The Steel of the Negroli

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PREPARATION FOR the exhibition "Heroic Armor of the Italian Renaissance: Filippo Negroli and his Contemporaries," held at The Metropolitan Museum of Art in 1998–99, addressed a number of art-historical questions surrounding the style, iconography, and authorship of Italian parade armors *all'antica* dating to the years 1530–55. The majority of works included in the exhibition were decorated with classicizing ornament in high relief, achieving a sculptural quality by means of embossing or repoussé. The virtuoso metalworking skill demonstrated by Filippo Negroli, members of his family, and contemporary armorers working in Milan, Brescia, and Mantua inevitably raised the technical question as to the medium employed by these craftsmen. Did they work in a soft, malleable iron, as art historians have tended to assume in light of the remarkable plasticity of the embossing, or were they using the harder medium of steel, appropriate for armor?

In order to provide an answer to this question the author of this article was invited by the exhibition organizers to conduct metallographic examinations on a number of armors by Filippo Negroli and his contemporaries. The armors made available for testing were mostly confined to examples in the Metropolitan Museum and the Hofjagd- und Rüstkammer of the Kunsthistorisches Museum, Vienna. Although the sampling was far from comprehensive, the conclusions are nevertheless suggestive. Of the more than thirty specimens tested, most were found to be of steel, an alloy of iron and carbon, and the hardest steel predominates in the best armors.

Metallography is the examination of a prepared metal surface by means of a microscope. A very small (1–2 mm square) sample of metal is detached from the artifact where it will leave no visible damage. On armor, the inside of the turned rim of a plate is particularly suitable for this. The sample is then embedded, polished until it is optically flat, and etched to reveal the crystalline structure of the metal. Of course, the individual atoms are too small to be visible, but they are arranged in regular patterns within grains, and the boundaries between grains become visible after etching.

It may be useful to summarize here some basic information about the technology of iron and steel production in the age of the Negroli. During the sixteenth century, iron was made as follows. Iron ore would be charged into a furnace with charcoal, and in some cases with limestone as well. The charcoal is burned, and a stream of hot gases (especially carbon monoxide, CO) ascends while the ore descends. At suitable temperatures, it is the carbon monoxide that enables metal oxides to be reduced. Iron oxide (FeO) reduces readily at about 800° C, well below the melting point of iron (1550° C). So iron particles will start to form at some point on their journey down the shaft. Solid iron thus formed will absorb carbon from the hot, carbon monoxide–rich gases until it reaches the combustion zone. If it absorbs a significant amount, its melting point will fall, perhaps even as far as the ambient temperature in the furnace, in which case it will melt, and then dissolve more carbon very quickly from direct contact to form the mixture that contains 2% carbon, "cast iron," which melts at 1150° C. The unreduced oxides present from the ore, as well as from the clay and stones of the furnace lining (CaO, Al_2O_3, SiO_2, the oxides of calcium, aluminium, and silicon) and any unreduced iron oxide, will react together to form a slag, a glasslike material whose free-running temperature will depend on its composition.

In the most primitive form of bloomery, a "bowl hearth" perhaps less than 1 meter high, the iron might be reduced but neither the iron nor the slag melted. The products would then have to be crudely separated by breaking them apart or else reheating them at a higher temperature to melt away the slag. Such a primitive operation would have been greatly improved by the later Middle Ages. A larger furnace, with a shaft up to 2 meters high, could be operated at a higher temperature (as a "bloomery hearth") to give as products a "bloom" of porous solid iron, which could be hammered to consolidate it, and an iron-rich slag, which could be "tapped off" (separated as a liquid flowing at 1100–1200° C). Any bloomery iron will

METROPOLITAN MUSEUM JOURNAL 34

The notes for this article begin on page 123.

contain entrapped slag inclusions of a composition generally similar to the tap-slag. On the other hand, if the shaft furnace was high enough, and so hot enough, it might be operated as a "blast furnace," yielding a liquid iron rich in carbon and a slag poor in iron. This liquid iron was at first regarded as a useless by-product, then used as a cheaper substitute for bronze in casting. Large cannon were being cast in iron by 1390, and at some later stage, methods for converting it to forgeable iron were discovered.

If an "indirect" or two-stage process was employed, the liquid cast iron would have been converted to iron or even steel by being wholly or partially decarburized in a "finery" by melting it and then submitting the liquid to an oxidizing atmosphere, or allowing it to drip through an air blast onto a charcoal hearth.[1] Some iron oxide would form as the carbon content of the iron was reduced and might react with the lining of the hearth (SiO_2 and perhaps Al_2O_3 and CaO could be present in the lining of the hearth, depending on its construction) so that the wrought iron produced in the finery would contain some finery slag, which might differ little in composition from extraction slag.

Published analyses of slags from fineries show that most of the elements present in bloomery slags are also present in finery slags, so that bloomery iron differs little from finery iron, except in price.[2] Either source could have supplied iron for armor in the sixteenth century; the finery might have been the source of iron for the cheapest "munition" armor (that is, inexpensive, ready-made harnesses of the kind acquired in bulk for foot soldiers). Microscopic examination of such irons (often generally called "wrought iron") will show equiaxed grains of iron (called ferrite) and slag inclusions, whose shape will depend on how much hot-working the iron has had. A small amount (up to 0.1% or 0.2%) of carbon might also be present as iron carbide.

Steel remained a luxury product throughout the Middle Ages and in the sixteenth century. According to Thorold Rogers, the price at which raw iron was sold in England varied between

about	1300	1400	1500	1550
	0.45	0.84	0.44	1.27 pence

per pound. It was usually sold by the hundredweight (50 kg). On the other hand, steel was sold at

1300	1400	1500	1550
1.65	1.60	1.20	2.32 pence

per pound. It was sold by the piece, later by the sheaf, garb, fagot, cake, or barrel.[3]

The words sheaf, garb, and fagot all have a similar meaning—a bundle, whether of sticks, arrows, or pieces of metal. The price difference suggests that steel was made separately from iron, and with two or three times as much difficulty. It might have been made in one of several ways:

1. Directly, in a shaft furnace with operating conditions midway between those of a bloomery and a blast furnace.

2. By case-carburizing pieces of bloomery iron, or selecting higher-carbon fragments from a heterogeneous bloom after breaking up, and forging them together (this might be the connection with those names that are synonymous with bundles).

3. The decarburization of liquid cast iron might be halted at an intermediate carbon content, that of steel. According to Walzel,[4] steel was made in Styria this way by letting the liquid iron from the blast furnace drip through an air blast onto a charcoal hearth. Obtaining anything like a consistent carbon content would have been difficult, if not impossible, and British attempts to make "puddled steel" by a similar direct process in the nineteenth century proved to be unsatisfactory. Steelmakers like Bessemer found that it was easier to remove all the carbon and then add a measured weight to give a steel of the chosen carbon content.[5]

4. A method related to method 3, sometimes called the "Brescian process," was described by Biringuccio in 1540 (to be precise, he ascribed it to Valcamonica, near Brescia), and his description was copied by Agricola a few years later.[6] A lump of bloomery iron ("weighing thirty to forty pounds") was supposed to be swirled about on the end of an iron rod in a bath of liquid cast iron for 4 to 6 hours, with crushed marble added, until it was somewhat carburized, and then taken out and forged into a uniform product. If this genuinely describes contemporary practice, and is not simply a misrepresentation of the finery process, then this method may have supplied the steel used by later sixteenth-century Milanese armorers.[7]

These different methods might produce steels, all of which would be heterogeneous because they would never have been melted, and all of which would contain some slag, though less slag than iron, because the carbon in the steel would have reduced some of the iron oxide in the slag. They would also contain up to about 0.5% or 0.6% carbon. If a steel, after forging, is allowed to cool in air then equilibrium conditions will prevail. The carbon that was dissolved in the iron above 900° C comes out of solution as a lamellar mixture of iron carbide (or cementite, Fe_3C) and ferrite (pure iron, Fe), called pearlite, which has a distinctive microscopical appearance. Very slow cooling or repeated hot-working may cause the layers of pearlite to spheroidize, or form globules of iron carbide in a ferrite matrix. (Completely spheroidized pearlite is sometimes called "divorced" pearlite.) If the steel is cooled more rapidly, or quenched, and equilibrium is not attained, then other crystalline products may form, and it will become very hard. However, no attempt was made to quench-harden any of the specimens discussed here. Indeed, Italian armorers had largely given up the practice of quenching after about 1510, even for field armors.

Metallographic tests have demonstrated that fifteenth-century Milanese knightly armor was generally made of steel and frequently hardened by slack-quenching (cooling at a rate insufficiently drastic to lead to full hardening of the steel). Armor of infantry quality was also frequently made of steel but air-cooled.[8] On the other hand, after the first decade of the sixteenth century, Italian armor was very seldom hardened by any form of heat treatment. At almost the same time there was a considerable increase in the frequency of etched and gilt decoration.[9] It seems very likely to the author that the two developments are connected, since any reheating for fire-gilding would reduce the hardness of a quenched steel. Evidently the customers of Italian armorers gave a higher priority to decoration than to hardness.

During the middle decades of the sixteenth century, the use of steel seems to have been less common, even for wealthy customers. The field armors of Cosimo I de' Medici and of Sforza Pallavacini (Hofjagd- und Rüstkammer, Vienna, inv. nos. A.406 and A.1181, respectively), both of them unadorned harnesses of probable Milanese origin about 1550–55 that were designed for use in battle, were rather surprisingly found to be made of slaggy wrought irons without carbon.[10] One can only speculate that relatively little money was spent or attention paid to such armors. On the other hand, most Italian armors dating to the last third of the century, including those attributed to the outstanding master Pompeo della Cesa (recorded 1569–93), were made of (air-cooled) steels.[11] There is some rather inconclusive evidence that Pompeo may have employed a cheaper grade of steel that was then available.[12]

Filippo Negroli used a medium-carbon steel, apparently the best that was then available. Variations in the carbon content are due to the fact that medieval and early modern "steel" was a very heterogeneous material, even if some craftsmen attempted to treat it in a consistent way. Some attempt might be made to homogenize it by folding and forging it out, perhaps more than once. The elongation of the slag inclusions present and the partially spheroidized nature of the pearlite frequently observed point to a considerable degree of hot-working, to be expected given such extraordinarily elaborate shapes, but no attempt was made to harden the armor by subsequent quenching.

At first sight, it may seem surprising that a material at least twice as hard as iron should be used for embossed and chased "parade" armors, which presumably were never intended to be tested on the battlefield or in the tournament lists. But since medium-carbon steels seem to have been frequently used by the Negroli and their contemporaries, it may be said in general that parade armors appear to have been made of better metal than the plain field armors of mid-sixteenth-century Italy.

One factor which should be considered is that the hardness of the metal enabled the chiseler to demonstrate his virtuosity, just as sculptors in the hardest stones demonstrated the highest levels of mastery. The material used by Filippo Negroli was about six times as hard as silver, so that many traditional silversmithing techniques were not generally applicable.[13]

An additional, and more practical, consideration is that while the steel was initially shaped by the armorer's technique of forging (hot-working), as the elongation of the slag inclusions demonstrates, the final chasing was done cold. Steel would, as explained above, contain fewer brittle slag inclusions than iron, so that certain metalworking techniques, especially chiseling, might be more successful if performed on steel than on iron. This is fundamentally the reason why armor plate containing a lot of slag is more prone to lamination, as examination of the internal surfaces of munition armors will illustrate. The microstructure of the armor of Carlo Gonzaga, a work of about 1540 attributed to Caremolo Modrone of Mantua in the Negroli exhibition catalogue (no. 50), which is made from a banded steel, shows such a lamination starting at a row of slag inclusions. This row would have been the consequence of the imperfect forging together of billets when trying to make a homogeneous sheet.

But the most important reason for using steel is surely the motive for making these armors. If they had been intended to be worn purely as decoration, then it would have been logical to use the softest practical material available, iron, as that would have been the easiest to work. Decorative though these "parade" armors were, they were still armor. In design, they were intended to show their wearers as classical heroes, and their ornate form might lead the modern observer to think (mistakenly) that, because they were primarily for ceremonial wear, they must be impractical for any other, more serious use. In fact they were, in terms of their metallurgy, every bit as functional as any contemporary field armor, although the process of forming the complex shapes tended to make the metal thin, and the deflective quality of the plates was lost with the creation of raised decoration. They were evidently expected to be fit for war, even if in practice they would never be worn in serious combat. The Negroli were regarded as the best armorers of Italy, and so they used the best available steel. In conclusion, these were not "parade" armors embossed in iron, but armors appropriate for parade, forged out of steel.

The hardness of the tested specimens has been determined by measuring the size of a microscopic indentation made when a diamond is pressed into the flat surface of a metal under a fixed load (100 g). The units of Vickers Pyramid Hardness (VPH) are kg/mm^2. Each hardness result quoted here is an average of several (usually ten) readings. Wrought irons have typical hardnesses of between 90 and 120 VPH. The hardness of a steel depends upon its carbon content (if its heat-treatment is not varied). A "medium-carbon" steel of about 0.5% carbon might have a hardness of between 220 and 250 VPH. The hardness of silver might be between 30 and 50 VPH (see note 13). Steels hardened by quenching might have a hardness of between 300 and 600 VPH. A GKN microhardness tester was used, employing a load of 100 g in each case.

Tabulated Results

The armors from which the samples were taken are identified here by their entry number in the exhibition catalogue by Stuart W. Pyhrr and José-A. Godoy, *Heroic Armor of the Italian Renaissance: Filippo Negroli and His Contemporaries* (New York: MMA, 1998). Below, under "Metallography of Samples," the individual metallography of each armor is discussed, accompanied by photomicrographs of the specimens.

I. Armors signed by Filippo Negroli of Milan

Cat. no. 18, Vienna A.498a		low C	
Cat. no. 29b, Wallace A.207			med C
Cat. no. 33, MMA 17.190.1720			med C

(total specimens 3; of which 0 are iron, 1 low-carbon steel, 2 medium-carbon steel)

II. Armors attributed to Filippo Negroli

Cat. no. 19, Vienna A.498 (+ 1 part, Bargello M.1502 or 1503)	iron	low C	
Cat. no. 21, MMA 04.3.202 (3 parts)	2 iron	low C	
Cat. no. 23e, MMA 14.25.714i (+ 1 part, Bargello M.1503[bis])		low C	med C

(total specimens 7; of which 3 are iron, 3 low-carbon steel, 1 medium-carbon steel)

III. Armors possibly made in the Negroli workshop, or by Milanese contemporaries, after 1545

Cat. no. 39, Vienna A.693			med C
Cat. no. 40, Cambridge M.19–1938 (3 parts)		3 low C	
Cat. no. 41, MMA 04.3.223 (6 parts)	iron	2 low C	3 med C
Cat. no. 42, Vienna A.693a			med C

(total specimens 11; of which 1 is iron, 5 low-carbon steel, 5 medium-carbon steel)

IV. Armors signed by, or attributed to, Giovan Paolo Negroli of Milan

Cat. no. 43, MMA 14.25.1855 (3 parts)	iron	low C	med C
Cat. no. 46, MMA 26.53 (4 parts)		3 low C	med C

(total specimens 7; of which 1 is iron, 4 low-carbon steel, 2 medium-carbon steel)

V. Armors made by contemporaries of the Negroli, probably in Milan

Cat. no. 37, MMA 49.163.3		low C	
Cat. no. 53, Vienna A.783			med C
Cat. no. 56, Stibbert 11586			med C

(total specimens 3; of which 0 are iron, 1 low-carbon steel, 2 medium-carbon steel)

VI. Armor attributed to Caremolo Modrone of Mantua

Cat. no. 50, Vienna A.632 med C
(total specimens 1; of which 0 are iron, 0 low-carbon steel, 1 medium-carbon steel)

VII. Armor made by contemporaries of the Negroli, probably in Brescia

Cat. no. 64, Turin C.11 iron
(total specimens 1; of which 1 is iron, 0 low-carbon steel, 0 medium-carbon steel)

Overall totals

Out of the 33 specimens examined, 28 were from armors attributed to the Negroli family, and of these only 5 were iron, while 13 were low-carbon steels and another 10 were medium-carbon steels (and 2 out of the 3 specimens from examples signed by Filippo Negroli were medium-carbon steels).

If the total includes armors made by their contemporaries in Milan as well, then 12 out of 31 were medium-carbon steels. This may be better expressed as a table:

Category	Iron	Low-carbon steel	Medium-carbon steel	Total
signed by Filippo	0	1	2	3
attributed to Negroli family	5	12	8	25
other Milanese	0	1	2	3
TOTAL MILANESE	5	14	12	31
other Italians	1	0	1	2
TOTAL	6	14	13	33

Metallography of Samples

I. Armors signed by Filippo Negroli of Milan

Cat. no. 18. Burgonet of Francesco Maria I della Rovere, duke of Urbino. Signed and dated 1532. Hofjagd- und Rüstkammer des Kunsthistorischen Museums, Vienna, A.498 (Figure 1).

The cross-section (Figure 2) shows a microstructure of ferrite and pearlite, corresponding to a carbon content of about 0.3%. This is a low-carbon steel. There are rows of very elongated slag inclusions, especially near one surface. The most prominent such form a line at about one-eighth of the section. Microhardness = 233 VPH.

Cat. no. 29b. Left cheekpiece belonging with parts of a burgonet with buffe of Francesco Maria I or Guidobaldo II della Rovere. The buffe is signed and dated 1538. Wallace Collection, London, A.207 (Figure 3).

The cheekpiece was examined on the lower rim, between turns of the roped decoration. The sample (Figure 4) shows a microstructure consisting almost entirely of pearlite with a little slag and a few ferrite grains along one surface. This is a medium-carbon steel (of perhaps 0.6%–0.7% carbon) which has been worked hot and afterwards allowed to cool in air. Microhardness = 282 VPH.

Cat. no. 33. Burgonet. Signed and dated 1543. The Metropolitan Museum of Art, Gift of J. Pierpont Morgan, 1917, 17.190.1720 (Figure 5).

The sample (Figure 6) shows a microstructure consisting mostly of grains of ferrite with some large areas of pearlite. The carbon content varies between 0.2% and 0.8%. Some of the pearlite has divorced into globules, and also into lines, of cementite. This is a medium-carbon steel, overall. Microhardness = 254 VPH.

Several other specimens, such as the right upper cheekpiece of cat. no. 41, MMA 04.3.223 (Figure 24), show a similar arrangement of particles.

II. Armors attributed to Filippo Negroli

Cat. no. 19. Cuirass of mail and plate of Francesco Maria I della Rovere. Ca. 1532–35. Hofjagd- und

Figure 1. Burgonet and mail-and-plate cuirass of Francesco Maria I della Rovere, duke of Urbino. The burgonet is signed by Filippo Negroli of Milan and dated 1532; the cuirass is attributed to him, ca. 1531–35. Hofjagd- und Rüstkammer, Vienna, A.498 and A.498a (photo: Kunsthistorisches Museum)

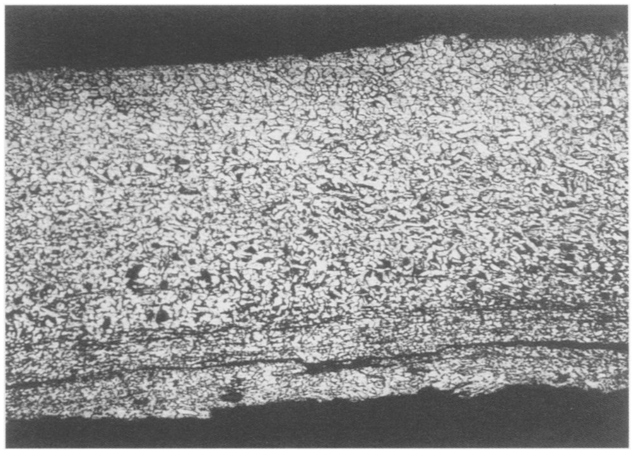

Figure 2. Sample from burgonet in Figure 1 (× 110). Cross-section. Ferrite, pearlite, and elongated slag inclusions (all photomicrographs were taken by the author)

Rüstkammer des Kunsthistorischen Museums, Vienna, A.498a (Figure 1).

The cross-section (Figure 7) shows a microstructure of ferrite (iron), consisting of ferrite grains with some slag inclusions. Some of the ferrite grains have been distorted where sampling took place, but the majority are equiaxed. This is, in effect, an iron. Microhardness = 198 VPH.

Cat. no. 19 bis. An upper arm piece of mail and plate (one of a pair) belonging to this cuirass.[14] Museo Nazionale del Bargello, Florence, M.1502 or 1503 (Figure 8).

The microstructure (Figure 9) consists of ferrite and pearlite, corresponding to a low-carbon steel of 0.3% carbon. Microhardness = 234 VPH.

Cat. no. 21. Burgonet. Ca. 1532–35, with some 19th-century alterations. The Metropolitan Museum of

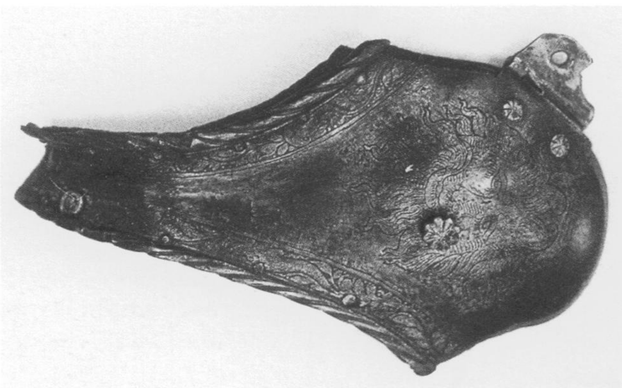

Figure 3. Left cheekpiece belonging with parts of a burgonet with buffe of Francesco Maria I or Guidobaldo II della Rovere. The buffe is signed by Filippo Negroli of Milan and dated 1538. Wallace Collection, London, A.207 (photo: José-A. Godoy; reproduced by premission of the Trustees of the Wallace Collection)

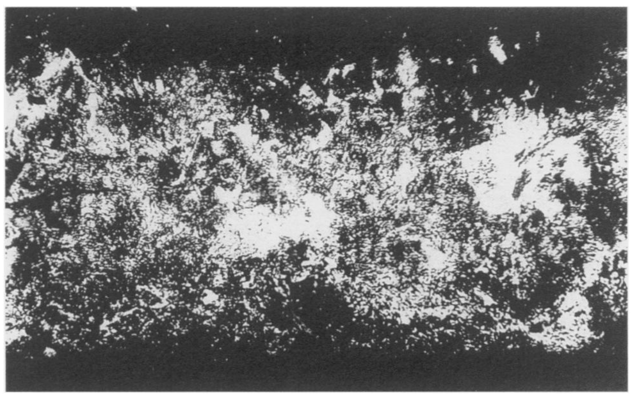

Figure 4. Sample from lower rim of cheekpiece in Figure 3 (× 190). Cross-section. Pearlite

Figure 5. Burgonet. Signed by Filippo Negroli of Milan and dated 1543. The Metropolitan Museum of Art, Gift of J. Pierpont Morgan, 1917, 17.190.1720

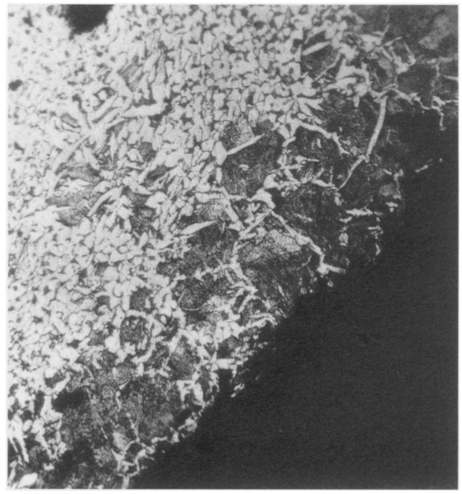

Figure 6. Sample from burgonet in Figure 5 (× 140). Pearlite and ferrite

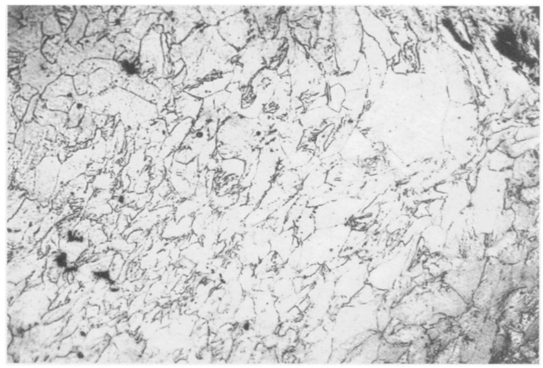

Figure 7. Sample from cuirass in Figure 1 (× 115). Ferrite and a little pearlite

Art, Rogers Fund, 1904, 04.3.202 (Figure 10). Three specimens were examined:

Left cheekpiece: The sample (Figure 11) shows a microstructure consisting entirely of grains of ferrite with a little slag. This is an iron.

Right cheekpiece: The sample (Figure 12) shows a microstructure consisting mostly of grains of ferrite with a little slag. This is also an iron. There are also two areas containing different metals, separate from the iron. One is full of a pink metal, apparently copper. The other is full of a lemon yellow metal, apparently brass. XRF analysis confirms that this is a copper-zinc alloy, of about 40% zinc. The copper is presumably from the decoration. The brass is presumably from a repair.

Figure 8. Upper arm defenses of mail and plate belonging to cuirass in Figure 1. Museo Nazionale del Bargello, Florence, M.1502–1503 (photo: Giuseppe Schiavinotto)

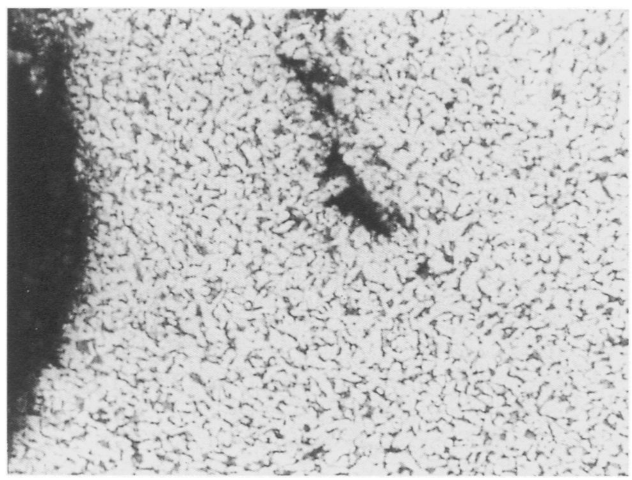

Figure 9. Sample from arm piece in Figure 8 (× 100). Ferrite and pearlite

Figure 10. Burgonet. Attributed to Filippo Negroli of Milan, ca. 1532–35. The Metropolitan Museum of Art, Rogers Fund, 1904, 04.3.202

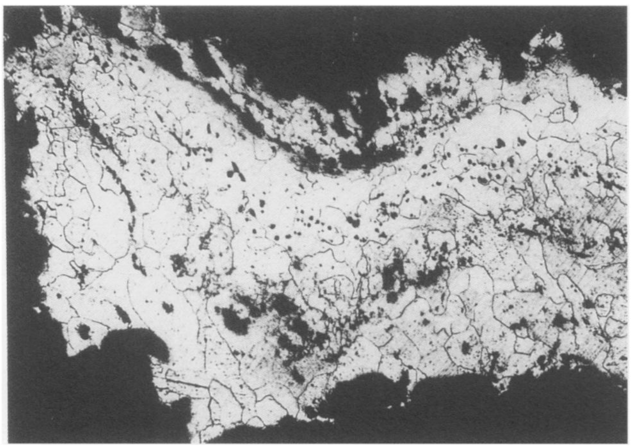

Figure 11. Sample from left cheekpiece of burgonet in Figure 10 (× 120). Ferrite and slag inclusions

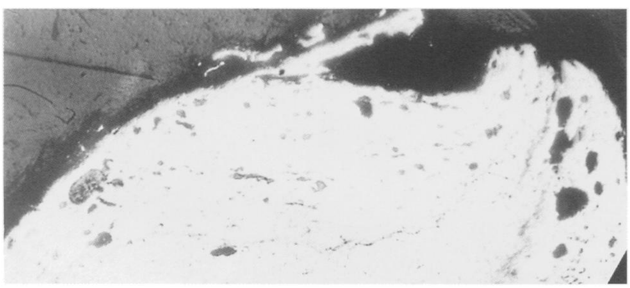

Figure 12. Sample from right cheekpiece of burgonet in Figure 10 (× 140). Ferrite and slag inclusions

Bowl: The sample (Figure 13) shows a microstructure consisting mostly of grains of ferrite with a little pearlite divorced to cementite, and some slag inclusions. The carbon content is perhaps 0.1%. This is a low-carbon steel.

Cat. no. 23e. Pauldron for the right shoulder, belonging to an armor of Guidobaldo II della Rovere. Ca. 1532–35. The Metropolitan Museum of Art, Gift of William H. Riggs, 1913, 14.25.714i (Figure 14).

The sample (Figure 15) shows a microstructure consisting mostly of grains of ferrite with a little pearlite, corresponding to a low-carbon steel, with a carbon content of about 0.2% (it proved impractical to measure the microhardness of this specimen).

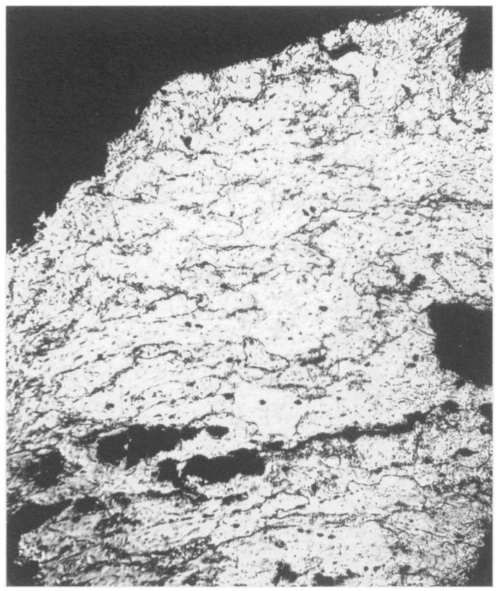

Figure 13. Sample from bowl of burgonet in Figure 10 (× 95). Ferrite and slag inclusions

Figure 14. Pauldron for the right shoulder, belonging to an armor of Guidobaldo II della Rovere. Attributed to Filippo Negroli of Milan, ca. 1532–35. The Metropolitan Museum of Art, Gift of William H. Riggs, 1913, 14.25.714i

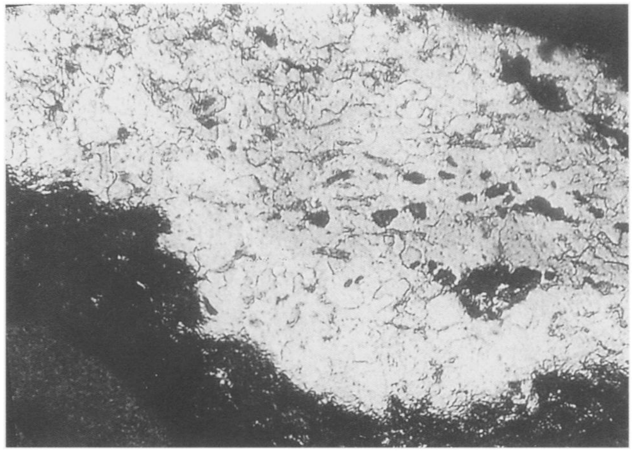

Figure 15. Sample from pauldron in Figure 14 (× 200). Ferrite and slag inclusions

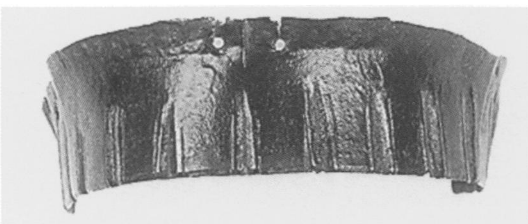

Figure 16. A lower pauldron lame belonging to an armor of Guidobaldo II della Rovere. Attributed to Filippo Negroli of Milan, ca. 1532–35. Museo Nazionale del Bargello, Florence, M.1503[bis] (photo: Giuseppe Schiavinotto)

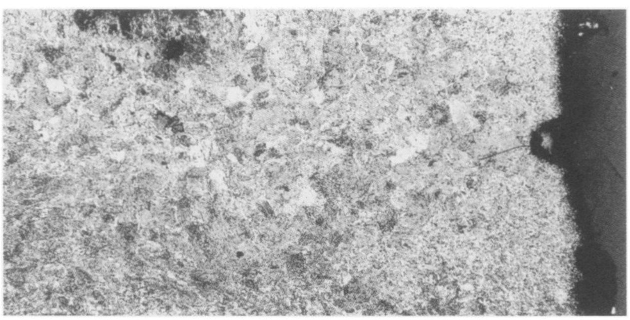

Figure 17. Sample from pauldron lame in Figure 16 (× 50). Pearlite and ferrite

Cat. no. 23 bis. The uppermost of the lower three lames belonging to the left pauldron of the same armor.[15] Museo Nazionale del Bargello, Florence, M.1503[bis] (Figure 16).

The microstructure (Figure 17) consists of ferrite and pearlite, corresponding to a medium-carbon steel of about 0.5% carbon. Microhardness = 210 VPH.

III. Armors possibly made in the Negroli workshop, or by Milanese contemporaries, after 1545

Cat. no. 39. Burgonet. Ca. 1550–55. Hofjagd- und Rüstkammer des Kunsthistorischen Museums, Vienna A.693 (Figure 18).

The cross-section (Figure 19) shows a microstructure of pearlite and ferrite, corresponding to a medium-carbon steel with a carbon content of about 0.6%. The ferrite grains are mostly concentrated into two or three narrow bands. At other parts of the section, corrosion cracks have opened up, especially along the lines where the carbon content falls. Microhardness = 261 VPH.

Cat. no. 40. Burgonet. Ca. 1550–55. Fitzwilliam Museum, Cambridge, M.19–1938 (Figure 20). Three samples were examined:

Bowl: The microstructure (Figure 21) consisted of ferrite and spheroidized pearlite, corresponding to a low-carbon steel of about 0.1% carbon.

Visor: The microstructure (Figure 22) consisted of ferrite and spheroidized pearlite, corresponding to a low-carbon steel of about 0.2% carbon.

Figure 18. Burgonet. Milan, ca. 1550–55. Hofjagd- und Rüstkammer, Vienna, A.693 (photo: Kunsthistorisches Museum)

Neck plate: The microstructure (Figure 23) consisted of ferrite and spheroidized pearlite, corresponding to a low-carbon steel of about 0.2% carbon.

Cat. no. 41. Burgonet. Ca. 1550–55. The Metropolitan Museum of Art, Rogers Fund, 1904, 04.3.223 (Figure 24). Six specimens were examined:

Lower plate of left cheekpiece: The sample (Figure 25) shows a microstructure consisting mostly of grains of ferrite with some slag, bounded by areas of pearlite, mixed with a little ferrite and noticeably less slag. The pearlite shows some spheroidization, presumably the result of hot working. The ferrite grains show little evidence of distortion. This is a low-carbon steel.

Upper plate of left cheekpiece: The sample (Figure 26) shows a microstructure consisting of a mixture of divorced pearlite and ferrite (the grains of which have been distorted in sampling), corresponding to a medium-carbon steel, with a carbon content of about 0.4%–0.5%.

Lower plate of right cheekpiece: The sample (Figure 27) shows a microstructure consisting mostly of grains of ferrite with a little spheroidized pearlite, corresponding to about 0.1% carbon. This is a low-carbon steel.

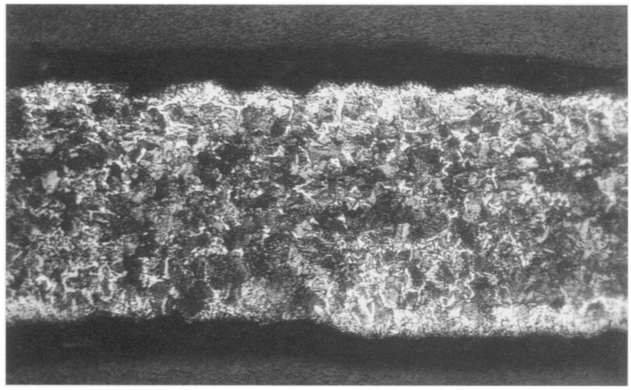

Figure 19. Sample from burgonet in Figure 18 (× 140). Cross-section. Pearlite and a little ferrite

Figure 20. Burgonet. Milan, ca. 1550–55. Fitzwilliam Museum, Cambridge, M.19–1938 (photo: Fitzwilliam Museum)

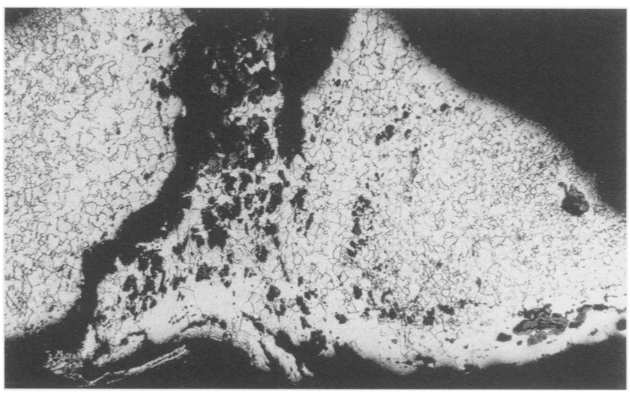

Figure 21. Sample from bowl of burgonet in Figure 20 (× 50). Ferrite, slag inclusions, and a little pearlite

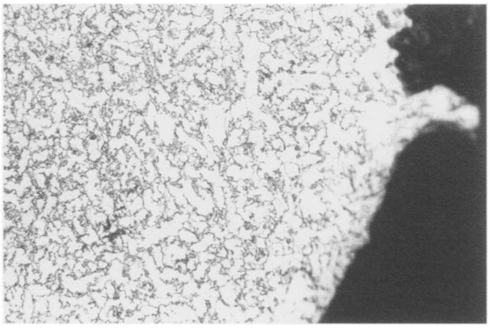

Figure 22. Sample from visor of burgonet in Figure 20 (× 200). Ferrite and spheroidized pearlite

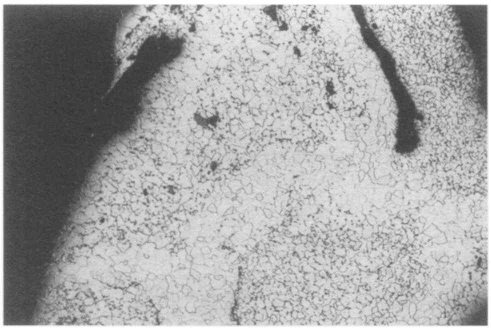

Figure 23. Sample from neck plate of burgonet in Figure 20 (× 50). Ferrite, slag inclusions, and a little pearlite

Figure 24. Burgonet. Milan, ca. 1550–55. The Metropolitan Museum of Art, Rogers Fund, 1904, 04.3.223

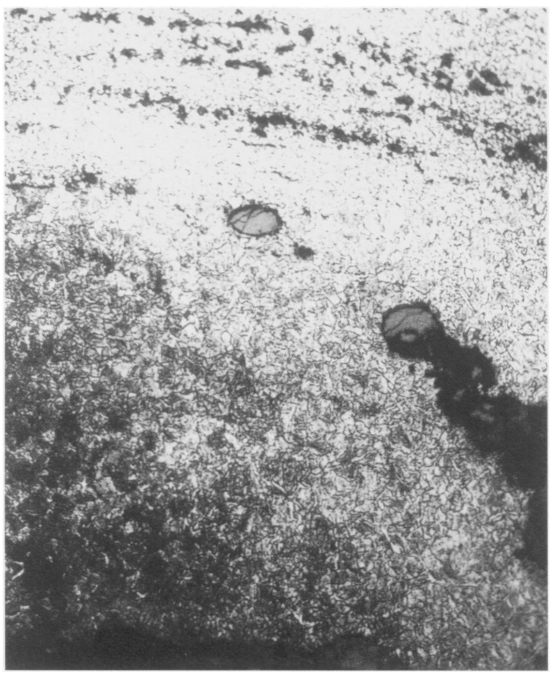

Figure 25. Sample from lower plate of left cheekpiece of burgonet in Figure 24 (× 115). Pearlite and ferrite with some large iron oxide inclusions

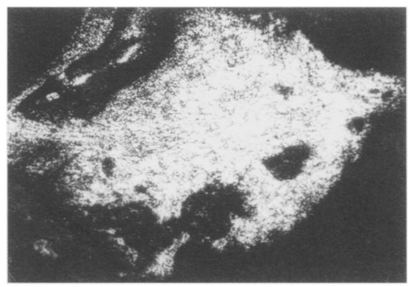

Figure 26. Sample from upper plate of left cheekpiece of burgonet in Figure 24 (× 160). Ferrite and partly spheroidized pearlite

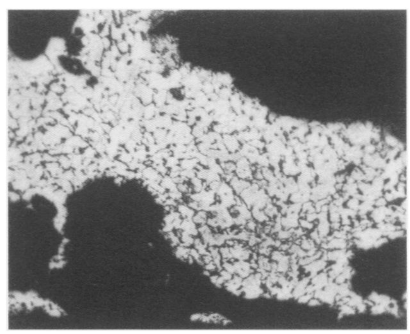

Figure 27. Sample from lower plate of right cheekpiece of burgonet in Figure 24 (× 120). Ferrite and some partly spheroidized pearlite

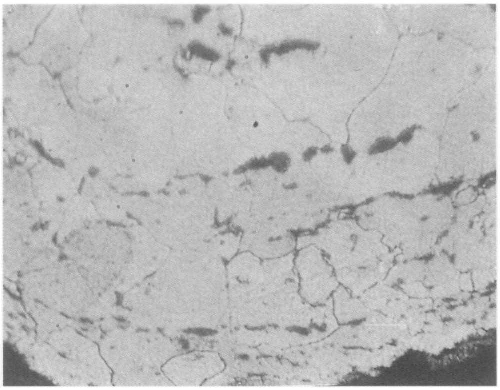

Figure 28. Sample from bowl of burgonet in Figure 24 (× 120). Ferrite and slag inclusions

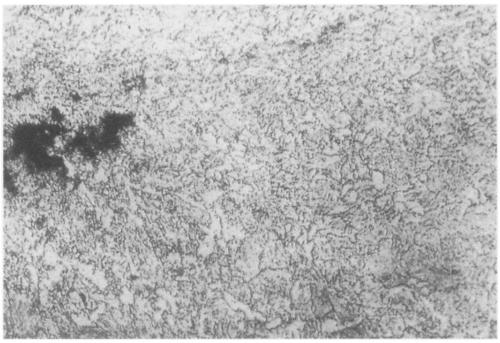

Figure 29. Sample from bowl of burgonet in Figure 24 (× 120). Partly spheroidized pearlite and ferrite

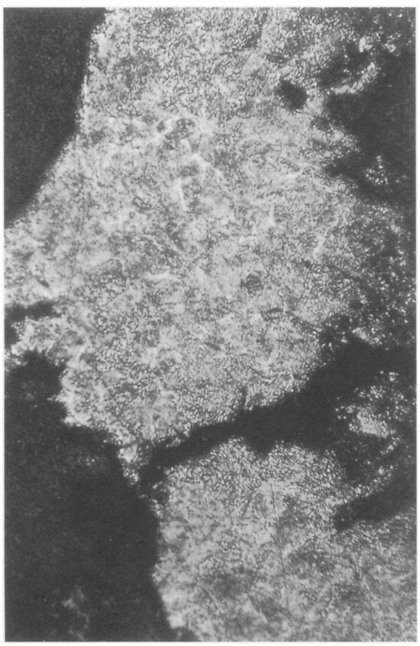

Figure 30. Sample from upper plate of right cheekpiece of burgonet in Figure 24 (× 180). Mostly pearlite (partly spheroidized)

Bowl: Two samples were taken. One (Figure 28) has a microstructure consisting mostly of grains of ferrite with a little slag. This is an iron. The other (Figure 29) has a microstructure consisting mostly of divorced pearlite, with some ferrite. The carbon content is about 0.6%. This is another medium-carbon steel.

Upper plate of the right cheekpiece: The sample (Figure 30) shows a microstructure consisting almost entirely of pearlite. Some of this has separated out into cementite, which has formed isolated globules as well as numerous rows of cementite. This suggests that this steel has undergone a good deal of reheating. (This is also a medium-carbon steel.)

Figure 31. Medusa shield. Milan, ca. 1550–55. Hofjagd- und Rüstkammer, Vienna, A.693a (photo: Kunsthistorisches Museum)

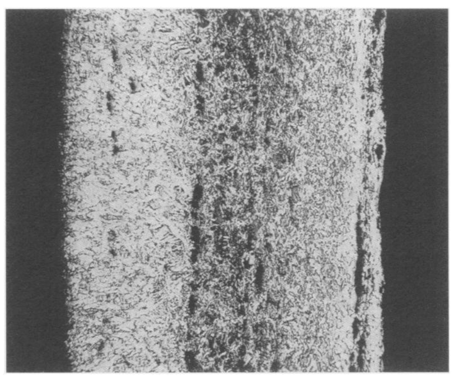

Figure 32. Sample from shield in Figure 31 (× 100). Cross-section. Pearlite and ferrite, with some slag inclusions

Cat. no. 42. Medusa shield. Ca. 1550–55. Hofjagd- und Rüstkammer des Kunsthistorischen Museums, Vienna A.693a (Figure 31).

The cross-section (Figure 32) shows a microstructure divided into three bands. The central band consists of pearlite and ferrite, corresponding to a carbon content of about 0.5%. The two outer bands consist largely of ferrite with a very little pearlite in one. The ferrite shows traces of distortion. There is a row of numerous slag inclusions within the ferritic band, near to one surface, but this does not seem to be associated with any change in carbon content. This may be a relic of an earlier folding operation during the forging of the plate. Overall, this is a medium-carbon steel. Microhardness = 259 VPH.

IV. Armors signed by, or attributed to, Giovan Paolo Negroli of Milan

Cat. no. 43. Breastplate. Signed; ca. 1540–45. The Metropolitan Museum of Art, Gift of William H. Riggs, 1913, 14.25.1855 (Figure 33). Three specimens were examined:

Breastplate: The sample (Figure 34) shows a microstructure consisting mostly of grains of ferrite with a little slag. This is an iron. Microhardness = 106 VPH.

Right gusset: The sample (Figure 35) shows a microstructure consisting of small grains of ferrite and pearlite, corresponding to a carbon content of about 0.2%. There is some distortion of the ferrite

Figure 33. Breastplate. Signed by Giovan Paolo Negroli of Milan, ca. 1540–45. The Metropolitan Museum of Art, Gift of William H. Riggs, 1913, 14.25.1855

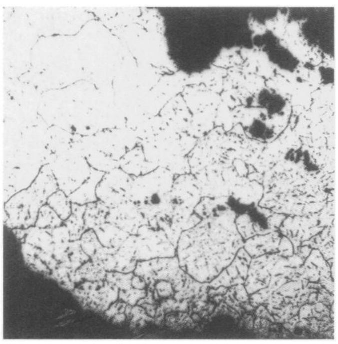

Figure 34 (× 110). Sample from breastplate in Figure 33. Ferrite and slag

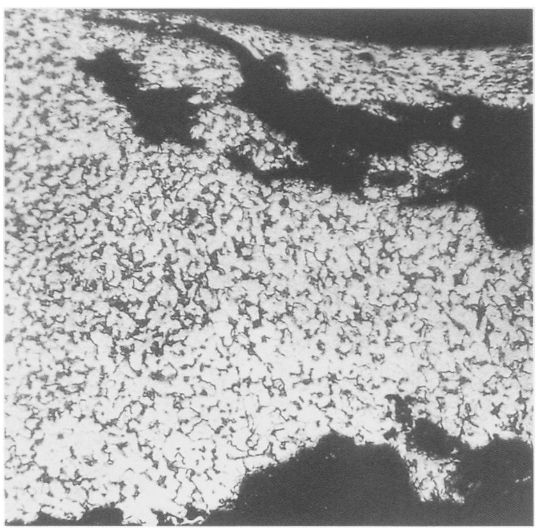

Figure 35. Sample from right gusset of breastplate in Figure 33 (× 200). Ferrite and some pearlite

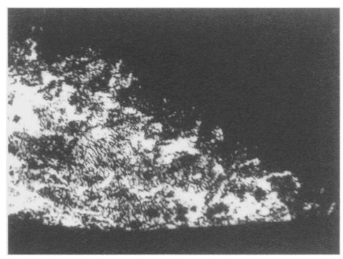

Figure 36. Sample from left gusset of breastplate in Figure 33 (× 160). Pearlite with a little ferrite

grains at the site of sampling. This is a low-carbon steel. Microhardness = 212 VPH.

Left gusset: The sample (Figure 36) shows a microstructure consisting of a mixture of ferrite and pearlite, corresponding to a carbon content of about 0.5%. This is a medium-carbon steel.

Cat. no. 46. Close helmet. Ca. 1540–45. The Metropolitan Museum of Art, Rogers Fund and Gift of George D. Pratt, 1926, 26.53 (Figure 37). Four specimens were examined:

Lower visor: The sample (Figure 38) shows a microstructure consisting mostly of pearlite, with some grains of ferrite, corresponding to a medium-carbon steel of about 0.6% carbon. The ferrite grains have been distorted in places, perhaps by sampling.

Bowl: The very small sample (Figure 39) shows a microstructure consisting mostly of grains of ferrite with a little pearlite, corresponding to a low-carbon steel with a carbon content of about 0.3%, and only a few slag inclusions. Some of the ferrite is distorted in places.

Figure 37. Close helmet. Attributed to Giovan Paolo Negroli of Milan, ca. 1540–45. The Metropolitan Museum of Art, Rogers Fund and Gift of George D. Pratt, 1926, 26.53

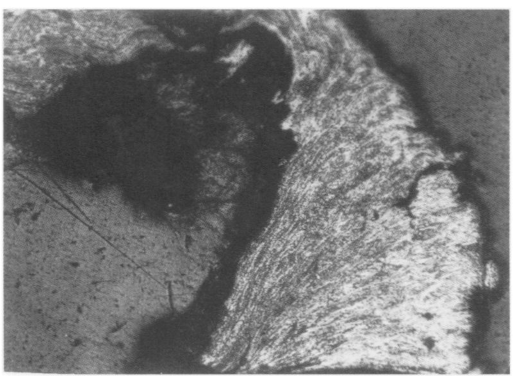

Figure 38. Sample from lower visor of close helmet in Figure 37 (× 120). Distorted areas of perlite, and ferrite

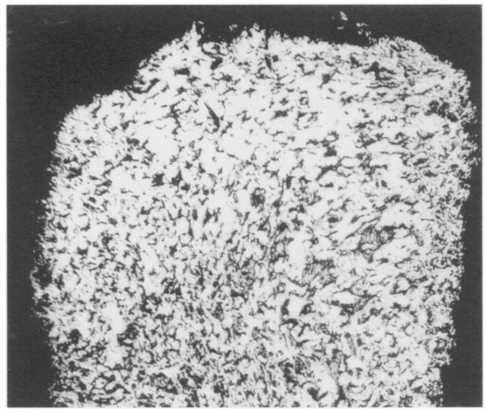

Figure 39. Sample from bowl of close helmet in Figure 37 (× 140). Ferrite and pearlite

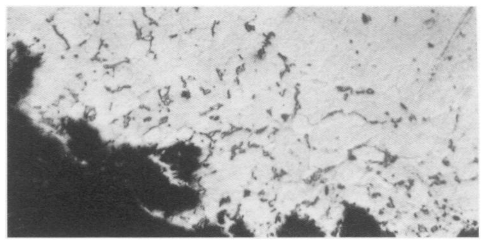

Figure 40. Sample from bevor of close helmet in Figure 37 (× 140). Ferrite slag inclusions and a little spheroidized pearlite

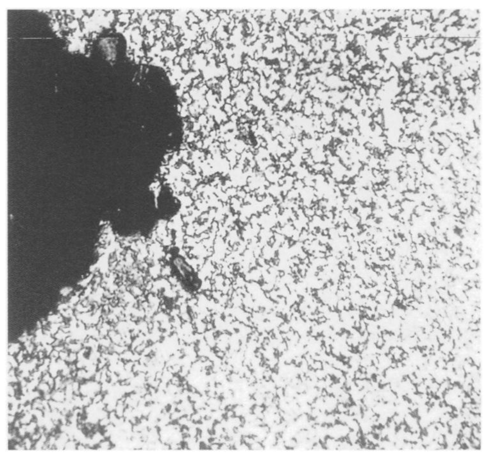

Figure 41. Sample from upper visor of close helmet in Figure 37 (× 200). Partly spheroidized pearlite and ferrite

Bevor: The sample (Figure 40) shows a microstructure consisting mostly of grains of ferrite with a little slag, and pearlite corresponding to a carbon content of less than 0.1%. This is another low-carbon steel. Microhardness = 218 VPH.

Upper visor: The sample (Figure 41) shows a microstructure consisting mostly of grains of ferrite with a little spheroidized pearlite, in small areas, corresponding to a carbon content of about 0.2%, and not very much slag. This is also a low-carbon steel. Microhardness = 215 VPH.

Figure 42. Burgonet. Italian, probably Milan, after 1545. The Metropolitan Museum of Art, Gift of Alan Rutherfurd Styvesant, 1949, 49.163.3

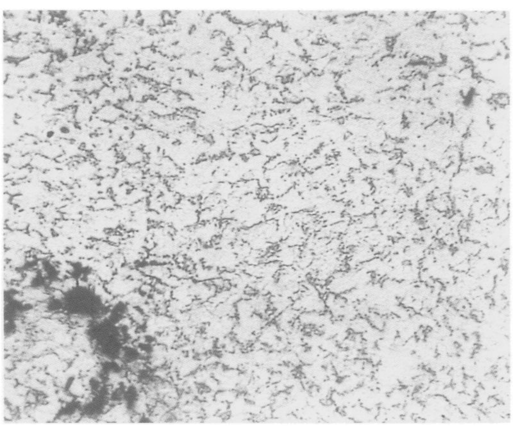

Figure 43. Sample from burgonet in Figure 42 (× 200). Ferrite and partly spheroidized pearlite. Some slag inclusions are also visible

V. Armors made by contemporaries of the Negroli, probably in Milan

Cat. no. 37. Burgonet. After 1545. The Metropolitan Museum of Art, Gift of Alan Rutherfurd Styvesant, 1949, 49.163.3 (Figure 42).

The sample (Figure 43) shows a microstructure consisting mostly of grains of ferrite with a little spheroidized pearlite, corresponding to a low-carbon steel of about 0.2% carbon.

Cat. no. 53. Helmet belonging to the Roman-style armor of Archduke Ferdinand II of Tyrol. Ca. 1547–50. Hofjagd- und Rüstkammer des Kunsthistorischen Museums, Vienna, A.783 (Figure 44).

The cross-section (Figure 45) shows a microstructure of coarse pearlite mixed with some ferrite, and a band predominantly of ferrite along one surface. These ferrite grains show some distortion, perhaps due a final cold working. Overall this is a medium-carbon steel of 0.6%–0.7% carbon content. Microhardness = 299 VPH.

Cat. no. 56. Lion-head pauldron for the left shoulder. Ca. 1540–50. Museo Stibbert, Florence, 11586 (Figure 46).

The microstructure (Figure 47) consists of pearlite and a very little ferrite, corresponding to a medium-carbon steel of about 0.7% carbon content.

VI. Armor attributed to Caremolo Modrone of Mantua

Cat. no. 50. Armor made for Carlo Gonzaga, count of Gazzuolo and San Martino. Ca. 1540. Hofjagd- und Rüstkammer des Kunsthistorischen Museums, Vienna, A.632 (Figure 48).

The cross-section (Figure 49) shows a microstructure of two bands consisting mostly of pearlite, sandwiching a band predominantly of ferrite, with a number of slag inclusions. A corrosion crack has opened up along the junction between a pearlitic and a ferritic band. The inference must be that pieces of different material were forged together into a plate, and the forge welding was imperfect. There is some distortion of the pearlite along one surface. But overall, this is a medium-carbon steel. Microhardness = 237 VPH.

Figure 44. Roman-style armor of Archduke Ferdinand II of Tyrol. Italian, probably Milan, ca. 1547–50. Hofjagd- und Rüstkammer, Vienna, A.783 (photo: Kunsthistorisches Museum)

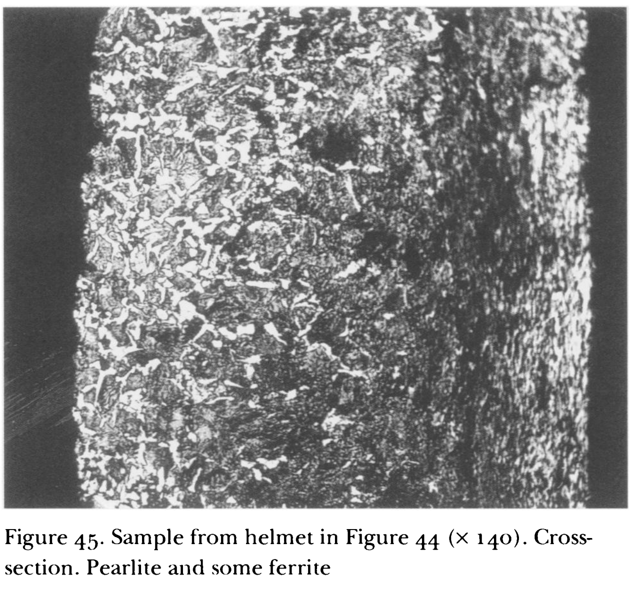

Figure 45. Sample from helmet in Figure 44 (× 140). Cross-section. Pearlite and some ferrite

Figure 46. Lion-head pauldron for the left shoulder. Italian, probably Milan, ca. 1540–50. Museo Stibbert, Florence, 11586 (photo: José-A. Godoy)

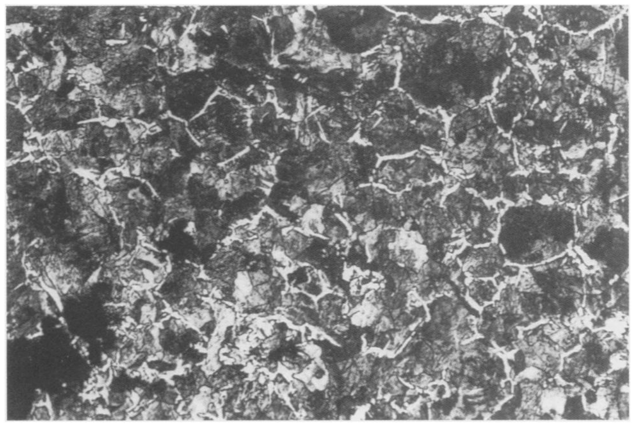

Figure 47. Sample from pauldron in Figure 46 (× 160). Pearlite and ferrite

VII. Armor made by contemporaries of the Negroli, probably in Brescia

Cat. no. 64. Breastplate of a corslet *all'antica*, probably made for Girolamo Martinengo. Ca. 1540. Armeria Reale, Turin, C.11 (Figure 50).

The microstructure (Figure 51) consists of ferrite with a very little pearlite, corresponding to an iron with a carbon content of less than 0.1%.

Figure 48. Armor made for Carlo Gonzaga, count of Gazzuolo and San Martino. Attributed to Caremolo Modrone of Mantua, ca. 1540. Hofjagd- und Rüstkammer, Vienna, A.632 (photo: Kunsthistorisches Museum)

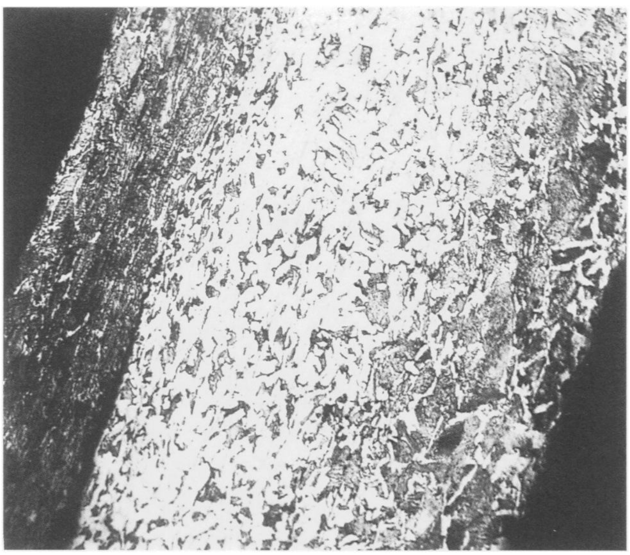

Figure 49. Sample from armor in Figure 48 (× 140). Cross-section. A band of pearlite, some of which has been distorted, next to a band of mixed ferrite and pearlite

Figure 50. Breastplate of a corslet *all'antica*, probably made for Girolamo Martinengo. Italian, probably Brescia, ca. 1540. Armeria Reale, Turin, C.11 (photo: Armeria Reale)

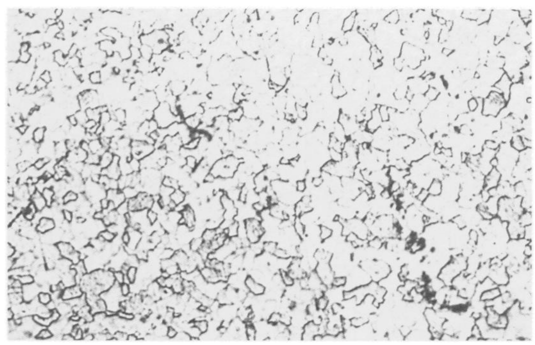

Figure 51. Sample from corslet in Figure 50 (× 90). Ferrite and slag

Appendix

Metallography of Samples from Armors not in the Exhibition

Samples of a number of embossed armors that were not included in the Negroli exhibition were taken for comparison.[16] Many of them are also made of steel. Even if their makers had no connection with the Negroli (except perhaps as rivals),[17] their aims were apparently similar, and similar materials were often employed.

MMA 14.25.597. Burgonet in the form of a dolphin. Italian, probably Milan, ca. 1535–45. The Metropolitan Museum of Art, Gift of William H. Riggs, 1913 (Figure 52).[18]

The sample (Figure 53) shows a microstructure consisting mostly of grains of ferrite with a little pearlite, corresponding to a very low carbon steel with a carbon content of less than 0.1%. In effect, this is an iron.

Figure 52. Burgonet in the form of a dolphin. Italian, probably Milan, ca. 1535–45. The Metropolitan Museum of Art, Gift of William H. Riggs, 1913, 14.25.597

MMA 14.25.602. Open burgonet with embossed decoration of tendrils. Italian, probably Milan, ca. 1530. The Metropolitan Museum of Art, Gift of William H. Riggs, 1913 (Figure 54).[19]

The sample (Figure 55) shows a microstructure of small grains of ferrite and pearlite, corresponding to an annealed medium-carbon steel of about 0.4% carbon. There is a line of slag inclusions down the center of the sample.

Figure 53. Sample from burgonet in Figure 52 (× 95). Ferrite, slag inclusions, and a little, partly spheroidized pearlite

Wallace A.106. Burgonet. Italian, probably Milan, ca. 1540. Wallace Collection, London (Figure 56).[20] Two samples were examined:

The sample from the edge of a hole in the nape of the neck (Figure 57) shows a microstructure consisting mostly of grains of ferrite with a little pearlite, corresponding to a low-carbon steel of perhaps 0.2% carbon.

The sample from the left side of the brow plate (Figure 58), adjacent to a hole, shows a microstructure consisting of a mixture of grains of ferrite with varying amounts of coarse pearlite, corresponding to a steel of perhaps 0.4% carbon in the central part of the plate and 0.2% carbon near the surfaces. There is a row of slag inclusions along the central line, which leads to a corrosion crack. This is presumably the result of a billet having been imperfectly forged when the original plate was made, and having opened up during subsequent working.

Figure 54. Open burgonet. Italian, probably Milan, ca. 1550. The Metropolitan Museum of Art, Gift of William H. Riggs, 1913, 14.25.602

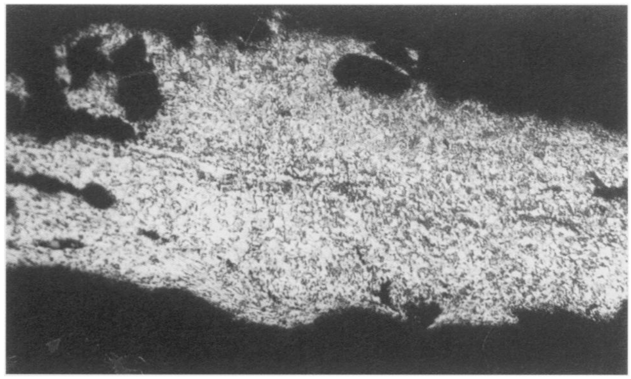

Figure 55. Sample from open burgonet in Figure 54 (× 140). Partly spheroidized pearlite and ferrite

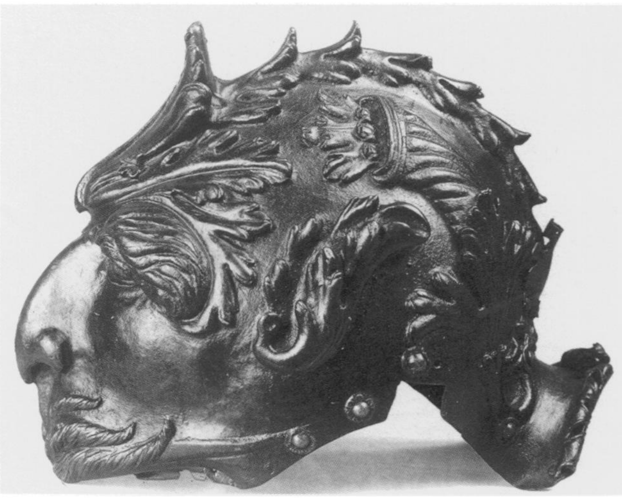

Figure 56. Burgonet. Italian, probably Milan, ca. 1540. Wallace Collection, London, A.106 (photo: reproduced by permission of the Trustees of the Wallace Collection)

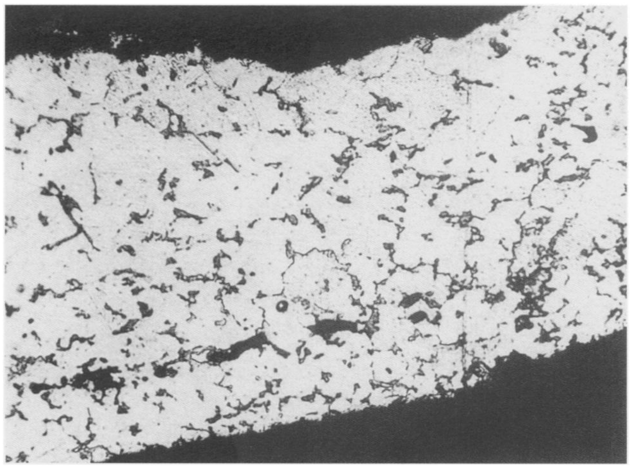

Figure 57. Sample from nape of burgonet in Figure 56 (× 200). Ferrite and pearlite

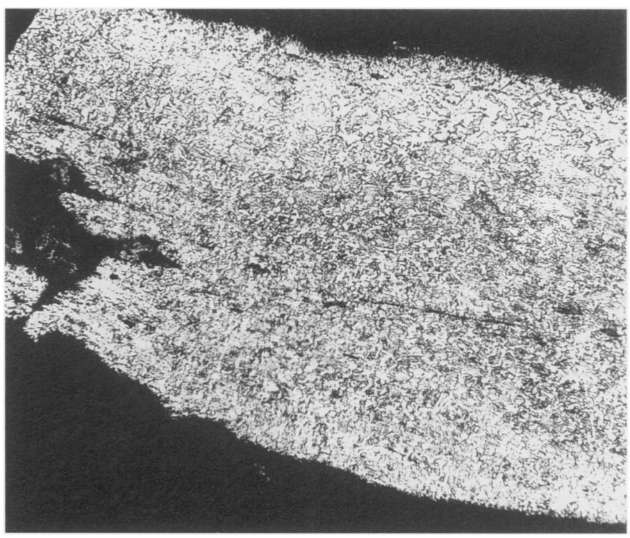

Figure 58. Sample from left side of brow plate of burgonet in Figure 56 (× 140). Cross-section. Pearlite and ferrite

Wallace A.108. Embossed burgonet. Italian, probably Milan, ca. 1540. Wallace Collection, London (Figure 59).[21]

The sample (Figure 60) shows a microstructure consisting mostly of grains of ferrite with a little grain-boundary cementite (from completely divorced pearlite). This is a low-carbon steel (0.1% carbon or less) that has undergone a good deal of hot-working.

Wallace A.205. Visor. Italian, probably Milan, ca. 1540. Wallace Collection, London (Figure 61).[22]

The sample (Figure 62) shows the lower right rim in section. Its microstructure consists mainly of pearlite (rather spheroidized) with a little ferrite and a few slag inclusions. This is a medium-carbon steel that has undergone a good deal of hot-working. Microhardness = 237 VPH.

Figure 59. Burgonet. Italian, probably Milan, ca. 1540. Wallace Collection, London, A.108 (photo: reproduced by permission of the Trustees of the Wallace Collection)

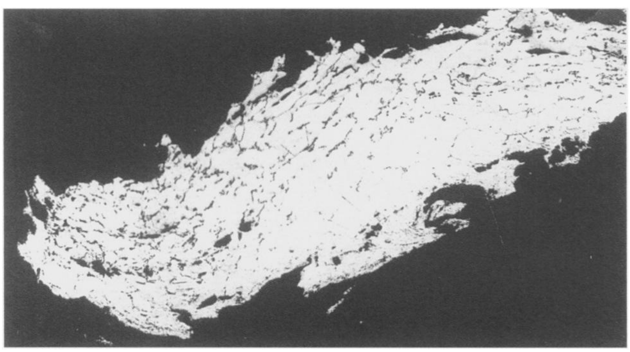

Figure 60. Sample from burgonet in Figure 59 (× 100). Ferrite and completely spheroidized pearlite

Figure 61. Visor. Italian, probably Milan, ca. 1540. Wallace Collection, London, A.205 (photo: reproduced by permission of the Trustees of the Wallace Collection)

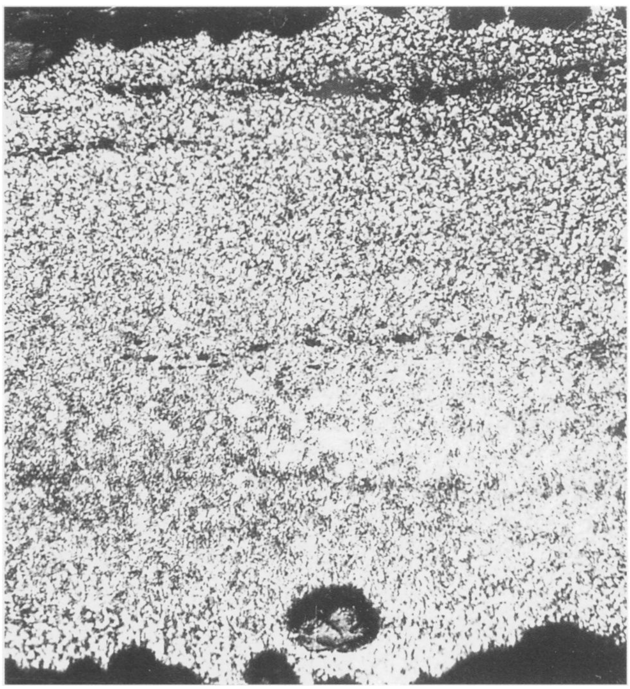

Figure 62. Sample from visor in Figure 61 (× 160). Cross-section. Partly spheroidized pearlite and ferrite

Figure 63. Pauldron. Italian, probably Milan, ca. 1530–50. Wallace Collection, London, A.241 (photo: José-A. Godoy; reproduced by permission of the Trustees of the Wallace Collection)

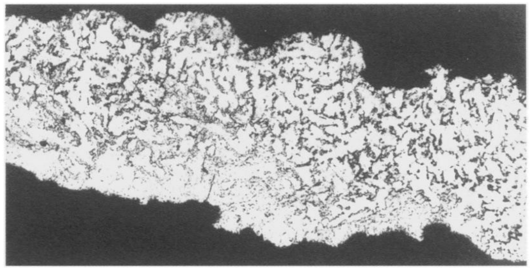

Figure 64. Sample from pauldron in Figure 63 (× 100). Ferrite and spheroidized pearlite

Wallace A.241. Pauldron in the form of a lion mask. Italian, probably Milan, ca. 1530–50. Wallace Collection, London (Figure 63).[23]

The sample (Figure 64) shows a microstructure consisting mostly of grains of ferrite with a little divorced pearlite, corresponding to a low-carbon steel (about 0.2% carbon) which has undergone hot-working.

Wallace A.353. Chanfron with embossed decoration. Italian, Milan or Mantua, ca. 1540. Wallace Collection, London (Figure 65).[24]

This was examined near the edge, in section. The sample (Figure 66) shows a microstructure consisting mostly of pearlite with a little ferrite, separated by a line of slag inclusions from a border zone, which is less than a quarter of the thickness of the section and consists of ferrite with a little pearlite. So the carbon content is about 0.5%–0.6%, except for this band of about 0.2%. Overall, this is a medium-carbon steel. The pearlite is largely divorced, showing that this steel has undergone a good deal of hot-working.

Figure 65. Chanfron. Italian, Milan or Mantua, ca. 1540. Wallace Collection, London, A.353 (photo: reproduced by permission of the Trustees of the Wallace Collection)

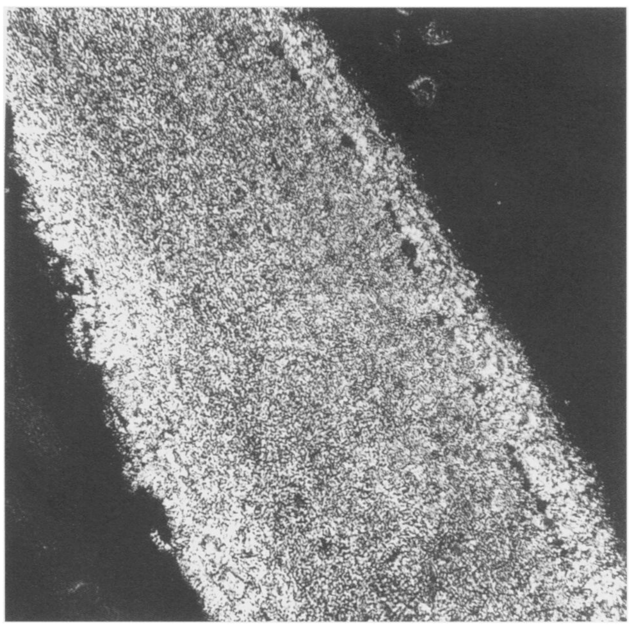

Figure 66. Sample from chanfron in Figure 65 (× 140). Cross-section. Pearlite and ferrite. Note the line of slag inclusions

Figure 67. Burgonet. Italian, probably Milan, ca. 1540–50. Armeria Reale, Turin, C.48 (photo: Armeria Reale)

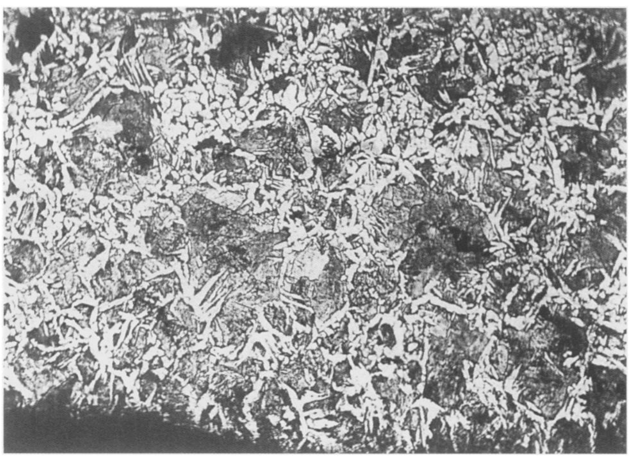

Figure 68. Sample from burgonet in Figure 67 (× 160). Pearlite and ferrite

Turin C.48. Burgonet (part of a composite armor *all'antica*). Italian, probably Milan, ca. 1540–50. Armeria Reale (Figure 67).[25]

The microstructure (Figure 68) consists of ferrite and slightly spheroidized pearlite, corresponding to an annealed medium-carbon steel of perhaps 0.5% carbon. Microhardness = 213 VPH.

Acknowledgments

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Notes

1. *The Coming of the Age of Iron*, ed. T. A. Wertime and J. D. Muhly (New Haven: Yale University Press, 1980), passim.
2. R. F. Tylecote, J. N. Austin, and A. E. Wraith, "Mechanism of the Bloomery Process in Shaft Furnaces," *Journal of the Iron and Steel Institute* 290 (1971), pp. 290, 342.
3. J. E. Thorold Rogers, *A History of Agriculture and Prices in England, 1259–1793*, 7 vols. (Oxford: Clarendon Press, 1866–1902), passim.
4. R. Walzel, "The 2000-Year Tradition of the Austrian Iron and Steel Industry," *Journal of the Iron and Steel Institute* 168 (August 1951), p. 366.
5. T. A. Wertime, *The Coming of the Age of Steel* (Chicago, 1962), p. 289.
6. V. Biringuccio, *Pirotechnia* (Venice, 1540), English translation, C. S. Smith and M. T. Gnudi (1942; reprint, New York, 1959), p. 67; and G. Agricola, *De re metallica* (Basel, 1556), English translation, H. C. and L. H. Hoover (1912; reprint, New York, 1945), p. 342.
7. A. R. Williams, "Slag Inclusions in Armour Plate," in *Bloomery Ironmaking during 2000 Years: Proceedings of a Conference Held at Budalen*, ed. A. Espelund (Trondheim, 1993), vol. 3, p. 115.
8. A. R. Williams, "Fifteenth Century Armour from Churburg: A Metallurgical Study," *Armi Antiche* 32 (1986), pp. 3–82.
9. A. R. Williams, "Italian Armour of the 16th Century in the Royal Armoury of Turin," *Armi Antiche*, 1987, pp. 27–75.
10. A. R. Williams, "Italian Armour and Cosimo de' Medici," *Journal of the Arms and Armour Society* 13 (1991), pp. 293–315.
11. A. R. Williams, "Milanese Armour and Its Metallurgy," in *Medieval Europe Brugge 1997: Papers of the Conference*, ed. Guy de Boe and Frans Verhaeghe (Zellik, Belgium: Institut voor het Archeologisch Patrimonium, 1997), vol. 11, pp. 61–70.
12. A. R. Williams, "Slag Inclusions in Armour," *Historical Metallurgy* 24 (1991), pp. 69–80. By contrast, German armor followed a somewhat different technology. It should be noted that the renowned Augsburg armorer Lorenz Helmschmied (recorded 1467–died 1516) hardened (by quenching and tempering) the armors that he made during the last quarter of the fifteenth century, but he did not directly gild them, instead applying their decoration by means of brass borders riveted on. Subsequently South German armorers found out how to combine the processes of gilding and tempering, and after them, the English Royal Armoury at Greenwich. On this subject, see A. R. Williams, "Augsburg Craftsmen and the Metallurgy of Innsbruck Armour," *Journal of the Arms and Armour Society* 14 (1993), pp. 121–46; and A. R. Williams with A. de Reuck, *The Royal Armoury at Greenwich, 1515–1649*, Royal Armouries Monograph No. 4 (London, 1995).
13. Pure silver after annealing—heating to redness and then quenching in water—has a hardness of about 30 VPH. The presence of a little copper hardens silver appreciably, and annealed "sterling" (92.5%) silver has a hardness of about 50 VPH. On standing for many days after annealing, its hardness will increase further to 90–100 VPH. Pure copper has a hardness of about 45 VPH. See *Metals Handbook*, 9th ed. (Metals Park, Ohio: American Society for Metals, 1978–89), vol. 2, p. 676.
14. The arm pieces were not included in the exhibition but were discussed under cat. no. 19 and illustrated as fig. 48 in Stuart W. Pyhrr and José-A. Godoy, *Heroic Armor of the Italian Renaissance: Filippo Negroli and His Contemporaries*, exh. cat. (New York: Metropolitan Museum of Art, 1998).
15. Formerly on loan to the Museo Nazionale di Castel Sant'Angelo, Rome, this lame was recently returned to the Bargello, where it is inventoried with the two mail-and-plate arm defenses M.1502–1503 (see Figure 8). For the sake of clarity, this single lame is referred to here by the inventory number M.1503[bis]. The relationship of this plate to the so-called bat-wing or Fame armor (cat. no. 23) was only recently recognized by Stuart Pyhrr (*Heroic Armor*, p. 139) based on a photograph taken by the author in 1986. It was on that occasion that the author tested the lame under discussion. The Bargello lame matches exactly the upper lame of the three-lame pauldron fragment in the Museo Stibbert, florence, which was exhibited in "Heroic Armor of the Italian Renaissance" (cat. no. 23d). Although published as belonging to the left pauldron, the Stibbert fragment was found at the time of installation in New York to fit perfectly under the right pauldron belonging to the Metropolitan Museum (MMA 14.25.714i, cat. no. 23e) and was displayed in that position in the exhibition. The Bargello lame, which thus belongs to the left pauldron (for which the main plate is in the Bargello, M.778, cat. no. 23c), was mentioned in the catalogue (p. 139) and is illustrated (but not specifically discussed) in C. A. Luchinat and M. Scalini, eds., *Opere d'arte della famiglia Medici*, exh. cat., Forbidden City, Beijing (Cinisello Balsamo: Amilcare Pizzi, 1997), p. 203, no. 78.
16. Tabulated results of the samples from armors not in the exhibition:

MMA 14.25.597	iron		
MMA 14.25.602			med C
Wallace A.106 (2 parts)		low C	med C
Wallace A.108		low C	
Wallace A.205			med C
Wallace A.241		low C	
Wallace A.353			med C
Turin C.48			med C

Category	Iron	Low-carbon steel	Medium-carbon steel	Total
other Italian embossed armor	1	3	5	9

17. Stuart Pyhrr informs me that all of the examples discussed below were examined by him, José-A. Godoy, and (with the exception of burgonet C.48 in Turin) Lionello Boccia, and were rejected as works by Filippo or Giovan Paolo Negroli.
18. B. Dean, *Handbook of Arms and Armor: European and Oriental, including the William H. Riggs Collection* (New York: Metropolitan Museum of Art, 1915), pl. xxxv; B. Dean, *Handbook . . .*, 4th ed., rev., with a chapter on the Bashford Dean Memorial Gallery by S. V. Grancsay (New York: Metropolitan Museum of Art, 1930), fig. 85; M. Scalini, *Armature all'eroica dei Negroli* (Florence: Bargello, 1987), pp. 29–30, fig. 20; L. G. Boccia, "Le armature dei Negroli," *Poiein/Quaderni di culture artistica del Ministero della Pubblica Istruzione*, 1993, no. 6, pp. 16, 22. Scalini (*Armature all'eroica dei Negroli*) attributes this burgonet to Giovan Paolo Negroli, suggesting that it belonged to a garniture of the future

Henry II of France; the attribution and French association were rejected by Boccia ("Le armature dei Negroli"). I thank Stuart Pyhrr for these bibliographic references and for those in the following notes.

19. Formerly in the collections of Samuel Rush Meyrick (for which see J. Skelton, *Engraved Illustrations of Antient Armour from the Collection at Goodrich Court, Herfordshire* . . . [Oxford, 1830], vol. 1, pl. LXX, figs. 2, 3), Alessandro Castellani (sale, Hôtel Drouot, Paris, April 7–8, 1879, lot 74), and Charles Stein (sale, Galerie Georges Petit, Paris, March 10–14, 1886, lot 135), and published in Dean, *Handbook* (1915), pl. XXXV, and idem, *Handbook* (1930), fig. 85.

20. J. G. Mann, *European Arms and Armour,* Wallace Collection Catalogues (London, 1962), vol. 1, pp. 111–12; A. V. B. Norman, *European Arms and Armour Supplement,* Wallace Collection Catalogues (London, 1986), p. 49; Scalini, *Armature all'eroica dei Negroli,* pp. 27–28, fig. 17. The authorship of this helmet has sometimes been ascribed to Filippo Negroli (notably by C. R. Beard, "A New-Found Casque by the Negroli," *Connoisseur* 101 [June 1938], pp. 295, 297), but this attribution was rejected by Norman (*Supplement*) and by Scalini (*Armature all'eroica dei Negroli*), the latter suggesting that the workmanship was more in the manner of Giovan Paolo Negroli.

21. Mann, *European Arms and Armour,* vol. 1, pp. 112–13; Norman, *Supplement,* pp. 49–51. The burgonet has been attributed both to Filippo Negroli and to the Mantuan armorer Caremolo Modrone (for a discussion of the attribution, see Norman, *Supplement*).

22. Mann, *European Arms and Armour,* vol. 1, p. 157; Norman, *Supplement,* p. 75; Scalini, *Armature all'eroica dei Negroli,* p. 11; Boccia, "Le armature dei Negroli," p. 16; and Pyhrr and Godoy, *Heroic Armor,* p. 143. The scaly decoration of the visor has caused some scholars to consider it part of the so-called bat-wing armor of Guidobaldo II della Rovere attributed to Filippo Negroli (*Heroic Armor,* cat. no. 23); however, the lesser quality of the visor's workmanship and subtle differences from the della Rovere harness have led others (Norman, Boccia, and, most recently, Pyhrr and Godoy) to reject the association of the pieces and the attribution to Filippo.

23. Mann, *European Arms and Armour,* vol. 1, p. 173; Norman, *Supplement,* pp. 81–82.

24. Mann, *European Arms and Armour,* vol. 1, p. 214; Norman, *Supplement,* p. 102. Stuart Pyhrr informs me that, despite the frequent attribution to Modrone, this chanfron compares more closely to the chanfron belonging to the Roman Armor of Archduke Ferdinand II of Tyrol, which is considered to be a Milanese work of ca. 1540 (*Heroic Armor,* cat. no. 53).

25. F. Mazzini et al., *L'Armeria Reale di Torino* (Busto Arsizio: Bramante, 1982), p. 325, figs 7, 7b, where the helmet is tentatively attributed to Filippo and Francesco Negroli.