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A TECHNICAL NOTE ON THE ARMOUR AND EQUIPMENT FOR JOUSTING

UN ESTUDIO TÉCNICO SOBRE LAS ARMADURAS Y EL EQUIPO PARA LA JUSTA

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Abstract - Resumen

This paper discusses the metallurgy of some jousting armours, and other aspects of their equipment. Armours for the joust with sharp lances (*scharfrennen*) were found to be sometimes thinner than armour for the joust of peace (*gestech*) but these examples were made of better metal. Appendices discuss the textile padding, which was an integral part of the protection offered by jousting armour, and some of the lances employed in the joust.

Este artículo analiza la metalurgia de algunos arneses de justa, y otros aspectos del equipo empleado. Las armaduras para la justa con lanzas afiladas (*scharfrennen*) han resultado ser en ocasiones más delgadas que las empleados para la 'justa de paz' (*gestech*), pero en este caso estaban realizadas con un metal mejor. Los apéndices analizan los acolchados textiles que eran parte integral de la protección que proporcionaba la armadura de justa, y también algunas de las lanzas empleadas.

Keywords - Palabras Clave

Jousting; Armour; Metallurgy; Gestech; Rennen.

Justa; Armadura; Metalurgia; Gestech; Rennen.

INTRODUCTION

In the eleventh and twelfth centuries, jousts were a practice for war, and the weapons employed were those used in war. These events were thus as dangerous as actual warfare and fatalities were not uncommon.

A critical aspect of lance combat was the striking of killing blows to the head. A less hazardous (and repeatable) method of practice in training was vital, and this led to the introduction -in the thirteenth century- of the coronel, a multi-pointed lance-head that could not penetrate the helmet sights, thus allowing the head to be struck with a greater degree of safety. The increased use of coronels, combined with the development of pieces of armour designed or adapted specifically for the joust, led to a distinction being drawn between 'jousts of peace'

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and 'jousts of war'. The former involved coronels and possibly some special pieces of jousting armour, while the latter was run in unaltered war equipment. Both forms remained popular throughout the late fourteenth and fifteenth centuries.

In the fourteenth century armour designed specially for the joust of peace starts to appear in written references as well as in illustrations, and by the end of the fourteenth century, special jousting helms were employed, securely fastened to the breast- and backplates. This design had the benefit of preventing brain injuries caused by rotation of the brain within the skull.

A guarantee of safety for the participants became much more important, as jousting grew more significant as a festive occasion and a celebration of chivalry. But for some time, the older and genuinely lethal practice of the 'joust of war' remained popular, declining in acceptability only in the late fifteenth century. By around 1490 the true joust of war -fought in unmodified war armour with the single-pointed war lance- gave way to much safer forms that attempted, in the spirit of romantic nostalgia, to imitate the appearance of these now obsolete exercises. Advanced jousting armour design, as well as the particular quality of the metal itself allowed the ancient tradition of lethal single combat on horseback to be celebrated in comparative safety[1].

By about 1420 a barrier known as the 'tilt' had been added to the paraphenalia of the joust of peace. The tilt separated the combatants in a joust of peace to prevent the horses colliding. Jousts of war, by contrast, were usually (though not always) run 'at random', that is in the open field with no separating barrier.

The specific terms of individual jousts varied enormously, and apart from very general distinctions between classes, there were not many attempts to codify the many different versions of the sport. However, the most advanced system of class organisation was devised at the very end of the fifteenth century at the court of the Emperor Maximilan I. The two most popular forms were the *gestech* , the most common form of joust of peace in Germany, and the *rennen* (sometimes known as *scharfrennen*) a new form of the game that has been misleadingly referred to as a type of joust of war. The *rennen* was not a joust of war because the armour it employed was just as specialised and just as unlike war harness as was armour for the *gestech*. However, *gestech* armour (*gestechzeug*) looked very different from *rennen* armour (*rennzeug)* because the designers of latter were attempting to suggest the appearance of war armour- the head of the *rennen* jouster was protected by a sallet (*rennhut*), a classic form of war helmet (albeit it a specially thickened variant), and the jousting shield (*renntartsche*) was disguised with a cloth cover so that it was less recogniseable. The *rennen* was also run with single-pointed lances, although the points were much stouter and blunter than true war points. It is often stated that *rennen* armours were thicker than *stechzeuge*, although this has not previously been established.

It is the aim of this article to present a picture of the protection available to jousters by detailing the thickness and hardness of the armour worn. Of course, the padding worn beneath the armour contributed to its defensive properties. The authors hope to determine the effectiveness of this protection against lance strikes and publish their conclusions in a future article.

METHODOLOGY

Thickness measurements were made with a vernier caliper as well as by an ultrasonic tester. An average of several readings is quoted wherever possible; otherwise the «Thickness» measured at the front in the deepest bolt-hole is given, where access permitted. Where a be-

[1] T. Philip D. Blackburn, David A. Edge, Alan R. Williams, Christopher B.T. Adams, M.A., 2000, «Head Protection in England before the First World War», Neurosurgery, Vol. 47, No. 6, 1261-1286, December.

vor was worn with a sallet, the total thickness is given. Surface hardness measurements were made with a Krautkramer electronic hardness tester. The hardness is measured on the Vickers Pyramid Hardness scale (VPH) of which the units are $kg.mm^{-2}$.

The surface hardness is quoted wherever possible to show whether or not the hardness of the sample examined microscopically is representative, or not.

In many cases, it was possible to detach a small (1 – 2 mm) sample from an inside edge of the armour for metallography (microscopic examination). The surface is polished down to optical flatness with 1µ diamond paste, and etched with nital/picral to reveal the microstructure. This may supply a good deal of information.

The metal used might be iron, visible as crystals of *ferrite* (abbreviated as F). Hardness 100 – 120 VPH.

It might be steel, visible as a mixture of *ferrite* and *pearlite* (abbreviated as P). The proportions of *ferrite* and *pearlite* are determined by the carbon content (abbreviated as C%). Hardness 180 – 260 VPH.

The hardness of a steel may be dramatically increased by heat-treatment. Quenching (plunging red-hot into cold water) forms a different crystalline material *martensite* abbreviated as M) of hardness 300-700 VPH, and sometimes *bainite* (see p. 147) of lesser hardness. But this is at the expense of brittleness, so tempering (gentle reheating) is required to reduce hardness and increase toughness. Tempered martensite is abbreviated as TM; overtempering may lead to the formation of globular iron carbide or cementite (Cem), softer than pearlite.

It is also possible to determine the microhardness during the course of metallography. This is generally more accurate than surface hardness measurements.

Microhardness was determined with a Vickers microhardness apparatus (100g load) averaging ten readings.

The carbon content cannot always be deduced from a martensitic microstructure, except from the microhardness, so the carbon content is quoted as an approximation, with the symbol ~. Some variation in microhardness is always to be expected when medieval steels were heat-treated.

EARLIER OBSERVATIONS

Some data on the metal employed in jousting armours has already been published by one of the authors[2].

There is a group of eleven *gestechzeuge* and *rennzeuge* dating from the late 15th century, but repaired (and re-marked) by mid-16th century masters such as Valentin Siebenbürger (who was born in 1510, a master in 1531, and died 1564) some 50 years later, displayed in the Germanisches National Museum, Nürnberg (abbreviated as GNM). Two of the Nürnberg armours have inscriptions etched with the date 1498. The four *rennhut* also bear the city mark of Nürnberg.

Specimens from seven of these as well as one from the Wawel Museum, Krakow, and one from the Chicago Institute of Art (abbreviated as CIA), all of comparable date, were examined, and the results obtained are summarised here.

Two further jousting helms (*gestechhelme*) from the Bavarian National Museum, Munich (abbreviated as BNM) were examined, and found to be iron or very low-carbon steels.

The *gestechhelm* made in Innsbruck by Christian Spör and therefore made of a medium-carbon steel, was not only unhardened, but in fact had been softened by annealing. This was apparently the consequence of the extensive forging which the shape of the helm necessitated.

[2] Williams, A., «The Knight and the Blast Furnace», Brill, Leiden, 2003, *passim*.

The only metallurgy more ambitious than any of the above was that found in a *rennhut* (possibly made by Lorenz Helmschmied for Maximilian I on the occasion of his second marriage to Bianca Maria Sforza in 1494) now in Veste Coburg Museum (inv.no. IA 2), and made of a steel hardened to 325 VPH.

Table of results:

Table 1. F = ferrite; P = pearlite; Cem = cementite (i.e. completely divorced pearlite); TM = tempered martensite. Page ref. is to Williams (2003); G = g*estech*; R= r*ennen*.
The microhardness determination are an average of ten readings; where an estimate has had to be made, it is shown as ~.
N made in Nürnberg. **A** made in Augsburg. **I** made in Innsbruck.

Museum	Joust	component	Mastermark	microconstituents	C%	Hardness (VPH)	page from ref#2
GNM 1308	R	Rennhut	Wilhelm von Worms **N**	F + Cem +slag	0.1	~ 150	678
GNM 1309	R	rennhut	Wilhelm von Worms **N**	F + P + slag	0.2	~ 150	678
GNM 1307	R	rennhut	Dated 1498 **N**	P + F + slag	0.7	297	679
GNM 1310	R	rennhut	Dated 1498 **N**	F + slag	0	~ 120	679
GNM none	G	helm	Valentin Siebenbürger **N**	F + P + slag	0.3	224	679
same		pauldron	**N**	F + Cem + slag	0.1		679
GNM 1312	G	helm	Valentin Siebenbürger **N**	F + P + slag	0.1		679
same		pauldron	**N**		0.2		679
GNM 1316	G	helm	Valentin Siebenbürger **N**	F + P + slag	0.2		680
same		pauldron	**N**	P + F + slag	0.6	276	680
Wawel 4769	G	Plate below breast	Konrad Poler **N**	F + slag	0		680
BNM 1082	G	helm	**A**	F + slag	0		390
BNM 1081	G	helm	**A**	F + slag	0		391
CIA 1982.2445	G	helm	Christian Spor d.1485 **I**	F + P	0.4	< 256	475
Veste Coburg IA2	R	rennhut	Lorenz Helmschmied 1494 **A**	TM + F	~ 0.5	148-425 av = 325	386

Virtually all of these jousting armours were made of iron or low-carbon steels. The very modest quality of the metallurgy found here might be explicable by the assumption that jousting armour, being only worn for a short time, could be made much heavier than battlefield armour, and the simplest way of increasing the protection offered by armour was to make it thicker. The much more sophisticated metallurgy shown in 15th century Italian armour and 16th century South German armour made for the battlefield was unnecessary in jousting armour[3]. The exception shown by the Helmschmied helmet, however, suggested that other factors might be involved. So a more detailed examination of some jousting armour was undertaken by two of the authors (AW+DE), and the results are presented here.

Hardness & Thickness of some jousting armours in the Wallace Collection, London, and in the Hofjagd- und Rüstkammer, Vienna

Wallace Collection, London A23; a composed *gestechzeug*, possibly made in Augsburg, since parts of the manifer bear a pinecone mark.

Weight

Helm = 8.94 kg tassets = (left) 1.71 (right) 1.66; pauldrons = (l) 1.55 (r) 1.47 kg.
vambrace = 1.75 kg. manifer = 3.3 kg
Breast = 7.06 kg back = 3.49 kg. Plackart and fauld = 3.02 kg
Total weight = 40.9 kg.

Thickness

The thickness (in mm) over the cuirass is shown (at intervals of 10 cm where possible) in fig. 1.

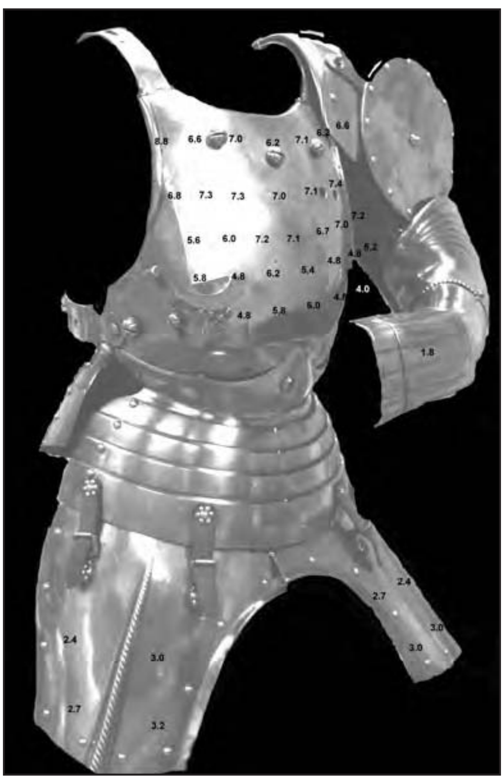

Figura 1.

3 Williams (2003) op. cit.

The thickness (in mm) over the proper right side of the helm is shown in fig. 2.
The thickness (in mm) over the proper left side of the helm is shown in fig. 3.

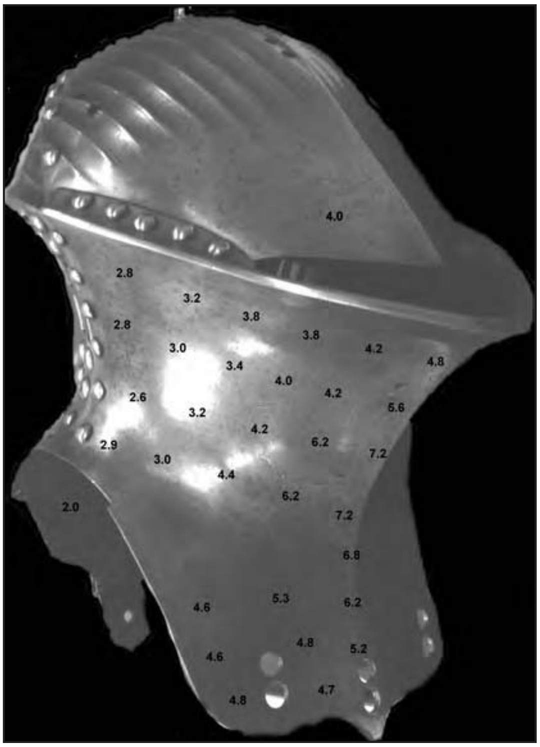

Figura 2.

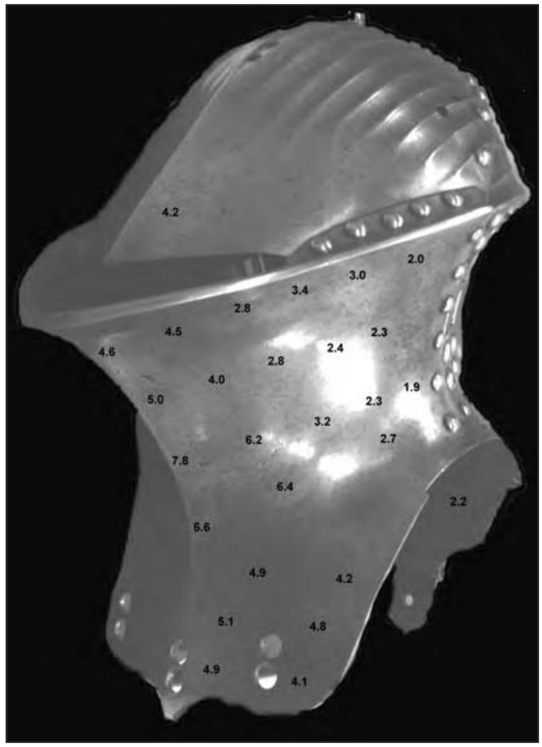

Figura 3.

Metallography

The microstructure of a sample taken from the breastplate consists of ferrite and a little pearlite, partly divorced into carbides (less than 0.1% C, fig. 4).

Figure 4. Microstructure of A23 breastplate; scale bar = 50 microns.

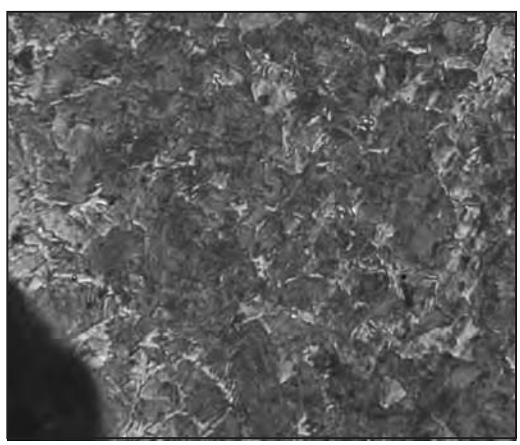

Figure 5. Microstructure of A23 helm; scale bar = 50 microns.

The microstructure of a sample taken from the helm consists mostly of pearlite and a little ferrite (around 0.6% C, fig. 5).

Data on 15 Armours for the Joust of Peace in Vienna

S. I.

(Old inventory number B.2) A jousting armour from a garniture made for Gasparo Fracasso (before 1502) and decorated with areas of etching and gilding.

The crowned **my** within a circle is on the helm (twice) etched & gilded. It is also struck once on the right arm; this mark is ascribed to Giovanni Angelo Missaglia [4] c. 1490.

Thickness of breastplate 4.3 mm; back 2.2 mm; pauldrons 4.9 mm.

Surface hardness of breast 180-240 VPH; helm 210-490 VPH.

Metallography: A specimen was taken from the right elbow defence. The microstructure consists of martensite and ferrite with some slag inclusions. The microhardness varies from 239 to 345 (average) = 310 VPH.

WA. 147. The armour discussed above (B2) is exhibited with a contemporary vamplate, struck with another mark (perhaps a dolphin around a cross?) ascribed to Francesco della Croce, c. 1490.

Metallography: The rim of the vamplate was examined in section. The microstructure consists of martensite, proeutectoid ferrite and pearlite with few slag inclusions.

The microhardness varies from 381 to 557; average = 464 VPH.

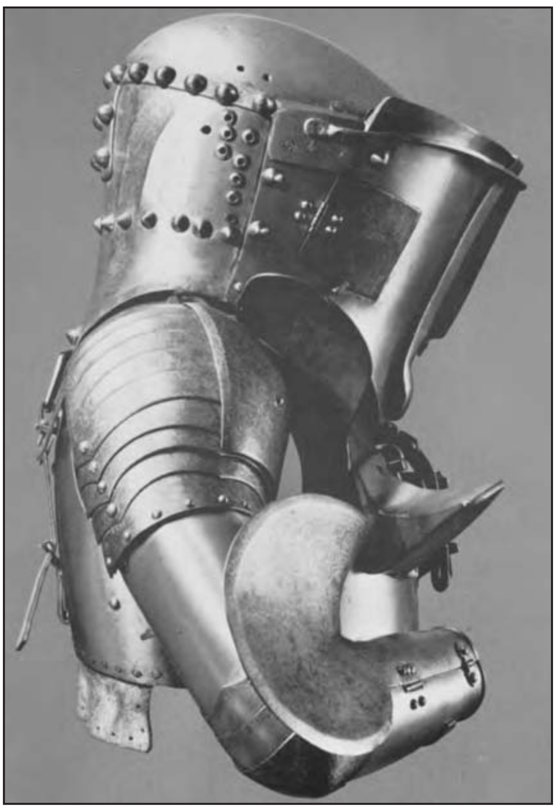

Figure 6. The jousting armour of Gasparo Fracasso.

4 Thomas, B. & Gamber, O. «Katalog der Leibrüstkammer» (Vienna, 1976) 184.

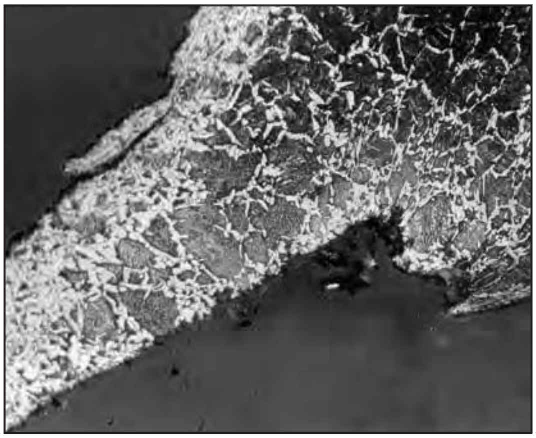

Figure 7. The microstructure of S.I.; magnification x 160.

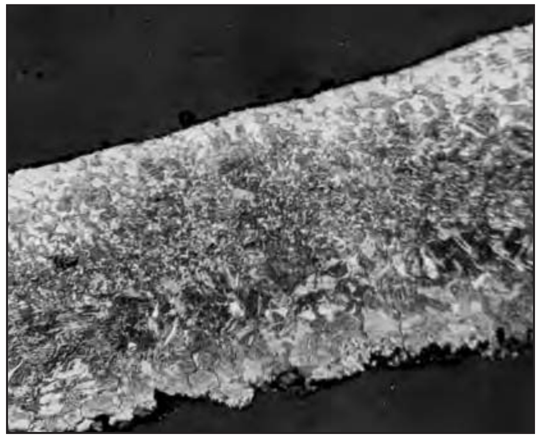

Figure 8. The microstructure of WA147; magnification x 160.

S. II.

(B.141) A jousting armour made in the Netherlands for Philip the Fair, or perhaps for his father Maximilian I, around 1500. Marked on the helm and the left elbow, with a crowned **h**. This master has been tentatively identified with the Brussels armourer Hugues Brugman[5]. This is one of five, now somewhat composite, jousting armours from the Netherlands, presumably from the Hapsburg armoury chamber in Brussels[6].

Metallography: A specimen from the elbow was examined. The microstructure consists of bainite and martensite with nodular pearlite around the ferrite grains and few slag inclusions.

The microhardness varies from 279 to 357; average = 308 VPH.

A specimen from the backplate was also examined, in section. The microstructure consists of ferrite and granular carbides with some slag inclusions.

The microhardness varies from 222 to 302; average = 261 VPH.

Figure 9. The jousting armour S.II made for a youth.

[5] Thomas & Gamber op. cit. 127.
[6] Thomas & Gamber op. cit. 149.

Figure 10. Microstructure of S.II elbow – a hardened steel. The acicular material is probably bainite, a non-equilibrium product of rapid cooling. (magnification x 160) – at higher magnification; the ferrite grains are seen to be surrounded by a dark-etching material which is probably nodular pearlite. This suggests it has been hardened by a *slack quench*, not a full quench.

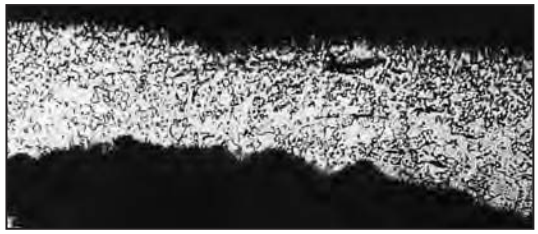

Figure 11. Microstructure of S.II backplate; a low-carbon steel; magnification x 100.

Figure 12. The jousting armour S.IV.

S. IV.

Netherlands/Augsburg.

This is one of a series of jousting armours (also including those from S.XI to S.XIV) made for Maximilian I possibly on the occasion of his wedding in 1494 to Bianca Maria Sforza. It has arms of Augsburg (fluted) form, and the decoration is said to be in the style of Jörg Helmschmied the Younger; with a helm of Flemish form added for the «foreign joust». A Netherlands origin for the helm has been suggested, to which an Augsburg armourer has added other components[7].

Thickness of breast = 4.3 mm.

Surface Hardness of Helmet and Breastplate ~ 190 VPH.

No metallography was possible.

[7] Thomas & Gamber op. cit. 148.

S. VI.

A *stechzeug* possibly made for the coronation of Maximilian I as Roman King in 1486, with the mark of Lorenz Helmschmied[8].

Thickness of Breastplate = 6.5 mm (obscured by targe & shield – total thickness 25.7 mm).

Surface Hardness of Helmet and Breastplate ~ 290 VPH.

No metallography was possible.

Figure 13. The jousting armour S.VI.

[8] Thomas & Gamber op. cit. 140 and Gamber, O. «Der Turnierharnisch zur Zeit König Maximilians I und das Thunsche Skizzenbuch» *Jahrbuch der Kunsthistorischen Sammlungen in Wien*, 53 (1957) 33-70, especially the Thun sketchbook, f. 66.

S. VII.

A *stechzeug* made for Archduke Siegmund by Christian Schreiner the Elder (fl 1452-1499) in Innsbruck, c.1483-4.

Marks of 6 dots on the bevor and 8 dots on the right pauldron[9].

Surface Hardness of Helmet and Breastplate ~ 275 VPH.

Metallography: A specimen from within the top plate of the left pauldron was taken. The microstructure consists of fairly uniform tempered martensite, mixed with an acicular material. A little proeutectoid ferrite is found along the surface, and there is also some acicular material (bainite?), but no pearlite is visible.

The microhardness ranges from 393 to 463; average = 431 VPH.

Figure 14. The jousting armour S.VII.

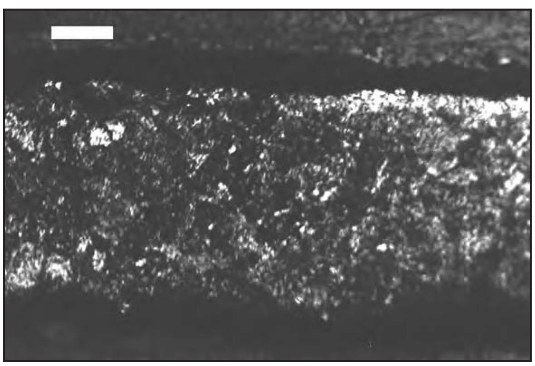

Figure 15. The microstructure of S.VII; scale bar = 100 microns.

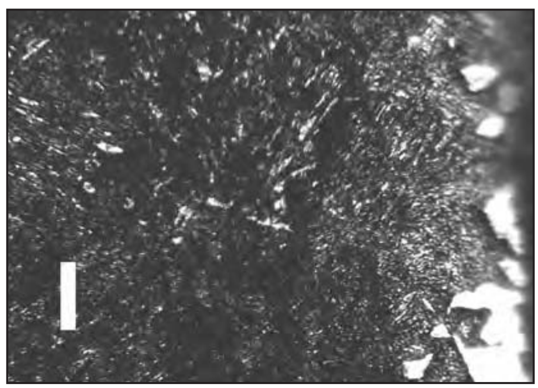

Figure 16. Tempered martensite, bainite and some ferrite grains; scale bar = 20 microns.

9 Thomas & Gamber op. cit. 137.

S. VIII.

A *stechzeug* made for Archduke Siegmund, c.1483, which has the mark of Caspar Rieder of Innsbruck on the left shoulder[10].

Thickness of helm = 11.2 mm; bevor 10.0 mm; pauldrons R 2.0 mm L 1.7 mm, backplate 2.4 mm.

Surface hardness of helm ~ 260 VPH.

Metallography: A specimen was taken from the lower rim of the sixth plate from the bottom of the left pauldron. The microstructure is a ferrite-carbide aggregate of uncertain morphology (distorted by sampling).

The microhardness averages 265 VPH.

Figure 17. The jousting armour S.VIII.

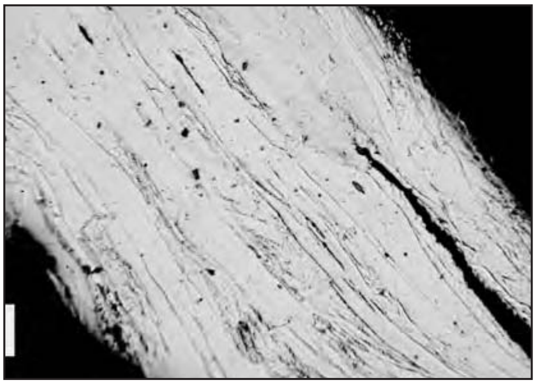

Figure 18. Microstructure of S.VIII; possibly a quenched low-carbon steel which has been distorted by cold work; scale bar = 50 microns.

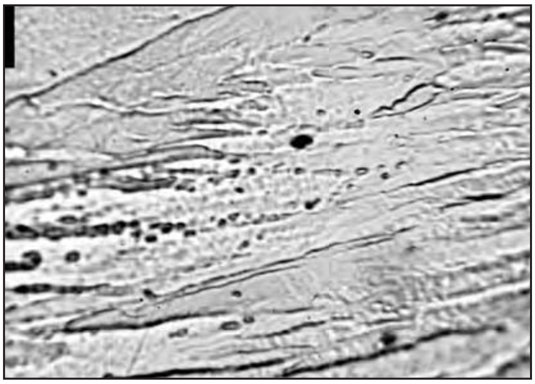

Figure 19. Microstructure of S.VIII at higher magnification; scale bar = 10 microns.

10 Thomas & Gamber op. cit. 139.

Figure 20. The armour S.XI (incomplete - without shoulders).

S. XI.

Parts of a *stechzeug* made for Maximilian I by Jörg Helmschmied the Younger of Augsburg in 1494. One of the series (extending to S.XV) made for Maximilian I, on the occasion of his wedding in 1494. The breast has a St.Andrew's cross on the lance-rest. Formerly labelled S. XIII.

Thickness of breastplate = 3.8 mm; helm 8.3 mm.

Surface hardness of breast ~ 255 VPH; helm ~ 277 VPH.

Metallography: A specimen from the rim of the hole punched at the top of the right pauldron (with internal inventory number B.9). The microstructure is shown in partial section. The microstructure consists of fairly uniform tempered martensite. A little proeutectoid ferrite is found along the surface, but no pearlite is visible. Microhardness ranges from 305 to 589; average = 506 VPH.

Figure 21. Tempered martensite and ferrite around a delamination; scale bar = 100 microns.

Figure 22. The jousting armour S. XII.

S. XII.

A *stechzeug* of Maximilian I, also probably from 1494; with Helmschmied & Augsburg marks on the lowest lame of each pauldron, just above the elbow. Attributed to Lorenz Helmschmied [11] (a number inside the arms is B165).

Thickness of helm = 3.1 mm. Thickness of breast = 5.1 mm.

Surface hardness of bevor and breastplate ~ 327 VPH.

Metallography: a sample was taken from inside the upper lame of a pauldron.

The microstructure consists of uniform tempered martensite, with no visible ferrite or pearlite and very few slag inclusions. The microhardness average = 551 VPH. This is a medium-carbon steel (perhaps 0.6 % C) which has been fully quenched and then tempered after fabrication.

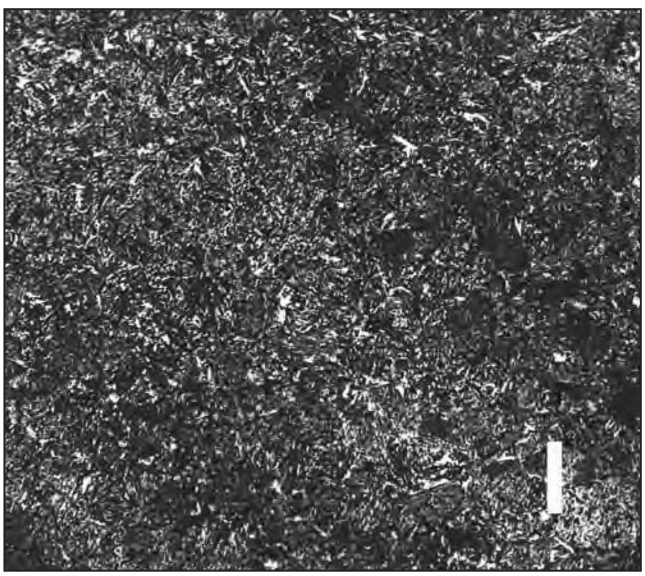

Figure 23. Microstructure of S. XII; tempered martensite; scale bar = 100 microns.

[11] Thomas & Gamber op. cit. 145.

S. XIII.

A *stechzeug* with the marks of Helmschmied and Augsburg on the helm.

Attributed to Jörg Helmschmied[12].

Thickness of breastplate = 5.7 mm (range 4.0 - 7.4 mm).

Stechhelm; thickness at lower rim 3.2 mm; thickness at upper rim 7.0 mm.

Weight of *stechhelm*: 9.1 kg.

Surface hardness of breastplate ~ 212 VPH; backplate ~ 280 VPH.

Surface hardness of helm ~ 248 VPH at back, ~ 330-400 VPH on top, ~ 495 VPH at front.

Metallography: a specimen was taken from the front of the *stechhelm.*

The microstructure consists of a fairly uniform mixture of tempered martensite with isolated grains of proeutectoid ferrite in varying concentration. These ferrite grains are often outlined by a dark-etching granular material. In places the martensite gives way to an irresolvable material, which is apparently also a transformation product, and might be bainite. Lamellar pearlite is not visible.

Microhardness range 239-412; average = 328 VPH.

Figure 24. Armour S. XIII (incomplete).

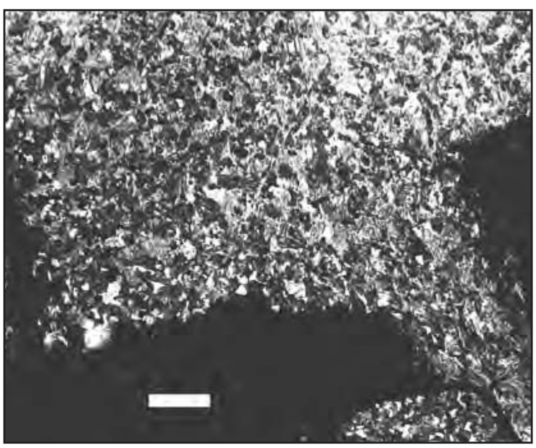

Figure 25. Microstructure of S. XIII; scale bar = 75 microns.

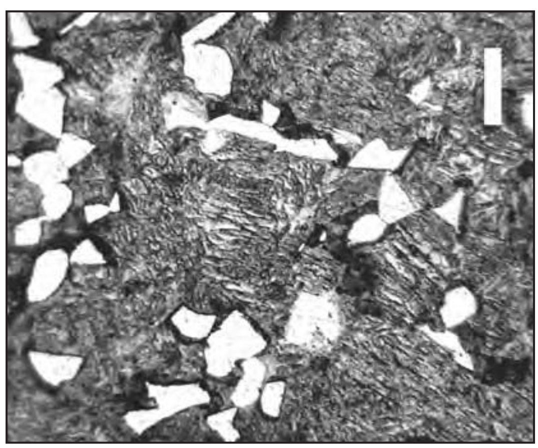

Figure 26. Martensite with nodular pearlite around the ferrite; scale bar = 15 microns.

12 Thomas & Gamber op. cit. 144.

S. XIV.

A *stechzeug* with the marks of Helmschmied & Augsburg on the helm, and probably also from 1494. Attributed to Lorenz Helmschmied[13]. The left arm has the same 2 marks and a 6-pointed star (the number inside the arms is B183, and number inside the *stechhelm* is B165). It is exhibited with a blind shaffron.

Thickness of breastplate at bolt-holes = 5.5 mm; at top 4.3 mm.

Helm in front = 4.2 mm. Left arm 1.8 mm. Right arm 1.8 mm.

Surface hardness of helm and breastplate ~ 333 VPH: left arm ~ 260 VPH, right arm ~ 235 VPH.

Weights of components: left arm including manifer 6.1 kg; right arm 5.0 kg.

Stechhelm 9.4 kg. Backplate (E176) 1.6 kg. Breastplate (including lance-rest and bolts for absent queue), 7.3 kg.

Total weight (without leg armour) 29.4 kg.

The *stechhelm* has 2 dents just below visor; one 13.2 x 22.2 mm oval depression around 2 mm deep, with another 11.5 x 6.5 mm and scratch 0.9 mm deep.

Metallography. A sample was examined from inside the right arm (B183), and another sample was examined from the front edge of the helm.

The microstructure consists largely of ferrite with some areas of an acicular material which might be low-carbon martensite, or perhaps bainite, concentrated near to one surface. These areas are slow to etch, and seem to have

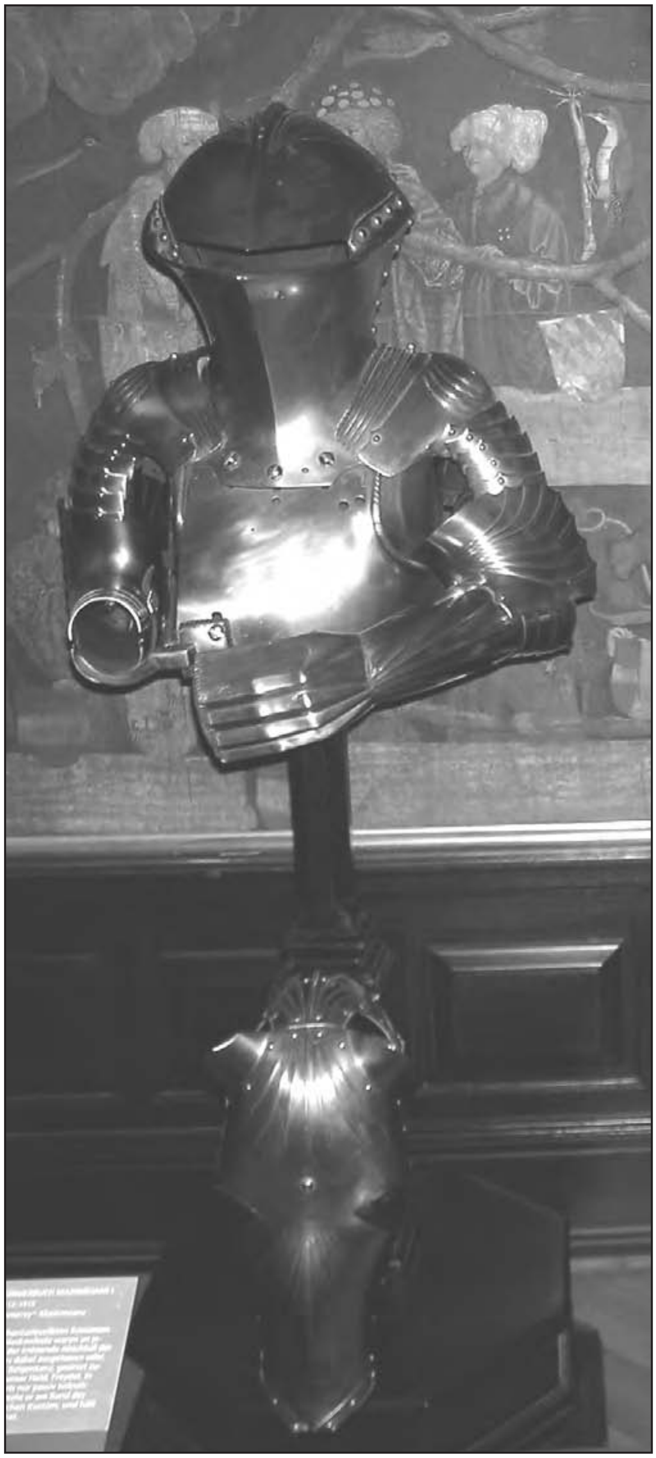

Figure 27. The armour S. XIV.

[13] Thomas & Gamber op. cit. 145 & pl.71.

undergone little or no tempering. This is a low-carbon steel which been quenched in an unsuccessful attempt to harden it.

Microhardness range 164-207; average = 162 VPH.

The helm (B.165). The microstructure consists of equiaxed ferrite with some large areas of pearlite (corresponding to a carbon content of perhaps 0.3%C). There are also numerous irregular slag inclusions.

Figure 28. Microstructure of arm (B183); ferrite and low-carbon martensite; scale bar = 75 microns.

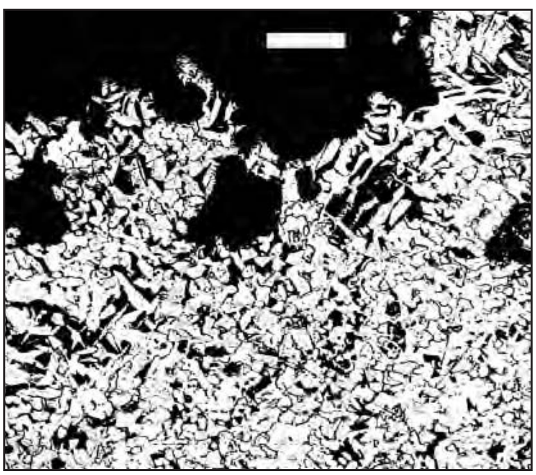

Figure 29. Microstructure of the helm (B165) ferrite and pearlite; scale bar = 75 microns.

Figure 30. The armour S. XV (incomplete).

S. XV.

Parts of a *stechzeug* made for Maximilian I in 1494; with an Augsburg mark.

Attributed to Jörg Helmschmied[14].

Thickness of backplate = 1.7 mm; pauldrons = 1.7 mm

Surface hardness of breastplate ~ 244 VPH; helm ~ 394 VPH; backplate ~ 310 VPH;

pauldrons ~ 355 VPH.

Metallography: A specimen was taken from the rim of the hole punched at the top of the left pauldron (with the internal inventory number B.169).

The microstructure consists of uniform very fine (almost irresolvable) pearlite, with an isolated area of martensite.

Microhardness ranges from 305 to 423; average = 358 VPH.

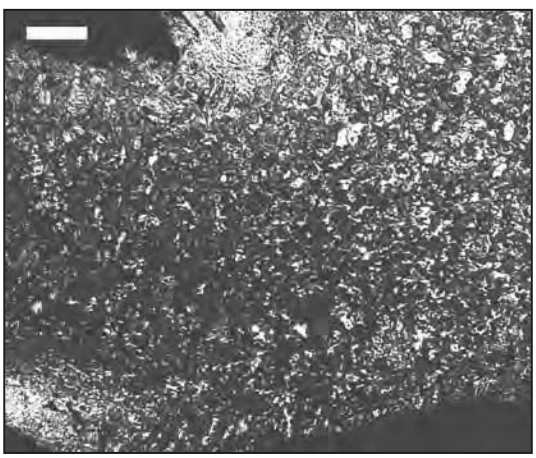

Figure 31. Microstructure of S. XV; scale bar = 75 microns.

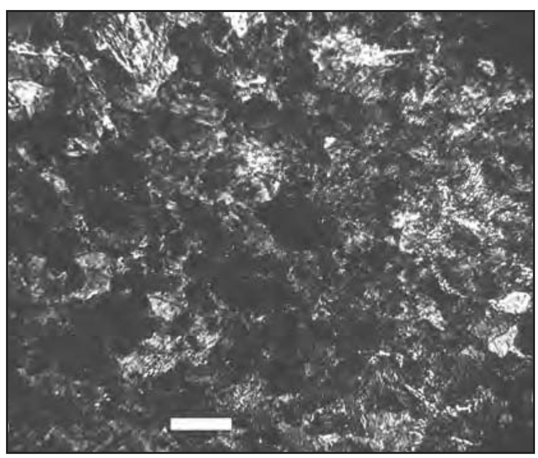

Figure 32. Microstructure; mostly irresolvable pearlite; scale bar = 15 microns.

[14] Thomas & Gamber op. cit. 144.

S. XVI.

A *stechzeug* for Duke John of Saxony, which was made up from arms by Matthias Deutsch of Landshut, as well as other parts by Konrad Poler[15].

Thickness of helm = 9.0 mm.

Surface hardness of helm ~ 191 VPH.

Metallography: A specimen was taken from within the main plate of the left pauldron (which has the internal inventory number B.180). The microstructure consists mostly of tempered martensite with a little proeutectoid ferrite. Some microcracks (presumably from quenching) are visible near the surface.

Microhardness ranges from 369 to 457; average = 436 VPH.

Figure 33. The armour S. XVI.

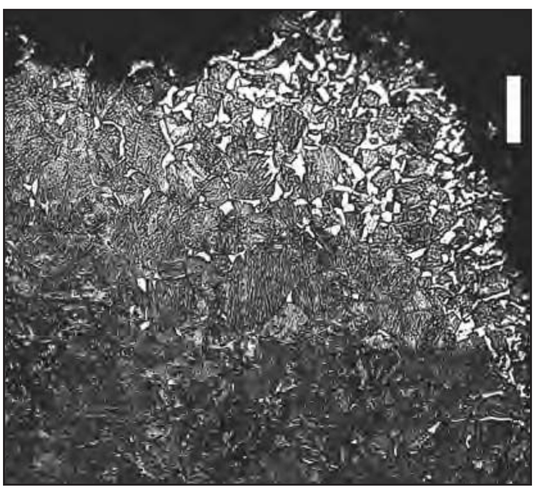

Figure 34. Microstructure of S. XVI; tempered martensite and ferrite; scale bar = 75 microns.

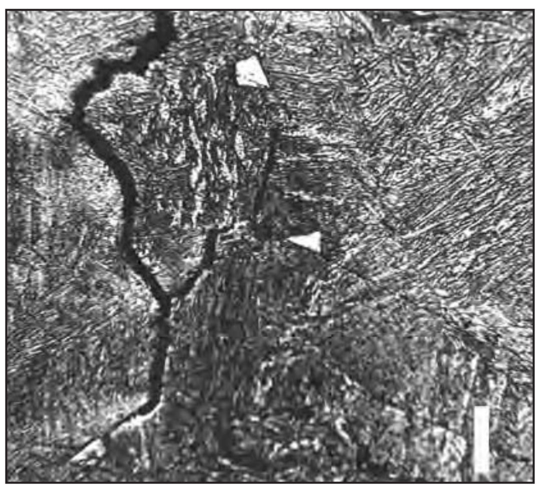

Figure 35. Martensite and (probably) bainite with a quenching crack; scale bar = 15 microns.

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[15] Thomas & Gamber op. cit. 142.

S. XVII.

Parts of a *stechzeug*, the breast of which has the master mark of K.Poler, and the internal inventory number B.90. Nürnberg, c.1495.

Thickness of breastplate at top = 4.5 mm. Thickness of left pauldron 1.5 mm; right pauldron 1.4 mm.

Surface hardness: left pauldron ~ 180 VPH; *stechhelm* ~ 140 VPH.

Weights of components: left pauldron 2.1 kg. right pauldron 2.0 kg. *stechhelm* 10.6 kg. There is a dent on breastplate 18.7 x 17.5 mm in extent, which contains a depression 6.2 x 3.1mm and 2.4 mm deep.

Metallography: A sample was examined from inside the helm. The microstructure consists mostly of ferrite, with areas of divorced pearlite arranged in bands. The overall carbon content is perhaps 0.1% C.

Microhardness range 138-152; average = 144 VPH.

Figure 36. The armour S. XVII.

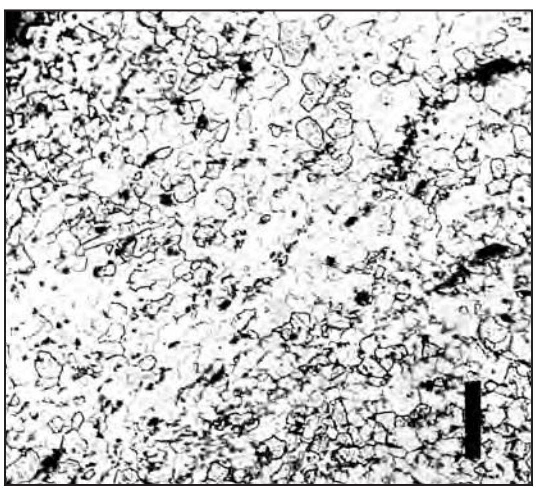

Figure 37. A low-carbon steel; ferrite with a little pearlite; scale bar = 75 microns.

Figure 38. The armour S. XVIII.

S. XVIII.

Parts of a *stechzeug*, made for Maximilian I by Konrad Poler of Nürnberg, c.1495. The breast has the master mark of K.Poler, and the internal inventory number is B.19, and it was previously labelled S. IX[16].

Thickness of helm = 10.4 mm; bevor = 10.9 mm; backplate = 2.2 mm.

Surface hardness of breast ~ 208 VPH; helm ~ 206 VPH.

Metallography. A sample was taken from the lower rim of the helm. The microstructure is shown in partial section and consists of coarse ferrite, a little pearlite (less than 0.1%C) and rows of slag inclusions.

The microhardness (average) = 191 VPH.

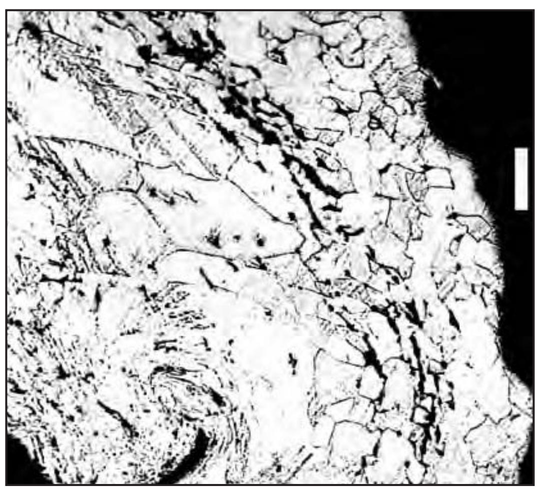

Figure 39. A low-carbon steel; ferrite with a little pearlite; scale bar = 75 microns.

[16] Thomas & Gamber op. cit. 147.

S. XIX.

Parts of a *stechzeug* made for Maximilian I, which has the master mark of Konrad Poler of Nürnberg[17] c.1510.

Thickness of breastplate 3.6 mm (range 2.9 – 4.2 mm); helm 6.4 mm; pauldrons 1.7 mm.

Surface hardness of breastplate ~ 185 VPH; helm ~ 209VPH.

Metallography: A specimen from a delamination within the front of the helm. The microstructure consists of ferrite and areas (making up less than a quarter of the section visible) of a dark-etching granular material. This does not appear to be lamellar pearlite. This is apparently a low-carbon steel which has undergone some form of heat-treatment.

The microhardness ranges from 168 to 264; average = 202 VPH.

Figure 40. The armour S. XIX.

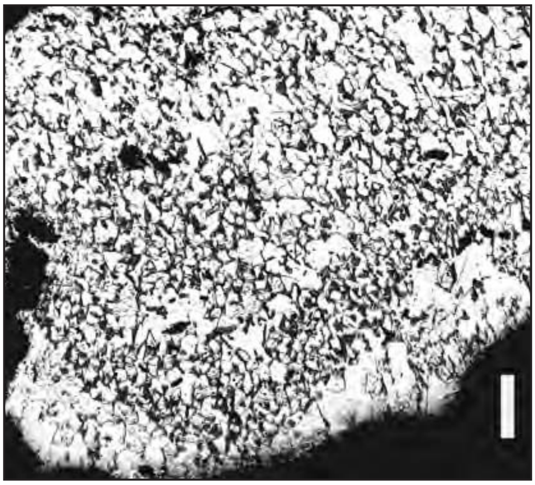

Figure 41. Ferrite and granular carbides; scale bar = 75 microns.

[17] Thomas & Gamber op. cit. 147.

Table 2. Tabulated results of data on the *stechzeuge* in Vienna. F = ferrite; P = pearlite; Cem = cementite (iron carbide) in a globular form; M = martensite; TM = tempered martensite; vfP = very fine pearlite, usually the result of an attempted quench.

A = made in Augsburg — **I** = made in Innsbruck
N = made in Nürnberg — **L** = made in Landshut
B = made in Brussels? — **IT** = made in Milan

Armour	Maker	Weight of helm (kg)	Weight of breast (kg)	Total weight (kg)	Thick-ness of helm (mm)	Thick-ness of breast (mm)	Thickness, other parts (mm)	Micro con-stituents in sample	Carbon content C %	Micro-hardness of sample (VPH)	Surface hard-ness of breast-plate (VPH)	Surface hardness of helm (VPH)	Location of sample for metallogra-phy
S.I	G.Missaglia **IT**					4.3	Pauldron 4.9	M + F	0.5	310	180 -240	210 - 490	Right elbow
vam-plate	della Croce ?							M + F	0.5	464	-	-	Vamplate rim
S.II	Master h **B**							F + M	0.5	308	-	-	elbow
S.II								F + Cem	0.5	261			backplate
S.IV	J.Helmschmied **A**					4.3		-------			~190		
S.VI	L.Helmschmied **A**					6.5		--			~ 290		
S.VII	Schreiner **I**							TM	0.6	431	~ 275	-	Left paul-dron
S.VIII	Rieder **I**				11.2		Back 2.4 Bevor 10.0 Pauldrons 2.0/1.7	F + Cem	0.1	265		~260	Left paul-dron
S.XI	J.Helmschmied **A**				8.3	3.8		TM	0.6	506	~ 255	~277	
S.XII	L.Helmschmied **A**				3.1	5.1		TM	0.6	551	~327		pauldron
S.XIII	J.Helmschmied **A**	9.1			7.0	5.7	Helm 3.2-7.0	TM + Cem + F	0.5	328	~212	~330-400	helm
S.XIV	L.Helmschmied **A**	9.4	7.3	29.4	4.2	5.2	Arms 1.8	F + M	0.2	162	~313		Right arm
S.XV	J.Helmschmied **A**						Back 1.7 paul-drons 1.7	vfP + M	0.5	358	~244	~394	Left paul-dron
S.XVI	M. Deutsch **L** & Poler **N**				9.0			TM	0.6	436		~ 191	Left paul-dron
S.XVII	Poler **N**	10.6				4.5	Pauldron 1.5	F + P	0.1	144	(Pauldron~180)	~140	helm
S.XVIII	Poler **N**				10.4		Bevor 10.9 Back 2.2	F + P	0.1	191	~208	~206	helm
S.XIX	Poler **N**				6.4	3.6	Pauldron 1.7	F + Cem	0.2	202	~185	~209	helm

Data on 6 rennzeuge and 4 other items in Vienna

Figure 42. The armour R.II.

R. II.

A *rennzeug* perhaps made for Philip the Fair, South Germany, c.1490[18].

Thickness of breastplate = 7.6 mm, (range 4.2-10.1); bevor 7.0 mm; tassets (right) 3.0 mm, (left) 3.3 mm.

Surface hardness ranges from 228 to 385 VPH.

Metallography: A specimen was taken from within the tail of the associated *rennhut* (which has the internal number B29).

The microstructure consists of ferrite and pearlite, with a carbon content of around 0.1%-0.2%. The microhardness average = 254 VPH.

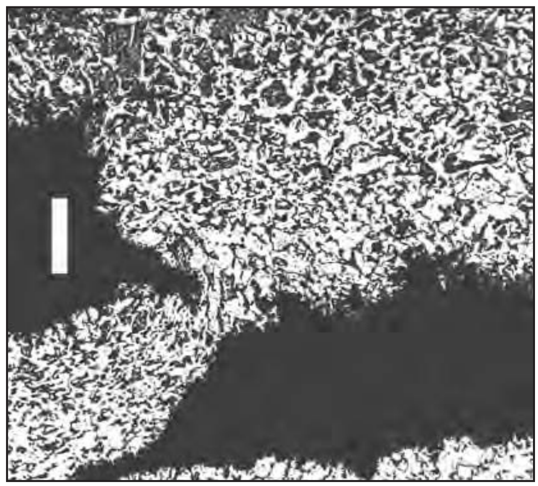

Figure 43. Microstructure of the *rennhut*; a low-carbon steel. The ferrite grains have been distorted by cold-working; scale bar = 75 microns.

[18] Thomas & Gamber op. cit. 160.

Figure 44. Front of R.IV.

Figure 45. Back of R.IV.

R. IV.

A *rennzeug* probably made for Duke John of Saxony (Johann der Beständige) by Matthias Deutsch, Landshut, dated 1498[19]. The rennhut bears the marks of Landshut and of a pointed leaf (marked inside B.171).

Thickness of breastplate = 5.2 mm (range 3.3 – 7.5 mm); bevor 3.5 mm.

Surface hardness of breastplate ~ 237 VPH; rennhut ~ 230 VPH.

Metallography: A specimen was detached from within the tail of the rennhut, where the rim has been folded over.

The microstructure consists mostly of pearlite with a little proeutectoid ferrite and a few inclusions of slag only. This is a steel of around 0.6% C and it is has not been hardened, for whatever reason. But if this had been fully quenched and tempered, as expected, it would have yielded a hardness characteristic of the usual products of Matthias Deutsch[20].

Microhardness range 241-292; average = 256 VPH.

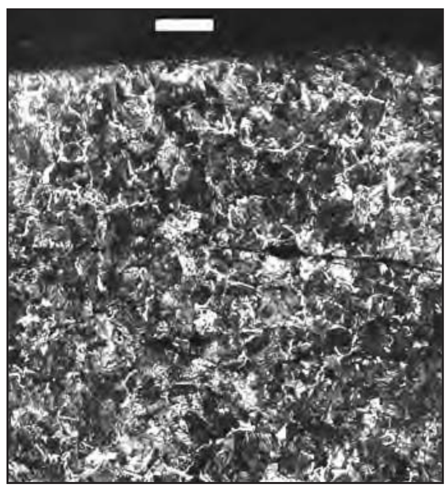

Figure 46. Microstructure of R.IV. Pearlite and a little ferrite. Note long slag inclusion; scale bar = 75 microns.

19 Thomas & Gamber op. cit. 163.

20 Williams (2003) 566-7.

R. VI.

A *rennzeug* probably made for Maximilian I, c.1495. Unmarked but decorated[21]. Probably the work of Lorenz or Jörg Helmschmied, although the possible re-use of another breastplate must be considered. The *rennhut* has the number B5 inside.

Thickness of bevor; average = 3.7 mm (range 2.5-5.0).

thickness of breastplate = 4.0 mm; breastplate at edge = 3.2 mm; backplate 2.1 mm;

sallet at tail = 1.6 mm; sallet over forehead 2.5 mm, with reinforcing plate + 3.0 mm.

Fauld plates; average = 3.1 mm (from 2.8 to 3.4).

Tassets, average = 1.8 mm (from 1.2 to 2.2).

Surface hardness

Fauld plates; average hardness (from 320 to 415) ~ 356VPH.

rennhut ~ 360 VPH; breastplate ~ 320 VPH; backplate ~194 VPH; tassets ~190 VPH; bevor ~ 310 VPH.

Weights of components: rennhut = 4.8 kg. queue 4.0 kg. Breastplate (with lance-rest) 7.7 kg, backplate 2.3 kg, tassets 9.9 kg, bevor 3.1 kg [total 31.8 kg].

Figure 47. Armour R.VI.

[21] Thun sketchbook (op.cit.) f. 58v.

Metallography

(i) From the plate covering the base of the breastplate, acting as a lower breastplate.

The microstructure consists of fairly uniform pearlite with a little ferrite, and very few slag inclusions. The microhardness (average) = 263 VPH. This is a medium-carbon steel (perhaps 0.6 % C) which has been given a fast air-cool after fabrication.

(ii) From inside the fauld plate above the knee-length cuisses.

The microstructure consists of tempered martensite with a little proeutectoid ferrite arranged in a network, and very few slag inclusions. The microhardness ranges from 272 to 311 VPH. There are areas of copper alloy embedded within the surface of the specimen. This is a steel of variable carbon content which has been hardened by fully quenching and then tempering. The copper (perhaps the remains of a repair as sallet B12 has also been repaired) was probably present before this hardening, as the martensite does not seem to have been overtempered. This is consistent with at least the lower breastplate and long cuisses being the products of the Helmschmied workshop.

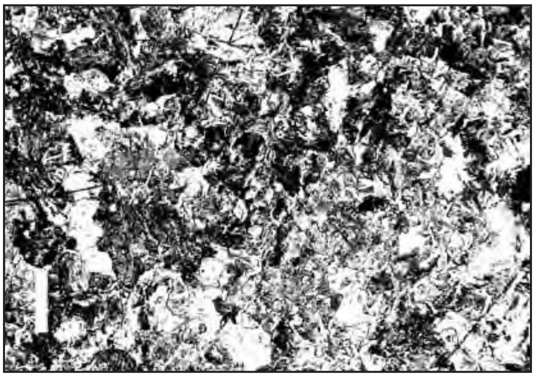

Figure 48. Microstructure of specimen from lower breastplate; pearlite and ferrite; scale bar = 75 microns..

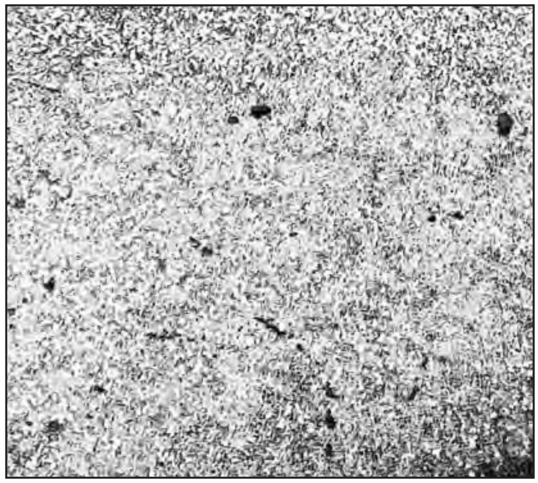

Figure 49. Microstructure of specimen from long cuisses; uniform tempered martensite; scale bar = 75 microns.

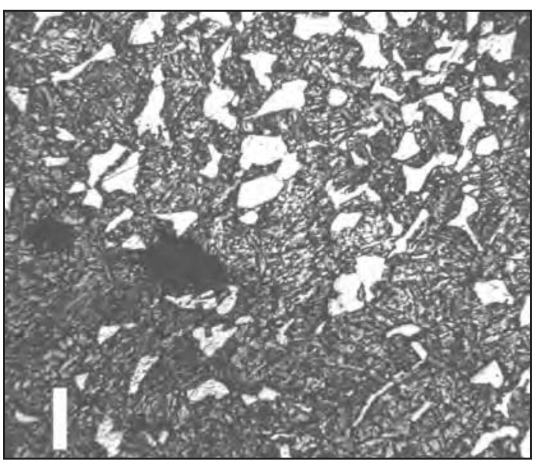

Figure 50. Microstructure of specimen from long cuisses at higher magnification. Tempered martensite and ferrite; scale bar = 15 microns.

R. VII.

A *rennzeug* described[22] as stylistically Innsbruck, c.1500, the armour is fitted with a large metal *renntartsche*, covered with leather and fastened by two threaded bolts to the armour.

Thickness of breastplate (from holes at front) = 6.2 – 6.4 mm. & at side 3.3 – 3.5 mm.

Surface hardness of bevor and breastplate ~ 186 VPH. No metallography was possible.

Hardness of the lance-head associated with R.VII ~ 160 VPH.

Renntartsche: Average thickness of metal = 2.6 mm; average hardness ~ 169 VPH.

But added to this is padding (apparently tow & leather) of between 18.8 mm and 27.8 mm in thickness. Samples of this were also analysed at BOKU (see below – Appendix 3).

Figure 51. Armour R.VII with targe detached, on floor.

[22] Thomas & Gamber op. cit. 162; where it is labeled as S. VII.

Figure 52. Armour R.IX with targe detached, in front.

R. IX.

A *rennzeug* described as stylistically Innsbruck, c.1515, but without a *rennhut*[23]

(there is an old number B12 inside the breastplate).

Thickness of bevor and breastplate = 7.5 mm (range 5.6-9.7).

Average thickness in front of head: bevor = 4.8 mm.

Surface hardness of bevor ~ 133 VPH; backplate ~170 VPH; breastplate ~ 120 VPH.

Weights of components: breastplate (including shoulder clasps) 9.0 kg.

Backplate 3.1 kg, bevor 2.4 kg, lance-rest 1.0 kg, queue 6.2 kg, tassets 10.0 kg [total = 31.7 kg].

Metallography: A sample was examined from the inside of the bevor where a fold in its shape ends. The microstructure consists of ferrite with some pearlite which has largely divorced (corresponding to a carbon content of perhaps 0.1% C) and arranged in irregular curved lines. There are also a few slag inclusions, similarly arranged.

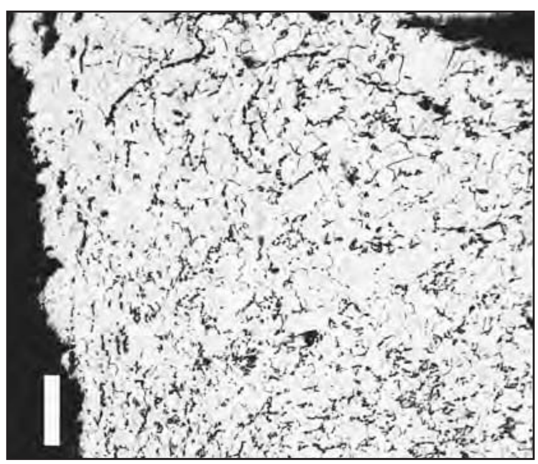

Figure 53. Microstructure of a sample from the bevor: ferrite and a little pearlite; scale bar = 75 microns.

[23] Thomas & Gamber op. cit. 166.

Figure 54. Armour R.X.

R. X.

This incomplete armour has its *rennhut* missing.

Germany (Saxony/ Nürnberg) c.1530 (no marks)[24].

Metallography: A flake was detached from inside the bevor. The microstructure consists of ferrite with slag inclusions. This is a wrought iron, like much North German armour[25].

Microhardness range 174-214; average = 193 VPH.

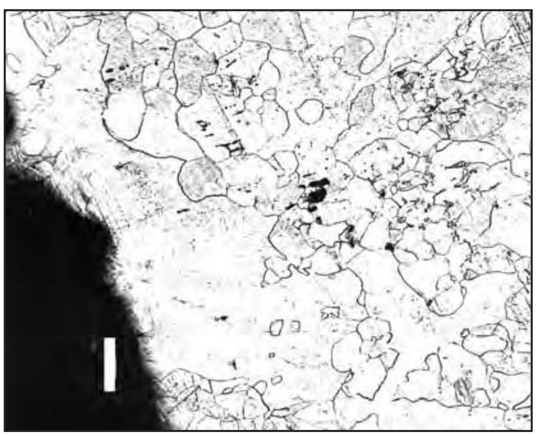

Figure 55. Microstructure of sample from bevor: ferrite only; scale bar = 75 microns

[24] Thomas & Gamber op. cit. 166.

[25] Williams (2003).

WA 26.

A *rennhut* made in Augsburg c.1495.

Attributed to Lorenz, or Jörg the Younger, Helmschmied[26].

The brow reinforce is made of two detachable plates. There is a punched hole in the crown of the skull, a petal of which was detached for analysis.

Thickness at front = 3.0 – 3.2 mm; at sides = 3.0 – 3.8 mm.

Metallography. The microstructure consists of a mixture of tempered martensite and ferrite. The areas around the slag inclusions apparently left by forging are entirely decarburised. Microhardness range 230-412; average = 320 VPH.

Other items of armour in Vienna made for the rennen.

Figure 56. Rennhut WA 26.

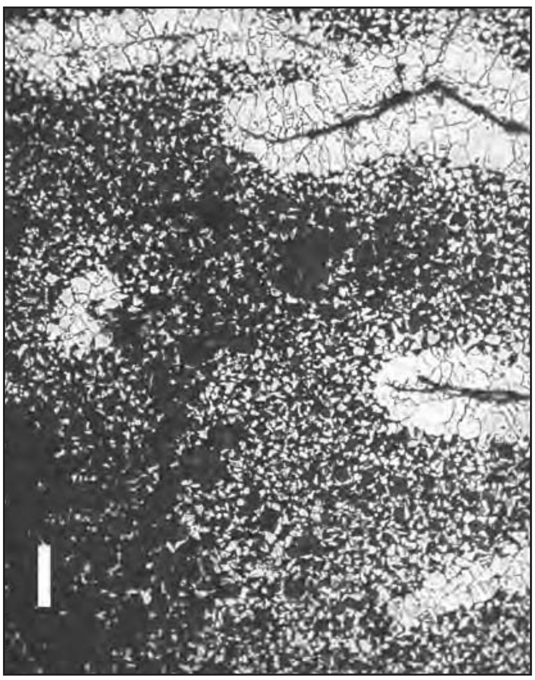

Figure 57. Microstructure; martensite, ferrite and slag. Note areas of decarburisation; scale bar = 75 microns.

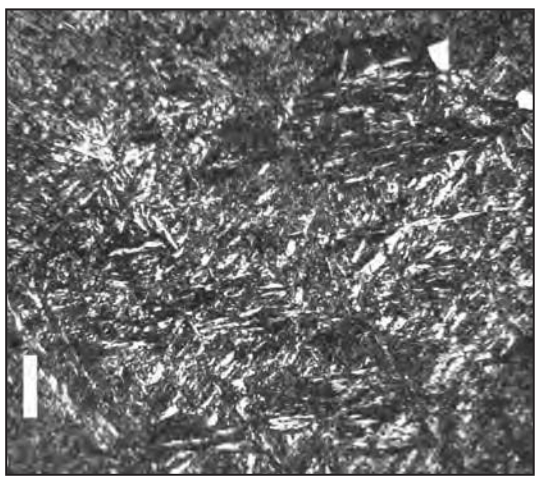

Figure 58. Tempered martensite; scale bar = 15 microns.

[26] Thomas & Gamber op. cit. 169.

B. 182.

A *rennhut* made in Augsburg c.1495. Attributed to Lorenz, or Jörg the Younger, Helmschmied[27]. The brow reinforce is made of two detachable plates. Has an 8-pointed star around the opening on the top of the crow. Indistinct marks on the tail of the sallet; possibly a helm and a *bindenschild*.

Thickness at front = 5.0 mm; at sides = 3.8 mm; at top = 2.6 mm; reinforcing plates = 3.2 – 3.4 mm.

Metallography: A flake was detached from the inside for analysis. The microstructure consists of pearlite which has been annealed so that it is completely divorced into carbides, both as isolated grains and as a network. The reason for this can only be surmised.

Microhardness range 128-152; average = 138 VPH.

Figure 59. Rennhut B182.

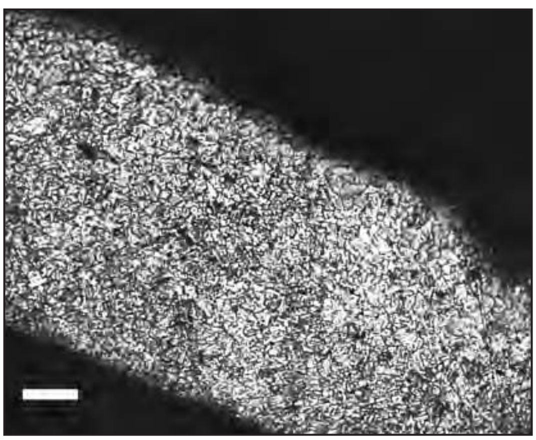

Figure 60. Microstructure of B.182; scale bar = 75 microns.

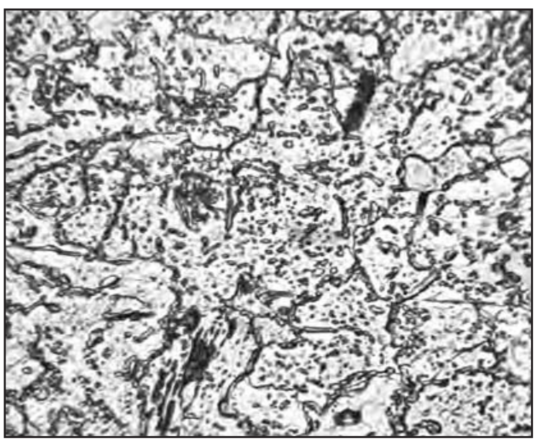

Figure 61. Microstructure of B.182. Ferrite and carbides; scale bar = 15 microns.

27 Thomas & Gamber op. cit. 169.

B. 12.

A *rennhut* made in Augsburg c.1495. Attributed to Lorenz, or Jörg the Younger, Helmschmied[28]. A brass rim around the edge conceals a repair to the tail.

Metallography. A flake was detached from the inside for analysis. The microstructure consists of tempered martensite with very little ferrite.

Microhardness range 469 - 749; average = 607 VPH.

Figure 62. Rennhut B.12.

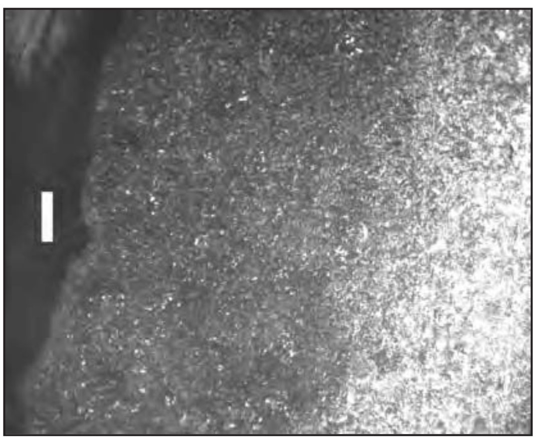

Figure 63. Microstructure of B.12. Uniform tempered martensite; scale bar = 75 microns.

[28] Thomas & Gamber op. cit. 173.

B. 174.

A pair of *dilgen* (leg guards), described as stylistically Innsbruck c.1500[29].

Decorated with a «wolfs teeth» pattern forged in low relief, and a solar face.

Metallography. A flake was detached from the inside for analysis.

The microstructure consists of a mixture of ferrite and pearlite, which is very fine in places. This is a steel whose carbon content varies between 0.2% and 0.8%, which has apparently been subject to a fast air-cool.

Microhardness range 295 - 357; average = 313 VPH.

Figure 64. One of the pair.

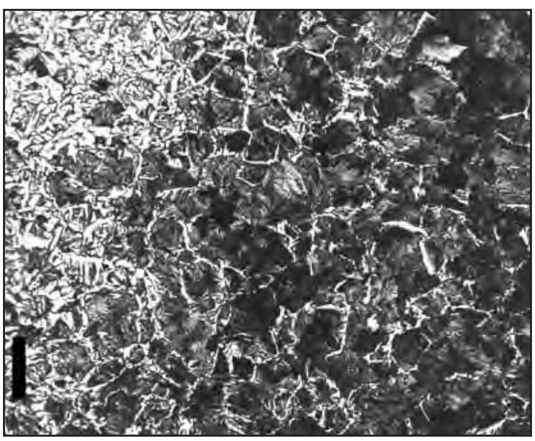

Figure 65. Pearlite and ferrite; scale bar = 75 microns.

[29] Thomas & Gamber op. cit. 168.

Items in the Wallace Collection for the rennen (A300, A301)

A. 300. A defence for the thigh; to be worn in the *rennen*, attached to the saddle.

With the mark of Caspar Rieder; Innsbruck, late 15th century.

The microstructure consists of pearlite which has been extensively divorced into cementite globules and ferrite. This is a steel of around 0.5 % carbon content which has undergone a good deal of hot working, or has been annealed.

Microhardness (average) = 235 VPH.

Figure 66. A 300.

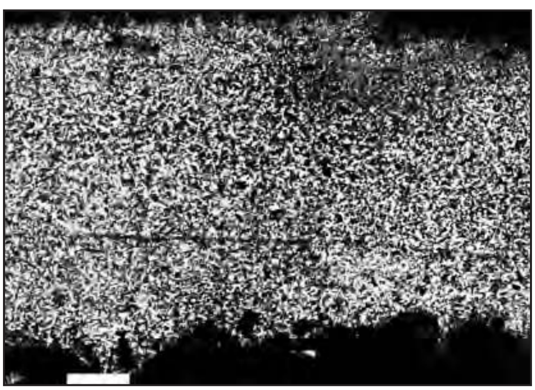

Figure 67. Microstructure of a section of A300; scale bar = 100 microns.

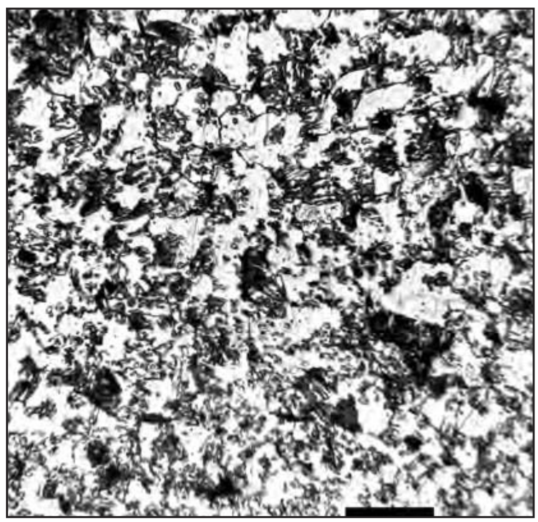

Figure 68. Microstructure of A300 at higher magnification; divorced pearlite; scale bar = 20 microns.

A. 301. Another; originally from Schloss Hohenaschau. South Germany, late 15th century.

The microstructure consists of ferrite and carbides. This is a low-carbon steel of perhaps 0.1% carbon in places. It has been quenched after fabrication, and the martensitic areas have a hardness of 191 VPH.

Figure 69. A 301.

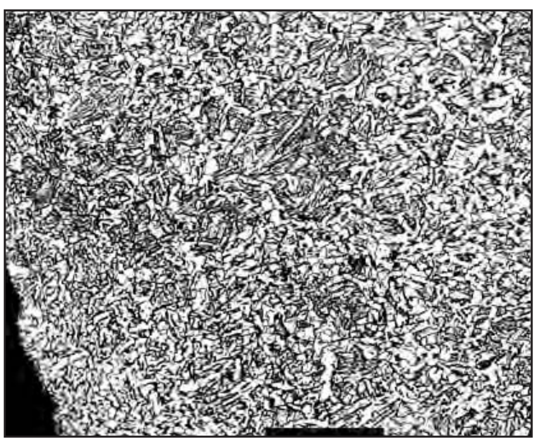

Figure 70. Microstructure of a sample from inside A301. Ferrite and a little martensite; scale bar = 50 microns.

Table 3. Tabulated results of data on *rennzeuge* from Vienna and the Wallace Collection
F = ferrite; P = pearlite; Cem = cementite (iron carbide) in a globular form; TM = tempered martensite; vfP = very fine pearlite, usually the result of an attempted quench.

A = made in Augsburg   **I** = made in Innsbruck
N = made in Nürnberg   **L** = made in Landshut

Armour	Maker	Weight of helm (kg)	Weight of breast (kg)	Total weight (kg)	Thick-ness of helm (mm)	Thick-ness of breast (mm)	Thick-ness, other parts (mm)	Micro-constitu-ents	Car-bon con-tent C %	Micro-hard-ness of sample (VPH)	Surface hardness of breast-plate (VPH)	Surface hard-ness of helm (VPH)	Location of sam-ple for metallog-raphy
R.II	S.Germany ?				(bevor 7.0)	7.6	tassets 3.0	F + P	0.3	254	228-385		*rennhut*
R.IV	M. Deutsch **L**				bevor 3.5	5.2		P + F	0.6	256	~237	~230	
R.VI	L.Helmschmied ? **A**	4.8	7.7 Back2.3	total 31.8	front 5.5 bevor 3.7	4.0		vfP + F	0.6	263	(bevor ~335)	~360	breast
R.VI long cuisses	L.Helmschmied ? **A**						1.8	TM + F	0.4	311			Fauld
R.VII	S.Germany ? (**I**?)					6.3	Targe 2.6 + padding	------			~186		
R.IX	Innsbruck ?		9.0	31.7	bevor 4.8	7.5 (+ bevor)		F + Cem	0.1		~120	(bevor ~133)	bevor
R.X	Germany ? (**N**?)							F	0	193			bevor
WA.26	L.Helmschmied ? **A**				3.2			TM + F	~0.5	320			helm
B.182	L.Helmschmied ? **A**				front 5.0			F + Cem	~0.3	138			helm
B.12	L.Helmschmied ? **A**							TM	~0.6	607			helm
B.174	Innsbruck ?							vfP + F	~0.6	313			*dilge*
A 300	Rieder, **I**							P + F	0.5	235			saddle plate
A 301	S.Germany ?							F + Cem	0.1	191			saddle plate

CONCLUSIONS

The breastplates of the *gestechzeuge* are generally in the region of 4 to 6 mm in thickness, while the helms (which were the principal target) are generally 8 – 10 mm in thickness, although a couple of Helmschmied products are notably thinner. They were able to achieve this, and maintain the safety of the jouster, by the use of much harder steel.

The breastplates of the *rennzeuge* are generally in the region of 4 to 8 mm in thickness, and the helms are of similar thickness. Again, the products of the Helmschmied family were often thinner.

DISCUSSION

The simplest solution to any perceived threat is simply to make the armour thicker, and this was frequently the favoured solution. The energy needed to penetrate sheet metal by a point increases approximately with the square of the thickness[30]. Where armour is only going to be worn for a short period of time, as in the *gestech*, the extra weight is not going to be a significant problem.

However, in the *rennen*, if run as an unhorsing joust, (with no backs to the saddles) then the extra weight will be a problem, as it will aggravate the impact of the rider with the ground. This is why the armour for the *rennen* should be generally thinner and lighter than the armour for the *gestech*. The superior metallurgical skills of the Helmschmied workshop enabled them to produce the lightest possible jousting armour which would confer the same degree of protection as the thicker products of their rivals.

To a first approximation, doubling the hardness of a metal will double its effectiveness as armour[31]. It should be remembered however that hardness alone does not mean that a material will make good armour – glass, for example, would be quite unsuitable. It is the highest possible work to fracture (which is usually associated with high hardness) that makes a good material for armour.

APPENDICES: THE DIMENSIONS AND COMPOSITION OF LANCES

The impact on the opponent from a lance is also the impact on the lance, and so the likelihood of the lance breaking can be assessed, if the dimensions and composition of the lance are known.

Impact tests on simulated targets are also being carried out, and it is hoped that we will be able to assess the performance of jousting armour in a later paper.

(i) Dimensions of lances

There is a group of 8 lances from the 15th century in the Hofjagd- und Rüstkammer. Their circumference was measured at thickest part: (from left to right of display)

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[30] In fact the power is not exactly a square term but about 1.6.
Atkins, A.G. & Blyth, P.H. «Stabbing of metal sheets: an archaeological investigation» *International Journal of Impact Engineering*, 27 (2002) 459-73.

[31] Williams (2003) 931.

B. 85. gestech lance 27 cm.
B. 84 boy's gestech lance 23 cm.
B. 1. gestech lance 40 cm. Length 453 cm.
B. 50. rennen lance 23 cm. Length 379 cm (the others were similar in length).
B. 15. rennen lance 25 cm.
B. 130. boy's rennen lance 24 cm.
B. 8. rennen lance 14 cm.
B. 13. rennen lance 24 cm.

Figure 71. Lances in Gallery.

Two (those at the ends of the display shown) were measured in more detail (B.85 & B.13) and one (B.1) has been analysed at BOKU and found to be spruce (see below – Appendix iii) but the material of all these lances appears to be similar, and there is no reason to suppose otherwise.

Detailed measurements of two15th century lances

B. 85. Lance with coronel (B.53 is number on coronel)– overall length 3465 mm.
End to graper 610 mm, shaft to coronel 37 mm, coronel itself 190 mm.
It is clearly not a hollow lance.
Diameter at several locations:

1	2	3	4	5	6
60	67	80	79	80	32 mm

1. below iron graper. 2. immediately above graper. 3. after widening of shaft. 4. halfway to end. 5. at damaged area. 6. of coronel.

Figure 72. Graper B53.

Figure 73. Point of B53.

B. 13. Lance without coronel; shaft length 3435 mm: (total almost exactly same, but with longer head) length of head 270 mm.

End to graper 700 mm. Slight taper starts 700 mm from socket of lancehead.

Diameter at several locations:

1	2	3	4	5
58	75	67	55	57 mm

1. below graper 2. above graper 3. at mid-length.4. at socket ~~55~~ . 5. at 350mm below the socket.

Figure 74. B 13 point.

<u>Detailed measurements of two 16th century lances from store:</u>

B. 140 (W.5a) with single point, has traces of bluish paint. Weight 9kg.

Length 3780 mm.

The ribs are 8 separate pieces fastened to central core. The handle & core seem to have been made in one piece. The base is hollowed to take the handle & core.

Length of ribbed section 1370 mm; length of tapered section 1750 mm. Length of head 240 mm.

Diameter at several locations:

1	2	3	4	5	6	7
75	100	55	105	81	70	55 mm

Location 1: start of base (length 525 mm). 2: end of base. 3: mid handle. 4: start of ribbed section. 5: end of ribbed section. 6: start of gentle taper. 7: end of gentle taper and start of socket of lancehead.

Figure 75. The point of B140 with the shaft of B134 in the background.

B. 134, with coronel, has traces of red paint. Weight. 8.5 kg.
Length 3850 mm (same as B.140 overall). Length of coronel is only 65 mm.

Diameter at several locations:

1	2	3	4	5	6	7
75	105	50	110	80	70	50mm

(locations as before)

(ii) Lance heads

It was thought to be useful to examine some of the detached lance heads also exhibited in Vienna, to measure their hardness. These are exhibited with the row of *rennzeuge* in Vienna, fixed to their bases; surface hardnesses are quoted.

R.X. 4-sided offset head; hardness 110 VPH.

Figure 76. Lancehead associated with R.X.

B.51 Length; 168 mm; socket is 8-sided, 55 mm across from side to side; hardness 160 – 190 VPH. But the point seems harder (380-530 VPH)*.

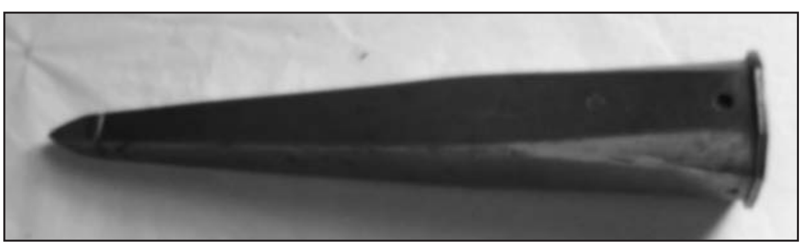

Figure 77. Lancehead B51.

3-pronged **coronel** (no number); length 192 mm overall; socket diameter 84 mm; hardness 150 – 190 VPH; tip 300 – 520 VPH*.

Figure 78. Coronel.

B35 (exhibited with *rennzeug* R.IV)

The offset shape of the point is evident. The socket is made from a sheet, joined by brazing, and riveted onto the solid point.

Socket is 80 mm across, hardness 130 – 160 VPH; tip 130 – 250 VPH. The tip has been flattened by use, suggesting that it has not been effectively hardened.

Figure 79. B35 Lancehead.

B.52 143 mm long overall; socket is circular, 68 mm diameter; hardness 150 – 200 VPH. The point is a solid block, apparently welded to a hollow socket, and it seems harder (260-560 VPH).

Figure 80. B52 Lancehead.

The points of these lance-heads were probably simply case-hardened, if they were at all hardened. The increase in apparent hardness* near the point might simply be due to work-hardening.

(iii) Lance wood analysis

A sample from the wooden shaft of the jousting lance (B.1 shown above) was analysed by Prof.Stefanie Tschegg (Head of Institute of Physics and Materials Science) & Dr. Milojka Gindl (also of the Department of Materials Science and Process Technology) in the University of Natural Resources and Applied Life Sciences (BOKU) Vienna.

From the SEM images it is clear that the wood used was spruce

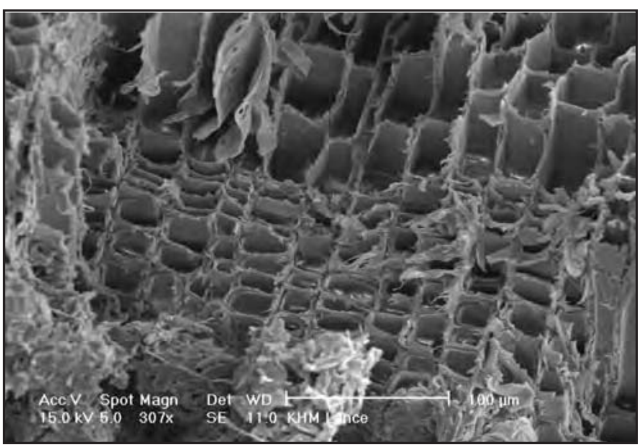

Figure 81. Lance 2, SEM picture of the wood.

(iv) Analyses of organic materials

Four specimens of textile material were analysed with electron microscopy by Mag. Martin Meischel (Technical University, Vienna) in collaboration with Professor Tschegg.

There were 2 specimens from a *renntartsche* in Vienna (R.VII):

from the outer layer of leather
from the inner layer of padding

There were also 2 specimens from an armour for the *gestech* from Schloss Ambras.
from a *gestechhelm* lining
saddle stuffing

The leather was identified as such (cowhide) and the padding from R.VII identified as sheeps' wool. The helm lining contained cotton, hemp and horsehair. The saddle stuffing contained horsehair, hemp, and other (not clearly identifiable) fibres.

Electron photomicrographs

Figure 82. Specimen (i) leather – from side of greater thickness; next to padding.

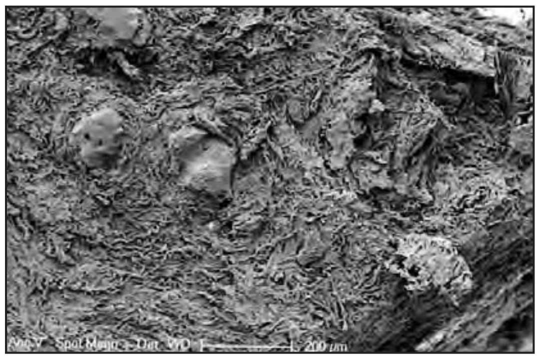

Figure 83. Specimen (i) leather – from other side.

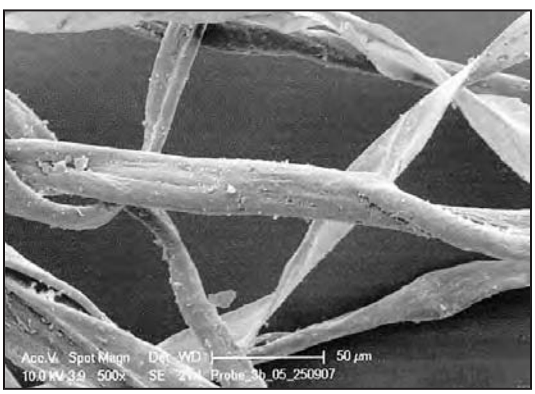

Figure 84. Specimen (iii) cotton from helm lining.

Figure 85. Specimen (iii) hemp (in cross-section) from helm lining.

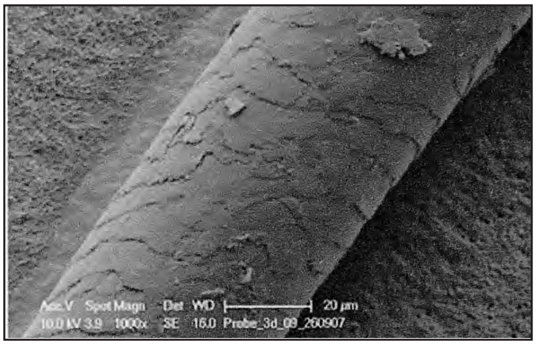

Figure 86. Specimen (iii) horsehair from helm lining.

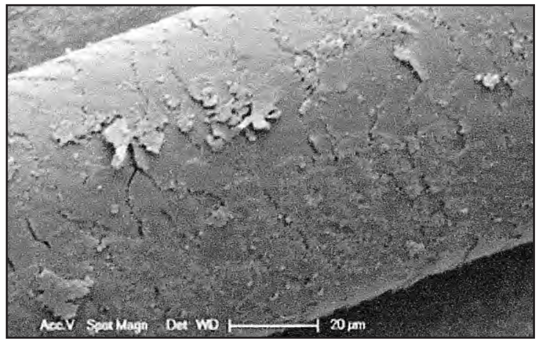

Figure 87. Specimen (iv) horsehair from saddle stuffing.

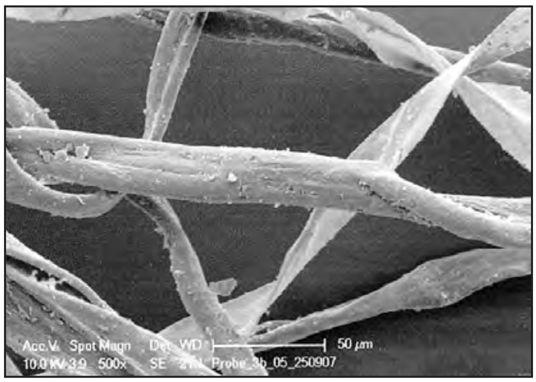

Figure 88. Specimen (iv) hemp from saddle stuffing.

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