

SOME EARLY MEDIEVAL SWORDS IN THE WALLACE COLLECTION AND ELSEWHERE

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ABSTRACT - RESUMEN

The analysis of eight early medieval swords shows that some were made from a single piece of steel, while others had a steel cutting edge welded on. Heat-treatment to harden the steel was undertaken in six out of seven cases; the other proved to be a modern replica.

El análisis de ocho espadas altomedievales muestra que algunas de ellas fueron hechas a partir de una sola pieza de acero, mientras que a otras se les ha soldado un cortante filo de este material. El endurecimiento del acero mediante forja fue realizado en seis de siete casos, mientras que el restante se demostró que era una réplica moderna.

KEY WORDS - PALABRAS CLAVE

Metallurgy, steel, hardening swords, welded-on edges.

Metalurgia, acero, forja de espadas, soldadura en los filos.

Two ostensibly medieval swords from private collections were recently examined in the Conservation Department of the Wallace Collection, London, and after studying them the opportunity was taken to compare them with swords of similar form in the Wallace Collection, as well as four swords from the reserve collection of the Hofjagd- und Rüstkammer, Vienna.

SWORDS FROM THE WALLACE COLLECTION, LONDON:

WC456

A sword in the Wallace Collection, London (A.456; possibly of the 10th century) which has an inscription which may be read **HLI** on the crossguard, and another, apparently **Ω** (an omega), on the blade. The blade length is 76.5 cm., while the total length of the sword is 90.2 cm.

The overall hardness of the blade was measured with a Branson Sonodur electronic hardness tester at 5cm. intervals along the centre and a cutting edge, and the results shown on the accompanying diagram. The average hardness in the centre was 238 VPH and on the edges was 189 VPH.

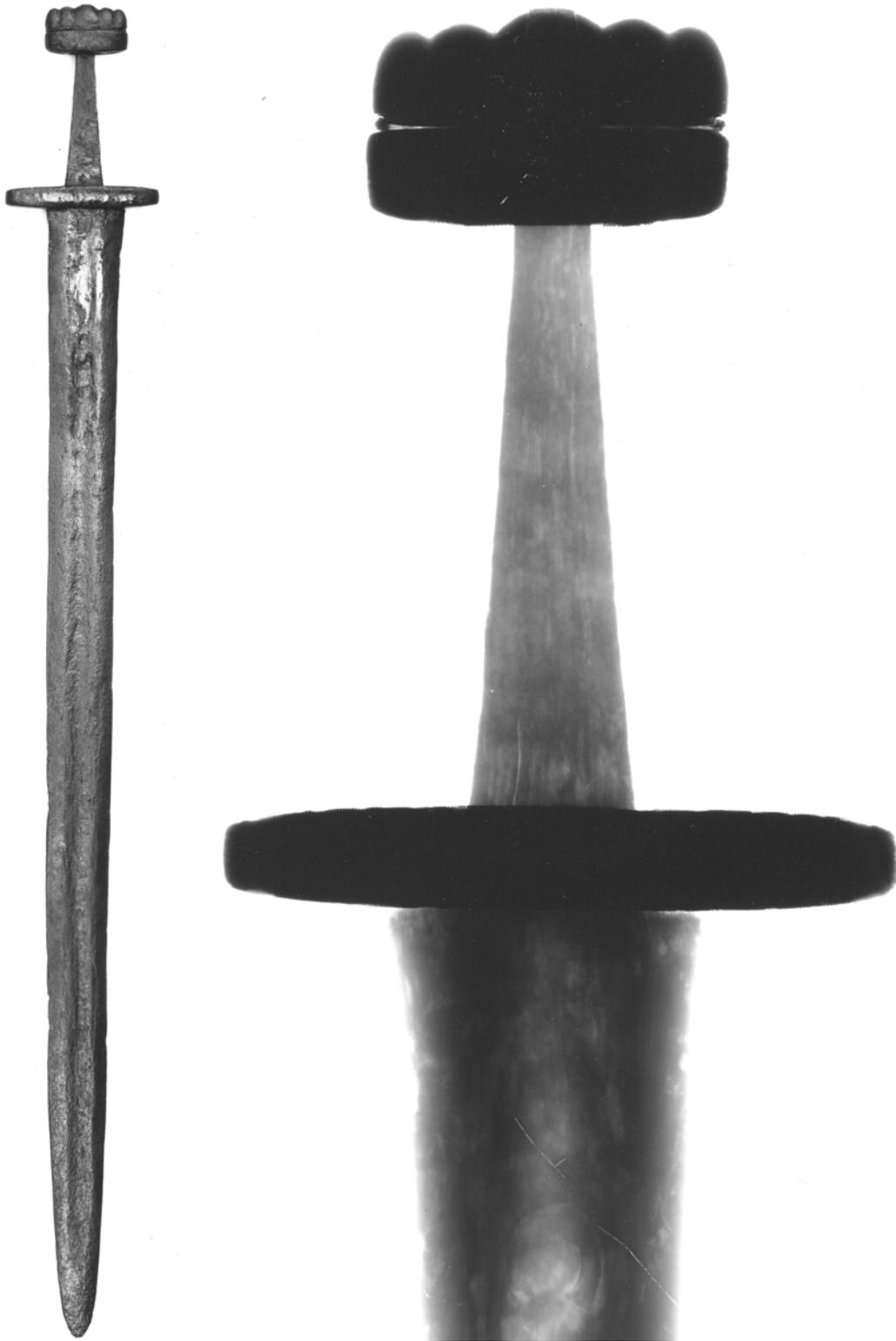


Fig. 1: 1.- Sword A456. 2.- A456, X-radiograph of hilt and part of blade Inscriptions on both sides of the blade are noticeable.

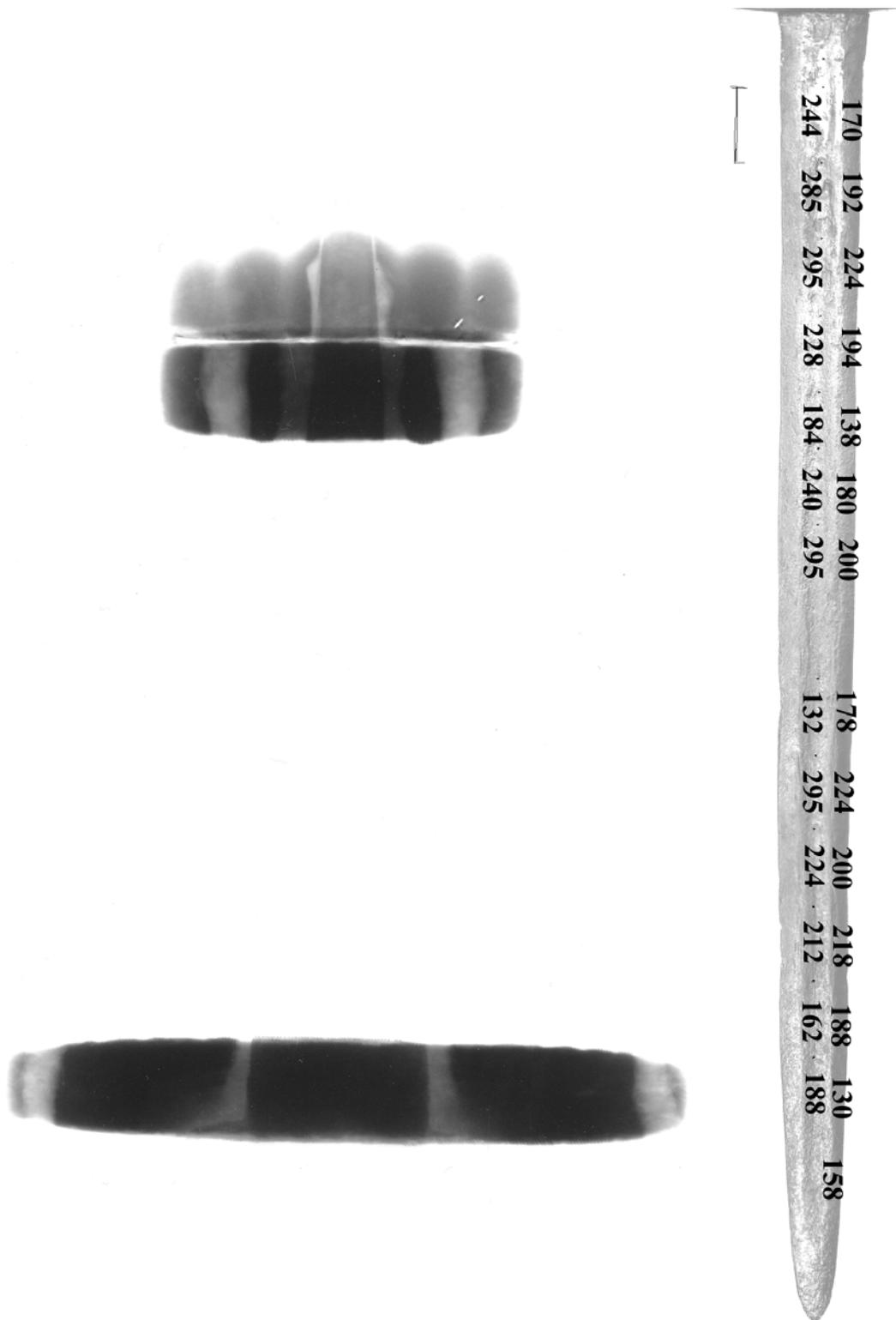


Fig. 2: 1.- Sword A456. X-radiograph of pommel crossquad, taken at higher energy.
2.- Photograph with surface VPH measurements.

WC457

Another sword in the Wallace Collection, London (A.457; possibly of the 12th century). The blade length is 82.2 cm., while the total length of the sword is 95.3 cm.

The overall hardness of the blade was also measured at 5 cm. intervals along the centre and a cutting edge, and the results shown on the accompanying diagram. The average hardness in the centre was 211 VPH and on the edges it was 279VPH.

FROM PRIVATE COLLECTIONS:

Sword (P.1) a «12th century» sword

The overall hardness of the blade was measured with a Branson Sonodur electronic hardness tester, and found to be below 200 VPH everywhere, except for the pommel, which was somewhat harder. Traces of welding (Fig. 4:2) were found at the joint of the hilt and the blade (Fig. 4:2).

A sample was detached from the edge of the blade below the hilt, and the microstructure is shown below. It consists of ferrite and a little pearlite, with no visible slag. The pearlite is concentrated in bands (where the carbon content reaches about 0.1%) and the ferrite grains there are somewhat smaller than the ferrite grains in the carbon-free areas. In both cases, however, the ferrite grain size is remarkable for its consistency.

The uniformity of the microstructure, and the absence of slag, both argue for a mild steel which has been homogenised by melting (i.e. after c. 1880) and the regularity of the banding suggests mechanical rolling. It is clear that this sword is a modern replica.

Sword (P.2) «Ulfbehrt» sword

A sword from a private collection, with an inscription on the blade, which may be read as **VLFBEHRT**.

A sample was detached from the broken end of the blade. Despite the presence of corrosion products, sufficient metal is present for the microstructure from the edge of the blade to the centre of the sword to be visible. It may be assumed that the microstructure of the other half of the blade will be a mirror-image of the half examined.

The microstructure of the central body consists mostly of ferrite with some small areas of martensite. The microstructure of the edge consists of uniform tempered martensite. No pearlite is visible, arguing for a full quench. The sudden change in carbon content at the joint, and the absence of a marked hardness gradient within the edge (which would argue for a carbon gradient in martensite) demonstrates that this blade has not been made by case-carburising an iron body. There is a lightly-coloured band within the martensite near to the joint, which suggests that an element (perhaps from a welding flux) has been segregated, and this has caused the martensite there to etch to a different colour.

The hardened steel zone is approximately 6mm in depth at the edge, falling to less than 2mm near the centre. Its average hardness is 467 VPH (range 423-540). The hardness of the core falls to 236 VPH. A microhardness profile is shown below.

The blade consists of a central body of a billet of low-carbon steel, around which a layer of medium-carbon steel (perhaps 0.5% - 0.6%C) has been wrapped. This forge-welding has been skilfully done, and very little slag seems to have been incorporated at the joint. This composite billet has then been forged into the shape of the blade, fully quenched and then tempered.

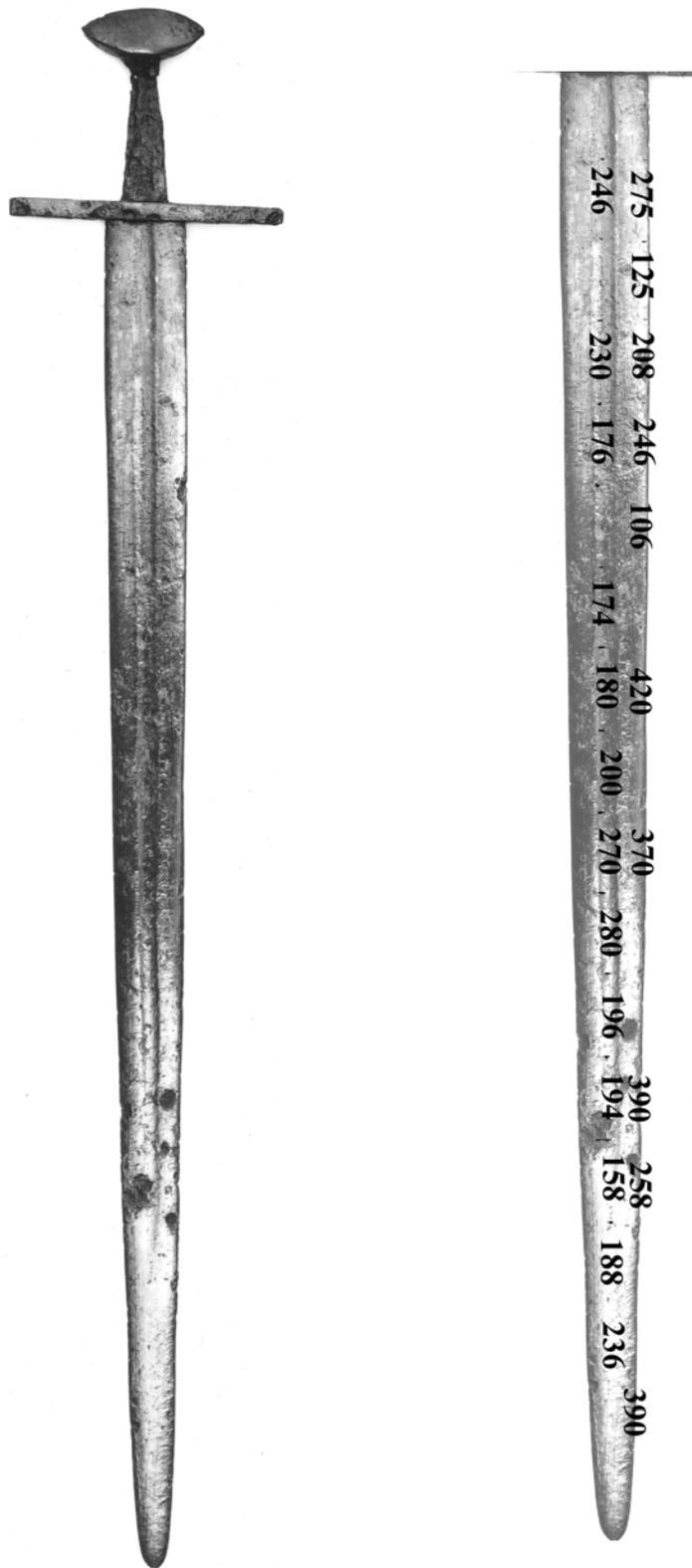


Fig. 3: 1.- Sword A457. 2.- A457. Photograph with surface measurements.

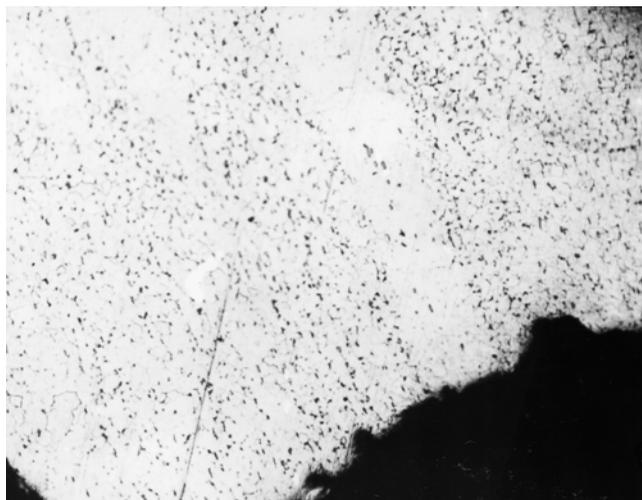
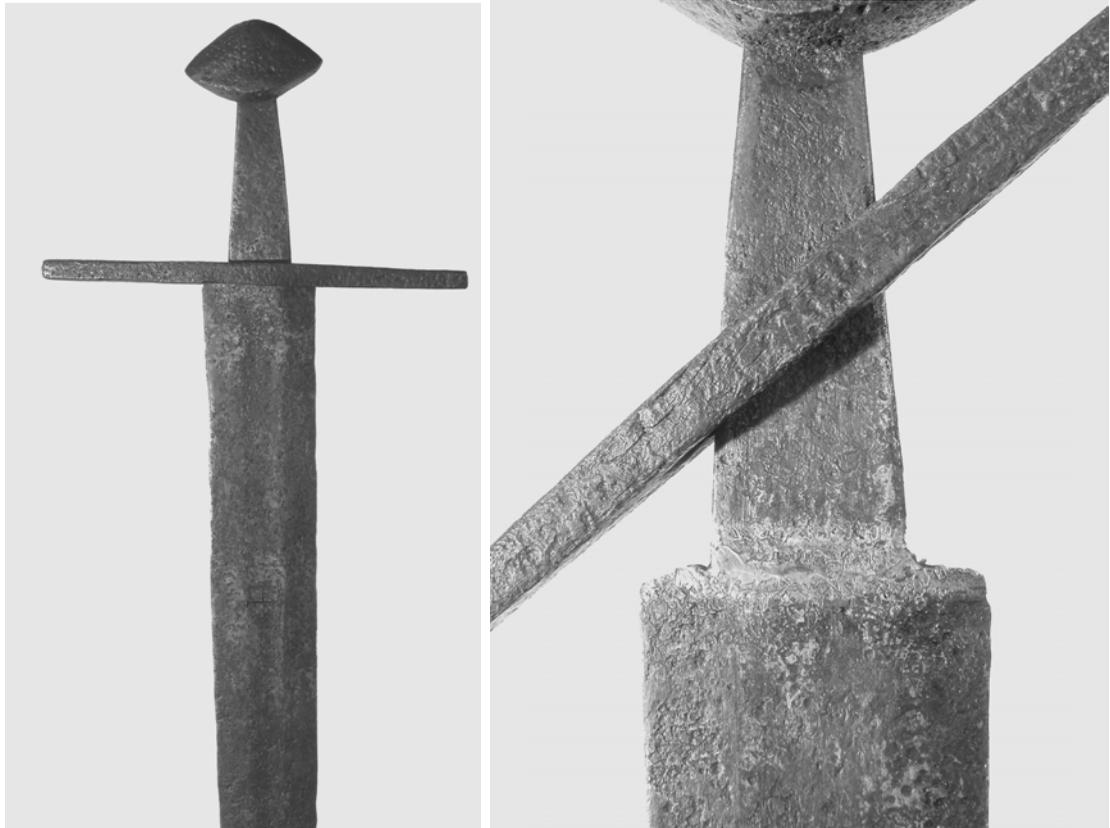


Fig. 4: 1-2.- Sword. Private collection (P1). 3.- P1. Photomicrograph at X 90 mag.

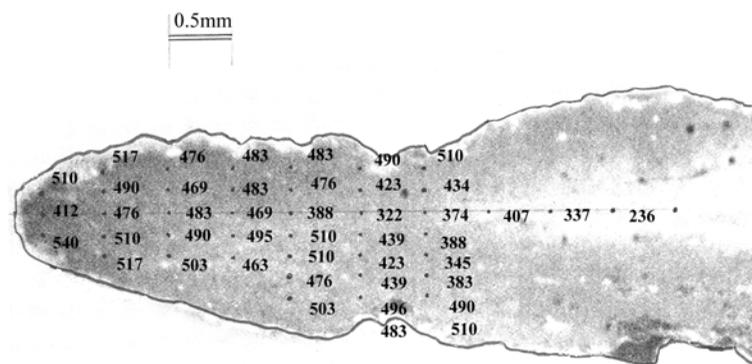
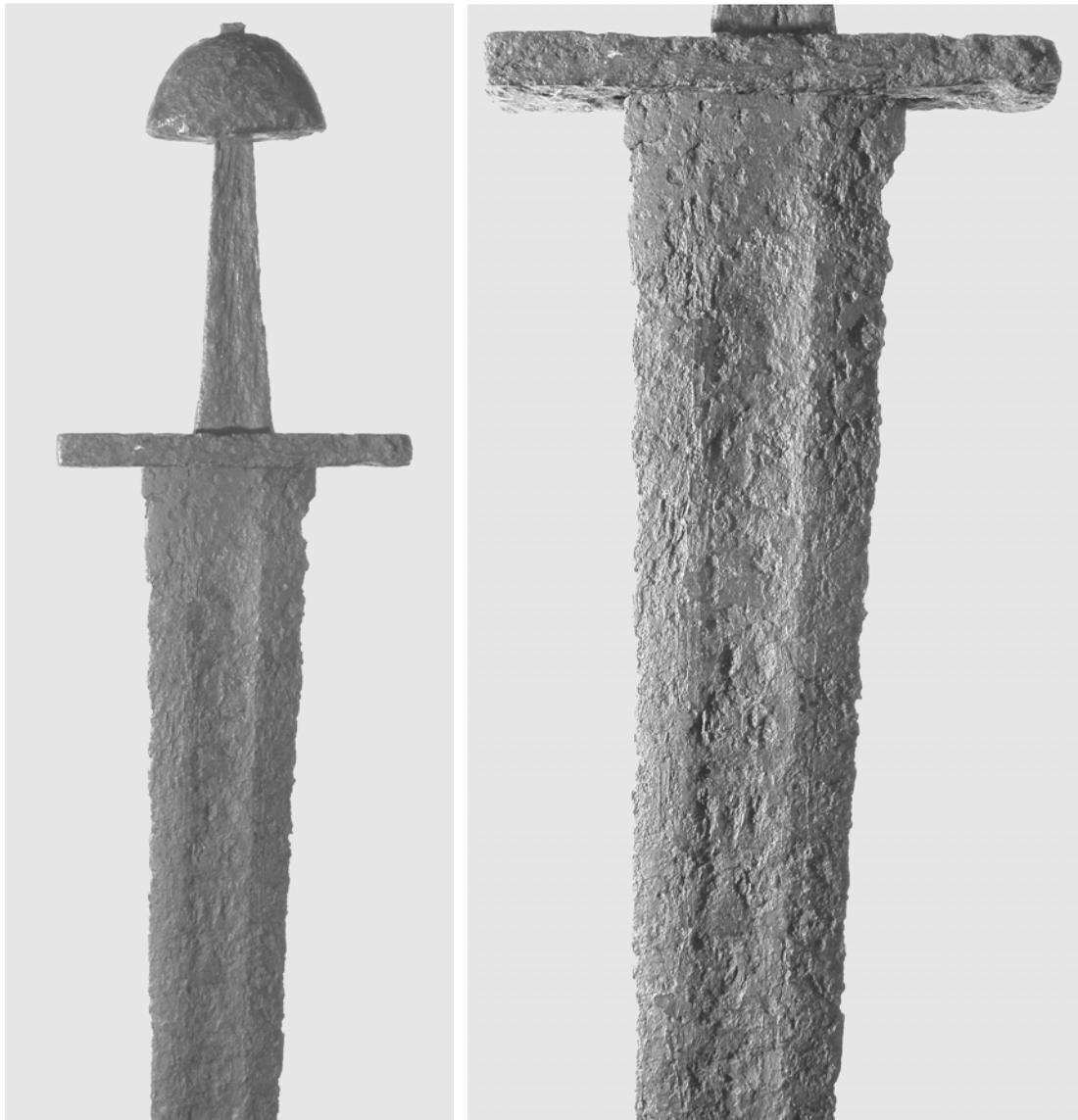


Fig. 5: 1-2.- Sword. Private collection (P2). 3.- P2. Microhardness profile of cutting edge.

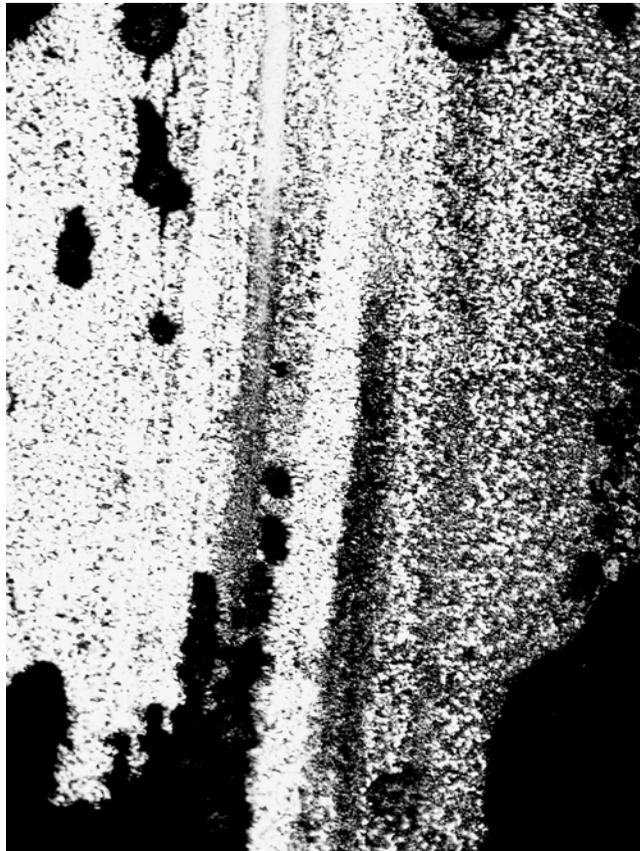
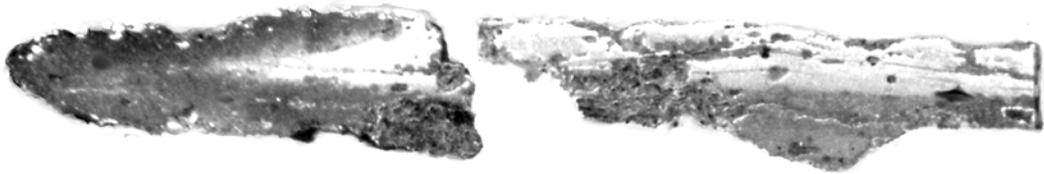


Fig. 6: Sword. Private collection (P2). 1.- Photomicrograph of section from edge to middle (15 mm in depth). 2.- Photomicrograph showing martensite and ferrite in bands.

Swords from the Hofjagd- und Rüstkammer, Vienna:

A.46

Sword with round pommel.

The surface hardness of the blade along the cutting edge was measured with a Branson Sonodur electronic hardness tester, and found to vary from 108 to 320; average = 176 VPH.

The condition of the surface made it possible to detach two specimens for microscopic analysis: A46F1 from the surface. A46F2 from the mid-edge.

The microstructure of A46F2 shows an area of quite coarse tempered martensite, with carbide granules visible at only 160X magnification, adjacent to an area of very fine pearlite with a little ferrite. There is more granular carbide in the zone between these two areas. The pearlitic area has evidently been cooled quickly, but not quite quickly enough to form martensite.

The microstructure of A46F1 shows areas of tempered martensite, mixed with varying proportions (but less than half) of ferrite grains. There are very few slag inclusions, but a number of corrosion cavities.

Without being able to view a section, one can only speculate as to its fabrication, but it seems that the outside and the cutting edges, at least, were made of steel. The blade was hardened by (almost fully) quenching, and then tempering.

Microhardness (100g load) ranges from 246 to 325; average = 305 VPH.

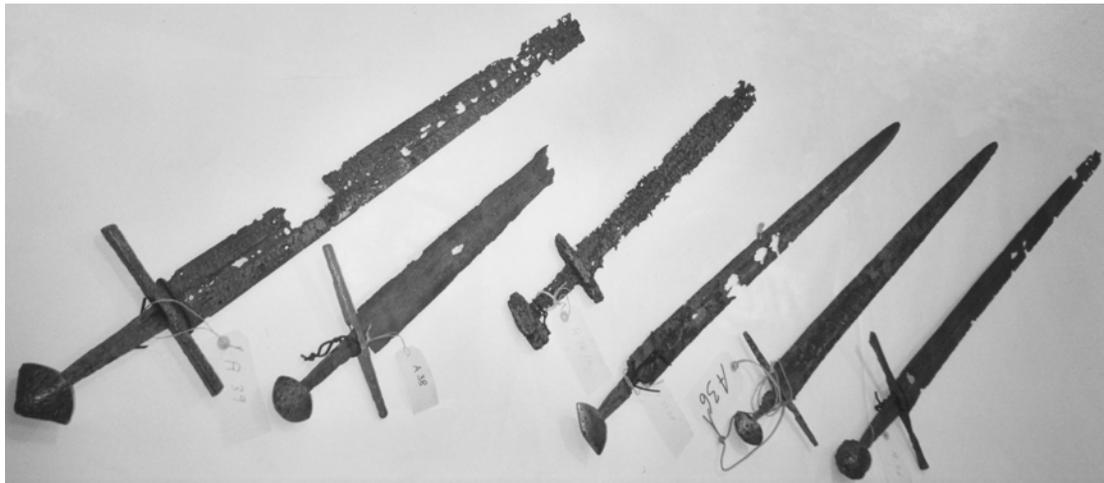


Fig. 7: Swords from the Hofjagd und Rüstkammer on storeroom table. From left to right: A39, A38, A2050, A2358, A36.

A.36.

Sword with round pommel.

The surface hardness of the blade along the cutting edge was measured with a Branson Sonodur electronic hardness tester, and found to vary from 119 to 520; average = 217 VPH.

The condition of the surface made it possible to detach 4 specimens for microscopic analysis.

A36F1 from the edge at 66 cm distance. A36F2 from the hilt near the pommel.

A36F3 from the hilt near the centre. A36F4 from the edge near the crossguard.

Both specimens from the hilt show microstructures of ferrite only with a few slag inclusions. It is scarcely surprising that the hilt is simply made of iron.

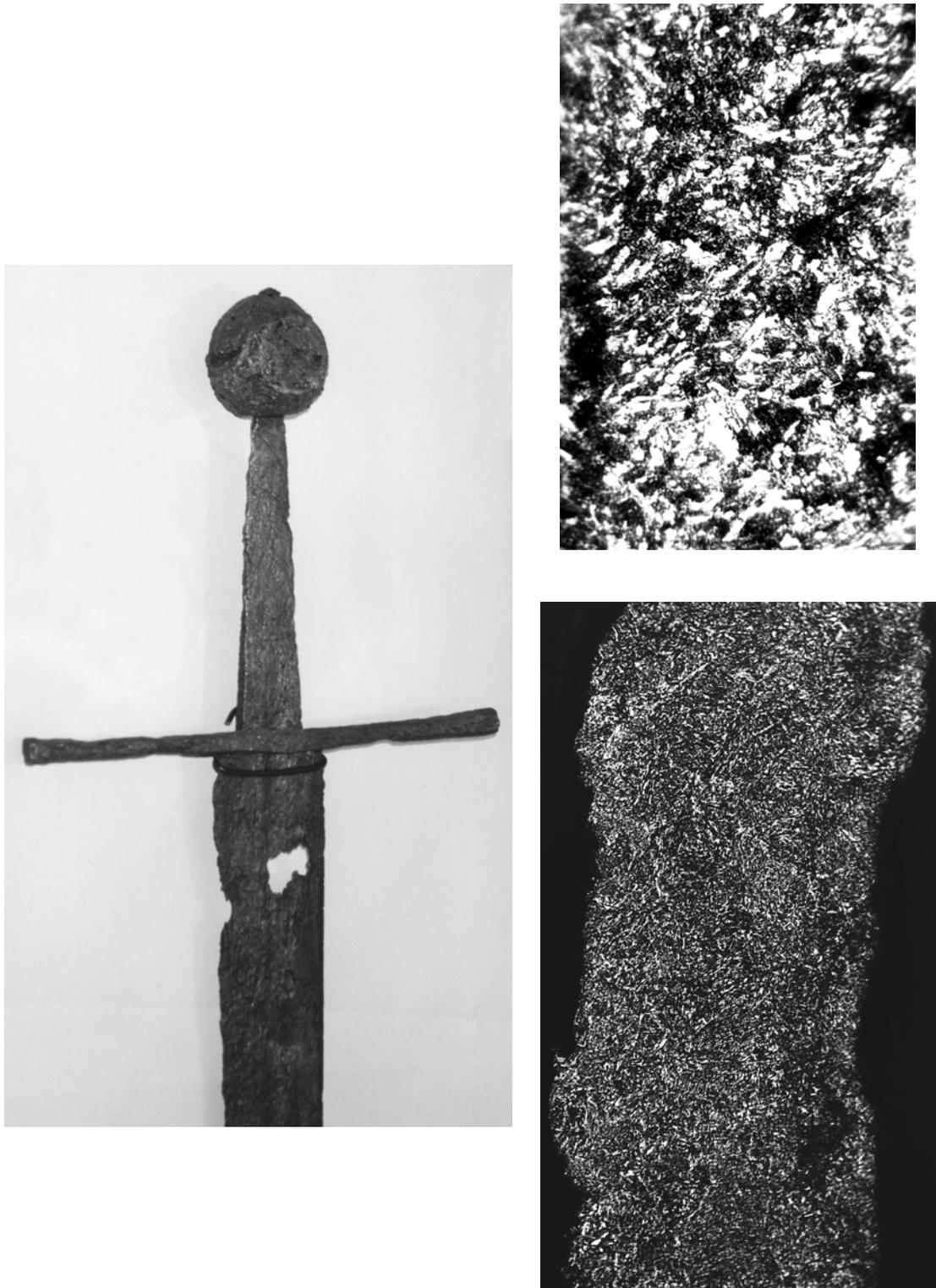


Fig. 8: 1.- Sword A46. 2.- Photomicrograph A46F2g x 800 shows de area where ferrite and granular carbides were formed on quenching, rather than martensite. 3.- Photomicrograph A46F2m x 160 shows the edge where it is fairly uniform tempered martensite.

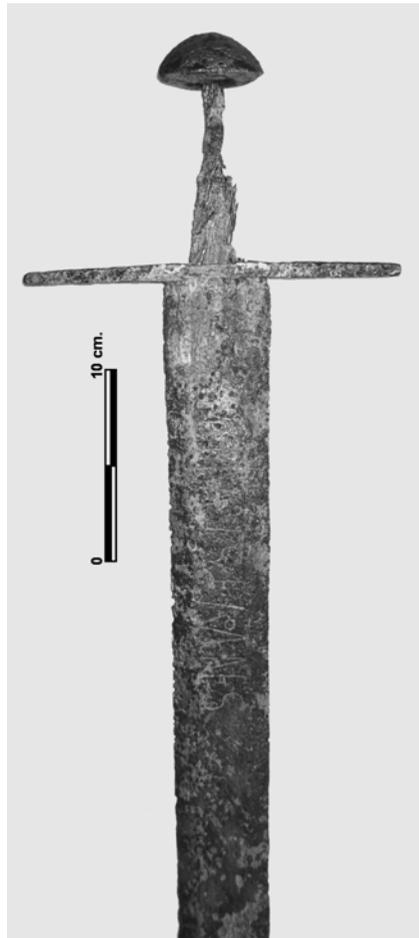


Fig. 9: 1.- Sword A36. 2.- Photomicrograph F1 x 160. Martensite near the edge.

The specimens from the edge show microstructures of tempered martensite mixed with ferrite (but no pearlite). In one sample (F4) at right angles to the length of the blade, ferrite predominates, and the areas of martensite are distributed in curving rows, presumably along forging lines. In the other sample (F1) tempered martensite predominates, with only a small area of ferrite.

Without being able to view a section, one can only speculate, but it seems probable that pieces of iron and steel were forged together to form the blade, with more steel along the cutting edges. The blade was then fully quenched and tempered.

Microhardness (100g load) ranges from 258 to 329; average = 300 VPH.

This is somewhat lower than the maximum surface hardness, but this could be explained by variations in the carbon content of the steel, perhaps 0.3% - 0.5%C.

A.2050

Sword with multi-lobed pommel.

The surface hardness of the blade along the cutting edge was measured with a Branson Sonodur electronic hardness tester, and found to vary from 91 to 200; average = 133 VPH.

The centre part of the blade shows a pattern-welded core.

The condition of the blade made it possible to detach 2 specimens (both showing the pattern-welded core) from the centre section for microscopic analysis.

The section of A2050F1 is parallel to the length of the blade.

The section of A2050F2 is at right angles to the length of the blade.

Both their microstructures show bands of high- and low-carbon metal. F1 shows a central band of pearlite mixed with a little ferrite (around 0.6%C) and some very elongated slag inclusions; on either side there are largely ferritic bands (around 0.1%C).

F2 shows a similar pearlitic band, with a smaller ferritic one.

This sword has been made by forging together pieces of steel (0.6%C) and iron. It has not been quenched after fabrication.

Microhardness (100g load) ranges from 199 to 322; average = 262 VPH.

A.39

Sword with brazilnut pommel.

The surface hardness of the blade along the cutting edge was measured with a Branson Sonodur electronic hardness tester, and found to vary from 104 to 365; average = 221 VPH.

The condition of the surface made it possible to detach 3 specimens for microscopic analysis.

The end of the blade had been broken off in the past, so it proved possible to take another sample from the tip, which shows the cross-section of the blade.

A39F1 from centre at 24 cm distance

A39F2 from centre at 61cm distance

A39F3 from edge at 48cm distance.

A39F1 Shows a microstructure consisting mostly of very fine pearlite (divorced to a carbide network in places), with little or no visible ferrite, but some cavities.

A39F2 shows a microstructure consisting entirely of tempered martensite, with a line of slag inclusions.

A39F3 shows a microstructure consisting entirely of rather coarse tempered martensite.

A39 Section shows a microstructure consisting entirely of tempered martensite, with a very little ferrite. There seems to be no visible variation from the edge to the centre.

This sword seems to have been made from a single piece of steel. After fabrication, it has been hardened by quenching and tempering.

Microhardness profile: Ranges from 239 to 318 VPH. Again, this is somewhat lower than the maximum surface hardness. The variations in hardness may be ascribed to varying carbon content, perhaps 0.2% - 0.5% C.

DISCUSSION:

From about the 3rd to the 10th century CE «pattern-welded» swords predominated in Europe, and they are the subject of a considerable literature (Anstee (1961), Smith (1962), Dunning (1964) Mihok (1993) and LaSalvia (1998) among others).

Pattern-welding (sometimes called «false Damascus» or «twisted Damascus») developed from the Celtic technique of piling as a means of making long blades from many small pieces of metal with varied compositions (Pleiner, 1993).

Pieces of iron and steel were twisted as they were welded together, and then the surface ground and etched with fruit acids to reveal a pattern, sometimes said to resemble snakes. The use of irons of high- and low-phosphorus contents, or even the presence of slag inclusions could lead to a visible pattern, even when there was little difference in carbon content between adjacent bands. The pattern visible on the surface may have contributed to their popularity, perhaps being reminiscent in appearance to blades made of «true Damascus» (wootz).

This technique was unlikely to improve the blade by making it stronger; indeed, pattern-welded blades were always likely to be less strong than one-piece blades, as the slag content would have been increased by the forge-welding, rather than reduced.

After about 1000 CE, the occurrence of pattern-welded blades diminishes, presumably because swordsmiths had access to more, and larger, blooms of steel, which made possible the forging of blades from a single piece (whether folded or not), although this technique was to continue in use in the Baltic states until as late as the 12th century (Anteins, 1968).

The sword from Vienna with a pattern-welded blade is typical of many such, being made from pieces of iron and medium-carbon steel (in this case, as high as 0.6% C) forge-welded together. Its edges would have been around 250 – 280 VPH.

It has not been hardened, which again is typical, as only a minority of such blades have been reported with hardened edges. Although it should be pointed out that a recent report by Lang (2003) describes a group of 5 pattern-welded swords from an Anglo-Saxon site in England, of which 3 had relatively high-carbon (~ 0.8% C) steel cutting edges that had been quenched to harden them. Another recent report (Selucka et al. 2001) describes a sword from a 10th century grave at Nemilany in Moravia, with an ULFBEHRT inscription on the blade, which is now kept in the Regional Museum at Olomouc, Czech Republic. Like the sword described here, it had a core of varying carbon content, of microhardness up to 235 VPH, with welded-on steel cutting edges which had been hardened, to 320 – 460 VPH, by quenching.

It should be observed that yet another blade with a similar inscription has been found by one of the authors to consist of a totally different metal. That «Ulfbehrt» sword was made of an air-cooled hypereutectoid steel of around 1.0% C (Williams, 1977). Since that account was published, a great deal more information has become available about the crucible steel industry of Central Asia (e.g. Craddock, 1995 and Feuerbach, 1997) and it seems likely that a cake of such a steel was the raw material for that blade; being virtually slag free and of hardness around 300 VPH, it must have been an exceptionally serviceable sword, and one which would keep its hard edges permanently. The maker of our «Ulfbehrt» sword had made what must have seemed to his customers at the time like a very good copy, with an edge hardness of over 460 VPH. Prolonged use might have altered their opinions; the cutting edge is only 6mm deep,

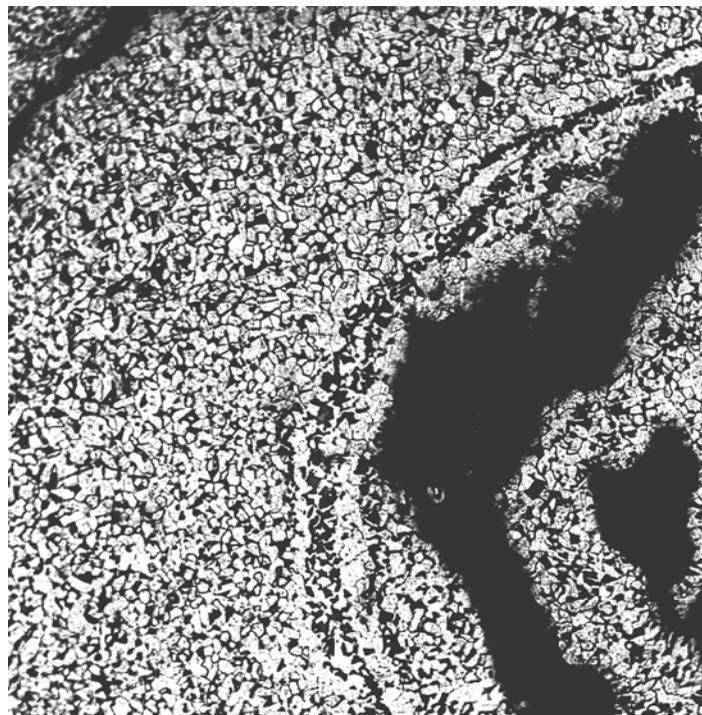
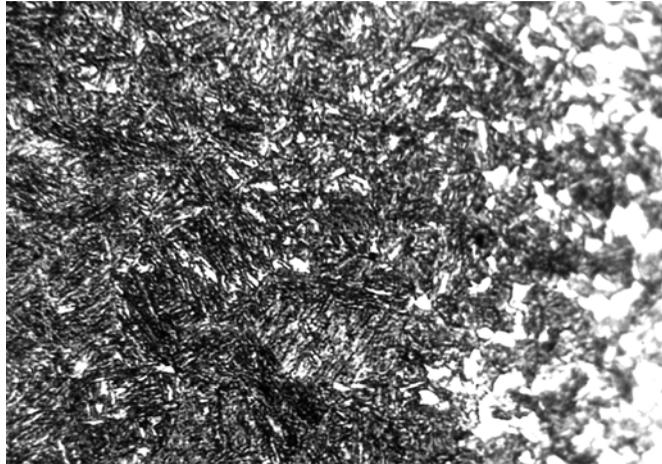


Fig. 10: 1.- Photomicrograph F1 x 800 tempered martensite and a little ferrite. 2.- Photomicrograph F4 x 160 at right angles to edge, ferrite and areas of martensite.

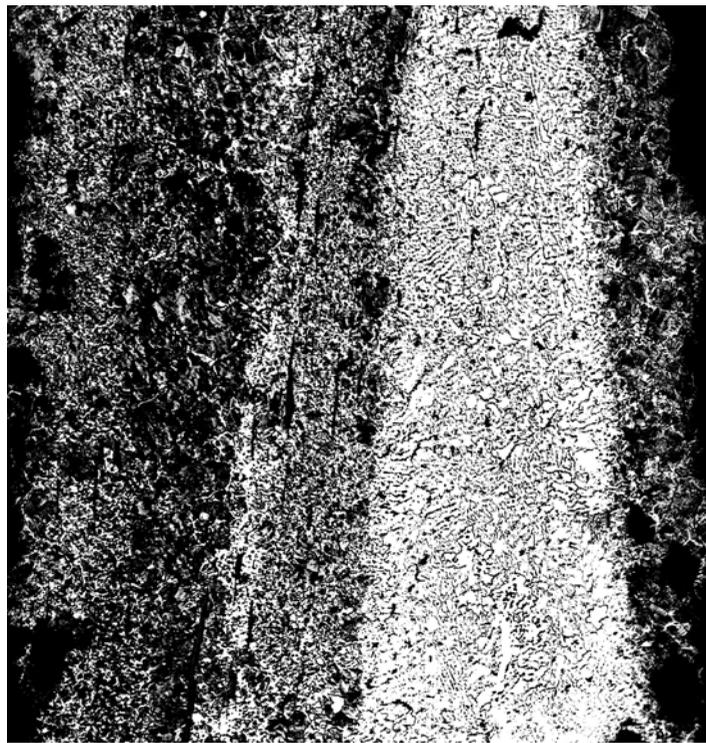
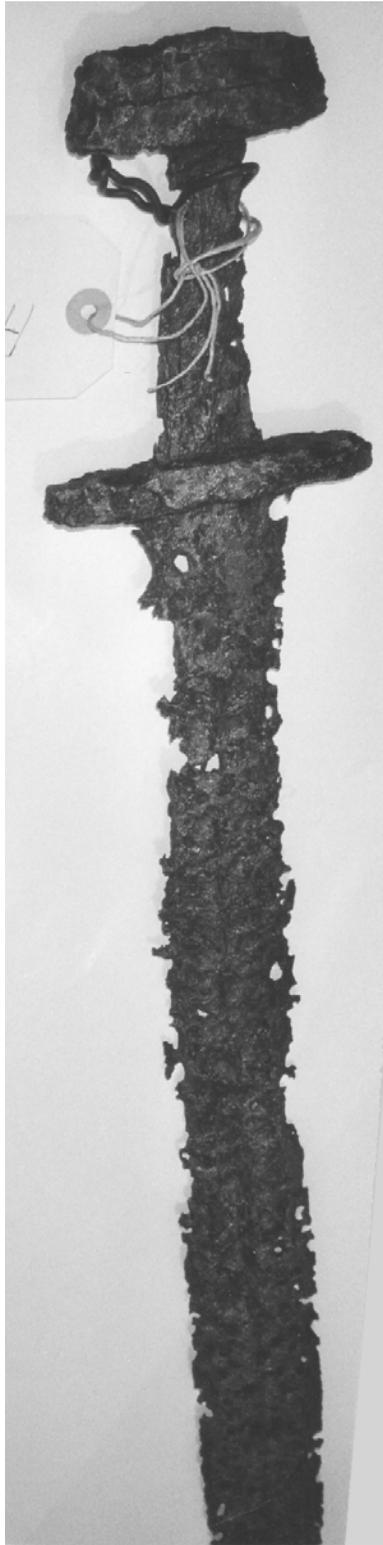


Fig. 11: 1.- Sword A2050. 2.- Photomicrograph A2050 F2X2 high – and low- carbon bands x 160, note the elongated slag inclusions.

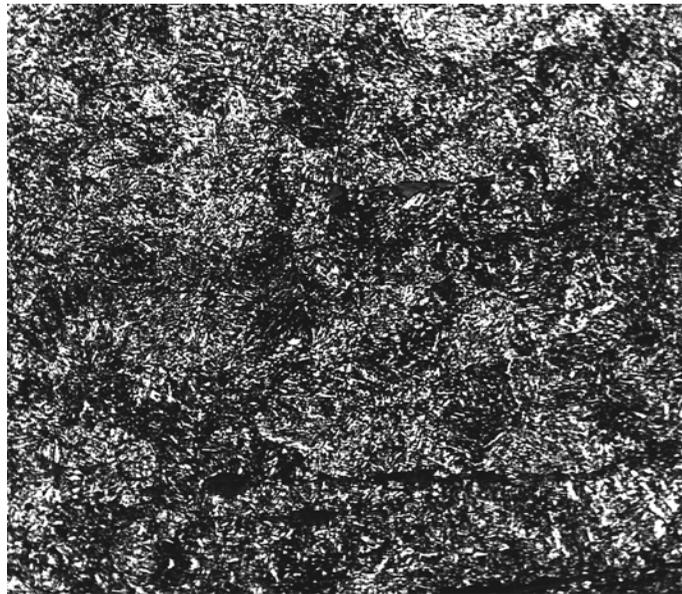


Fig. 12: 1.- Sword A39. 2.- Photomicrograph A39 sect 160; tempered martensite and elongated slag inclusions at X 160 mag.

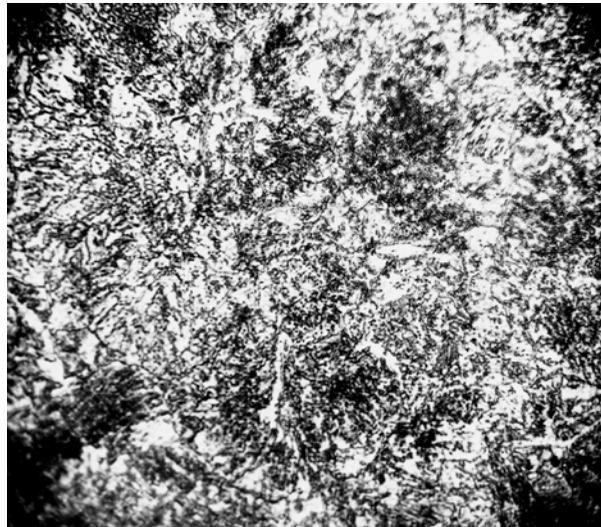
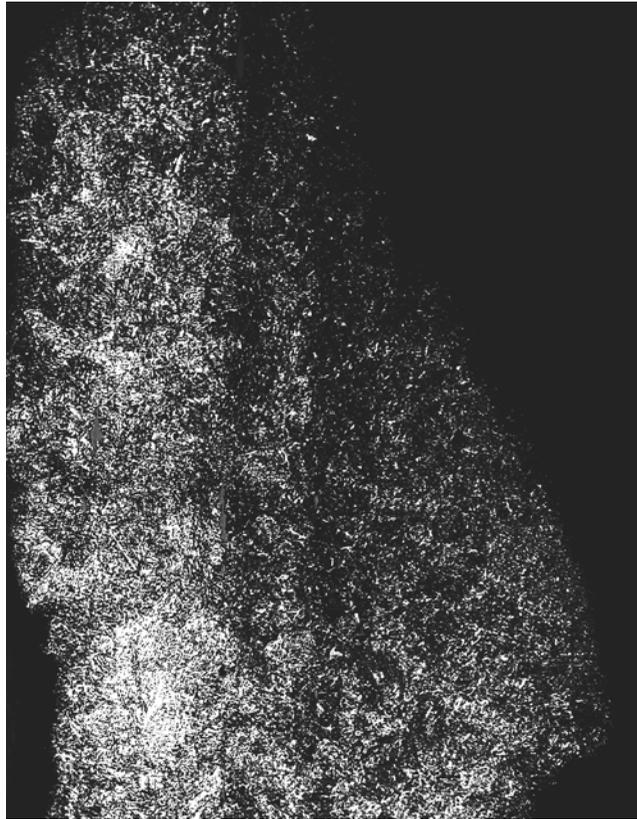


Fig. 13: 1.- 2.- Photomicrograph A39sect2 x 90; tempered martensite. 2.- Photomicrograph A39F2 X 800; tempered martensite and some acicular material.

and could have been removed by a few years of regular sharpening on a grindstone. It is also distinctly higher in slag content, and therefore more likely to fracture on impact.

Two of the other swords from Vienna have at least the edges made of hardened steel, with hardnesses in the region 300-350 VPH. Without sectioning them we cannot know for certain, but it seems probable that they were made by a method akin to that of the «Ulfberht» sword, in which steel edges were joined to an iron core by forge-welding. This not only enables better use to be made of an expensive raw material, steel, but also makes full-quenching feasible with much less risk of cracking or warping the blade.

The other sword from Vienna (A39) seems to have been made from a single piece of steel, albeit not of high carbon content as the maximum microhardness recorded was a moderate 318 VPH. However such a reasonable hardness, allied to a fairly low slag content, would still have yielded a very serviceable blade.

All of the swords from Vienna (unsurprisingly in view of their provenance) and our «Ulfberht» sword were swords of high quality. It is difficult to generalise on the basis of the small database that we have, but a great many medieval swords may have been of very modest metallurgical quality indeed. For example, Panseri published some years ago (1954) an analysis of an example of a 12th century knightly sword which consisted merely of a piled core and carburised (ferrite/pearlite) edges of hardness around 200-250 VPH, which would not have been significantly better than many Celtic swords of 1500 years earlier.

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