chosen by Braun for display in the "Landwehr Zeughaus".

The seals were certainly not attached after 1869, as by that time the "Königlich Bayerische Landwehr" was disbanded by the Bavarian King. The Zeughaus from 1870 on was maintained by the BNM.[416] One of the aforesaid 19 marked items is still in the BNM [ref_arm_1798][417]. Some of the items of the Munich Zeughaus in the 1920ies or -30ies were given on loan to the BAM in Ingolstadt. Within time, for several objects their provenance was forgotten, access numbers got lost by extensive cleaning with an acetous liquid. From 2012 on several items in the BAM were brought back to the Stadtmuseum.[418]

The Italian armourers apparently not only produced armour of a common style, but they also marked the pieces with marks of the same type. This was often one or two letters underneath a crown, a cross with a split lower end or an abbreviation line. Armour bearing such marks is frequently considered to be of Italian origin. It has never been discussed that armourers of other, not Italian production regions might have taken advantage of the good reputation of Italian armour by adding similar marks to their items. While such deceptions are known to have been frequently undertaken by producers of blades[419], this question has never been asked when marks on armour pieces had been discussed. Also in modern times, reproduced armourer's or city marks might have been stamped into genuine plate to raise its value. Obviously marks resembling original models have been reproduced and stamped into the

411 Wackernagel mentions different versions of marks resembling a monk-head found at different kinds of arms and armour. His mention of a new variant of this mark in the "Landwehr"-time refers probably to the lead seal, see: Wackernagel (1982a), p. 28 + 187-188.

412 In the course of the studies in the store where the objects are stored today due to time limitations it was not possible to check if also later armour is marked by this lead seal.

413 Wackernagel (1982a), p. 30 + 37.

414 For more details on the "Landwehr" see: http://www.bayern-buergerwehr.de/Geschichtliches.html.

415 Braun published the first partly illustrated catalogue of the Zeughaus: Braun (1866).

416 Wackernagel (1982a), p. 38.

417 In November 2012 the author informed the responsible of the Stadtmuseum Munich that this helmet does actually belong to the Zeughaus inventory.

418 The author helped to identify the helmet [ref_arm_1749] – until then considered to be a loss of war – and several other items as formerly belonging to the Zeughaus inventory.

419 See for example: Reitzenstein (1964), p. 19.

plate of reproductions. The suit [ref_arm_4128] is certainly not genuine, but the belonging type-VII helmet – made in the German style – bears a mark of Italian type.

It seems as if some reproducers marked their objects to define them as copies. If Schedelmann is right with his assumption that the suit [ref_arm_4141] is made by Leopold Winkelmayer[420], the mark found under the nape-cutout of the suit's backplate [ref_arm_3349] must be that of this 19th century Vienna armourer. This is very likely as the mark appears like a stylized "W". By his mark maybe also some further works can be attributed to Winkelmayer's workshop: the helmets [ref_arm_1899], [ref_arm_1857] and the chin/throat protection [ref_arm_3202]. As the single unmarked chin/throat protection [ref_arm_3194] in shape and size is very similar to the aforesaid and to the one belonging to the Altena suit [ref_arm_3172], it is very likely that all three were made by Winkelmayer.

8.4 Discussion of the possible genuine appearance of armour

The mapping of items dispersed to different locations that once belonged to one suit is a difficult task. Several scholars tried to locate the parts of certain suits of armour. The most prominent of such enterprises was probably the re-arrangement of the Lorenz Helmschmied suits formerly in the armoury of Schloss Ambras in Innsbruck and now in the HJRK in Vienna. Fortunately, a sketchbook attributed to Lorenz Helmschmied showing[421] many drafts of "Garnituren" of armour, suits with parts exchangeable for different combat use, helped to identify the single pieces. [422]

Whenever no contemporary illustration of the suit in question is preserved, the ridge-decoration, etchings and applications, but also the constructional details, can serve for the attribution of single parts to one suit. But care has to be taken, as the modern eye tends to ascribe only perfectly matching parts to one genuine composition. The extant breast- and the backplate of the suit [ref_arm_4090] do not match perfectly, which led Ortwin Gamber to the suggestion that they belonged to different suits[423]. For the breastplate [ref_arm_3611], Thomas and Gamber were suggesting that about 1490 the lower edge of the pelvis-lames had been hammered flat secondarily and the copper alloy bands got detached for the attachment of torso-upper leg-protections [ref_arm_5143] [ref_arm_5144]. The torso-upper leg-protections were detached in the 1970ies to reveal the "original" appearance of the plate.[424] At the sides they were probably riveted directly to the lowest pelvis-lame and towards the center by an interior leather strap, as the missing rivets at these locations suggest. The different rivets and "empty" holes suggest that different alterations were made, probably also in the times when the suit was restored in the 1800s. Nevertheless, the small holes necessary for riveting the decorative bands are missing and therefore Thomas' and Gamber's assumption becomes questionable. It was not possible to examine the lames interiorly, but from the outside also no traces of a former embossing is visible. At each side of the lowest lame, towards the centre and towards the back-lames, a pair of holes is visible. Next to a yellow-headed rivet at the torso-upper leg-protections, the head of a rivet of type-a is visible. These holes maybe once held the rivets for an interior leather strap that fixed the torso-upper leg-protections to the pelvis-lames, leaving the yellow-rivets at their upper edge for decorative purpose only. A second possibility is that the single yellow-head rivets at the central upper edge of the lowest pelvis-lame together with the joint-rivets at the side of the

420 Schedelmann (1964a), p. 52-53, fig. 1.

421 The book got lost in World War II.

422 Gamber (1957).

423 Gamber (1977), p. 39.

424 Thomas and Gamber (1976), p. 100.

pelvis once fixed exterior leather straps to which the torso-upper leg-protections were buckled. Whatever the purpose of the holes was, it is clear that they were not drilled without reason. In the case of the said torso-upper leg-protections, it is possible that they belonged to the breastplate from the beginning.

All the aforesaid approaches are not unproblematic, as contemporary artworks show that the single parts did not always match perfectly. For example at the late 15th century sculpture [ref_ill_art_5160] the lines of the back- and the breastplate do not properly meet under the arm cutouts. This miss-match is also found at the sculpture [ref_ill_art_5367] and here also the lower edge of the pelvis-lame at the backplate is designed different from the pelvis-lame of the breastplate. At the front-protection it is left plain – probably to allow a close fit of the torso-upper leg-protections – and at the backplate the lower edge is decorated and stiffened by a ridge. But also the single segments of one armour part did not always fit perfectly: on a sculpture of about 1480 an armoured man wears a breastplate with a thorax-plate under the arm cutouts extending much wider towards the back than the abdomen-plate [ref_ill_art_5207]. Also in the Middle Ages, time was a precious good and if there was an urgent need for a the wearing of armour, the noble fighters could not wait until a customized suit was finished. It should be considered that armour was not necessarily made to measure and could have been bought in different sales, from different makers to form one suit.

To tell which segments of an extant suit are genuine and which are reproduced in most cases is only possible when items once got completed or broken parts got replaced. The examination of the in- and exterior plate surfaces might help to identify replaced parts. The patina or the corrosion in such cases often differs slightly from the genuine to the reproduced parts, the older ones are expected to look more worn out or aged. The more plate segments an armour piece comprises, the simpler the comparison of such details becomes. By the nature of the human body, usually the armour for the limbs, the hands and feet consists of more different segments than protections for the torso, for the head and for the neck. The first group is often extant in pairs and if both sides of the body are at hand, there is even a wider basis for comparisons. In the SKD there are three pairs of type-IV hand-protections [ref_arm_1238] [ref_arm_1201]; [ref_arm_1199] [ref_arm_1236]; [ref_arm_1202] [ref_arm_1239]. The right hand-protection of each pair is most likely entirely reproduced. The in- and the exterior corrosion-pattern suggests this assumption.

The helmet [ref_arm_1365] is probably an altered so called “Birnhelm” of the last quarter of the 16th century. The brim was lost or got cut off and was replaced by a new one resembling a 15th century helmet often called “Capacete”. The skulls of these two helmets are very similar – if not same – in shape. The difference is that the brim of the later type curves deeper at the ears and is more pointed at the front and the back than at the 15th century type. A Birnhelm is available comparatively cheap on the antique market, as hundreds or even thousands of objects survive, especially of the plain and undecorated arsenal-version. A lot of money can be made by the modification of such a helmet, turning it into a rare and thus expensive late medieval type. In the mentioned case the skull is most likely genuine. It shows the typical delaminations and is of rather heavy quality. The brim has a very sharp edge at the interior where it is probably welded to the skull. The plate of the brim is thin, equal in thickness and showing no delamination. Also the appearance of the corrosion is different from the skull.

Still care has to be taken with a too quick condemnation of single segments. Each armourer – the medieval and the modern – works a little different, and several contemporary workers might have finished one item. There were certainly different charges of plate used in the same workshop, with different marks left by different hammers and different remains of hammer scale etc. Also the plate-thickness differs purposely, for example the segments of

the pelvis protection of a torso front were usually made of thinner material than the upper parts. Another problem with the differentiation of the surfaces is that different corrosion traces could derive from the replacement or repairing of segments in times when the item was still in use. Finally the interior surface of certainly genuine examples can also look as it has just left the workshop [ref_arm_1978].

8.5 Authenticity discussion of single chosen objects

For a detailed discussion of the problem of authenticity the finding and subsequent comparison of objects that share a great deal of common features can be of immense help. In the following the presumable influence of some original items on reproductions will be discussed.

8.5.1 The "Sigmaringen" armour in Detroit

Many features of a genuine suit of armour in the Detroit Institute of Arts [ref_arm_3214][425] are found similarly on numerous comparable examples in other collections. The DIA armour suit has been sold from the Hohenzollern armoury at Schloss Sigmaringen via a New York art dealer to the collector William Randolph Hearst, from whose collection it went to the property of the Detroit Institute of Arts.[426] As it is displayed at the moment it is a composition of reproduced and genuine parts. The genuine parts are the breast- and the backplate, the shoulders, the knees and the upper legs. The certainty about the authenticity of these parts derives from the observation of the obviously skillful mastership by which they were created and the marks of Lorenz Helmschmied found at all the aforesaid plates with the exception of the shoulders. A comparison to the objects kept in the court armoury at Vienna attributed to the same master make the relationship undoubted. The flaps at the upper legs and the pelvis-lames of the breastplate are completions, as all details are made more crudely.[427]

The hand-protections, the lower arms, the elbows, the upper arms, the lower legs and the feet as well as the helmet and the neck-protection are reproductions. Stuart Pyhrr ascribes these reproduced parts to the workshop of an anonymous armourer of Munich around 1870.[428] As also other armourers completed suits without leaving any mark, the reproduced parts of the DIA suit could also well have been made in Vienna, Paris or any other city. The suit in the DIA must have been completed at some time before 1904. The catalogue of the Gimbel collection of reproductions, published in this year, shows a copy of the suit including all the aforesaid completed parts [ref_arm_4131].[429] The latter differ slightly from the installation now in the DIA and especially the leg armour is made very crude. All other parts do clearly show that the DIA suit served as a model for this reconstruction.

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425 Published by: Richardson (1954), p. 6-7; Gamber (1957), p. 43, 48 and Levkoff and Hearst (2008), p. 20-21.

426 It was bought by the DIA in 1953, see Levkoff and Hearst (2008), p. 20.

427 The museum files already record these presumptions in an examination report from November 1950 when the armour was still in the Hearst collection. Here it is suggested that also the pelvis-lames of the backplate are completions: "Backplate authentic, except extension plates at sides and three garde-rein lames (which are apparently old metal, but restorations)". It is not mentioned where this certainty comes from, now that the metal is already considered to be old and the craftsmanship fits well to the rest of the plate.

428 See: Levkoff and Hearst (2008), p. 21

429 Most of the items of this collection are now part of the collections in the Marksburg (Braubach, Germany).

Several other reproductions of this suit were made. In the Park of the Schloss in Sigmaringen an exact copy of the suit is standing in a wall-niche next to the entrance stairs [ref_ill_art_5350]. Investigations on the date of this plastic could maybe help to further narrow down the date when the completions on the genuine suit were made. In the Meersburg there are iron casts of the left upper leg and knee and of the left upper- and lower arm in the scale 1:1 with the original [ref_ill_art_5251]. The Galerie Fischer in Luzern in 1964[430] sold a smaller-scale iron cast of the suit, whose legs served as the smoke pipe of a chimney [ref_ill_art_5376]. The catalogue suggests the mid-19th century for the making-time of the cast. In the SKD there is a breast- and a backplate, resembling very closely the Detroit suit [ref_arm_3629] [ref_arm_3321]. The whole suit is possibly a reproduction. The belonging neck-protection is not functional. It lacks the obligatory holes for the lining and it is a unique example of an elaborately worked neck-protection that surprisingly lacks the comfortable articulated upper lame. It is furthermore the example with the lowest weight [ref_arm_3175], compared to all extant items of the same type. A similar, due to the lack of lining-holes not functional neck-protection is [ref_arm_3054]. It is surprising that all parts of the Dresden suit, including the attributed helmet [ref_arm_1725] bear the Nuremberg mark – a mark generally found very rarely at armour from before 1500. Several back- [ref_arm_3280] [ref_arm_3289] [ref_arm_3314] [ref_arm_3400] [ref_arm_3402] [ref_arm_4779] and breastplates [ref_arm_3582] [ref_arm_3583] [ref_arm_3594] [ref_arm_3603] [ref_arm_3629] [ref_arm_3729] [ref_arm_3805] [ref_arm_3289] [ref_arm_3971] [ref_arm_4006] [ref_arm_4015] [ref_arm_4052] are found in various collections, all of them are most likely reproductions after the Detroit [ref_arm_3401] [ref_arm_3757] or other, very similar genuine Vienna models [ref_arm_3299] [ref_arm_3300] [ref_arm_3301] [ref_arm_3611] [ref_arm_3613] [ref_arm_3614] [ref_arm_3615]. Schmidt probably offered reproductions of the entire DIA suit, as an image of a very similar suit in his catalogue suggests [ref_arm_4082].

8.5.2 Various neck-protections

Many of the aforesaid reproduced parts might have been made in a Munich workshop, as the formal similarity of the neck-protections with items shown in the catalogue of the Atelier Ernst Schmidt suggests [ref_arm_4089]. The Schmidt neck-protections are usually attached by a plate-tongue, stuck through a staple riveted to the breastplate. This type of joint can neither be found at any certainly genuine armour nor at any contemporary artwork. It is therefore most likely an invention of a copyist of the late 19th or early 20th century. At the Schmidt pieces, the lower plate of the neck is usually embossed where the turned edge of the breastplate underneath is located. This feature is also not found at genuine neck-defenses. Therefore, also the neck-protections [ref_arm_3039] [ref_arm_3031] [ref_arm_3054] might be reproductions of his Atelier.

8.5.3 A suit in the BMA

In the BMA there is a suit of armour [ref_arm_4141] that closely resembles the works of Lorenz Helmschmied in Vienna and the DIA suit. Laking in his chapter on forgeries included an image of the suit, saying that it is a Bavarian reproduction[431]. He admits that this is a quality of reproduction that is very deceptive. The arguments that brought him to this conclusion are superficial and short:

430 Galerie Fischer (1964), lot 199.

431 Laking (1920), p. 119, fig. 1532.

It is rather difficult to point to any actual defect in its general form; but we can distinguish a certain over-modelling of the fronts of the jambs, and we may also suggest that its pointed sollerets are purely imaginative in form. Again, if we examine the surface of the metal, we shall find that it is leaden and lustreless, of a colour that no amount of cleaning would bring to that splendid black glossy appearance of true XVth century plate.[432]

In his 1964 article on reproductions, Hans Schedelmann – without including a reference – attributes this suit to the workshop of Leopold Winkelmayer in Vienna.[433]

In November 1955 this suit was bought by the Museum in Altena from the Munich art-dealer Xaver Scheidwimmer for the price of 4000,- DM. It was described as coming from the Kuppelmayer-collection in Munich, being a 19th century reproduction made in Vienna and modeled after the suit [ref_arm_3258] in the HJRK in Vienna.[434]

None of these descriptions mentions the mark, showing what could be a stylized "W", under the nape-cutout of the backplate [ref_arm_3349]. It has no similarity with any other mark of the late Middle Ages and could well stand for the name "Winkelmayer". This mark indicates that the suit was not necessarily made to deceive a potential buyer and was first sold as a reproduction.

Leaving aside that the mark might tell about its maker, this suit is a very good example for demonstrating how difficult it can be to find words for what the specialist "feels" when testing authenticity. The craftsmanship is very good, the metal of the breastplate shows delaminations and the rivets have caps of copper alloy embraced to their heads, just as many genuine rivets at other items have. The only things that remain strange are the – in proportion to the upper plates at the front and the back – uncommon narrow pelvis-lames and the almost symmetric upper end of the upper-leg-protections. Furthermore, the absence of sliding rivets at the hands and the upper legs leaves these parts very stiff. All parts are generally made with the greatest care and are of wonderful craftsmanship, the buckles and the gilded copper alloy applications cannot easily be distinguished from other, probably genuine examples. Interestingly, the helmet [ref_arm_1702] of this suit is certainly no reproduction, but a very rare example of a late 15th century variation of type-VII helmets.[435] The maker of the rest of the suit intended to match the helmet by adding the copper alloy bands. Too busy with the testing of the suit's authenticity, the former scholars missed this important detail. Probably also the lower leg-protections are genuine examples of the 16th century.

8.5.4 A type-VIII helmet in the Royal Armouries

Karen Watts tried to find proof for the prevalent mapping of certain items in the Royal Armouries to the workshop of the London forger Thomas Grimshaw. Her considerations start with the examination of two helmets bought by the Tower Armouries in 1851 from Samuel Pratt – an art dealer said to have been Grimshaw's accessory. Not all of the further

432 Laking (1920), p. 119.

433 Schedelmann (1964a), p. 52-53, fig. 1.

434 Data taken from the museum-register.

435 See chapters [Type-VII] and [Reproduced ornaments on genuine armour].

mentioned helmets can be revised here, so only one will be chosen to make clear how problematic some preceding approaches to the authenticity question had been.[436]

The helmet [ref_arm_1657], a type-VIII "great basinet", is too heavy in comparison to any other helmet of the same type, she argues. As a comparative piece, she quotes the weight of the helmet [ref_arm_1443], which is of type-II (mid 14th c.) and not of a 15th century type-VIII – and therefore actually not comparable. Comparable[437] are merely "great basinets", made from older type-IV helmets, to which lower shoulder-plates were riveted in the first half of the 15th century ([ref_arm_1653] [ref_arm_1655] [ref_arm_1768][438]). The skulls of these helmets all have a point, projecting slightly backwards and leaving the rear profile in an almost straight vertical line. The "Grimshaw skull" is pointless with a slight medial ridge at the egg-shaped apex. The only similar skull the author knows from a 19th century drawing only, its present location is not known and therefore its authenticity cannot be tested [ref_arm_4219]. As this skull-shape is so unique, it is unlikely that the Tower item is a composition of a genuine skull and secondarily attached lower plates. Nevertheless, it is possible that further helmets similar to this example existed, but all of them are lost or not known.

Watt's argument that the helmet must be a reproduction as the main edges of this helmet were not turned over wire but instead left unfinished is rather a proof of authenticity. As far as the author knows, no "great basinet" from before the mid-15th century has any edge turned. Also her arguments that try to support the impossibility of the spring-lock at the forehead of the skull, holding down the visor, are not comprehensible as well. The statement that the *"spring-catch on this visor is designed to hold the visor down. In effect, the wearer is trapped, as it is very difficult to get an arm round the pointed visor to release it"* presumes that late medieval fighters were immobile. There are hundreds of late medieval helmets, of different types, that have a spring catch holding down the visor (e. g. [ref_arm_1704]). This could usually be released on the right cheek, just some 15 cm away from the position of the catch at the "Grimshaw helmet". Each spot of a medieval helmet can easily be reached by its wearer's hand, now and then. It is nevertheless suspicious that the lock of the "Grimshaw helmet" is not found at any other medieval helmet. The reasonable of Watts' arguments for the helmet being a reproduction are the impracticality of the helmet, as the wearer could hardly see through the sight when the visor is closed and the interior marks from the plate-rolling.

The sum of suspicious features and the Pratt-provenance makes it very likely that this helmet is a reproduction. Nevertheless, it is a part of the history of armour-making and therefore it is sad to read that the item *"has rusted now completely"* in the storage of the Royal Armouries. With each unattended and not accessible "forgery" the chance is shrinking to find better arguments for the mapping of armour as reproductions of originals.

8.5.5 A type-II helmet in the Royal Armouries

Karen Watts in her article on armour made by the forger Thomas Grimshaw argues why she considers the type-II helmet [ref_arm_1468] of the Royal Armouries as genuine. This helmet appeared without any documentation of its provenance in 1974 in a Sotheby's auction,

436 See the discussion in: Watts (1992), p. 102.

437 This means: also equipped with a pointed visor and the skull being worked from a separate plate. The other similar helmets of type-VIII have usually the skull worked in one piece with the nape and rear shoulder protection.

438 Maybe also [ref_arm_1658], but as the present location is not known and only a poor image of the front is at hand it cannot be said with certainty that it belongs to this group.

denounced to be one of the Pratt/Grimshaw fakes, but was eventually considered and acquired as genuine by the Royal Armouries. Watts describes some details that argue for the authenticity of this helmet, like the correct placement of the rivets for the lining etc. In her opinion, Grimshaw would not have bothered with such details. An accurate reproduction would have made the study of originals necessary, but Grimshaw seems to have worked from depictions only. Watts draws the following conclusion:

> *"In fact, it is not a fake at all, but is generally accepted as a genuine helm of the fourteenth century."*[439]

The obscure *"general acceptance"* and the assumption that it could not have been made by Grimshaw as it is of alleged too good quality, are used as a proof of authenticity. The *"general acceptance"* cannot be retraced in any document. Only one article repeats her claim that the helmet is genuine. This was written 15 years before Watts' by Derek Spalding but was not quoted by Watts.[440]

The concerned helmet is almost identical to another example in the National Museum of Scotland [ref_arm_1461]. The only major difference is that the Leeds head piece, unlike the Edinburgh one, has no breathing holes at the left cheek. The helmet in Edinburgh is made of very thin plate (min. 0.6; max. 1.9 mm; skull front left 0.6 mm; skull front right 1.8 mm; cheek left 1.7 mm; cheek right 1.4 mm)[441]. How thin the plate at the front indeed is, can easily be seen at the deformed and broken out cross-shaped holes and at the hole that uncovers the wire inside the inwards rolled lower edge. As the weight of both helmets differs only by 0.11 kg or 4 ounces[442], the plate-thickness of both pieces might be more or less the same. Due to the thin material, such helmets are very unlikely to have been used in battle or tournament.

The Edinburgh and the Leeds helmets are both made of three plates only: a cone-shaped "tube" covering the skull from above the line of the ears upwards, closed at the crest by a slightly embossed plate and a second tube, protecting cheeks, ears and nape. The tubes show no seam, therefore they must have been produced via the forge welding of a roll. It is not clear why the armourer put so much effort in this construction. No other helmets are constructed this way. As the armourer already forge-welded the plates, he could have made the helmet already from one single tube only with an inserted comb-plate. Many comparable helmets have their skull made of one piece from above the ears with several lower plates attached, protecting the face and the nape [ref_arm_1465] [ref_arm_1466] [ref_arm_1471] [ref_arm_1481] [ref_arm_1490]. Other examples also have the skull made of several segments [ref_arm_1457] [ref_arm_1484] [ref_arm_1486] [ref_arm_1488].

In his article "Four helms of the fourteenth century compared"[443] Alan Williams says that he took a single flake from the interior of each of the two discussed helmets for his metallographic examination[444], the dimensions of the sample are not given. All testing results concerning these two items derive from these particles. He quotes the hardness of the helmet

439 Watts (1992), p. 104.

440 Spalding (1981).

441 It was not possible to examine the Leeds head piece and no measurements for comparisons are published yet.

442 Watts (1992), p. 104.

443 Williams (1981).

444 Williams (1981), p. 81-82.

[ref_arm_1461] at 430 VPH at an outer layer of 0.3 mm thickness and the average hardness of the helmet [ref_arm_1468] at 290 VPH.[445] For the helmet [ref_arm_1461] he suggests that the material was soft iron that got case-carburized as it was only harder at an outer layer. Williams does not explain how he found out that the hardness of the helmet [ref_arm_1461] was higher at an outer layer. The conventional hardness testing method can only distinguish between harder and softer layers if several sections of the material are tested.

The author of this study will try to reconstruct the processes necessary to case-carburize and to harden such a helmet:

The first possibility for the manufacture would be that this helmet had been case-carburized and hardened after the mounting of all the ready-shaped and ground pieces. The plates either got carburized before they were mounted, or the mounted helmet was packed into a carbon rich coat and heated for a long time. After the hardening, the surface must have been dark from oxidation products. This would be very difficult to be cleaned off around the rivets and the overlapping edges, if the helmet should appear "white".

A second possibility would be that the plates got hardened before mounting. This is very problematic, as they easily get deformed by handling or quenching, which can cause fitting problems when the parts are being mounted. A supportive construction would be necessary for each single piece to avoid deformation throughout the hardening process.

The sample-flakes for the metallurgical analysis were detached from the interior. The interior of armour is a mirror of what the outer surface had looked like before grinding. Case carburizing would only make sense if also the exterior surface or the armour-piece would be of increased hardness. The case carburization was most likely applied before the grinding, as otherwise too much of the carburized "steel" layer would get lost. A hardness test at the exterior surface of the helmet could help to determine if the plates were case-carburized before grinding – the hard layers would have to show nearly the same thickness.

The most likely explanation of a very thin harder layer, presumably only found at the inside, is a randomly obtained case carburization. As described in the chapter on plate production[446], the single plates worked in one pack were possibly prevented from welding together by some clay liquid mixed with charcoal dust. The heating of these packs for forging could, under the right conditions, result in the diffusion of carbon into the iron.

The discussed helmets are of such masterly craftsmanship that the higher price for the use of steel would not matter compared to the costs for carburizing the iron plates. It was also not a problem to produce plates of the required formats from steel. The plates of the discussed helmets are rather small, compared to those of helmets driven from one single plate. All the necessary techniques and tools were available.

If the two helmets were made in the 14th century, they were certainly made of wrought-iron. They offer a very unique chance to learn more about the 14th century armour making, as no other pieces of armour are so closely related to each other – they might even come from the same workshop, as suggested by Spalding[447]. Future testing might compare these two helmets in more details.

445 Williams (2003), p. 731.

446 See chapter [The making of plates].

447 Spalding (1981), p. 8.

8.5.6 An electro-plated helmet in Delft

In a few cases, objects can be definitely identified as reproductions, for example when an item was made by the technique of electro plating[448]. Jan-Piet Puype in 2003 identified an early 17th century helmet, the so called "golden helmet of Delft", as a product of this method. The detail-observations that led to this conclusion are absolutely reasonable and comprehensible.[449]

In 1999 the "Legermuseum" in Delft got a hint, that there is a helmet almost identical to the Delft example kept in the Eremitage in St. Petersburg. Both objects were compared closely and many parallels were confirmed. The decoration and shape of the object resembled very closely the St. Petersburg example, but some technical details differed. While the plate edges of the Eremitage helmet were rolled, they were found to be massive at the Delft head piece. The plume holder and the rivets at the Delft helmet seemed to be worked in one piece with the plate of the skull. After the recognition of these and other eye catching differences, the Delft example was suspected to be a modern copy of the Eremitage helmet. It was found to be unlikely that the Delft helmet was cast, as the plate was too thin to be made by this technique. Nevertheless, at a crack the material showed a similar appearance to cast iron. Puype thus ordered a metallurgical analysis of a detached sample of the item. The helmet was found to be neither cast nor forged. The results of the metallurgical examination left only one possible answer: The helmet was most likely made by electro plating, which probably required a mold made from the original item in St. Petersburg. The latter is documented as part of the collections as early as 1869. However, the documents of the museum do not mention that a mold ever has been made from the original. Puype suggested that the helmet has maybe not been made to deceive but rather for study or any other purpose.

The author found one more argument that supports Puype's suggestion for the item being made by electro plating. It might be a coincidence: Also in St. Petersburg – where the presumable model for the Delft helmet is kept – by the late 60ies and 70ies of the 19th century a chemist named Klein brought the electro-plating of iron artifacts to perfection. While it is not recorded that he made copies of armour, it is documented that he had made an iron shield showing an embossed scene of an amazons-battle.[450] Due to these facts and to the close vicinity of Klein's laboratory to the artifacts in the Tsar's collections, it is possible that it was him or his workshop that made the copy of the Petersburg helmet.

8.5.7 A recently sold helmet of type-VII

While Boeheim intended to detect grooves on rolled plate under purposely applied hammer marks, other scholars assumed the same forger behind similar hammer-marks. In the catalogue of the 2011 Klingbeil Collection-sale, the description of Lot. No. 182 reads as follows:

448 See also chapter [Notes on the history of armour reproduction and restoration].

449 Puype (2003).

450 Volger (1873), p. 366.

[…] The interior shows unusual hammerwork, the result of using a hammer with a very small head. This style of workmanship is characteristic of Raymond Bartel, the armourer to William Randolph Hearst. A sallet of similar construction also showing characteristic small hammer marks was made by Bartel and included as an addition to the sale of the armoury of the Dukes von Ratibor, Galerie Fischer Waffensaal des Schlosses Grafenegg, II. Teil, May 2, 1934, lot 67.[451]

The description is formulated very carefully, trying to avoid a final judgment on the authenticity of this helmet. Nevertheless, it is strongly suggesting that the helmet is a modern reproduction. The catalogue description of the quoted "sallet" [ref_arm_5129] sold by Fischer in 1934 does not say that it was a reproduction made by Bartel.[452] It was offered as a genuine item. It remains obscure, where the author of the in Bergé's catalogue description got his information from.

After Bergé's catalogue was published, the author tried to find further proof for the suggestion that small hammer-marks are characteristic for Bartel's works. One popular example of his work is the left hand-protection [ref_arm_1147] at the Glasgow suit [ref_arm_4117] which he made as a replacement for the lost original. It is a copy of the extant right counterpart and was made when the suit came into the possession of William Randolph Hearst in the early 20th century. Bartel marked his hand-protection at the interior of the cuff with a tilting helmet over the capital letters "R. B.". It seems as if he did not use wrought-iron, as no delaminations are to be found. The plate does not show unusual hammer marks interiorly. But hand-protections might require less forging-work and therefore the hammer-marks might be different to those found inside a helmet. There are certainly more of Bartel's works still existing, but the author could not examine any helmet before this study was finished.

The former owner of the concerned recently sold type-VII helmet, Karsten Klingbeil, in February 2011 gave permission to the author to examine some of his items. In this course, images of the helmet were taken, also of the interior hammer-marks [ref_arm_4242].[453] How problematic it is to judge an item by hammer-marks only is explained in the following notes.

In the DHM there is a helmet with eye-catching similar small hammer marks [ref_arm_1713]. This helmet has not been inventoried and has therefore no access number. Maybe future research will find out more on the provenance of this helmet. Interiorly the helmet shows a layer of a copper colored brazing-solder. The outer surface is brownish and rough, maybe from a treatment with an acetous liquid, either for cleaning off corrosion products or from imitating a patination. The plate at many locations shows delaminating layers typically for a mechanically refined iron. Its general shape is corresponding with many other similar items and is at no point uncovering an unprofessional hand. There is no evidence for this helmet being a reproduction.

451 Pierre Bergé & associés (2011), lot nr. 182.

452 Galerie Fischer (1934).

453 The catalogue fails in showing an image of the helmet's interior. Only one reference to a sale of a similar helmet attributed to Bartel is given, published in a very rare auction-catalogue of 1934. For the reader it is therefore very difficult to compare the hammer marks to those on other objects and to check the truth in the statements of Pierre Bergé.

Two similar helmets of type-VII in the HJRK show clearly that genuine helmets[454] could show totally different interior hammer marks. While very large facets are visible at [ref_arm_1890], those inside [ref_arm_2209] are very small. The two Vienna helmets are an example for what the careful observer will recognize when looking at a huge number of different items: hammer marks can be very different from object to object and therefore they cannot serve as an indicator for authentic or not-authentic items.

There are many more helmets that – according to their hammer marks – would have to be suspected to be made by Bartel, if the Bergé's catalogue description is correct: [ref_arm_1730] [ref_arm_1728] [ref_arm_1805] [ref_arm_1804] [ref_arm_1923] [ref_arm_1856]. Also torso front-protections of the best provenance show small hammer marks at the interior e. g. [ref_arm_3524]. It is very unlikely that all these items were made by this modern armourer.

Looking for hammer marks can only help when objects extant pair-wise are concerned. The difference from the left to the right counterpart of limb or hand-protections might suggest that the items were not made by one hand and that one of them could be a completion. Additionally it should be avoided to overestimate the significance of hammer marks for any question on the making of armour: Many extant objects had suffered so badly from corrosion that one cannot judge what mark derives from a hammer and what from rust. It needs no proof that certainly the armourers of the Middle Ages also did not all use one single hammer. For sure they also employed hammers with heads of different sizes. Thus the sizes of the hammer marks on genuine objects in some cases might show small dimensions. It is a very arguable approach to define a certain piece as a reproduction due to its hammer marks, especially as readers usually cannot check the truth of statements given. Catalogues do usually not include images of the object's interior.

8.6 Ideas for new approaches

8.6.1 Perspectives for non-destructive metallurgical testing: Synchrotron Radiation Computed Laminography

The author intends to find a scientific method suitable for the non-destructive testing of armour. The desired result would be the detection of fingerprints which a certain refining method had imprinted into the structure of the armour material. Such fingerprints could help to narrow down the time frame in which a certain artefact might have been produced.

X-ray based examination is certainly a reasonable choice whenever an artifact should be prevented from any damage. In the recent years scientists of the KIT and the ESRF developed a specialized X-ray based scanning method called "Synchrotron Radiation Computed Laminography (SRCL)"[455]. This method uses synchrotron X-ray beams, produced by an electron storage ring. This method promises to surpass the aforesaid limitations of computed-tomography by the following advantages:

- Better flux densities: This provides for the possibility of generating high resolution images of ~1µm, due to the increased number of X-ray beams per mm^2. The image contrast is very high. The used energy can be optimized for different material, geometries or research questions.

454 The objects of the HJRK form a historically grown collection of ancient arms and armour of the Habsburg family. As no acquisitions to the collections from private hands were made is almost impossible that these helmets are reproductions.

455 For the basics of this method see: Helfen et al. (2005) and Helfen et al.

The disadvantages are:

- Access to devices: This method is extremely complicated and expensive. Probably only one "beamline" is suitable for the intended examination of armour plate: Beamline ID15a of the ESRF.

The synchrotron technique provides beam-energies high enough to scan also thicker metal-volumes (< 5 mm). It is particularly suitable for the scanning of flat, laterally extended volumes: The sample is fixed to a rotating table. The angle-position towards the direction of the X-ray beams can be adjusted. It was found that a 30 degree angle in most cases is the best position to scan plate-like materials. By this method the beams travel with a nearly constant wavelength through the material. In comparison to conventional CT-scanning, by this sample-positioning image-artifacts are reduced. The revealed images are of a very high resolution, i. e. inclusions or cavities of ~1µm size can be detected. Currently, for the concerned testing of armour-plate no further-advanced imaging technology is available in the entire world.

Fortunately, the author was in good contact to Daniel Hänschke, a PhD student working at the Laboratorium für Applikationen der Synchrotronstrahlung (LAS) of the KIT. On his request, three of his colleagues researching at the ESRF generously carried out scans of samples provided by the author. Daniel Hänschke processed the revealed image-data. [456]

Four samples of differently refined iron samples were scanned. The intention was to non-destructively visualize structural differences between the samples – left by different refining methods.

Each sample had the size of about 1.0 x 5.0 x 5.0 mm. The 3-D reconstructions (references in the headlines) show a volume of ca. 0.6 x 1.2 x 1.2 mm in close vicinity to the sample's center. In the following, it will be described which parameters on each specimen were known and what was expected to be seen in the images. The results of the examination will be introduced and discussed.

8.6.1.1 Sample 1 [ref_vid_syn_c45] (3-D reconstruction of defects)

This was a modern, not heat-treated steel (C45) with a carbon content of 0.45%, produced by the modern Linz-Donawitz-Method. It was expected that the images of the interior volume would show a homogenous structure with only little inclusions, analogue to existing metallographic examinations of such material. In the synchrotron-scans a homogenous, not structured mass with only few small globular dark areas is visible [ref_ill_syn_c45_xView] [ref_ill_syn_c45_yView] [ref_ill_syn_c45_zView].

8.6.1.2 Sample 2 [ref_vid_syn_ha] (3-D reconstruction of defects)

This sample was cut from a badly damaged and corroded hand-protection-cuff[457] of about 1600. This item is certainly genuine, as it is preserved in archaeological condition, incomplete and of no value that would give any benefit to a forger. It was therefore expected that the material would be made by a pre-industrial wrought-iron process, showing an inhomogeneous, presumably layered defect structure. Delaminations were already visible at several spots of the cuff. The scan-images of the interior – orthogonal to the plate-surface –

456 The author is indebted to Lukas Helfen, Elias Hamann, Angelica Cecilia and Daniel Hänschke for the generous, uncomplicated and professional examination of the material-samples and the help with the interpretation of the images.

457 Thanks to Mr. Robert Weis from Hermann Historica in Munich who donated this item for the purpose of its examination.

clearly show a layered structure [ref_ill_syn_ha_locA_xView] [ref_ill_syn_ha_locA_yView] [ref_ill_syn_ha_locB_xView] [ref_ill_syn_ha_locB_yView].

In the views in parallel to the plate surface [ref_ill_syn_ha_locA_zView] [ref_ill_syn_ha_locB_zView], thin, dark[458] layers in between nearly homogeneous brighter layers became visible – both crossing all the scanned volume with only few interruptions. The darker layers are about 5 to 8 µm thick and the brighter layers are approximately twice as thick. The dark layer is interrupted by a net of fine, brighter lines. The structures of each different dark layer are oriented to exactly the same direction.

As these structures are found at several parallel levels, it is very likely that they do not derive from randomly arranged inclusions of the smelting process. It is more likely that the darker areas actually remark the lamellar welding seams, actually the former workpiece-surface before the welding in the refining process. These areas might be hollow spaces, emerged where the brighter layers had not entirely welded together or they are inclusions of hammer-scale that occurred on the surface before the white-hot segments were welded together. In any case, the net of lines probably marks the locations where the different, bright ferritic layers actually welded together entirely. Why these nets are of an oriented structure cannot be explained yet. The orientation might derive from the equal hammering of the plate. It is also possible that the rolling of the plate might result in such a structure. A third explanation is that the orientation of the ferritic crystal-microstructure determines the orientation of the visible net-structure. Finally, the net might have been the "channels" through which the welding fluxes penetrated the welding-seams.

8.6.1.3 Sample 3 [ref_vid_syn_pud] (3-D reconstruction of defects)

This specimen is said to be a 19th century iron, made in the puddle-process. The particular specimen was secondarily rolled into plate-dimensions from some scrap iron[459]. Due to the manufactured refining of puddle-iron, it was expected that the interior structure would show many inclusions or defects, probably arranged in an oriented structure. The sample was scanned at two different locations. The scan-images of a view orthogonal to the plate-surface [ref_ill_syn_pud_locA_xView] [ref_ill_syn_pud_locA_yView] [ref_ill_syn_pud_locB_xView] [ref_ill_syn_pud_locB_yView] show narrow, lame-like dark structures inside a brighter surrounding volume. They are found on different levels and do not correspond with similar neighboring structures. The view in parallel to the plate-surface [ref_ill_syn_pud_locA_zView] [ref_ill_syn_pud_locB_zView] clearly shows dark fibers, oriented to one direction. The fibers are repeatedly interrupted by fine, brighter lines, running orthogonally to the central fiber-axis. In the center of the sample, one dark layer – extending throughout all the scanned volume – is visible. This might be a laminar welding-seam from refinement, but, other than the darker layers in sample 2, this shows a more randomly arranged conglomeration of darker areas of varying sizes. The fibers and the narrow lames are either slag inclusions or hollow spaces that got elongated by the forging and the rolling processes.

8.6.1.4 Sample 4 [ref_vid_syn_blo] (3-D reconstruction of defects)

This sample was cut from a bloom left in an early refining stage. The bloom was produced in a traditional Japanese Tatara-furnace by Achim Wirtz in 2010[460]. The spongy bloom had

458 In the reconstructed images high densities are shown in white. The lower the density, the darker the color of the voxel becomes.

459 It was generously provided by the "Real Wrought-iron Company", Lyndhurst.

460 The author is indebted to Achim Wirtz for the donation of many samples and a lot of support in the understanding of the hand-operated iron-refining techniques.

been red-heated and simply forged by the hammer. The volume had not been folded and forge welded. It shows comparatively large, nearly homogeneous sections with only few small darker, elongated areas in between [ref_ill_syn_blo_xView] [ref_ill_syn_blo_yView] [ref_ill_syn_blo_zView]. It is interesting to see that the hammer-forging had already resulted in the inclusions or defects becoming laterally extended or elongated in short fibers. Nevertheless, comparatively large areas are nearly free of inclusions.

8.6.1.5 Outlook

The structures of all four samples clearly differ from each other. This delivers hints on how the material might have been refined. It would be interesting to examine the same samples with the help of conventional metallographic methods. Especially sections of sample 2 in parallel to the plate-surface should be examined, to test if the net structure also becomes visible in the microscopic images. One conclusion very important for the appraisal of conventional metallographic testing can be drawn. In the images of sample 2, layers nearly free of inclusions are visible. This suggests that a metallographic examination of one layer only might not be representative for the whole of the material. An incorrect sampling might lead to the mistaken conclusion that the examined material would not be wrought-iron, but rather modern steel, as the volume would show no impurities. One fact needs to be considered for the examination of any iron based material: All material that is obviously delaminating or if microscopic or X-ray images show a layered or a fiber structure, is actually produced by a wrought-iron technique. An examination of the entire plate-section in 3D is indispensable for the detection of such structures.[461]

As said above, objects of art might have been produced of two types of iron or steel:

1. Mild-steel, which is a modern, since the 1860s industrially processed iron based-material. It is nearly free of defects, without refining-structures, and with homogeneously spread chemical components (Bessemer, Thomas-Martin, Donawitz et al.).
2. Wrought-iron which was produced either by mechanically cleaning a bloom (direct process: forging, folding, fire-welding) or since the 14th century by reducing the carbon content of cast-iron (indirect process: oxidizing condition in a refining-furnace, further welding and fire-welding necessary). One of these indirect-methods is the so-called “puddle-process”, developed from the mid-18th century on and used until the 1920s. Wrought-iron produced by any of these methods inevitably shows impurities (slag inclusions, hammer-scale, charcoal, welding fluxes) and defects induced by the fire-welding process.

Established methods for metallographic analysis allow a confident differentiation between wrought-iron (inclusions, defects, fibred or layered structure) and mild steel (homogeneous)

461 The author described such an erroneous conclusion in details as he personally knows of similar illogical sampling methods carried out by a circle of renowned German, British and US-American scholars. In one particular case the samples were illegally broken off from an interior delamination of a very rare 15th century breastplate in a Berlin museum. The object was damaged but the results were never published. Thus the author of this paper is unable to quote any report. The conclusions on the metallographic testing were defined in a personal email to the author as follows: “We tested the Berlin […] brust quite some time ago and it proved to be modern metal, the sort of thing car-bodies are made out of.” The author later personally examined the breastplate and easily found the spot where the sample-flake was detached. On request the museum administration informed the author that the sample was taken without approval. Images taken by the author a few years earlier clearly proved the recent damage. The fact that the material – due to the visible delaminations – must have been made in a forge-welding process and that only one layer was examined was entirely ignored by these three scholars.

only. However, an item determined to consist of wrought-iron could be a modern (19th century) reproduction made of puddle-iron. Only insufficient scientific attempts have been made to tell the younger puddle-iron material (indicating forgeries) apart from the wrought-iron produced by older techniques. For a differentiation, it can be expected that, concerning the microstructure, material made by the puddle process differs from material produced by the direct process. On the same concern, a further crucial fingerprint could result from the fact that the rolling of plate was not developed before the late 17th century. The material of ancient armour had to be forged into billets and subsequently into plates by means of a powered hammer. Essential indications will therefore be provided by differences in the morphology of inclusions between rolled and hammered plate. The diagram [ref_ill_dia_aut] tries to visualize the conditions on how plate-armour material might be classified as genuine or modern.

Future, improved studies of historical iron-based material might help to tell by which production technique the material of an iron artwork had been made. For such studies, the author suggests reproducing a forge-welded iron from material produced by the direct process and a second one produced by the indirect process. One part of each of these materials should be rolled; another part should be hammer-forged into the dimensions of thin plate. Such material could be scanned by synchrotron-laminography. The results might tell, if the net structure can be reproduced and if the refining-processes, the rolling or the hammering would result in different structures. Plate was most likely not rolled before the second half of the 17th century. If structures could clearly be distinguished, in the future it might be possible to tell if an item was made of rolled wrought-iron plate and could thus not be genuine. Also further tests[462] of historical materials are necessary to assemble a wider data basis for comparisons.

By the time this paper was printed, the author together with a team of other scientists had already scanned about 55 further iron samples at the ESRF. The images are waiting to be interpreted, the results will subsequently be published.

8.6.2 An appeal to all interested scientists

Until today, the mental arts and the natural sciences had not worked together closely enough on interdisciplinary approaches to the aforesaid problems. The disciplines did not really learn from each other's experience. William's metallurgical approaches ignored the question of authenticity and did not compare wrought-iron to mild-steel metallurgy. The approaches of the humanities on the other hand did neither research the historical sources on the armour-making technologies, nor did they summarize their past findings in a way that would provide an understandable and comprehensive overview to the natural scientist – an indispensable platform for the latter to develop advanced testing-methods.

In the case of describing complex products of elaborate craftsmanship, the need for the understanding of technologies becomes indispensable. Only reading about them or watching others executing them is usually not enough. A somewhat uncommon demand on scholars working on the subject should be made here: The describer's hands need to feel the processes that lead to a ready product. This does not mean that the scholar has to become a master craftsman or artist himself. But he has to feel how a white-hot metal is reacting when beaten by a hammer; he has to feel the resistance of steel when it is filed, sawn or ground. Only the combination of academic knowledge and the personal experience of simple craftsmanship will allow him to draw a complete picture of the artifacts he is about to examine. Just like it

462 E. g. laminography, metallography, X-ray diffraction etc. For a time period of developing non-destructive testing methods for the validation of the results, probably also destructive methods need to be applied to the same samples.

is necessary for a non-musician to once sit down at the piano and to try to repeat the pianist's performance if he wants to get an idea of the effort it takes to compose and/or to render a beautiful song. This study is based in the art history-discipline. The time range and the financial possibilities of this thesis were limited. Metallurgical testing can only be undertaken with the help of specialists.

The examination of formal and technological features would only deliver useful information, if the revealed data could be compared to the same data-classes tested on other examples. The smaller the choice of samples, the higher is the risk of including circular arguments within a final statement, as data deriving from reproduced or altered parts may have a greater influence on any result. With a larger quantity of pieces to be compared, the quality of the data would raise. For the correct interpretation of the revealed data, the understanding of the historical techniques of armour manufacture is indispensable. This would include the understanding of the techniques available in both times – the classical plate-armour period from 1350 to 1650 and the period of reproductions from 1800 until today.

It is of course difficult for scientists specialized on the testing of modern materials to familiarize with the various aspects of ancient, not standardized techniques. As explained above, the conventional testing methodologies provide only limited possibilities for authenticity-testing. The involvement of specialists is nevertheless indispensable, as only they can imply all the possibilities that not yet considered sophisticated testing-methods might provide for new approaches to the authenticity problem. For example, an interesting approach to the dating of metals provided in a comprehensive manner by Gerhard Sperl can be developed further. He suggests that the methodology of observing the "Oswald-Reifung" on iron-artifacts could help to date the material. Nevertheless, it has to be anticipated that this technique is not unproblematic, as it damages at least a small spot of the examined object.[463]

The author of the present paper suggests focusing on the non-destructive testing-methods. If each generation of scientists would have to damage the artifacts to get to a result, in the end nothing would be left to examine [ref_ill_art_5388]. Existing X-ray based analysis-methods, such as 3D-imaging provided by conventional or synchrotron computed-tomography, can possibly be advanced for approaches to the topic. Maybe the different techniques of different times left some sort of distinctive fingerprint on the microstructure, e. g. the texture, and the chemical composition.

463 Sperl (2001)

9 Summary

So what is the outcome of this study? Is the picture of late medieval European plate armour production now more complete? Can the findings promote future studies on the subject?

For future studies on late medieval - and maybe also later armour - certainly the most important outcome of this research project is the digital collection of so many artworks. Even though the data is not completed yet, it builds a stable basis to build on. Furthermore, the concept of the database is suitable to get extended to armour of later times, but also to depictions of armour in artworks. The author already encouraged a young postgraduate, Christopher Retsch from the University of Bamberg, to study armour rendered in late medieval effigies. The cooperation between both projects is already fruitful. The author could already use for this paper a lot of information provided by C. Retsch and the latter already uses the author's database and the findings of this paper in return.

The terminology suggested proved to be useful to oversee the huge amount of data and information that entered this study. The terminology-jungle could be reduced to a really low number of distinct types and terms, charts and images helped to visualize the classification structure. Anyway, at the beginning it might be difficult for the reader to follow the author's thoughts and to remember the different definitions. Nevertheless, future preoccupations with the topic now can discuss and possibly improve the suggested definitions. There are certainly many open questions; some terms and types might have to be altered; the terminology needs to be extended to other armour groups e. g. tournament armour. Further type-differentiations might become necessary for the description of contemporary, earlier and later armour parts. An internationalization of the terminology can help to shorten communication ways, to make them faster and to avoid misunderstandings. This will provide the basis for the reconstruction of many unclear questions on the armourer's craft.

The brief history of plate armour from a technological point of view provided an insight on the armourer's constructional considerations, on how he met with the demands of wearability and security. For the first time type-combinations common in different times and regions were closely described and classified. The author's systemization shed a new light on the development of armour, aside from the often quoted mutual influences of armour and clothing-fashion. It became clear that many construction-variations were actually in use across regional borders throughout a longer period. The armourers obviously exchanged or copied not only stylistic, but also constructional details with or from each other.

The chapter on technological features probably provides the key-findings of this study. For the first time constructional details were compared and classified with such care. The comparison of the defined features help to identify cross-type groups of armour. Some features – like copper-alloy applications or turned edges – could be attributed to certain regions, times or even masters. For the first time, the different joint-variations found on extant armour were classified and explained. Comparisons of dimensions and weight allowed suggestions on the customization of the items. Wherever findings could help to approach the question on authenticity, different aspects and considerations were discussed closer.

This study did not intend to write the history of armour entirely new. Nevertheless, the new approach to the topic from a technological point of view delivered several "hard facts" on different or common features found at two or more items. In the future, descriptions could become more precise than they had been in earlier publications that usually approached the topic from an esthetics point of view. The database assembled for this study provides nearly endless possibilities for further comparisons that promise a lot of new findings. This database will hopefully be accessible for any researcher one day.

A yet unworked field of research is on the crafts that supplied tools and parts to the armourers. In a short chapter on this topic the author tried to show that the value adding of armour production was not only carried out in the armourer's workshop. The armourers depended on a number of crafts that had to deliver various indispensable products. These considerations show once more how many different materials and technologies were combined in a product like armour. Future research on this topic might help to find additional aspects and to further differentiate between what an armourer made himself and what he actually bought in.

The discussion on the history of armour preservation and the closely linked problem of authenticity cannot provide the whole picture of the topic of the omnipresent confusion on facts about extant historical armour, caused by the ravages of time. Nevertheless, this chapter for the first time provides a detailed overview on this important topic. More intense document-studies on the reproduction-industry of the 19th century will certainly reveal important findings that might also be connected to existing artifacts. It is very unlikely that many reproduced items were destroyed throughout the last 200 years. If this is correct, the items must still exist. There are hundreds of presumably reproduced items in various collections that were not included in this study. There is a good chance that the maker of many of such armour-suits or- parts can still be tracked down. A research project could focus especially on the history of these items (Burg Ranis, DE – suit; Hohenschwangau; Stadtmuseum Köln, DE – suit; DE – suit; Palazzo Venezia, Rome, IT – suit etc.). Also research on the restorers of ancient arms and armour might shed more light on the problem of reproductions and restorations. Last but not least, different natural-scientific examination methods might reveal new recognition. The key to success might be intense interdisciplinary cooperation.

In the chapter on the metallurgy or armour production the author tried to build the basis for future interdisciplinary approaches. Starting from the discussion of historical iron production techniques, for the first time source-based reconstructions on the historical method of plate-production were demonstrated. Different methods for the metallurgical testing of armour on quality and authenticity questions were discussed. The study ends with suggestions on future interdisciplinary approaches. Finally, the preliminary results of a promising 3D imaging method were presented.

In the last chapter practical advices for approaches to the mapping of plate armour to the times of its production, to the place of its production, to its maker and to its authenticity. The authenticity of single chosen objects and object groups is discussed in details. Finally some ideas for new, interdisciplinary approaches are quoted. The author was able to initiate a new, promising project on the non destructive authenticity testing of armour.

The author hopes to have contributed to the completion of the perspective on the production and reproduction of late medieval plate armour. He has tried to provide as much information as possible in images or videos to ease the traceability of his thoughts. It was his special wish to provide a stable data basis – assembled from preceding studies and new findings – from which the research on historical armour can start into a new age.

At a certain stage each scientist has to end the search for further perceptions and to open the discussion on the various introduced suggestions. May this be fruitful and may it help to better understand an artistic, but unfortunately nearly vanished craft – the craft of the armourer!

Appendix

For all references see the attached DVD or (when reading the file on a computer) use the hyperlinks in the text.

The author tried to get permission for the publishing of each of the images taken by other photographers. Whenever copyright issues might be offended, please contact the author and the right-owner will be reimbursed according to the common fees.

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Collections

Germany

Germanisches Nationalmuseum Nürnberg – Dr. Baumeister

Bayerisches Armeemuseum Ingolstadt – Dr. Müller, Herr Sieker, Herr Wirth

Augustinermuseum Freiburg – Dipl. Rest. Kai Miethe

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Austria

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Art Institute Chicago – Dr. Neet

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