VIKING AGE SWORDS

from Telemark, Norway. An Integrated Technical and Archaeological Investigation

NORSKE OLDFUNN XXXIII

Irmelin Martens and Eva Elisabeth Astrup
with contributions from Kjetil Loftsgarden and Vegard Vike

CAPPELEN DAMM AKADEMISK

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Back cover photo: Sword, C24217, found Århus nordre, Hjartdal, Telemark. Photo: Kirsten Helgeland. ©The Museum of Cultural History, UiO/CC BY-SA 4.0.

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PREFACE

This book is the result of the cooperation between chemist Eva Elisabeth Astrup and archaeologist Irmelin Martens, both former professors at Museum of Cultural History at the University of Oslo.

The investigations presented in this book are intended to offer a metallographic analysis of Viking Age swords as an equal and important part of archaeological research on such weapons. The choice of swords from Telemark county was made partly because of the research on iron extraction I had carried out there.

Primary questions concerned weaponsmiths' knowledge and skills, but obviously such issues are closely related to a wide range of problems relating to the societies where the smiths lived and worked. Although we have raised and discussed some of these topics, it is beyond the scope of this project to fully explore societal factors.

I look back on the long-lasting collaboration between Eva Elisabeth Astrup and myself with much gratitude. This endeavour included the study and interpretation of X-radiographs, as well as many fruitful discussions of various aspects of Viking Age weapon production. Unfortunately, E.E. Astrup was unable to take part in the concluding discussions because of health problems. Our cooperation has always been very pleasant and rewarding and has added much to my knowledge and understanding of many complex questions. Her contribution goes far beyond the metallographic investigations and the other chapters where she is directly involved, and has been crucial to my intention and ability to finish this book. She was always conscious that her investigations are part of archaeological research, and her archaeological knowledge is extensive, yet always accompanied by open-minded curiosity.

Chapters 1, 2, 3, 4, 6.8 and 7 are written by me, chapter 5 written by Astrup and me, chapter 6 written by Astrup and chapter 6.7 is written by Vegard Vike.

We owe much to the Museum of Cultural History, University of Oslo, both for giving us office space and many other facilities during many years after retirement, and for financial support on several occasions. In the final phase, several members of the museum's staff, headed by Anne-Lene Melheim, have helped us in many ways, and I want to express my gratitude to all of them. Our special thanks goes to Ellen H. Holte for digitalising the photographs; to Johnny Kreutz for the drawings; Kjetil Loftsgarden for his very competent editorial work and good advice; Marianne Moen for correcting our English; Magne Samdal for producing the maps; Lisbeth Skogstrand, Unn Plahter and Anne Skogsfjord for help with illustrations; and Espen Uleberg for invaluable help with the main find table. Vegard Vike's participation in taking and producing digital X-radiographs has been indispensable. I am also grateful to the external reviewer for valuable criticism and comments. Last, but not least, I want to thank the editors Ann Kristin Gresaker, Marte Ericsson Ryste and Katia Stieglitz at Cappelen Damm Akademisk.

Oslo, September 2021
Irmelin Martens

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1. INTRODUCTION

Norwegian Viking Age swords were single or double-edged one-handed weapons, both of which were produced using the same types of metal, most often with iron hilts. With a blade length of 70–90 cm, and often richly decorated hilts, these swords have become defining artefacts of the period. The number of Viking Age swords found in Norway is by far the largest in any country. No exact number is available, but a reasonable estimate is more than 3,000. This is close to double what was known at the time of Jan Petersen's defining work on Norwegian Viking swords, *De Norske Vikingesverd* (1919).

In this book we will examine the approximately 220 Viking Age swords found in the county of Telemark (formerly Bratsberg amt) in southeastern Norway (see Figure 1).[1] Using X-radiographs and metallography, combined with hardness measurements, we shed new light on the materials and techniques used for the production of the swords, in addition to examining the cultural and historical contexts.

Where find circumstances are known, the swords come from graves. Many swords are single finds, but even such finds are usually assumed to be from burials. Occasionally weapons can also occur in votive deposits (Lund 2009:31–69).

The high number of swords is not the only feature distinguishing Norway. There are several hilt types that are numerous here – and some less common ones – which are rarely found outside the country, and which are undoubtedly of indigenous origin and manufacture (as discussed in Chapter 4).

The great number of single-edged swords is another characteristic trait for Norway. They were common, albeit with decreasing frequency, throughout most of the period. Petersen calculates 370 (1919:6) such swords. All blades were of the same shape, with a straight back and the edge curving to the tip (R 498).[2] The same type of hilt is found on both single and double-edged blades.

The large number of known Norwegian Viking Age swords means that swords were not only a weapon for society's upper classes, but also a symbol of free men. This is indicated by the wide distribution of finds in all parts of the country, including high numbers in the interior parts of Eastern Norway, where the central parts of Telemark are situated (Martens 2003:55ff).

As we will argue, these features show that there was comprehensive indigenous production of swords. This is a vital point for our studies and for understanding the social contexts of weaponsmithing in the Viking Age.

1.1 THE AIM AND METHODS OF RESEARCH

The aim of the research is to study the materials and techniques used on indigenously produced swords, while considering the degree of specialisation needed to produce them. We start with the specifications for a high quality sword both as a functional weapon and an aesthetic status object. A well-crafted sword needed a combination of strength, elasticity and sharp edges. Undoubtedly, only an experienced blacksmith could make such a sword. The prerequisites to achieve both functions are:

1. Good knowledge of the materials used and the ability to improve iron quality by carburisation in a predictable and successful way.
2. Skilled execution of the smithing process and possibly also secondary treatment: quenching and annealing.

The methods applied to study the blacksmiths' knowledge and skills are X-radiographs and metallography, combined with hardness measures. Metallography reveals far more details on sword blade construction, materials and possible secondary treatment, but can only be applied to a limited number of items; while radiographs can be used on all blades in which the metal has been preserved. A combination of the two methods is therefore important.

Blade typology or the ways in which pommels were fastened to the upper guard have not been considered – X-ray photographs of the guards were not made, and one characteristic of the most common indigenous hilt types is that they have no pommels.

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[1] All swords and other archaeological artefacts are identified with their corresponding museum number. Artefacts from the Museum of Cultural History are designated as C.xxxx, e.g. C.5544. Information is available at UniMus, a database of archaeological artefacts and samples from the archaeological university museums of Oslo, Stavanger, Bergen, Trondheim and Tromsø. See the university museums' web portals <http://unimus.no>

[2] R and a following number will in this publication relate to key artefacts in "Norske Oldsager" (Rygh 1885).

Figur 1.1. *Overview map with an outline of Telemark county. Map: K. Loftsgarden, KHM (CC BY-SA 4.0).*

Background

Single-edged swords, dated to the Merovingian and early Viking periods, without preserved hilts are found in all regions of Norway. The most numerous type is characterised by a straight back, with the edge curving to the point (R 498). These swords have not been subject to technical investigations, and the quality of the blades is therefore unknown. X-radiographs of all the Danish specimens of the same blade shape showed a simple construction, not comprising pattern welding or welded-on edges (Nørgård Jørgensen 1999:46). This makes it reasonable to suppose that the Norwegian swords were made in the same way.

Bergljot Solberg's (1984) comprehensive investigation of Norwegian spearheads from the Merovingian and Viking periods shows the same simple construction. Based on the number of weapons found in Norway and the simple construction of many, we argue that a certain number of weaponsmiths were at work in Norway at the beginning of the Viking Age. We further argue that manufacturing was decentralised in general, without the use of advanced techniques. Nevertheless, we should note that it may be difficult to discern which weapons were imported and which were made domestically (Martens 2004).

Specialisation

Radomir Pleiner's (2006) approach to the question of specialisation is of great relevance to our research. In his comprehensive work *Iron in Archaeology: Early European Blacksmiths* from 2006, Chapter XI deals with reconstructed technologies, based on the metallography of a large number of weapons and tools, carried out by himself and others.

Pleiner divides smithing techniques into three levels:

1. Simple techniques, comprising working of low carbon and heterogeneous wrought iron. Simple shaping of one piece of material and forge-welding of carbon-poor iron, including piled blades (Pleiner 2006:196–200).
2. Advanced techniques includes additional carburising, heat treatment, forge-welding of iron and hardenable steel in several different combinations, among them steel shells, iron-steel-iron sandwich, edge steel. Welding-in the steel, either as scarf-welding or butt-welding i.e. perpendicularly to the long axis of the artefact's cross-section "surface to surface" (Pleiner 2006:200–212, Figure 71).
3. Top techniques comprises striped blades (see Pleiner 2006:XXVIII, 2–4), pattern-welding, making of chain-mail and plate armour, lock-smithing and clock-making.

It is important to study sword production in a wider technical context. The same smiths most likely made both swords and spearheads, and consequently it is important to take the production of spearheads into account as well.

In her study of spearheads found in Norway, Solberg based her research on X-radiographs of 881 Viking Age (c. 750–1050 AD) spearheads (1984:246). She states that several of her type groups were made in specialised or highly specialised workshops (1984). She does not define the two terms, but from the text it is obvious that pattern welding was carried out in highly specialised workshops, while some decorative elements, like horizontal circles on elevated parts of the socket, believed by her to have been made by using a lathe, were produced in specialised workshops. As metallography did not form part of her project, the materials used and smithing qualities could not be examined. Nevertheless, her results are of great interest to our work, as 99 of the finds are from Telemark.

Both of the criteria Solberg used, pattern welding and decorations, refer to the aesthetic appearance of the spearheads, not their qualities as weapons. For pattern welding she used a modified version of Jüri

Selirand (1975), in all nine pattern types including single, double and serrated strip patterns, swords 1–3 (1984:Figure 19). As with sword blades, it is difficult to distinguish between imported and indigenously made items. Advanced techniques include inlay decorations on sword hilts and spearhead sockets. The study of such decorations can therefore reveal the technical skills mastered by Norwegian blacksmiths.

Typology

Petersen's typology (1919) based on hilts has been widely used in European Viking Age research and has proved very serviceable. Several other typologies have been published, but we prefer Petersen's, supplemented by the comprehensive and more systematic one by Alfred Geibig (1991). Some remarks and revisions are appropriate, such as an effort to combine typology with hilt decorations (Chapter 4).

1.2 WEAPON PRODUCTION AND SOCIETY

The research area, Telemark, is large and diverse, stretching from the Hardangervidda mountain plateau in the north to the milder coastal regions in the south. Settlement conditions vary considerably within the county, and some general outlines are presented in Chapter 2. Lakes and rivers connected settlement areas, and in combination with other lines of communication, they are a good indication of the location and type of centres one can expect to find there (see map Figure 2.1a and below Chapter 7).

It was revealed at an early stage in our investigations that advanced smithing techniques were introduced to, and carried out in Norway in the Viking Age, probably in smithies attached to centres, i.e. royal or chieftain's farms, or to marketplaces within their domain. Key questions for our research were: How specialised was sword production in Telemark and how was it organised? New techniques were certainly not indigenous inventions. In order to compare the knowledge and skills achieved by Norwegian weaponsmiths during the period, a survey of other technical investigations was necessary. In our project we have stressed collaboration between technicians and archaeologists, and relevance to specified archaeological problems.

Our aim is to clarify the transference of skills in Telemark and to search for places (communities) where technically advanced blacksmiths were at work. In order to approach these questions the find distribution within Telemark is important, and because of the inner variations in topography, we have found it necessary to divide the county into four parts (Maps, Figure 2.1a–b).

At this stage of research, possible places for smithies mastering top techniques must rely on a concentration of high-level objects. We are, however, aware of the need for better and more accurate criteria in future investigations.

One basic question relates to access to raw materials. Initially, the relation between iron extraction and weapons production was most relevant, and the choice of Telemark as the area for investigation partly relied on Martens' excavations of the extensive iron extraction sites at Møsstrond in the municipalities Vinje and Tinn (Martens 1988). Today other conditions are equally relevant, such as the question of who had access to other metals, especially silver and copper for inlay decorations on sword hilts and spearhead sockets, and how these metals were spread and distributed inland, even though only a limited number of weapons were equipped with such decorations.

The results of the Kaupang excavations in the neighbouring county of Vestfold underline the importance of access to raw materials. Unn Pedersen states, "The survey of the evidence from Kaupang leaves us in little doubt that the non-ferrous metalworkers had access to exceptionally good raw materials" (2016:194). Further, "Non-ferrous metalworking seems to have reached Kaupang as a fully developed craft." And, "The discussion of the finds from Kaupang has concurrently shown that there are other types of sites at which non-ferrous metalworking was carried out in a similar manner" (2016:197–198).

The finds from Kaupang are all remains of casting procedures, but access to raw materials were independent of craft techniques, and the same holds true for the problems of how advanced techniques were spread from innovation centres to other areas. The Kaupang finds are predominantly from the 9th century, while indigenously made inlay decorations on weapons before c. 900 AD is uncertain. In the 10th and 11th centuries, an ample supply of silver is well substantiated by the many silver hoards. These are distributed mainly in the coastal areas with concentrations that may indicate centres (Grieg 1929:201).

1.3 FOREIGN INFLUENCES

Finally, we attempt to address the problem of source areas for advanced smithing techniques introduced in Telemark during the Viking Age. Relevant investigations are limited in number, but in connection with our studies of, for example, inlay decorations we find that it is high time to question the exaggerated importance of the Carolingian realm as the production centre for all the best quality weapons found in Central and Northern Europe.

2. TELEMARK COUNTY: A BRIEF PRESENTATION OF GEOGRAPHY AND IRON AGE SETTLEMENTS

2.1 THE GEOGRAPHY OF TELEMARK

More than 200 Viking Age swords have been found in Telemark, the majority having been produced within the county. Before delving deeper into the swords and their production, it is necessary to provide an outline of Telemark, its geography and Viking Age society.

Merely two percent of the area consists of cultivated land today, and by contrast close to 60 percent is above the tree line. The two municipalities with the most extensive mountain areas are Vinje (c. 2,600 km^2) and Tinn (c. 1,530 km^2, Figure 2.1a–b).

In a brief description of Telemark, it is natural to use the main watercourses as guide-lines. From northern Telemark there are two main branches of rivers and lakes, both of which converge in Lake Norsjø, the southernmost of the great lakes. The short river Elstrøm/Skienselva connects Lake Norsjø to the sea.

The series of great lakes stretching into the interior are low-lying: Lake Bandak lies only 72 m and Lake Tinnsjø 191 m a.s.l., thus forming important communication routes, particularly suitable for boat transport in the summer and transport with sledges in winter (Resi 1987:98–99, Figure 5).

The eastern branch

The eastern branch flows into the northeastern end of Lake Norsjø, with its headwaters on the southeastern part of Hardangervidda, where several lakes at around 1,100 m a.s.l. form a central part of large hunting grounds for reindeer.

The largest tributary flowing into Lake Tinnsjø is Måna, whose outlet is approximately 5 km further south. Its headwaters lie in the southwestern part of Hardangervidda. The main river, called Kvenna, flows into Lake Møsvatn, and the Måna river runs eastwards from there through the narrow valley of Vestfjorddalen, forming the famous waterfall Rjukanfossen on its way through.

The valley south of Lake Tinnsjø is mostly sparsely populated forest land, and Heddal/Hjartdal, the valley by the other river flowing into Lake Heddalsvann, was more important for settlement, and formed an important overland route as well.

The western branch

Lake Bandak and the lakes to the east, Lake Kviteseidvann and Lake Flåvann, form the western branch. The lakes are long and narrow and separated only by short streams. The river from Lake Flåvann down to Lake Norsjø has several rapids; six sluices in different places were necessary here when the Telemark Canal was built around 1890 (Figure 2.2).

The western branch consists of a complicated set of tributaries with headwaters from Hardangervidda in the northwest, to the borders of Setesdal in the south. Parallel to the situation on the northern end of Lake Tinnsjø, several rivers have their outlets in or near the western end of Lake Bandak.

Other tributaries

Between the two main branches, there is a smaller river flowing into the northern end of Lake Norsjø: this river between the eastern end of Lake Seljordsvatn and Lake Norsjø leads through Bø and Sauherad.

The Nidelv watercourse

The great lakes in the southwest, Lake Vråvatn-Nisser and Lake Fyresvann, belong to another river system, Nidelv, flowing into Skagerak west of Arendal. Especially from Lake Fyresvann, several side valleys lead into a vast forest and mountain area with many deserted farms from the medieval period (Martens 1989), but so far none of these have finds attesting to settlement in the Viking Age.

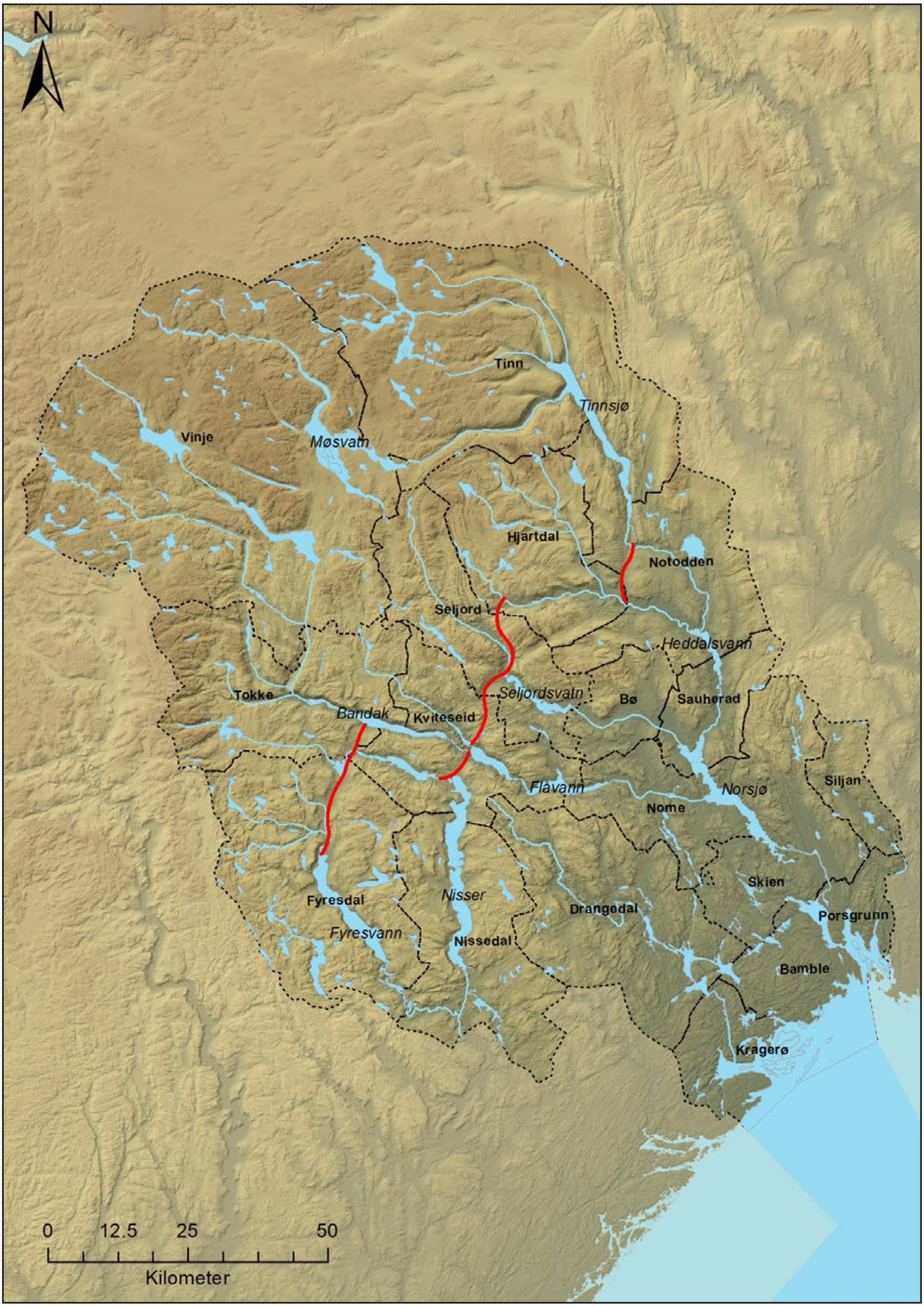

Figure 2.1a. *Topographic map of Telemark with some communication lines marked. Map: M. Samdal, KHM (CC BY-SA 4.0).*

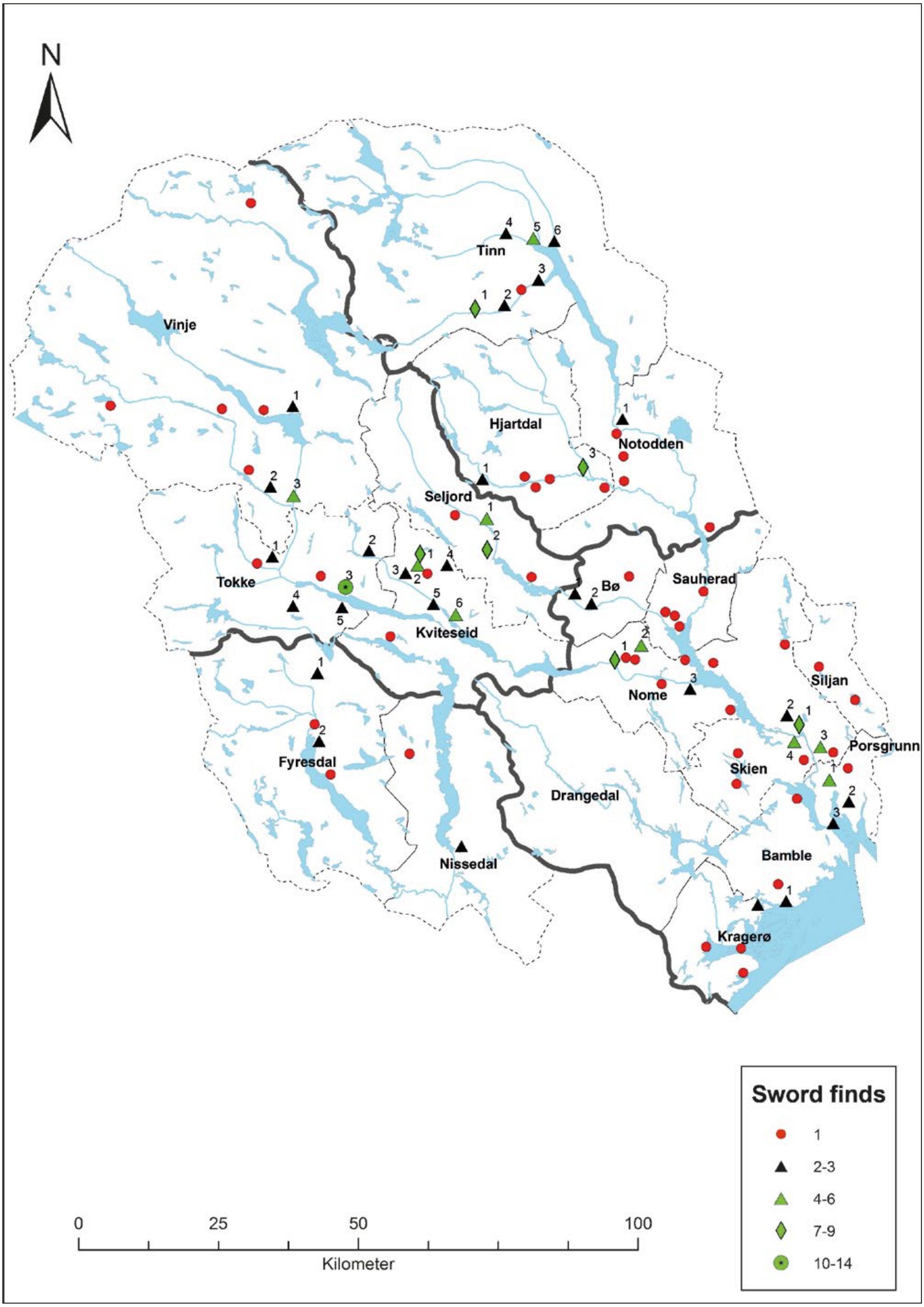

Figure 2.1b. Map of Telemark showing distribution of sword finds. For details see find list in appendix. Map: M. Samdal, KHM (CC BY-SA 4.0).

Figure 2.2. *The valley between Lake Flåvatn og Lake Norsjø. 1950–1970. Photo: Normanns kunstforlag (CC0 1.0).*

Figure 2.3. *Gjerpen, Skien, east of Skiensfjord. 1831. Photo: Mittet & Co (CC0 1.0).*

Important features

The lower parts of Telemark stand out as having both arable land and the most favourable climate of the region. Gjerpen includes the largest productive area, but the western side of the watercourse, especially up to the northern end of Lake Norsjø and including Bø have considerable areas of good farmland (Figure 2.3). Farther north, both sides of Lake Heddalsvann and Heddal Valley have nearly continuous settlement (See also Kaland 1972:141–159).

The great lakes and watercourses above Lake Norsjø are central to settlement, and a large part of the arable land is found near lakes and rivers. The steep hills and mountains surrounding the lakes often plunge directly into the water, making the shores uninhabitable. Thus only limited areas, often by the outlets of small rivers, favour more extensive settlement, and churches are often situated in such places. Examples of this are Lårdal by Lake Bandak and Kyrkjebygda by Lake Nisser (Figure 2.4).

Far more important are the inner ends of the great lakes, as they have the largest areas of arable land. In several cases two or more rivers have their outlets there, their valleys leading to other communities farther up in the mountains, in areas rich in resources. Together, these features make the inner ends very conducive to settlement (Figure 2.5).

In several places, the overland crossings between the great lake systems are short and easy to traverse. Sword C.5544 from Hafsten in Notodden indicates a transition road between the southern end of Lake Tinnsjø and the Hjartdøla watercourse. Some are marked on the relief map, but there were of course more such crossings.

In some places, there were severe obstacles on the overland roads, for example in Vestfjorddalen in Tinn. The road through the valley past Rjukanfossen was considered dangerous in later times. Such passages did not stop communication. One often had to use steep paths up into the mountains to where the terrain was more favourable for transport and then go down again farther on.

There were several crossings westwards to Setesdal, and the northernmost farms in Setesdal now belong to Vinje. Traffic between Telemark and Hardanger across Hardangervidda followed several paths, which are well known from more recent times (Roland 2001; Loftsgarden 2019).

2.2 SETTLEMENT AND ORGANISATION

The outline of the geography of Telemark forms the background for a brief presentation of the county's Iron Age. The Early Iron Age in Telemark was the subject of Jens Storm Munch's Master's thesis, published in 1965 (Munch 1965). Many new finds have been added to KHM's collections since then, as well as several archaeological excavations.[3] Since the early Mesolithic, hunters have taken advantage of the mountain areas, while the valleys probably had a local population subsisting in part on agriculture from the Late Neolithic (Mikkelsen 1989:321–22). Most probably these inland areas were inhabited continuously from the Late Neolithic, but the extent and economy of the settlements are uncertain.

The inland population maintained knowledge of various resources in forests, mountains and lakes, including elk, reindeer, fur-bearing animals and fish, while the extensive grazing lands were important for a farming economy. How, and to what extent, they utilised these various resources depended both on their technology and socio-political organisation, which governed both exploitation and commodity exchange. Iron extraction from bog ore is a good example of an activity dependent on both factors. Although iron was produced since the Early Iron Age in Telemark, it became extensive by the late Viking Age. Iron production became a more regionally specialised craft, with massive amounts of iron produced in hundreds of sites, mostly located in the northern part of Telemark (Martens 1988; Loftsgarden 2019b, 2020).

Several investigations have revealed that specialised handicrafts in Scandinavia were produced on central farms belonging to the elite and in marketplaces (Ljungkvist 2006:94 with references; Skre 2007:Chapter 20). Even though central farms in Telemark were mostly of a more moderate size than those mentioned by Ljungkvist, an important premise for our investigation maintains that specialised weapon production was carried out on such farms.

In relation to the socio-political organisation of Telemark, we have used Bjørn Myhre's paper, "Chieftains' Graves and Chiefdom Territories in South Norway in the Migration Period", as a starting point (Myhre 1987). The geography of Telemark, with its distribution of arable land and communication routes, is considered crucial at all times, and his results are relevant to our work.

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[3] Excavation reports at least from 2005 are available here: https://www.duo.uio.no/

Figure 2.4. *The central part of Lårdal towards Lake Bandak, 1880–1890. Photo: A. Lindahl (CC0 1.0).*

Figure 2.5. *The northern end of Lake Tinnsjø, 1947–1948. The farm Mårem at the mouth of the valley to the right. Photo: Mittet & Co – Lie-Svendsen (CC0 1.0).*

Myhre used richly furnished graves, defined as those containing at least two out of three of the following groups of objects: imported glass (except beads), bronze vessels and gold objects (1987:170). The distribution of such objects may indicate areas of wealthy settlements found close to the centres of social and political leaders (1987:171). He also studied fortified areas indicated by the distribution of hillforts, depending here on Munch's study of the numerous hillforts in Telemark (Munch 1965:113–138).

Through these methods, Myhre found two centres in Telemark: one in present-day Skien municipality, consisting of former Solum and Gjerpen; and a second centre by the northern end of Lake Norsjø, in the municipalities Sauherad and Bø, possibly also including two finds from Lunde, by the river between Lake Flåvatn and Lake Norsjø.

These centres lie in the southern part of Telemark, now called Grenland, which is very likely an old name (Munch 1965:14–17). Studies of written sources have confirmed that Grenland originally comprised only the inland region, i.e. the communities Nome, Sauherad, Bø and Heddal in Notodden, while Gjerpen and Eidanger (Porsgrunn) on the eastern side of the Skiensfjord, whose old name was Grenmar, belonged to Vestfold. Solum, Bamble and Kragerø constituted the old region Vestmar (Vale 2012:Chapter V). We find it convenient to use the name Grenland for all three old regions.

There are some interesting finds outside Grenland: a rich grave find from Nordgarden in Seljord (Munch 1965:Figures 11–18; Straume 1987:No 30), and three Westland cauldrons on the communication line from the western end of Lake Bandak past Lake Børtevann to the western end of Lake Vinjevann.

Hillforts

There are numerous hillforts in Telemark, and all are situated within Grenland. The dating is largely uncertain, as only a few have been excavated and dated. The Late Roman and Migration periods are considered most important in relation to their building and use. Munch presents 27 hillforts in Telemark, most of them in the central area within Grenland and enclosing the two centres Myhre found, and the settlement areas between. Since Munch published his list, at least eleven more hillforts have been found, mostly with the same distribution, but with three farther southwest in Bamble.

There are 21 known forts in Skien (Midtlid 2004:84; Finmark 2009:42). Åke Midtlid emphasises that many are situated where one could either control traffic on the waterways or the roads leading into the central habitation areas, and he claims that they belong to a comprehensive plan made by a hierarchical society (2004:96).

Burial mounds

Another group of monuments must also be considered. Large burial mounds were the resting places of high status persons. When not excavated the mounds are as difficult to date as the hillforts, but generally many, perhaps the majority, belong to the Late Roman and Migration periods (Ringstad 1992:114ff).

As well as complications in dating, size designations are difficult. A diameter of 20 m is often used to designate a large mound, but such measures are often not very accurate. The very big ones, measuring 25 m or more in diameter are the really interesting ones in this context, and deserve special attention.

The largest group is found in Solum, Skien, where there are at least twelve mounds of approximately 35–45 m in diameter. They are not placed together in a burialground like at Borre (Myhre 2015), but instead lie scattered over a distance of about 2.5 km on the farms Bjørntvet (6), Kongerød (2) and Klyve (4), all on a ridge sloping gently down to the river in the east. From here one could control the overland route from the sea to the southern shore of Lake Norsjø. Their dating is uncertain.

A collection of twelve large mounds within a limited area indicates a centre of great importance. The high number makes it likely that they were built during an extensive timespan, probably from the late Roman Iron Age onwards, though one cannot exclude the possibility that the earliest date from the Bronze Age.

In the other centres marked on Myhre's map, Bø and Sauherad, there are several large mounds, up to 30 m in diameter. Similarly, they are not found in one burialground or on one farm, but rather in several burialgrounds in various parts of the municipalities.

The last area of interest is the central part of Seljord by the western end of Lake Seljordsvann. On Myhre's map it is marked as a place with one category of objects, in this case a glass from the Nordgarden find mentioned above, from the first part of the 5th century. This is unfortunately badly documented, but may be from a large mound (Munch 1965:Figures 17–18; Straume 1987:No.30, Tafel 52–53).

Outside Grenland, the central part of Seljord has a spectacular collection of large burial mounds on the farms Nordgarden, Utgarden and Nes. Three are about 25 m in diameter, one is 22 m and two approximately 20 m. The farm names Nordgarden and Utgarden show that they were secondary parts of an original, now abandoned farm named Selaker.

The documentation we have added strengthens Myhre's model, depicted in his Figure 13 (1987). In Telemark the most prominent centre was found in Skien where all branches of the Telemark watercourse flowing into Lake Norsjø meet the sea. The economic interests of the rulers extended far into the interior where the farm-based population utilised resources within a large area. This promoted economic growth in the inland valleys, resulting in burials containing dateable objects, in several cases imports like the three Westland cauldrons in Tokke and Vinje. The connections, including the utilisation of outland resources, were probably directed from the centres in some way.

Munch and Kaland stress the connections between the inner parts of Telemark and Western Norway for the Early Iron Age and the Viking Age respectively (Munch 1965:112; Kaland 1972:168–69). We do not in any way deny that such connections existed, but we see the connections along the watercourse to Skien as far more important (see below).

Merovingian and Viking Periods

The Merovingian period has in general few finds, and we have not traced any finds from this period in Solum, Skien. Notably, this area has few finds from the Viking Age as well. In our base material only six swords come from Solum, one of them from Bjørntvet, an M-type single-edged specimen.

Gjerpen, on the eastern side of the river, has a small number of Merovingian period finds and two early Carolingian type swords from the transition to the Viking Age (C.1878 and C.25396, Martens 2006a). From then on, Gjerpen stands out compared to the rest of Grenland, which in general has relatively few Viking Age finds.

Find distribution in the Viking Age

Both the distribution of swords in general, and the concentration of such objects are important in order to elucidate the economic networks and social hierarchy of Telemark in the Viking Age. The map (Figure 2.1b) shows the spatial distribution of Viking Age swords in Telemark. Most have come to light accidentally, many by destruction of a burial mound or even a group of mounds. In our analysis, concentrations of more than six swords are deemed significant (7–9 and 10–14).

All, except the one in Morgedal, are situated in areas which combine favourable farming conditions with strategic communication positions. It is the interior valleys that are rich in finds in our relevant period, and Kaland has demonstrated that the greater part of the finds come from places with the best conditions for agriculture, though even marginal areas have contributed (Kaland 1972:141ff). The swords are concentrated in an inland belt stretching from Fyresdal in the southwest to Tinn in the northeast (Figure 2.1b).

Tinn is an outstanding municipality for Viking Age weapons. The Rjukan concentration of seven swords has some items of special interest, and in addition to these the Mårem concentration of five swords elicits special attention. Mårem was obviously an important farm, situated close to Lake Tinnsjø between two rivers leading away from rich hunting grounds (Martens 2009). All in all, Tinn has yielded eleven swords with inlay decorations on the hilts (Martens 2009), and three spearheads with such decorations on the socket. These finds will be discussed in more detail in the concluding chapter.

Among the weapons from Seljord is the T-type sword from Utgarden (Petersen 1919:Figure 121). Most of the other ones are of ordinary Norwegian types.

A penannular brooch from Seljord is worth noting, considering the archaeological material strongly indicating that the cloak and penannular brooch were connected to a group of men holding central political positions (Glørstad 2010:280–86). The Seljord brooch has plain ball-shaped ends (group IIIB), dated to 850–900 AD (Glørstad 2010:331). This is one of eight penannular brooches from Telemark. Another such brooch, a thistle brooch (group IIIA) comes from the prominent farm Mårem in Tinn. The other six brooches were found on centrally situated farms in different parts of Telemark (Glørstad 2010:327–324).

In earlier works, we have interpreted the prosperity indicated by the great number of finds in the middle inland zone as a result of its central position in the trade between coastal and mountain regions (Martens 1987:76ff, 1988:148–49). The farmers there were the primary receivers of iron and other goods from forests and mountains, delivering grain, house timber and other necessities in return (necessities here taken in a wide, cultural sense). They may even have played a role in the organisation of iron extraction. The graves are above all rich in weapons and tools, testifying to an abundance of iron, although the most intensive iron production in Telemark started in the late Viking Age and continued in the early and high Middle Ages (Larsen 2009; Loftsgarden 2017).

In contrast to the early Iron Age, there is an abundance of finds in the valley zone in the Viking Age, but fewer finds in the lowland and coastal areas. Even if such a shift in find distribution is not representative for other parts of Southern Norway, the problem of change in political organisation is a general and complex one. Myhre has suggested that a few strong, petty kingdoms were established, and from their political centres widespread economic systems were created (Myhre 1998:26).

The many large grave mounds in Solum indicate continuity into the Viking Age, while the finds signal a shift in importance towards Gjerpen. A possible explanation for this is that Solum and Gjerpen were parts of different political units (see above).

The Skien area most probably remained central during the Viking Age. Hones from the quarries in Eidsborg, a short distance from Lake Bandak (see map 2.1b), were shipped out through Skien (Nymoen 2011). These hones were widely distributed in Northern Europe, among other places in Haithabu. Of the hones from Haithabu, 22.5% most probably come from Eidsborg, dating to the entire occupation period, 8th–11th centuries (Mitchell et al. 1984; Resi 1990:15, 53). During the 10th century the medieval town of Skien was established (Myrvoll 1984). Controlling the trade of inland resources such as iron and whetstones was most likely fundamental to establishing the town.

Tinn, Seljord and Kviteseid are the most likely candidates for smaller centres where specialised weaponsmiths could have had their workshops. Sauland and Ytre Flåbygd are also worthy of consideration. By the Nidelv watercourse, ending near the possible trading settlement at Vik, Grimstad (Larsen 1986), Fyresdal has yielded several interesting finds.

3. WEAPON PRODUCTION IN TELEMARK IN A WIDER CONTEXT

3.1 THE FUNCTIONS OF THE SWORDS

Swords had several functions beyond merely being a weapon: they were a means of power and they were status symbols. In most countries and periods, swords are less numerous than spearheads and other kinds of weapons, a fact which identifies the sword as the weapon of the leading classes in society. This is not the case in Norway in the Viking Age, where swords were at least equal to spearheads in number, and in several regions more numerous (Martens 2003; Petersen 1919:6).

Viking Age swords have come to light in all parts of the country. Most of them are from the inhabited fjord, lowland and valley areas, but even mountain areas have yielded finds, both in the form of graves and stray finds (Skjølsvold 1980:Table 1; Martens 1988).

Their distribution within Norway (see below for Telemark) indicates that a considerable part of the male population had the right to carry a sword and that swords were markers of men's general status, for example that of freeholding, land-owning farmers (Martens 2003). This is expressed in the medieval Gulathings Law. The oldest part of the law, dating back to the Viking Age, states that every free man should have a set of weapons: spear, shield and axe or sword (GL 309; Hofseth 1982).

Swords were also most likely used as gifts, for instance as part of long-distance exchange. Two inland rural districts, Vågå in Oppland and Tinn in Telemark, stand out because of the unusually high number of swords with decorated hilts that were found there, most of them coming from a few centrally situated farms. We have interpreted these sword finds as indicators that these farms held prominent positions in long distance exchange connections (Martens 2009).

3.2 THE ORIGIN OF THE SWORDS

As this investigation is focused on swords made by Norwegian blacksmiths, it is appropriate to briefly outline some important factors in the debate on the origin of sword types. This question is certainly complicated, and one must always keep in mind that hilts and blades were often made separately, and in many cases far apart. Imported hilts were obviously fitted onto indigenously made blades and vice versa.

One problem is the lack of objective criteria for deciding the origin of the swords, which has often resulted in turning to belief – including wishful thinking. Recent scientific investigations on the provenance of iron are very promising, but it is beyond the aim of this brief survey to deal with this complex topic (Charlton 2015; Rose, Télouk, Klein and Marchall 2019).

Some sword types were undoubtedly of indigenous origin and production. The C-types have the upper guard and pommel in one piece, while the M, Q and Æ types lack pommels, a feature not found on international types. The C, M and Q-types were numerous in Norway, but hardly ever found outside the country.[4]

The five double-edged blades found together at Hulterstad in Öland, Sweden, are of great interest. They all have ULFBERHT inscriptions or inlaid signs (Arbman 1937:232; Thålin-Bergman 2005:50–51; Modin and Modin 1988:100–01), and have been interpreted to be imported blades intended to be equipped with hilts in Sweden.

Blades with ULFBERHT and other inscriptions have attracted the interest of archaeologists and metallurgists. One of these is Anne Stalsberg (2008) who presents a table comprising all the ULFBERHT swords she has been able to collect from the available literature. The table presents the systematic variations in inscriptions, and their combinations with variations of marks on the rear side of the blade. It is, however, the hilt types that are of primary interest here. These are varied, covering a vast timespan, and her division between the middle and late Viking Age is not correct, since several types placed separately are contemporaneous. The point to be stressed here is the difference in hilt types between Germany and Northern and Eastern Europe in general (finds from Belgium and

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[4] All letter designations refer to Petersen's (1919) typology.

Switzerland, numbering two and one swords respectively, are too few to be significant). In Germany the X-type dominated, with seven or eight out of twelve type-determined specimens. Most belong to Geibig's combination type 12, dating back to at least the early 10th century. In the north and the east of Europe, where the relevant swords together completely outnumber the German ones, the hilt types S, T, V and Z were the most common, besides the H-type and a few X-types. In Norway, five swords have R-type hilts, as well as one find from Hamburg (Müller-Wille et al. 1970). According to Geibig's map Abb.44, the R and S-types, his combination type 10, and U/V/W combination type 11, were found solely in the northernmost part of Germany, mostly in Schleswig in or near Hedeby, while types T and Z are not included at all in his typology (Geibig 1991).

Even though the number of German finds is small and the representativity is problematic, these differences are considered significant, and they must be taken into account in future studies on sword production and distribution. Another difference is also worth mentioning: The R, S, T, V and Z-type hilts have fine inlay decorations, while the X and Y, as well as other late types, were undecorated (as seen in Figure 3.3). There are actually no hilt types with inlay decorations in western continental Europe later than Petersen's O III, Geibig's combination type 6. Geibig states that from the early 10th century, sword hilts made in the Frankish area are void of inlay decorations (Geibig 1991:138). Swords of the English L-type were decorated, and Vera I. Evison has identified a typological series from Petersen's L-type to a sword from Wallingford Bridge (Evison 1968).

What are the consequences of these specified differences? First of all one always has to be very careful when discussing the origin of swords. Strictly speaking, one should always keep hilts and blades apart, considering that they both can be made at a great distance from one another.

Opinions on indigenous versus imported swords have often been centred on pattern welding and blade inscriptions. Did Norwegian weaponsmiths master pattern welding or are all pattern-welded blades imported? This problem remains unsolved. A point in favour of indigenous pattern welding is the existence of some pattern-welded, single-edged blades. The number is unknown, though certainly small and not indicative of a widespread practice (see Chapter 7). Further, one cannot exclude the possibility that twisted blanks for pattern welding were imported and processed into sword blades and spearhead blades in Norway.

Although double-edged blades are certainly the most common with hilts of undoubtedly foreign make, such hilts were also fitted onto single-edged blades in a not insignificant number. This holds true even for the ones dated earliest, going back to the middle or late 8th century (Martens 2006a). And of course, double-edged blades of indigenous make can just as well have been fitted onto imported hilts.

Solberg has maintained that the spearheads' European distribution is a good indication of their origin (1991:247). Spearhead types with a wide distribution outside Norway most probably originated elsewhere. This is certainly also the case for sword hilts. This does not mean, however, that production did not exist in Norway. Petersen's H/I type is the most numerous one in Norway, as well as in Sweden (242 specimens) and Finland (Androshchuk 2014:List 1; Kivikoski 1973:112, Tafel 94:831–2). They have hilts with inlay decorations in geometric patterns. The H/I types are definitely of continental origin, but was there also production in Norway? Petersen states that 73.1% have double-edged and 26.9% single-edged blades (19 blades were indeterminable) (Petersen 1919:94). Were the single-edged blades fitted onto imported hilts? These questions cannot be answered without a detailed investigation (Martens 2004, 2006a).

Further, we must not forget that several continental hilt types were undecorated. Two good examples are Petersen's type B, corresponding to Geibig's combination types 1, I–VI and 5, II–VI, and Petersen's type X, Geibig 12, I and 15, III (Geibig 1991:16). Petersen's B was the model for the C-type, the earliest of the most common indigenous ones.

3.3 NORWEGIAN SWORD TYPES AND SWORD PRODUCTION

Sigurd Grieg's idea of community blacksmiths, unspecified but tacitly understood as a high number of independent smiths distributed all over the country, was based on the premise of a self-supporting economy with little exchange of goods, which was the dominating view at that time. This view is no longer viable since a comprehensive surplus production of iron has been well documented (Grieg 1922:92–93; Martens 1988). Considering the role weapons played in society, not least in social relations – both horizontal and vertical – it is likely that weapon production was subject to certain set regulations. Norway was not, however, such a well-organised society that a strict level of control was possible.

The most skilled weaponsmiths were probably attached to royal or chieftains' farms, and eventually towns in Norway, such as Kaupang, which was under royal control (Skre 2007:Chapter 20). These were the sites where new techniques were introduced, and where silver, copper and other metal alloys used for decorations were most easily obtainable.

Background

At the beginning of the Viking Age an unknown number of weaponsmiths were at work in Norway. The activity was decentralised, and in general without the use of advanced techniques. Iron itself was readily available, not least in Telemark, where it was produced at numerous sites in the mountain and valley regions (Martens 1988; Larsen 2009; Loftsgarden 2020). There were marked differences in skills between those who worked with iron and iron producers, unfortunately often named smiths, and experienced weaponsmiths.

During the Viking Age the number of finds increase considerably. Double-edged blades came into use with gradually increasing frequency, nearly taking over completely during the 10th century.

From the late 8th century, iron hilts are fitted onto both kinds of blades. There are some early examples of foreign hilts mounted on single-edged blades, for example the specimen from Ytre Kvarøy, Nordland (Vinsrygg 1979:67; Martens 2006a:224). It is likely that hilts of Petersen's type A were made in Norway prior to 800 AD, while the earliest indigenous type found in larger numbers was type C, occurring around 800 AD, with a very wide distribution.

The most important indigenous sword types are Petersen's types C, M and Q; other types were found in smaller numbers. The M and Q-types are closely related. Both types, as well as the later Æ-type lack pommels, a trait which, as far as observed, occurs solely on Norwegian hilt types. Most likely hilts and blades were made as a unit for these swords, and thus their blades, both double and single-edged ones, were made by Norwegian blacksmiths.

These sword-types' extensive distribution in Norway is important in trying to estimate the number and location of weaponsmiths at work here at the same time. Still, it is far from clear what decentralised production means. An approach to these issues rests on several assumptions. First of all, the Viking Age was a dynamic period when new techniques and skills were introduced to and spread from a small number of "innovation centres" to a greater number of more widely distributed weaponsmiths. What determined their localisations? And did independent craftsmen who produced weapons exist?

3.4 DEGREE OF SPECIALISATION

Weaponsmiths were specialists. Elizabeth M. Brumfiel and Timothy K. Earle give a very simple definition of specialisation: the existence of individuals who produce goods and services for a broader consumer population (Brumfiel and Earle 1987:5). Generally there is a wide range of specialists: from the full-time, highly skilled ones employing the most intricate techniques; to the part-timers mostly producing raw materials, like specialised hunters or iron producers. The definition of specialisation used here is: production of raw materials and further processing of them using knowledge and skills mastered only by a minority of the population (Martens 1995:176). For the weaponsmith, it can be added that he could deliberately choose between different steel qualities and combine them in special ways. He was able to improve steel quality by means of carburisation and other heat treatments (Martens 1995:178). No doubt, the skills and degrees of professionalism varied among weaponsmiths.

The training of professionals involves several intricate processes. Weaponsmiths obviously learnt their skills as apprentices to experienced professionals, probably often sons to fathers. Adopting new and advanced techniques needed something more, by way of social/professional contacts between smiths working in different places.

This investigation concerns sword blades and the techniques and skills needed to produce different blade constructions, but spearheads also need to be considered. Solberg (1984, 1991) characterises spearheads produced in highly specialised and specialised workshops. She also claims that uniform shapes for spearheads found dispersed over large areas demanded a limited number of workshops, while greater variations in shape indicate more widespread production. She also finds differences in distribution among her three investigation areas. Her type group VI consists of both kinds: the first ones, which she defines as imported, are mostly found in coastal areas and often in combination with swords of foreign origin; the others dominate her region 3 covering the inland of Eastern Norway, and are mostly found with indigenous swords (Solberg 1991:246, 250ff). Region 3 is very large and heterogeneous, with several communication lines to central coastal areas. She offers no information on local differences within this region.

The crucial point however, is the level of specialisation in weapon production found in Norway in the Viking Age.

The problem of specialisation involves several other factors too, such as the question of whether weaponsmiths made only weapons, and if so how many different kinds? There have also been questions raised about continental weapons, as to whether decorated hilts were made by the same blacksmith who made the blade, or by separate craftsmen.

3.5 INLAY DECORATIONS

Sword hilts and spearhead sockets have decorations utilising the same techniques: forged patterns or inlay/encrusted decorations in silver, copper alloys and niello. The two inlay kinds have been found on different sword hilt and spearhead types (for a description of the two techniques see Blindheim 1963:38–9; Fuglesang 1980:Appendix 1).

It has generally been accepted without discussion that inlay/encrustation techniques, frequently used on sword hilts and spearhead sockets, were employed in Norway from the beginning of the Viking Age. This view is connected to the idea that the H-type swords were an indigenous type (Petersen 1919:101; Blindheim 1999:75). This is highly questionable, and it is more likely that these techniques were introduced to Norwegian blacksmiths some time during this period. Thus a simplified study of the patterns, in order to shed some light on this question has been necessary.

There are indications that sword hilts with inlay decorations were made in Norway from around 900 AD. The relevant hilt types O II, R, as well as the S and T-type hilts with Jellinge-styl decorations were widely distributed in the Nordic countries, while S and T-type hilts with other decoration patterns had an even wider distribution. Together with V and Z-type hilts they have been found around the Baltic Sea as well, with some examples even further south. However, they are not included in Geibig's typology because they are not found in his investigation area, the former West Germany. R-type swords were found in the vicinity of Hedeby.

Inlay/encrustation decorations on spearhead sockets is a new element introduced with Petersen's I/K types, Solberg VII.2A-B, VII.2C around 900 AD. In some areas such decorations were also found on E-type spearheads (Solberg's VI.4) from the early 10th century. The patterns are, with a few exceptions, geometrical including fishbone (see below), while decorations in the Ringerike or Urnes style were found on other, later spearhead types. This survey has been limited to earlier patterns.

The Byggland find (C.27454) contained three spearheads with inlay decoration (catalogue f, g, and h):

Figure 3.1. *Spearhead sockets from Byggland, Kviteseid. Photo: O. Holst, KHM (CC BY-SA 4.0).*

two with well-preserved sockets of types VII.2A, B and C respectively, depicted in Blindheim (1963: Figures 5–7), here Figure 3.1. The decoration patterns, which Charlotte Blindheim named Aa, consist of horizontal fishbone lines combined with plaited ribbons, triangles, and on spearheads h and g step-ribbons on the top. Six more spearheads with similar decorations found in Telemark caused Blindheim to interpret these as items made by the Byggland smith (l.c.48). Since 1963, four more decorated sockets from Telemark have been recognised (C.20129 Notodden, C.29700c Tinn, C.27051 Nome and C.28440 Hjartdal). On three of them the patterns were badly preserved, but they are most likely fishbone (Ge 1). C.29700c was found in the same grave as one of Blindheim's examples (Blindheim 1963:Figure 15).

There are some other concentrations of inlaid sword hilts and spearhead sockets, in two cases (By, Løten, Hedmark, Vik, Sogn and Fjordane) found in a grave rich with blacksmith tools. Both the Byggland and By graves contain draw plates for making wire; the Byggland find has a mould for an ingot as well. There is also strong evidence of working with silver and copper alloys. These concentrations have been interpreted as signs that other blacksmiths/workshops employed the inlay technique (Martens 2002). The By concentration dates from the late Viking Age, around 1,000 AD. In order to support these implications, a study of pattern types based on available literature was carried out.

Inlay patterns

Little attention has been paid to these patterns, their variations and distribution. One problem is the small number available in publications. In many cases only faint traces of the decorations are visible, moreover more decorated sockets are frequently discovered on X-radiographs or during laboratory treatment. Another obstacle is the low quality of some published photographs. In addition, as they were made by specially qualified smiths, one must always bear in mind that some may have had an individual touch.

The simplified study of the inlay patterns presented here does not include the classification of interior patterns, and while other details are included, a more comprehensive study would certainly be rewarding. Likewise no classification of Early Viking Age decorations has been made, as this would demand a comprehensive special investigation. Vertical stripes are most common on the H-type hilts, though more intricate patterns occur, as seen on the Killingtveit hilt (Figure 3.2), probably in the later part of the production period. It is worth noting that a pattern with narrow, stepped rhombi (Ge 3) was found on I-type hilts, for example the sword C.23127 from Oppland, Norway. No Z-type specimens with well-preserved decorations suitable for classification are available.

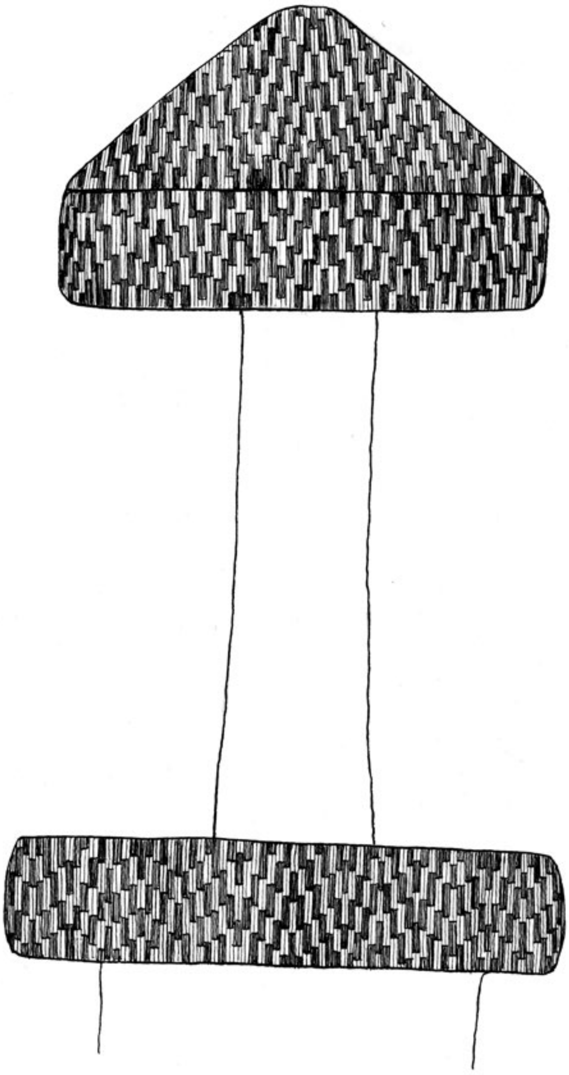

Figure 3.2. *The H-type hilt C.21325 from Killingtveit, Vinje, (reconstruction). Drawing: Unknown, KHM (CC BY-SA 4.0).*

Blindheim divided inlay patterns on spearhead sockets into Aa and Ab. Blindheim's group Ab needs further division, and Aa and Ab are renamed to Ge, meaning geometric. Here, five such patterns Ge 1–5 are identified, where Aa fishbone pattern is Ge 1, and patterns dominated by holes, often surrounded by silver rings (Petersen's type T), is Ge 5 (Figure 3.3). It is important to be aware that the pattern on a sword hilt or a spearhead socket is classified according to the dominating pattern element, as two pattern types can be combined on the same item, for example Ge 5 with its indistinct animal elements.

There are two distinctly different patterns with rhombi being the dominating element. These are Ge 2

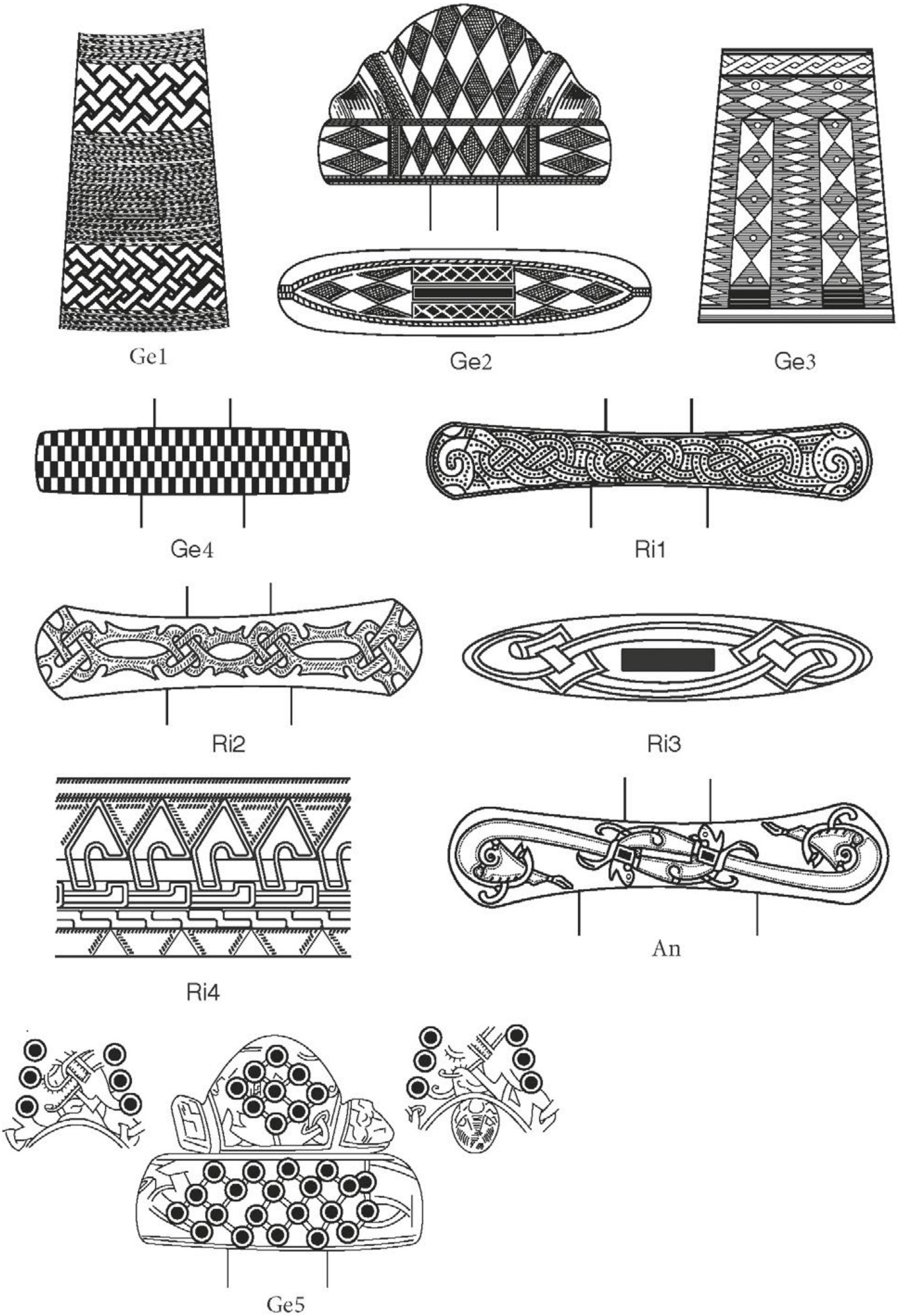

Figure 3.3. *Inlay pattern types found on sword hilts and spearhead sockets. Drawing: J. Kreutz. The image is not covered by the CC-BY license and cannot be reused without permission.*

with relatively wide rhombs and straight outlines, and Ge 3 with narrow rhombi and stepped outlines. The two patterns can, however, be combined.

A second group has ribbon decorations, and four distinct patterns have been discerned, differing in design, interior patterns and background, named Ri 1–4. It is important to note that the Ri 1 pattern is found on O and R-type hilts, while Ri 2 is most common on S-type hilts. Another point worth noting is that Ri 1 patterns coincide with Ri 3 ones on the over and underside of the guards, while the Ri 2 patterns are combined with Ge 2 ones.

Several S and T-type hilts have Jellinge-style ornaments (Petersen 1919:Figures 115,120; Müller-Wille 1973). A large number of spearheads have ornaments in Ringerike and Urnes styles (Fuglesang 1980; Creutz 2003), and there are probably ornaments in other animal styles as well. Therefore, they form a third pattern group named An, but no subdivisions are made.

The closest parallels to Norwegian Ge 1 patterns come from the graves at Birka (Arbman 1940:Tafel 9). The patterns on two of them, Tafel 9, 5 and 9, 6, have a different, open pattern on the upper part of the socket. Their blade construction is not specified in the tables presenting the results of the X-radiograph examinations by Thålin Bergman (Birka spearheads, Table 12), but rather on the sketched drawing, Figure 43, No.2 from the right, and another spearhead with a socket decoration most probably has a welded-on strip (Thålin Bergman 2005).

Anne Pedersen depicts three Danish spearheads with Ge 1 patterns, but the pictures are too small for detailed investigation and the number is too low to be significant (Pedersen 2014:Plates 11, 4, Plates 43, 2 and Plates 45, 2). Lena Thunmark-Nylén (1998) depicts one specimen from Gotland having dense fishbone combined with a horizontal ribbon of Jellinge style animals. It has even got a runic inscription (Thumark Nylén 1998:Tafel 241).

Spearheads with Ge 1 decorations on the socket have not been found outside Scandinavia, where another pattern type dominates: a geometric one with narrow, horizontal rhombi, alone or in combination with other elements (Ge 3). There are depictions of pattern type Ge 3 on items from Gotland (Thunmark-Nylén 1998:Tafel 238, 243–44), Finland (Lehtosalo-Hilander 1985:Figure 1, 1), Estonia (Mägi Loûgas 1993:Figure 1, 1) and from the Russian Kaliningrad enclave (Mühlen 1975:Tafel 18, 8–9). It is difficult to determine whether such rhombi occur alone, e.g. on Thunmark-Nylén (1998:Tafel 238,2). More commonly the socket has a vertical division where the rhombi alternate with wider Ge 2 rhombi (Thunmark-Nylén 1998:Tafel 238, 3 and 244, 1).

In Norway such spearheads are rare. The author is only aware of three specimens, but there are probably more. One is the K-type C.28015, a single mountain find from Kalhovd in Tinn, the second from the well-known Gjermundbu find, discovered after Grieg's publication (Grieg 1947:Plate IV,10; depicted in Martens 2002:Figure 2, 2004:Figure 7). The sword in the grave is of the S-type with Ri 1 decorations. A third specimen comes from Nesna, Nordland, C.5613, depicted as R 531, possibly found in a grave with an M-type sword (Sjøvold 1974:285). The pattern does occur on spearheads from Denmark and Gotland (Pedersen 2014:Plates 8, 2 and 5; Thunmark-Nylén 1998:Tafel 243), but the distribution of this pattern type is otherwise uncertain.

The narrow rhombus pattern, Ge 3, is common on sword hilts as well, and Ge 2, 3 are the only pattern types common on both kinds of weapons, though new finds may of course alter this. The Ge 3 pattern is found on I-type swords (Arbman 1940:Tafel 1, 2) and is perhaps the most common on V-type hilts. The pattern stands alone on the side panels of the guards and the central part of the pommel, while the sidepieces have other ornaments.

The Ge 2 pattern with T-type hilts had a very wide distribution. Petersen (1919:Figure 121) is from Utgarden, Seljord, while the specimen depicted as Ge 2 in Figure 3.3 is found in Slovakia (Ruttkay 1975:Figure 8, 2). The T-type hilts with such decorations are rare, and Fedir Androshchuk (2014:77) lists only one uncertain specimen from Sweden. There are no finds in Denmark, and we do not know any from around the Baltic.

The V-type hilts with Ge 3 decorations were more numerous and had a very wide distribution. Petersen lists six examples (Petersen 1919:155), all with a Western Norwegian provenance, though more recent finds have been made in southern Vestfold and Telemark (Blindheim 1999: KXXV, Plate 36) and at least two in Trøndelag (Stalsberg 2008: N 38 and N 42). C.20955a from Seierstad, Larvik, was found with a fragmentary spearhead with Ge 1 decorations depicted in Blindheim (1963:Figure 20). Last but not least, there is sword C.35841a from Ballestad, Skien. There are sixteen V-type swords in Sweden and eight to ten specimens in Denmark (Androshchuk 2014; Pedersen 2014:79). The inlay Ge 3 patterns of the V-type swords display only small variations. These were widely distributed in the Nordic countries and the Baltic. Vytautas Kazakevicius provides the number fourteen, while one is depicted (Kazakevicius 1996:Figure 69), but nothing is said about patterns on the others. Bernt von zur Mühlen states, "Nach ihrer Verzierungsweise sind die eben angefürten Schwerter sehr gut mit denen aus Westeuropa und dem frankischen Reich zu vergleichen" (Mühlen 1975:36). No V-type swords in Poland or Hungary were found in the relevant literature.

The great similarities in patterns on V-type hilts indicate that their production was not widespread, and the marked distribution of spearheads with similar patterns suggests an eastern location of smithies. However, the wide distribution of weapons, both sword hilts and spearheads with Ge 2, 3 decorations leaves the production areas uncertain, although Scandinavia cannot be ruled out. For weapons with Ge 3 decorations the most striking trait is the difference in distribution between swords and spearheads. Most probably, these sword hilts were not made in Norway, however an indigenous production, for example in southern Vestfold and in northern Rogaland/Hardanger, cannot be excluded. These examples illustrate the complexity of origin and distribution studies.

Another very different and distinct ribbon pattern, Ri 4, was found on Gotland spearheads (Thunmark-Nylén:Tafel 239, 1 and 244, 2). A similar one comes from Skåne, as well as one from Brandenburg, Germany (Strömberg 1961:Tafel 66, 7).

The examples given above should not in any way be taken as a complete list, but they are considered sufficient to demonstrate regional differences in the distribution of inlay patterns. This obviously means a

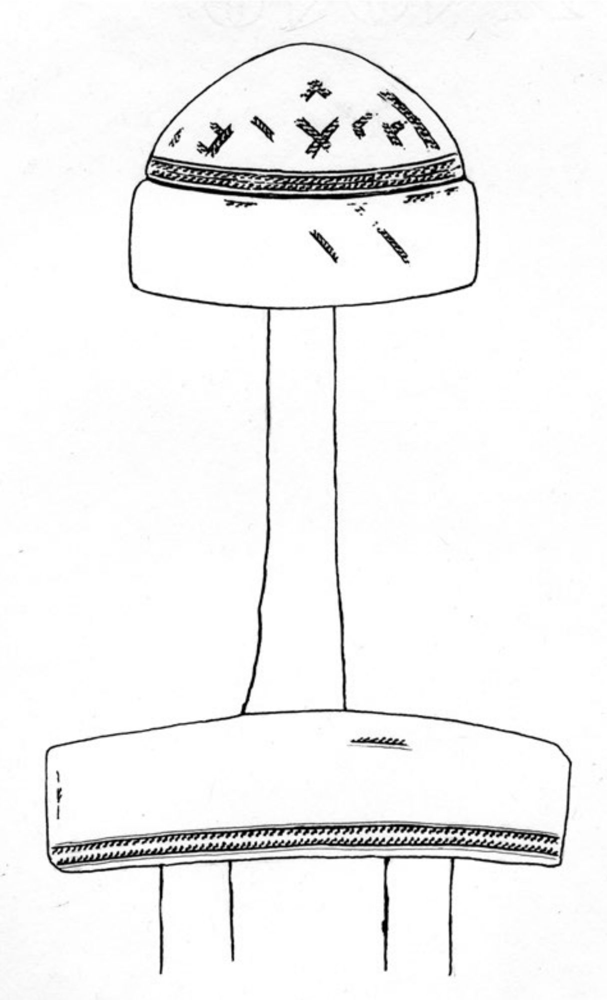

Figure 3.4. *Sword hilt C.23364 from Bøen, Tinn (reconstruction). Drawing: Unknown, KHM (CC BY-SA 4.0).*

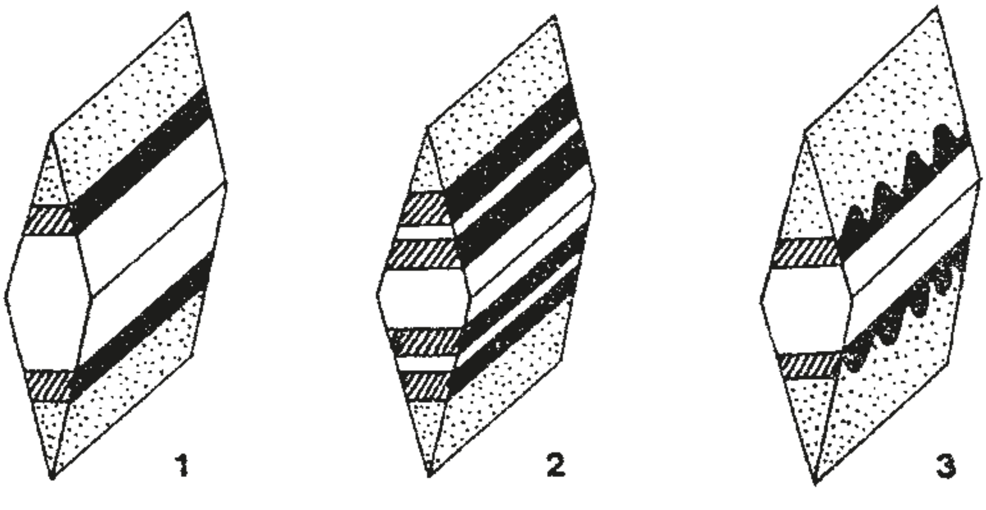

Figure 3.5. *Narrow and serrated strips forged into spearhead blades (pattern welding 1–3) (after Solberg 1984, Figure 19; Selirand 1975). The image is not covered by the CC-BY license and cannot be reused without permission.*

decentralised, regional production of spearheads with inlay decoration, starting c. 900 A.D. This conclusion also includes blade constructions with plain and serrated strips (see below Chapter 7).

The sword hilts of Petersen's type P support the view of indigenous production of inlay decorations. The P-type lacks a pommel, a feature otherwise restricted to the indigenous types M, Q and Æ, and no P-type swords are known outside Norway. Several of their hilts have inlay decorations with a dense vertical fishbone pattern, which is unique to this type. They are dated to the early 10th century (Petersen 1919:Figure 109).

Two such swords were found in Telemark, both in Tinn (C.36841 Åpålen, C.54843/1 Bøen, Rjukan). From the same farm, namely Bøen, came the X-type sword with a unique inlay decoration: narrow diagonal ribbons forming open rhombi (Met. 14, Figure 3.4) and a spearhead with Aa decoration on the socket (C.10899). This rhombus pattern is distinctly different from Ge 2 and 3 with rhombi.

Contemporaneous with the early decorations on spearhead sockets, a new smithing technique using inlaid plain or serrated strips on the blade came into use, and can be found on many spearheads with decorated sockets (Figure 3.5). This may indicate that the two techniques were introduced together.

Solberg's Table 11 shows that Petersen's M-type spearheads, Solberg VII.3A and B, were also forged with MS 1 and MS 3 blades, indicating continuity in indigenous smithing traditions (1984:Table 11). Only six M-type specimens have been found in Telemark, and only one with Ringerike style decorations (C.29878b). Consequently, we will not discuss this continuity any further.

3.6 OTHER RELEVANT ARCHAEOLOGICAL FEATURES

All three of the most numerous sword types, C, M and Q, have been found all over the country, as far north as Norse settlements extended (see Petersen 1919:distribution tables; Sjøvold 1974:276, 278, 279). Variations in frequency among regions often correspond to general variations in find numbers, and the greatest number of M and Q-types come from Eastern Norway.

The earliest, the C-type going back to around 800 AD, was developed from the continental B-type, which Geibig split up into combination types 1.I–VI and 5.II–VI (Geibig 1991:Abb.1, 16), and has an upper guard and pommel made in one piece. The distinction between B and C is not always clear, as indigenous swords can very well have separate upper guards and pommel, and the C-type hilts vary in shape. There is, however, a distinctive difference in blades. While double-edged blades dominate the B-type hilts (14 to 8), the C-types demonstrate the opposite trend (40 to 67) (Petersen 1919:61, 68).

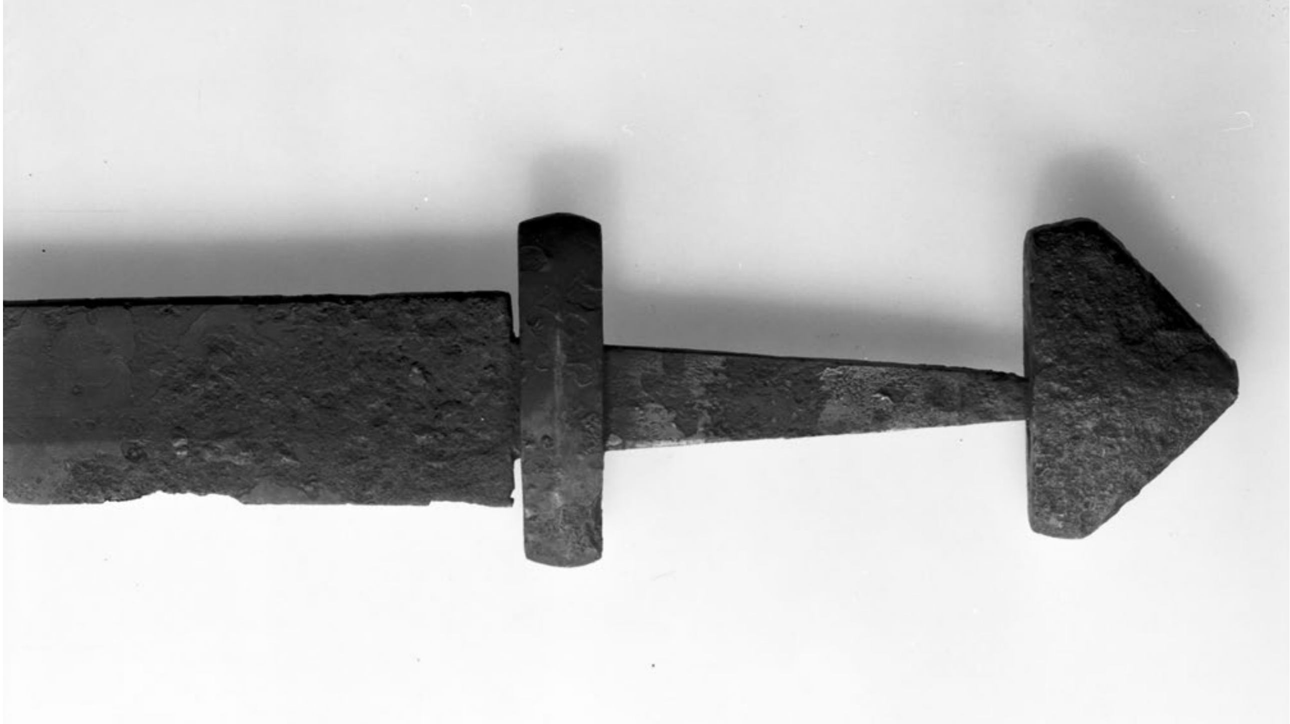

Figure 3.6. *The C-type hilt C.24217 from Risvold, Hjartdal. Photo: K. Helgeland, KHM (CC BY-SA 4.0).*

The M-type hilts, without a pommel are characterised by Petersen as the simplest possible form having two guards and a grip (1919:117). There are some variations in shape, for example between his figures 98 and 99, both found in the same area of Romerike north of Oslo. No investigations of possible regional variations in the three numerous types have been carried out. The Q-type is held to be developed from the M-type, and the changes show that the weaponsmiths knew about general fashions in hilt shapes.

Very few of these swords have blades with pattern welding or inscriptions. One such is the C-type sword from Århus, Hjartdal, Telemark (C.24217), which has a single-edged pattern-welded blade (Liestøl 1951:76, Figure 1b).

M-type spearheads: An example

A relevant study is Kristina Creutz's thorough investigation of Petersen's M-type spearheads from the countries around the northern part of the Baltic Sea, including eastern Central Sweden, the southern part of Finland, Estonia, Latvia and the adjacent part of Russia. Creutz found 355 examples in all, many with silver decorations on the socket (2003:17–18, 40). She groups them into M1–M8, based on the width of the blades and other striking features, such as facets or a knob at the transition between socket and blade (2003:37). The main dating is 11th century, but she does not detail the chronology.

Creutz has identified 25 smiths making M-type spearheads, through a partly impressionistic method based on "the personal touch" visible in details of craftsmanship (2003:137). Her study is fascinating and convincing in relation to some of the identified blacksmiths, while a very small number of spearheads identify others: in ten cases, there are only two examples. More than 50% of the spearheads could not be attributed to any particular blacksmith. The diagrams (Creutz 2003:59) show that the subtypes M1–8 are found in all countries with few exceptions, though in varying frequencies, and it is difficult to see regional differences in the material. The M-type spearheads were produced during a relatively long period, and some differences may therefore be chronological.

Creutz uses the concept "smith zone" to denote a certain area within which a specific smith was active, mainly to be understood as the outlet or working area of a craftsman, the area where he found his customers, or where he was allowed to work and to supply people with weapons. A smith zone may also correspond to the area of a leader of some kind, as well as indicating a production centre (Creutz 2003:192–3).

Some of the smiths have been connected to a single burial ground, and a distribution map shows that some were situated close to each other (Creutz 2003:162). Finland differs from the other areas by having only three identified smiths whose products enjoyed extensive distribution. The investigation demonstrates that M-type spearheads were most likely made in all parts of her very wide investigation area, indicating close connections between those who organised and those who carried out the production. Details depend on population density, social organisation and other factors that cannot be considered here.

Special types and variants

Further, it is interesting to take a closer look at the Norwegian weapons which fall outside the ordinary types: Petersen's special types, Solberg's variants, and especially their find locations. Petersen's special types are a mixed lot. Some have turned out to be ordinary types of continental origin (Sp.1 and 2, plus 4 with only the lower guard preserved), or closely related to the Anglo-Saxon L-type (Sp.7, 14, 15). Sp. 20, (two specimens) are of an ordinary, possibly V-type, which have lost their pommels and only have the fastening bow left. Most of the others, Sp. 3, 5, 6, 8, 9, 10, 11, 16 and 17 are probably the products of inventive Norwegian blacksmiths.

Petersen does not define a minimum number of examples needed to make an ordinary type, but it is plain from his work that a special type comprises a maximum of three swords. No search has been made for later acquisitions of such swords, but as far as we know there are very few, and Petersen's information is reliable. Even though it numbers four specimens, the G-type is included among the special ones.

Solberg emphasises the small number of spearheads that are non-classifiable because of lack of specific typological elements and/or symmetry. They amount to only 1.3% of the material from both the Merovingian and Viking periods. Accordingly, the standard spearhead is the product of a specialised workshop, many made by highly specialised smithies (Solberg 1984:141). She describes a total of 14 variants, eight of which (Nos. 7–14) were from the Viking Age. The majority were found in her Region 3, comprising the eastern Norwegian counties Hedmark, Oppland, Buskerud and Telemark. All are in the main inland areas, and only Buskerud and Telemark have short coastlines.

One could perhaps expect the indigenous special types and variants tohave come to light far away from central areas, but this is not the case. Sp. 8 and 9 were found on the same farm, Finstad in Løten, Hedmark, in an area that probably had a specialised smithy in the 10th century, in addition to not being far from the centre Åker in Vang, Hamar (Martens 2002:181). Three out of four Var.8 spearheads, as well as a Var.9 and a 13, were found in the same area.

Sp.5 and 11, and Var.10 were found in Vågå, a municipality with an unusually high number of swords with decorated, partly imported hilts (Martens 2009). The two Var.10 spearheads have complicated MS patterns (No.8) and are probably imports belonging to a real type with at least five specimens in Finland (Solberg 1984:147).

The four G-type swords are of some interest here. This type differs from all others because the guards curve into spirals (Petersen 1919:Figure 71). As mentioned above, it is classified here as a special type made by an inventive Norwegian blacksmith. No more such swords have come to light since 1917 (Hernæs 1985:find lists). Two examples were found quite far apart in southern Buskerud (Kongsberg and Røyken), the other two equally far apart in Oppland (Gjøvik and Øystre Slidre). It makes sense that all four were made by the same blacksmith, and this seems not unlikely considering inland communication routes.

Likewise, Sp.18 and spearhead Var.8 and 9 with three specimens each, had a wide distribution, but not far from central habitation areas, a feature significant for our understanding of weapon production in general.

Most of these special types and variants are difficult to date, but Petersen places most of the swords in the 9th century, while more of the spearhead varieties belong to the 10th century.

Chronology

One of the aims of this investigation is to trace technical development in sword blade production in Norway during the Viking Age. There are no other technical investigations to rely on, but again Solberg's investigation of spearheads is relevant. The indigenously made spearheads from the 9th century, of her type groups VI and VII.1 (Petersen's types A–E and type F respectively) include heterogeneous objects. Many of the VII.1 group items have decorations consisting of horizontal circles in elevated areas on the socket, made in specialised workshops (Solberg 1984:81–83). Such workshops probably existed in all her three regions, but type VII.1C seems to have been manufactured in the inland regions only (Solberg 1984:112).

By the introduction of the VII.2 spearheads (Petersen's type I) c. 900 AD, new smithing techniques appear on the blade. It is therefore relevant to search for a parallel development on sword blade constructions.

Blacksmith graves

The last find group to be considered is that containing graves with blacksmith tools. This is a problematic and much discussed group, the main problem being whether they should be called blacksmith graves at all (Straume 1986:46ff; Pedersen 2016:21–23; Barndon and Olsen 2018:77ff). It is difficult to decide which of the buried persons were actually blacksmiths. At least a certain number of blacksmith tools are needed in order to designate them in this category, and Petersen has shown that if such graves are required to have three or more such tools, their number decreases markedly (Petersen 1951:110). Multipurpose tools, such as hammers and files, should not be included when numbering these graves.

Jørgen Bøckman maintains that all blacksmith tools found in graves represent smiths' graves as a *pars pro toto* burial custom (2007:91). This is certainly a problematic viewpoint that cannot be accepted without further investigation.

Blacksmith tools found in graves have always been recognised to be iron smithing tools. Bøckman carried out a detailed analysis of the tools' functions based on Petersen's archives and his own practical experiences. He found that many of the tools were small and suited only for work in other metals, bronze silver etc., and were used for jewellery production (2007:Chapter 5). To what extent smiths used small tools to create inlay decorations also remains uncertain, but it is interesting and relates to the question of indigenous production and H/I-type hilts.

A central question here is the relationship between skilled smiths and central farms or places. Graves containing high status objects like bronze cauldrons and gaming pieces, as well as blacksmith tools, could be status markers rather than indications of a trade (Petersen 1951:111). Liv Helga Dommasnes maintained that the idea that a man's honour included activities for which he was responsible but did not necessarily carry out himself, was an important factor in interpreting the meaning of grave goods. Having a skilled weaponsmith in his employment could certainly add to a man's honour (Dommasnes 2018:44).

An intriguing example is the grave from Englaug in Løten, Hedmark, dated to c. 1,000 AD. Besides a T-type sword with a decorated hilt in Ge 5 pattern, it contained pairs of stirrups and spurs, thus belonging to the group of equestrian graves interpreted by Helge Braathen and others as the burials of men with a special political function in society (Braathen 1989:141, 162ff; Glørstad 2010:270–71). It also contains a large number of blacksmithing tools including rare and special objects, such as an ingot mould and a draw-plate for making wire, indicating a specialist blacksmith as well as a man of high status (Martens 2002:175). The find location of Englaug is closely connected to the large cemetery at By, going back at least to the beginning of our era (Martens 1969). It has been suggested that he may have been a member of the By/Englaug family. Another nearby grave mound contained a hammer, a file and a pair of tongs, but these tools can only be considered vague indications of a blacksmith grave.

Other burials with several blacksmith tools do not contain high status objects, and may have hardly any weapons at all, thus making them difficult to date. This is the case with a grave from Ytre Elgsnes in Troms, which has the most blacksmith tools found in a grave in Northern Norway (Simonsen 1953). Povl Simonsen suggests a date in the 9th century. Nicolay Nicolaysen excavated another grave from Besseberg in Eiker, Buskerud, and it is unlikely that all status objects were overlooked (grave 1 in Nicolaysen 1891:76–78). Other examples, such as B 1068–89, have badly documented find circumstances.

The Byggland find from Morgedal, Kviteseid in the middle of Telemark, dated to c. 950 AD, is relevant to several aspects of this discussion. It contained more than 20 blacksmith tools for both coarse and fine work (Blindheim 1963; Martens 2002). Based on the interpretation that the spearheads with inlay decorations were produced by the deceased, the grave thus contained no imports or special status objects. The find was discovered by the farmer, and an excavation was carried out by Blindheim and Erik Hinsch (Blindheim 1963).

There have been questions raised as to whether this was a grave at all, as the site showed some unusual traits. An alternative interpretation is a burnt-down smithy, as well as possibly a grave built over a burnt smithy (Østigard 2007:144–48). Julie Lund has interpreted the find as a votive deposit, referring to similarities in both content and find circumstances to other deposits in southern Scandinavia (Lund 2009:167–69). This is an interesting and certainly a not unlikely interpretation. I have visited the find location ourselves, and I disagree with the idea that it is a wetland deposit. The numerous weapons and implements were placed under a cairn on a small elevation by marshy land on sloping ground, not a real bog. The objects had a much wider distribution than the limited charcoal rich layer, and there were no indications of a forge. Only a few small pieces of slag are included in the museum collection, and nothing is said in the report about more slag. This repudiates the idea of a smithy on the spot, and argues even more strongly against iron extraction there.

Frans-Arne Stylegar has suggested that there are several burials in the cairn where the find was discovered (2014). However, many of the weapons and tools were spread in a seemingly disorderly way, but the four swords were found with two pairs lying parallel and with the hilts in opposite directions. Both pairs lay in the outer part of the cairn away from the charcoal layer where most of the blacksmith tools were found (Blindheim 1963:29).

The comprehensive number of blacksmith tools still gives the impression of being one man's equipment. In any case, we see the find as a proof of a blacksmith's work in the vicinity[5].

The find is so unique in many ways that a definite determination of the find category is difficult. Altogether, the find circumstances suit a grave better than a smithy, and we interpret it as a grave for a very special and highly esteemed blacksmith who mastered a wide range of techniques.

The graves treated here are certainly very few in number, but they can be used to argue in favour of a connection between smiths' graves and centres.

A further challenge connected with the blacksmiths is where they were buried, when considering whether they were itinerant or a settled part of society. The identified graves place them within ordinary society, but this leaves open the question of where an itinerant craftsman, perhaps even brought to Norway from abroad, would have been buried.

3.7 PRELIMINARY CONCLUSIONS

The hypothesis is that weapons of different kinds, including swords and spearheads, were made in Norway during the period preceding the Viking Age. Solberg considers her group type V to be of indigenous Norwegian manufacture, and that differences in the distribution of subtypes "may simply represent different regional manufacture traditions" (1984:50–51).

The number of finds increases greatly in the Viking Age, accompanied most likely by the number of blacksmiths. The problem in relation to their number, localisation and social connections needs to be divided into several questions. One basic factor is the very wide distribution of common Norwegian sword types, which must rely on connections between the producers. Three possible explanations are suggested:

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[5] The few slag pieces wrongly interpreted as remains of iron extraction, include a plano-convex slag-cake, formed in the smithing hearth, probably the piece Blindheim (1962:36, 50) wrongly described as a lump of raw iron. There are no indications of iron extraction in the find.

1. The number of weaponsmiths was very small, and the weapons from each smithy had a very wide distribution.
2. The number of smiths was greater and production more decentralised, but there were close connections between the smiths or their employers.
3. The blacksmiths were itinerant and produced the same types independent of where they practised their skills.

Itinerant craftsmen including blacksmiths are often mentioned in the literature, but it is harder to find a discussion of the social conditions for their existence outside the Viking Age towns. Did Norwegian Viking Age society allow independent craftsmen to move freely from one place to another, and if so what about their personal security? It is more likely that they were exchanged among leaders.

To what extent was weapon production regulated and how could such regulations be enforced? These questions are again closely connected to the equally old question of the smiths' social status as a free man or a slave.

The graves containing blacksmith tools mentioned above, along with a small number of others, are interpreted here as the graves of specialised blacksmiths. They leave no definite traces of their products, but Blindheim's (1963) interpretation of the weapons and other objects in the Byggland grave as the smith's own products is plausible, and is supported by other concentrations of decorated weapons surrounding such graves (Martens 2002).

Several of these graves were found in cemeteries or otherwise in places supporting the idea of the smiths as free men belonging to a local community. This does not exclude the existence of blacksmiths with other backgrounds, which are not recognisable in the grave finds.

The smiths' belonging to the farming community does not solve the problem of their working conditions, whether they were independent or attached to centres/chieftains. The uniformity of hilt and spearhead types all over the country indicates their links with centres, as the elite normally command long-distance internal connections, which would have been more difficult for independent blacksmiths to establish and maintain.

Further examination of potential Norwegian blacksmith graves is still necessary as Bøckman's investigation has further demonstrated. One interesting factor is their location in relation to chieftains' farms and possible centres, which deserves further study.

The Byggland grave is not centrally placed, but the distances to the core areas of Kviteseid and Seljord are only about 10 km and 15 km respectively as the crow flies. The overland crossing between the two areas passes Brunkeberg not far from Byggland (Figure 2.1a–b).

A connection between the blacksmith buried at Englaug and the centre at Åker, about 10 km to the west, was previously suggested (Martens 2002:184). The Elgsnes grave came to light on the peninsula forming the northwestern point of the large island Hinnøya. On the inner side of northern Hinnøya, lies the farm Trondenes, the seat of one of the mighty chieftain families of Northern Norway. Another important such farm, Bjarkøy, is situated on a smaller island not very far north of Hinnøya. One possible explanation for the location of these graves is that blacksmiths attached to chieftains were recruited among local artisans and were buried on their family land.

In 2014, a grave with blacksmith tools was excavated at Nordheim in Sogndal, Sogn and Fjordane county. This grave was situated a few kilometres away from the central part of Sogndal, and no Viking Age or medieval farm is documented to have been there, though it cannot be excluded as a possibility. Randi Barndon and Asle Bruen Olsen suggest a location beside a road leading northward from Sogndal (Barndon and Olsen 2018:67). If found on a farm, the grave can be interpreted as another example of a local artisan attached to a central farm in Sogndal, where Kvåle stands out as a probable location. Kvåle was a high-status farm in the medieval period, but comparable high status in the Viking Age has not been securely confirmed (Iversen 1999:56).

The Nordheim grave is dated to around 800 AD and is thus an early example of such graves. The tools include items for working in soft materials as well as an H-type sword with a hilt decorated with vertical bronze stripes (Barndon and Olsen 2018:70 and Figure 5). This begs the question as to whether such decorations were produced in Norway at this early date.

Centres were probably instrumental in a continuous apprenticeship training system and in the spread of new technical skills. Another factor leading towards the same conclusion is access to raw materials, at least metals such as copper alloys and silver used for hilt and socket decorations.

However, one must be cautious, and rather than propose a rigid system, accept the possibility of the existence of smiths working for a limited local population, and not necessarily making only weapons of simple construction. They could also very well have maintained some level of contact with more centrally placed colleagues.

4. ON SWORD TYPOLOGY

In this work we apply the widely used typology of Petersen (1919). However, before venturing further, some remarks on typology, relevant both to the Telemark material and in general, are necessary.

About typology

The primary role of typology is to provide type determinations that supply basic information about an object's shape and dating, making them intelligible to researchers everywhere. In terms of wider use, it is important to take into account the basic characteristics of both the typology and the relevant material.

For sword typology – as for all iron weapon typologies – it must be remembered that all iron objects are shaped during the forging process, in contrast to objects cast in moulds. This simple fact accounts somewhat for deviations found throughout the Viking Age. It is therefore surprising that the great majority of swords can so easily be classified according to specific types.

4.1 ON PETERSEN'S AND OTHER SWORD TYPOLOGIES

Like all others, this typology is based on the hilts, which consist of three parts: the lower guard, upper guard and pommel. Being three-dimensional, they are characterised by side-view, length-section and cross-section (Figure 4.1). Side-view is preferred to side-section because of decorations on the surface. Even though the shape of the lower and upper guards is the same in most cases, one finds a large number of combinations. Exceptions in which the two guards are not uniform were found on certain late hilt types, including types X and Y, in which the upper guard and pommel are in one piece, sometimes with a rudimentary division.

Naturally, a typology that can be used in all countries where such swords have been found is a great advantage for comparative studies. This does not mean, however, that there are no problems attached to the use of Petersen's or indeed other typologies. Normally, both in museum catalogues and publications, type determinations are given without further details or deviations, and erroneous determinations do occur. Of course scholars have used typologies differently, and in many cases the need to place swords within a type has overshadowed the deviations from the type's characteristics. During our work, we have tried in vain to ascertain interesting details of certain sword hilts in the literature, but the only safe way to confirm details is to study the swords themselves. Depictions normally show the side-view, while length-section and/or cross-section are omitted. It is in many cases important to consider all three dimensions.

To these elements of shape, one must add the decorations, consisting of three types: forged line decorations, inlaid, or encrusted decorations, which use one or more other metals such as silver, copper alloys and niello, often in combination with metal threads for marking divisions. For a brief description of the two techniques, see Chapter 3.5. A few types, above all O I, have cast guards in copper alloys with decorations. The decorations are type specific, even though variations within the same type can be considerable and the same patterns are found on two hilt types, O II and R, while decorations on the S-type are distinctly different (Martens 2002). Geometric patterns are found on several hilt types (H/I, K, O III, T and V) from the 9th and 10th centuries. No systematic studies of combinations of hilt types and patterns have been carried out.

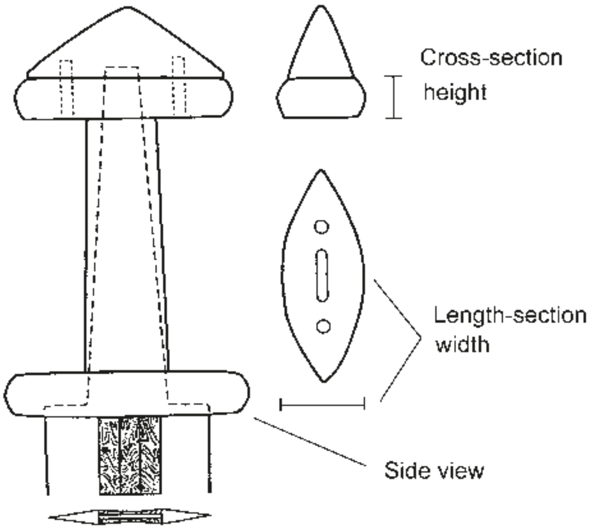
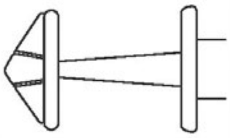
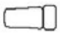
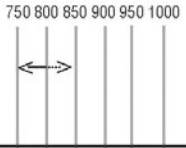
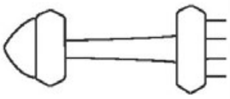
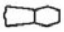
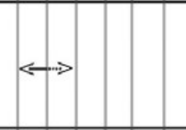
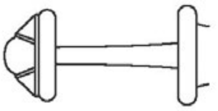
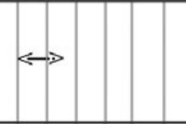
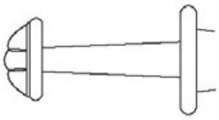
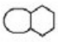
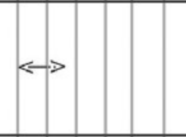
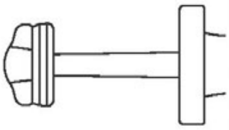
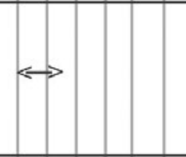
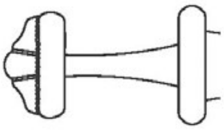
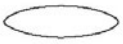
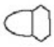
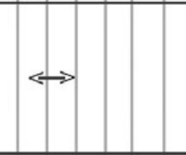
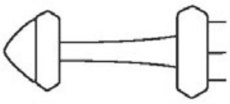
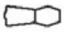
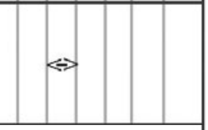
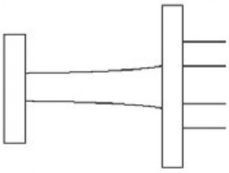
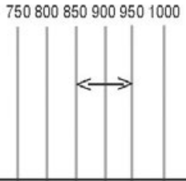
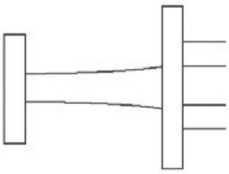
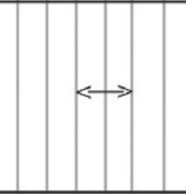
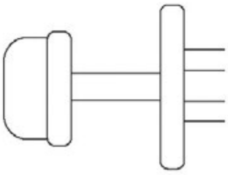
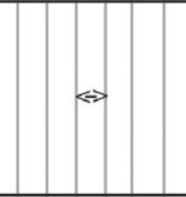
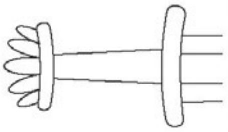
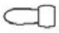
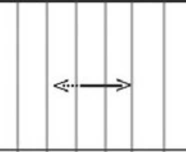
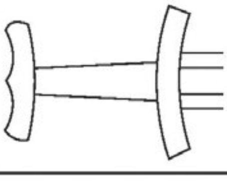
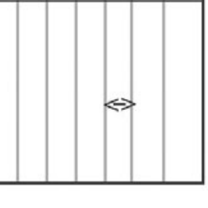
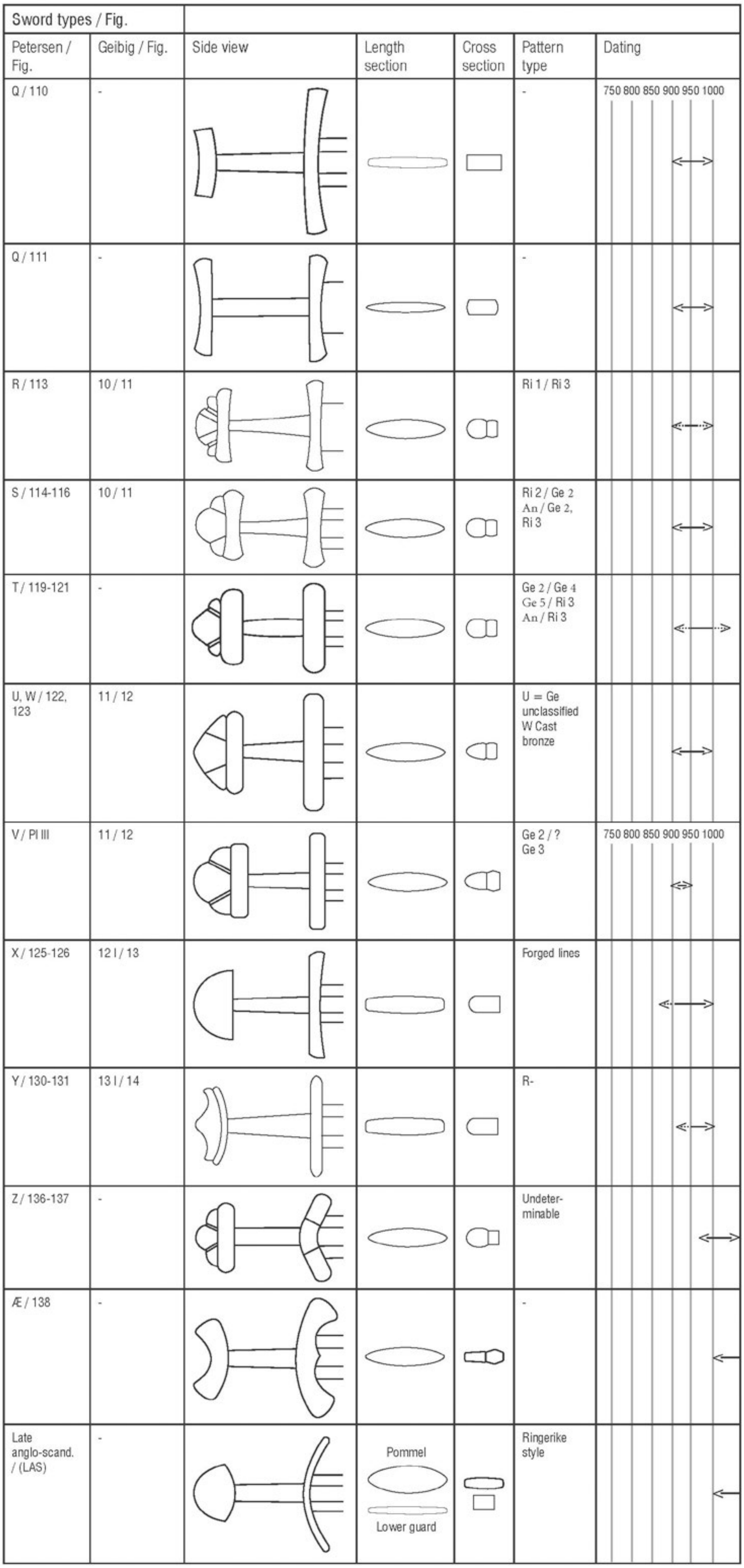


Figure 4.1. Terminology for sword hilts (after Oakeshott 1960). The image is not covered by the CC-BY license and cannot be reused without permission.

Sword types / Fig.						
Petersen / Fig.	Geibig / Fig.	Side view	Length section	Cross section	Pattern type	Dating
A / 52	-				Forged lines	
B / 53	1 I-VI, 5 II-VI / 2,6				-	
Sp 1 / 55-56	-				Not classified	
Sp 2 / 72	2 / 3				Not classified	
-	3 / 4 Mannheim				Not Classified	
-	4 / 5 Mannheim - Speyer				Not classified	
C / 57-58	-				Forged lines	
M / 98	-				-	
M / 99	-				-	
N / 103	8 / 9				-	
O I-III / 104-105	O III, 6 / 7 O I-II, 9 / 10				O I Cast bronze O II Ri1 O III Unclassified geometric	
P / 109	-				Fi	



Sword types / Fig.						
Petersen / Fig.	Geibig / Fig.	Side view	Length section	Cross section	Pattern type	Dating
Q / 110	-				-	750 800 850 900 950 1000
Q / 111	-				-	
R / 113	10 / 11				Ri 1 / Ri 3	
S / 114-116	10 / 11				Ri 2 / Ge 2 An / Ge 2, Ri 3	
T / 119-121	-				Ge 2 / Ge 4 Ge 5 / Ri 3 An / Ri 3	
U, W / 122, 123	11 / 12				U = Ge unclassified W Cast bronze	
V / Pl III	11 / 12				Ge 2 / ? Ge 3	750 800 850 900 950 1000
X / 125-126	12 I / 13				Forged lines	
Y / 130-131	13 I / 14				R-	
Z / 136-137	-				Undeterminable	
Æ / 138	-				-	
Late anglo-scand. / (LAS)	-		Pommel Lower guard		Ringerike style	

Figure 4.2. *Summary of Viking Age hilt types with decoration types and dating. Drawing: J. Kreutz. The image is not covered by the CC-BY license and cannot be reused without permission.*

Petersen describes and depicts the side-view of the guards and the length-section normally of the upper guard (which he incorrectly calls *tversnit*, meaning cross-section), often depicting the cross-section of the upper guard and the pommel as well. However, he is not consistent in his presentation. He mentions variations in shape within a type which are in fact quite common, but even when this is taken into consideration, each type stands out because of its combination of shape elements. Tests have demonstrated that these individual element combinations are specific to each of Petersen's types. This is perhaps the main reason why the typology has proved to be so applicable, and the naming of the types with simple letters from A to AE has added to its popularity. Decoration is briefly described, though it is not a real part of the type definition.

A typology scheme based on Petersen's depictions and descriptions with several corrections and supplements, and with the corresponding combination types and figures in Geibig's typology, is presented in Figure 4.2. Early Carolingian hilt types are problematic, and are not included in the typological scheme. They are basically individual examples with fine inlay decorations, although indigenous undecorated specimens may occur (Petersen 1919:Figure 55a; Martens 2006a). Details of the side-view of the pommels differ, for example Sp.1 has oblique, while the other three have vertical partitions. Sp.2 and Mannheim-Speyer guards have angular cross-sections, while Sp1 and Mannheim types have slightly convex ones. Sp.2 and Mannheim-Speyer often have geometric decorations (Menghin 1980:Abb.8 and 6).

The scheme presented here is very schematic, listing only the main characteristics. Geibig's Abbildungen demonstrates that deviations are not unusual. Common decoration schemes are added for several types, while for other types decorations are individual, and a classification is not possible without comprehensive studies of the swords. Of course, distinguishing, for example, between oval and rounded length-sections can be difficult.

Petersen's typology was constructed for the swords discovered in Norway, which constitute by far the greatest number found in any European country. Although the foreign material at his disposal for comparison was limited, Petersen was fully aware that the Norwegian material included both imported and indigenously made swords, as opposed to Anders Lorange who believed that all swords in Norway were imported (Lorange 1889). However, finding sound criteria for distinguishing between the two remains problematic (Martens 2004).

Petersen (1919) made two very important statements. The first was that Viking Age swords did not form a typological series, starting with type A and ending with AE:

> The study of typology involves several problems, not least because of the extraordinary abundance of and extensive changes in particular details. There are only a few cases in which there occurs a continuous development of a typological series over a longer timespan in the way that we find from several other periods, e.g. Stone Age axes without shaft holes, Bronze Age sword grips, bucket-shaped pots, cruciform brooches from the early Iron Age or oval brooches from the Viking Age. There are only a few cases in which we can demonstrate that late or the latest Viking Age weapons were developed from early Viking Age ones. [Petersen 1919:21–22, our translation]

This is supported by Geibig (1993) in his publication of the early Carolingian hilt from Rostock-Dierkow. He points out that the shape and decorative elements on this hilt can be found on a considerable number of hilt types, and that the elements belong to a common pool of established forms from which they could be individually selected and combined (Geibig 1993:218).

Petersen's other statement was that weapons were changing over time:

> It has turned out that because of the comprehensive amount of Viking Age weapons that we have, and through a thorough knowledge of this material, it is in fact possible to establish a chronology of forms. By making up a detailed relative chronology within the two centuries, an absolute chronology will appear as a result, even if it is not correct in all details. With a thorough knowledge of the extent of the material obtained, we can place each type within the two and a quarter centuries covered by the Viking Age in Norway. Wherever possible, I have also used ornamented objects of other kinds to support the dating, but as previously stated these other objects can only be used with great care when dating single finds, and even more so when dating types. It is the closed finds with many objects, as well as the comparison between such finds, that allow secure dating and not just a single ornamented item. [Petersen 1919:18, our translation]

He was able to establish a chronology, although

> The investigation has demonstrated that it is dangerous to base chronology on typological similarity. There is a similarity between Figs. 62 and 121 (E and T-types), but the first is from the earliest and the second from the latest Viking Age. Of course, clearly demonstrable typological developments have also taken place, which can be used as support for the dating, although we cannot rely solely on that. [Petersen 1919:201, our translation]

In fact, he had few other objects to rely on, and the object type most often included in the grave finds were oval brooches belonging to female dress, always leaving one in doubt as to whether all the objects belonged to the same grave. New research including physical anthropology has verified that women's graves with weapons do occur (Price et al. 2019). Thus such combinations can be reliable. Petersen had to rely on find combinations with other weapons, thereby leading to circular conclusions. Even so, his chronology is still valid with some adjustments.

4.2 OTHER TYPOLOGIES: COMPARISONS PETERSEN/GEIBIG

Several other typologies have been presented after Petersen's (see Geibig 1991:13–19: Research history, where Abb.1 presents the correspondence between different typologies). Some studies, such as Willfried Menghin's, are valuable supplements relating to early Carolingian swords, which made it clear that Petersen's special types 1 and 2 are ordinary if not numerous types (Menghin 1980). Other scholars have also worked on a limited number of types, or have reduced the number of types considerably. However, such simplified systems do not fulfill the need for an adequately detailed classification, and can be directly misleading.

The most systematic and detailed element-based typology was made by Geibig (1989 and 1991). He depicts six different views/sections, but he constructs his combination types based on four elements, and the variations of each element are numbered. The elements are: side-view (Seitenansicht); cross-section (Schmalseitenansicht); length-section (Knaufaufsicht) of the pommel/upper guard; and the length-section (Parierstangenaufsicht) of the lower guard, with the latter two depicted as projections, not sections. These elements are sufficient for distinguishing between the combination types, and encompass a number of variations within some of them.

The cross-sections of the upper and lower guards are normally the same, and this is very often the case for the length-sections as well. Geibig describes the side-view of the guards briefly. The side-view of the guards is important for two reasons: Firstly, the side view is the element that is most sensitive to fashion changes and thus has a chronological value. Very briefly – and not without exceptions – early guards are short, straight and often wide, while later ones are curved, often with singly or doubly extended ends. They are often longer too. Secondly, in many cases the side-view of one guard can produce a secure type determination even when the other guard and pommel are not preserved, especially when remains of the decoration are still preserved.

One of the advantages of Petersen's typology is certainly that it is built on few elements, and Geibig has demonstrated this to be sufficient. Even though they rely partly on different elements, Geibig can always correlate his combination types to Petersen's types. Still, Geibig's classification system has its weaknesses, at least from a Norwegian point of view. He does not take decorations into account, and they ought to be included in the description of the types.

Geibig's typology was constructed for swords found in the former West Germany (Bundesrepublik Deutschland), and several of Petersen's types are not included. Among these are the common Norwegian types M and Q, but other ones with a much wider distribution in Northern and Eastern Europe, for example the D, E, T and Z-types, have also been omitted. Even though the problems relating to the representativity of find distribution of these latter types are substantial, they raise some interesting questions.

Bearing in mind that nearly all hilts were shaped by hand during forging, the question remains: How much can an item deviate from its type characteristics and still be ascribed to that type? This is not just a theoretical question, but one which is relevant to several problems of production. The remarks below seek to reveal some of these problems.

Petersen and Geibig have handled type-forming questions in different ways. In most cases Petersen gives a general type description including variations, while Geibig has divided some of his combination types into several varieties, such as his combination types 1 and 5, both of which comprise six variants. The first one corresponds to Petersen's type B, the second to Petersen H/I (5 I) and B (5 II–VI). Thus type B is split into a total of 11 variants. Geibig describes the combination type 1 variants as "a greater, loosely connected group" (1991:28). Further "The combination types 1 and 5 combine a wide range (spectrum in the German text) of hilt forms rich in variations with similarities in the pommels' cross-sections as well as the side-views" (1991:29). In his summary of combination type 5, he points out the straight sides of the pommel in side-view as the main characteristic of variant I "a closed (*eng geschlossene*) homogeneous group sharply delimited from the other variants" [our translation].

For both combination groups, variant I has the most finds, seventeen and six respectively. For the others the numbers are small, in five cases only one hilt, and one may therefore question whether the variants are real or just the result of the hilts being hand-shaped (Geibig 1991:186–87).

Allowing variations within types is better than splitting a type into several subtypes, in part because similar deviations are often small in number. There is no doubt, however, that in many cases type determinations have been used too freely.

Origin and production areas for widespread sword types are difficult to find. There is no doubt that the Carolingian realm and its successors played a central role and were probably a core area for fashion development. The production area problem must be split into several separate considerations because of the fact that a hilt type originating in one area can very well have been produced in several places lying far apart. Such questions are difficult to handle both methodically and in practice.

This is a highly relevant issue in relation to Petersen's H/I type, which is the most numerous type in Norway, Sweden and Finland. (Androschuk 2014:246–67; Kivikoski 1973:15; Petersen 1919:89). It is no doubt of continental origin, and some very early swords from Croatia have been placed in a group between a special type 1 and the H-type (Müller-Wille 1982:134–35, Abb. 20). Petersen cites the number of H swords as 213 and the I swords as 16. The numbers have increased greatly since then. Were all these hilts imported or were many, perhaps the majority of them, produced in Norway? This question depends on the technical skill of Norwegian weaponsmiths, in terms of whether they mastered the inlay decoration technique. If so, there were probably only a small number of smiths working in central places, such as royal or noble farms, who did.

Geibig's combination types 1 and 5 are very widely distributed in Europe. Geibig's placing of the sword from Medvedica in Croatia (Vinski 1983:Abb.2, 1) in combination type 5 is convincing (Vinski 1983:42). This sword hilt, like the one from Joshoven in Bayern has a coarse inlay decoration with vertical strips, one of the characteristics of the early H-type swords. Geibig points out the difference between the two in the cross-section of the pommels, and ascribes the Joshoven sword to his variant 5 II, Plate 9. Geibig places all the other variants of types 1 and 5 in the late 8th century, and are thus older than 5 I, which was probably developed at the very end of the same century. What this means in terms of the production of 5 I is hard to say. These complex questions need a far more thorough investigation.

On divisions of later types

A few words are needed on some late types, specifically the relationship between Petersen's X-type and Geibig's combination types 11 and 12. Combination type 11 encompasses Petersen's types U, V and W, and in Geibig's description he refers to Vinski, who describes a transition type between W and X. The X-type is challenging. Geibig splits it into two combination types, 12 and 15. Both have upper guard and pommel in one piece. 12 I, Geibig's Figure 13, which is the only one of Viking Age date, corresponds to Petersen's Figure 124.

Geibig places Petersen's type X, Figure125, in combination type 11, as it is closer to this than to his combination type 12 (Geibig 1991:56, and Abb.12).

For the W-type, however, Petersen's main characteristic is not the shape of the hilts, but the material they are made of. "The guards are totally made of bronze, with the upper guard and pommel cast in one piece" (1919:156, Figure 123). He does not describe the shape, but both Figures 123 and 126, as well as Geibig's Abb.12, show a straight lower guard, while Figure 125 has a slightly curved lower guard. Moreover, both Figures 125 and 126 show slightly extended ends on the underside. These variations are in accordance with Geibig's depiction of combination type 12 (Figure 13). The W-type is not an independent type, but a variant on the X-type, made in cast bronze. This is a parallel to the O-type, which Petersen divides into three variants, according to material and decoration (Petersen 1919:126–29). Any transition type between W and X is thus irrelevant.

As to shape, Petersen's Figures 125 and 126 are the most common in our material. However, four of these, C.23364 and C.29700a–b from Tinn and C.24739 from Kviteseid, deviate from the X-type in one important characteristic, the upper guard and pommel are in two pieces. This links them to the U-type, which can also have copper or brass decorations. Petersen described the U-type pommels as relatively low, and on his Figure 122 the guards are low as well.

The four swords mentioned above stand out because of their very high lower guards: the height of the lower guard on the sword C.23364 from Bøen, Rjukan, Tinn (Met.14) is 2.3 cm. There are some other hilts of similar shape from Telemark that have high guards, among them C.29700a–b. The heights of the lower guards are 1.8–2.3 cm and 2.5 cm respectively. Two others, from Seljord C.17401 and Kviteseid, measure 2.1 and 1.8–2.0 cm in height, and a third one, C.13933 from Fyresdal, measures 1.8 cm, while the other four from Telemark measure only 1.4–1.6 cm in height. The Bøen sword also stands out because of its inlay decoration, which is very unusual on the X-type. The pattern is unusual as well. The decoration forms open lozenges on the pommel and probably on the upper guard (Figure 3.4).

Despite the four specimens having a separate pommel, they are categorised as X-types, or rather Xa-types to indicate the variant. One argument for this is that a high lower guard is also found on other X-type swords, possibly forming a Norwegian variant of the type. Even some Q-type specimens have such high guards.

Type Y, Geibig's combination type 13 (Figure 14), shows several variations, difficult to express through a simple scheme. The pommel's two concave lines meeting in a central top point is a distinctive feature. However, the material used here, consisting as it does of only three or four specimens, is too limited to warrant further remarks.

The distribution of Geibig's combination type 11, presented on his map (Abb.44), shows a concentration in the Hedeby area. The W-type sword, found near Schleswig (Plate 164) is so similar to Petersen's Figure 123 from south Trøndelag that it is likely they were made in the same workshop.

The V-type is the most numerous and widespread of combination type 11. It has a high three-partite pommel and a distinctive geometric inlay decoration (Petersen 1919:Plate III). According to Petersen (1919:155), the pommel does not have convex sides in the cross-section, but the cross-sections can vary. The V-type is certainly a distinct type. The U-type swords are more difficult to place, as they are few in number. Petersen lists eight finds, none of which feature in our material. They are close to the V-type in shape, but with lower guards and pommel. Petersen mentions decorations on some: "Narrow, flat ribbons of brass or copper, stripes on only one hilt" (1919:153). It is possible to see it as a variant of the V-type.

4.3 REMARKS ON SOME LATE EUROPEAN SWORD TYPES

Turning to some late Viking Age types, one noteworthy detail is found on several hilt types: the convex, on some types nearly globular, cross-section of the pommel (R, S, T, Z). This starts in the 9th century with the D and E-types (not included in Geibig's typology), which have moderate convex cross-sections with a rounded top. For chronological reasons, Petersen rejected a typological connection between the E and T-types, but there are E-type finds from the 10th century bridging the gap. In her treatment of spearhead types VII, 2A and B (Petersen's types I and K), Solberg refers to one spearhead of each type found in combination with an E-type sword. Both spearhead types are dated to the period 900–950 AD. Solberg, referring to Petersen's dating of E-type swords, believes the sword found with the K-type spearhead to be an old item included in the grave (1984:94–95). There is no reason for this, as there are other examples of E-type swords found with 10th century spearheads. The sword C.22324a from Hedmark was found with a spearhead of Solberg's type group VII, 2C. A typological connection between the E and T-types implies that the T-type goes back to before 950 AD.

The two types have another special feature in common: a decoration with small pattern-forming indentations on the sides of the guards and the pommel. Even the lozenge on the pommel, found on several T-type hilts, occurs on an E-type sword from the Baltic, as well as on some specimens from Gotland (Kazakevicius 1996:Figure 21; Thunmark-Nylén 1998:Tafel 224:2, 225:1), a detail strengthening a connection between the two types (Figure 4.3).

Unfortunately, cross-sections of the pommel are not often depicted or described in the literature, but such a distinct detail as the convex/globular one, in use for a long time on a limited number of types, is certainly worth noticing. Moreover, the production and distribution of these hilts is a question that deserves a special investigation (see Chapter 7).

The two swords from Tinn, C.21211 from Såem and C.28239a from Mårem, have caused problems because they do not fit into any current typology. Petersen, with hesitation, places the first one in his Z-type, where it certainly does not belong. Their pommels show no rudiments of upper guards, and the lower guards are low and without extended ends, and overall very different from the heavy ones on the Z-type hilts (Figure 4.4). Signe Horn Fuglesang mentions the Mårem specimen as one of two examples of swords decorated in the Ringerike style. The other is in the Moesgård Museum in Århus, Denmark, and she places both in the X-type, although in two different sub-types (Fuglesang 1980:42; the Århus sword is depicted in Evison 1968:Plate XVI B).

A close parallel is the sword from the Thames at Battersea, London (Wilson 1965:32–33, Plate II; Evison1968:174, Figures 2a, 4b; Pedersen 2004:Figure 1).

Figure 4.3. *Pommel and upper guard from E-type sword from Gotland (after Thunmark-Nylén 1998:Tafel XXX). The image is not covered by the CC-BY license and cannot be reused without permission.*

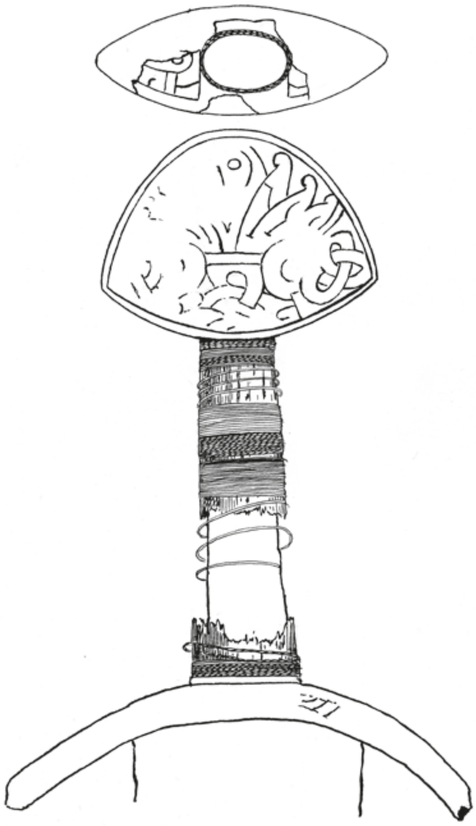


Figure 4.4. *Sword hilt of L-type, C.28239 from Mårem, Tinn. Drawing: Unknown, KHM (CC BY-SA 4.0).*

Evison places it in the X-type, but with an acanthus motif silver decoration and a markedly curved lower guard, it does not fit into this type. According to Geibig, the X-type combination types 12 and 15 are never decorated. David Wilson states that "the acanthus ornament of the pommel of this object … is quite close to the Winchester School of painting" (1965:33). As far as can be seen from the drawing of the sword from the River Frome (Evison 1968:Figure 7a) it is very like those from Tinn, but it's lower guard is markedly more curved.

These swords form a type of their own here named LA, even though they have traits in common with several other sword hilts – which is in fact quite a common phenomenon. The find locations lie far apart and reveal no clue to their place of production. Neither does the Ringerike style of decoration, as this style "seems to have been applied both in Scandinavia and is fairly well represented in the South of England and in Ireland" (Fuglesang 1980:77). Pedersen interprets the Moesgård sword as an Anglo-Scandinavian weapon made either in Scandinavia under English influence or in England under Scandinavian influence (Pedersen 2004:47), which is a very reasonable conclusion.

In her publication on the sword from Wallingford Bridge, Evison describes a typological development that took place in England from the L-type to the Battersea sword. In addition, she presents some more swords which do not fit into the ordinary types, such as the Mileham and River Frome finds (Evison 1968:Figures 2b and 7a; Wilson 1965:Plate VIA). The individual character of these as well as other late Viking Age sword hilts is noteworthy. Unfortunately, decorations can be badly preserved – if at all – and some have only a part of the hilt left. Even though they have traits in common, they never form real types to which one can easily assign even a small number of hilts. The reason for this cannot only be the occasional find context, such as river finds and the late date, as other real, contemporary types like the Z or X (Geibig combination type 15) do exist. Likewise, the many M-type spearheads decorated in the Ringerike style show a similar pattern (Fuglesang 1980; Creutz 2003). There is no convincing explanation as to how this individuality is related to the production of these hilts, apart from it very likely being decentralised.

4.4 THE NORWEGIAN M AND Q HILT TYPES

One main characteristic of these types is the lack of a pommel, while another is that they are undecorated.

Petersen believes that the M-type is of foreign origin, "but, of course, when first introduced, it could easily have been copied and produced at home" (1919:121, our translation). There is no doubt that these swords were indigenously made and, as Petersen points out, they are hardly ever found outside Norway. Blindheim (1999:81) and other Norwegian archaeologists have argued for an indigenous origin of the type, and there is no reason to doubt this. Moreover, all hilt types lacking a pommel, M, Q, P and Æ, are very rare outside Norway.

There are two reasons for closer study of the M and Q-types here. They are the most numerous ones in the Telemark material: 51 M-types and 31 Q-types respectively, as well as some uncertain ones. They are definitely indigenously made, and it is likely that hilt and blade were forged and fitted together by the same smith. Therefore, these swords have the potential to reveal local variations in smithing traditions. In addition to the shape and size of the guards, their welding seams are often cracked or visible, and their different positions could be an additional indication of such traditions. In the Telemark material, their distribution does not confirm this. Other reasons for more precise descriptions would be to define a distinction between M and Q-types, and to improve the possibility of type-determining swords which have only one (usually the lower) guard preserved.

Petersen gives a general description of the M-type:

> The guards are straight or slightly curved and of equal heights. The cross-section (i.e. length-section) is of approximately equal width, most often with transversely cut, more rarely rounded, ends. The sides are normally flat, though they can be slightly convex, but never keeled. The guards are never decorated. [Petersen 1919:117, our translation]

This description covers both Figures 98 and 99. There are several variations in guard shapes, forming partially distinct variations and some seemingly casual element combinations. He describes the form elements of Figure 98 as the most common ones, and this is certainly correct for the Telemark finds. The length-section is depicted as rectangular, but normally the length-sides are slightly convex. The cross-section is rectangular. The other variant, Figure 99, has a length-section with rounded ends and a cross-section with convex sides. Most probably Figure 99 is originally a distinct variant, but in many cases the two are mixed.

For the Q-type, the matter is more complex. Petersen's general description relates to the guard shapes of the previous types. Petersen states that the guards are slightly curved for the whole length. The ends can be higher than the central part (extended ends in the terminology applied here). They usually have a rectangular cross-section, but can be convex more often than on the M-type. Here too, his description covers all variants, and that makes it a bit vague for some elements. He points to R 502 as a late variant. R 502 is in fact another specimen of Figure 111.

Starting with Petersen's Figure 110, the length-section has convex outlines and transversely cut ends, in side-view the ends are extended on the lower and upper side respectively (Figure 4.5). Some specimens have very heavy guards with a height of up to 2.3 cm on the ends. In Figure 112 no length section is depicted, but in the Telemark collection some classified as 112 have pointed oval or more rounded oval length-sections, as in Figure 111. In the side-view the upper guards have more extended ends than Figure 110, and Petersen calls it a transition form to the Æ-type. The guard ends can even taper. Overall, it is very difficult to distinguish between 110 and 112, and they are all variations of the main type in Figure 110. The connection with the M-type (Figure 98) is clear, most probably by a direct evolution from the M to the Q-type.

Petersen's Figure111 (R 502) represents something new, but it is closely related to other contemporary types like O III, with a wide distribution outside Norway. The length-section is elongated oval or pointed oval with rounded ends. In side-view the upper and lower lines of the lower and upper guard respectively are straight, but sometimes with double-sided extended ends. The under and upper lines are curved, the cross-section rectangular or with convex sides. The type elements on Figures 110 and 111 can be mixed.

Most probably, the curving and the end extensions become more pronounced over time, leading from the Q to the Æ-type. This development, as well as the increasing length of the guards, are clear signs that Norwegian blacksmiths were familiar with the evolution of European trends.

One question that arises when dealing with these types is how to distinguish between M and Q-types when the guards are curved. There are two distinctions one can use here, the first of which is the side-view. They are to be classified as M-swords when curved guards have parallel sides, not extended ends. This trait needs to be combined with the second distinction, which relates to the length and height of the guards. The shortest lower guard on an M-sword is 7.8 cm

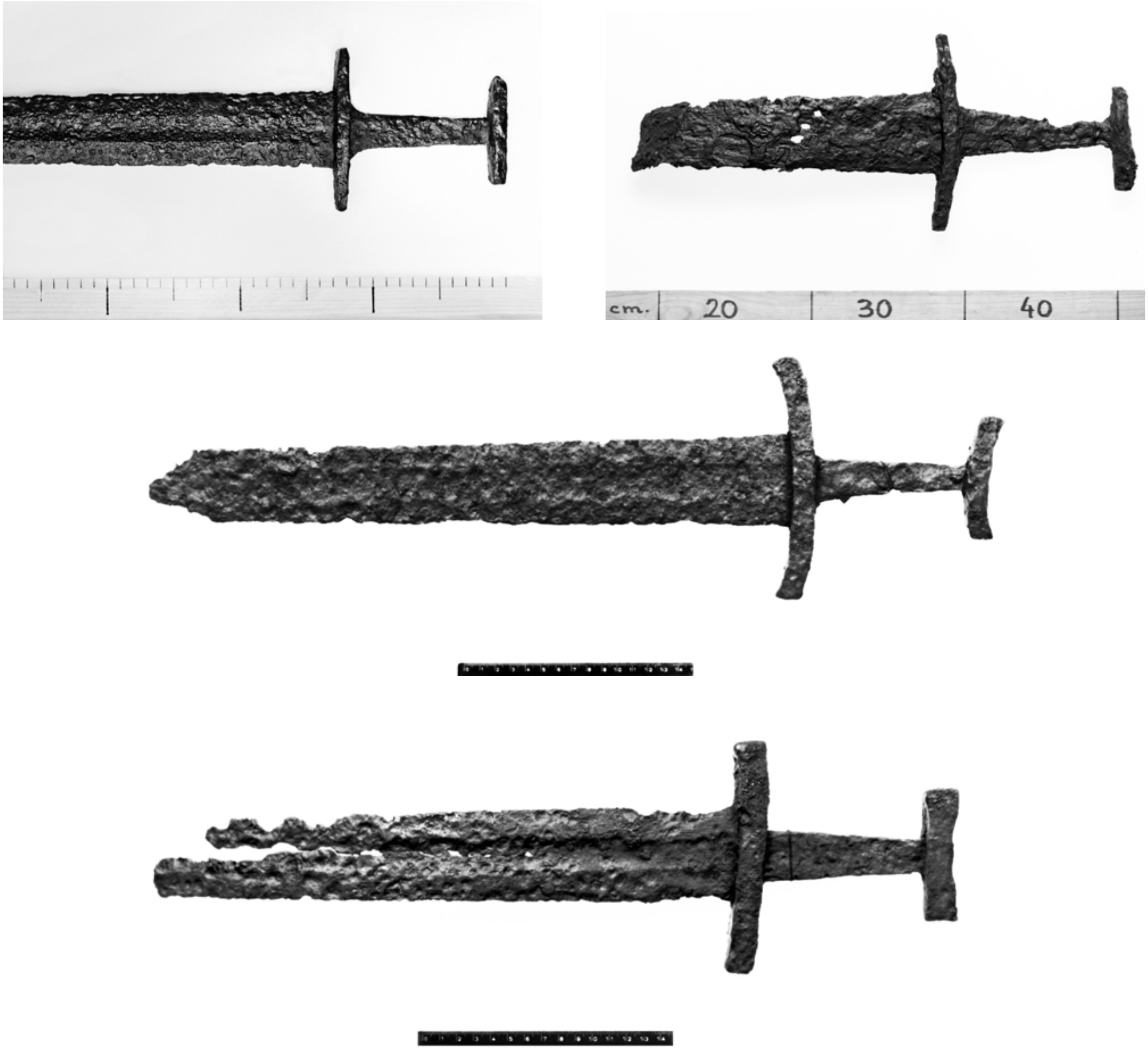


Figure 4.5. *Hilts from M and Q-type swords: 1. C.34271 Nissedal, M; 2. C.30067 Skien, M; 3. C.26828 Tinn, Q; 4. 23018 Tokke, Q. Photo: Unknown, KHM (CC BY-SA 4.0).*

long, and on nine specimens from Telemark does not exceed 10 cm in length. The majority are 10–12 cm long and only a few exceed 12 cm. Q-type guards are never shorter than 10 cm, and many guards are longer than 12 cm. The longest one from Telemark measures 15.7 cm, while Petersen defines 16.7 cm as maximum length. For guards of middle length between 10 and 12 cm, no distinction between the two types based on length is possible. While the height of the M-type guards never exceeds 1.2 cm, the Q-types are frequently higher and can be up to 2.2 cm high (one sword, 30049). Hilts, being both long and high, make a very heavy impression.

In the Telemark collection, only one guard is preserved on several swords, in most cases the lower one. Many of these have length-sections with slightly convex sides and transversely cut ends, like the M and Q-swords. This length-section also occurs on the X- type (Figures 124, 125) and on the Y-type (Figure 130). The length of the X-type (Figure 125) varies. Some swords with only one guard can be safely placed in the M-type, but for those with curved guards or extended ends a secure determination is difficult. As the Q-type is more numerous than X and Y, this type is most probable even for damaged finds.

4.5 CHRONOLOGY

As stated above, Petersen was able to establish a weapon chronology, despite the fact that he had few independent objects to rely on. For the most part, his chronology has proved reliable.

Turning to the Telemark finds, the situation is no better. In the few cases where there are other kinds of objects in a grave, they do not contribute to closer or more secure dating.

The Telemark finds have another disadvantage too: Very few graves have been excavated by archaeologists, and the documentation for a majority of them is insufficient, stating only that the objects were found in a burial mound. In some cases, it is obvious that items from more than one grave have been mixed, and in several cases this may apply to items from more than one mound. And of course, finds can be mixed without obvious indications that this happened. On the other hand, one has no guarantee that all weapons in a grave were taken care of after excavation.

A key question in an investigation of smithing techniques and blade construction is the need for exact dating. The swords cover a timespan of nearly 300 years, and changes and improvements have obviously taken place during those centuries. Changes were processes, taking some time to spread throughout a production area. Except for specific new techniques that can coincide with new hilt types, such changes cannot be dated exactly. One of our goals is to study this development. Even though one has to keep in mind that a blade and hilt can be made separately and that swords can be heirlooms, the only way to study such phenomena is by typology and find combinations. Further, there is no reason to doubt that for the ordinary Norwegian sword types, hilt and blade were made as a unit.

Weapons were personal belongings and were normally buried with their owners. High quality swords, with pattern welding or inscribed blades and/or finely decorated hilts are most likely to end up as heirlooms, combined with other weapons of a definitely later date. Such practices can, however, be obscured by new "modern" hilts being mounted on old blades. Such valuable specimens are few in number, and most sword hilts with inlay decorations (except H-type hilts) are from the 10th century, some belonging to the last part and into the 11th century. The possibility of tracing such renewals is small without a special investigation of a greater number of specimen combinations than the Telemark finds.

Because of uncertain documentation, exact numbers of secure find combinations are unreliable. There are 31 finds with two or more weapons besides the sword, which certainly or most likely belong to one grave. The weapon types are spearheads, axes and shield-bosses. Rattles, a Norwegian tool type connected to horse gear (R460–463, Petersen 1919:Figures 46–50), form a typological and chronological series, but have been found only twice with swords without other weapons, and can thus for the most part confirm the dating of the weapon combinations (Petersen 1919:48–50, 1951:43–46). Many graves contain arrowheads as well, but they are of little value to chronology.

Besides swords, spearheads are the weapons that can be most precisely dated, and for these Solberg's PhD dissertation from 1984 is significant, mainly because she had a much greater number of finds to rely on than Petersen had. One important group of spearheads, her type group VI, corresponding to Petersen's types A–E (except for Petersen's D, Figure 11) was published in a separate paper in 1991 (Solberg 1991).

The most numerous combination of swords with one other weapon is sword and axe, which occurs in 30 finds, while swords and spearheads occur in 11 finds. Shield-bosses are not common, and except for one find, they are always found in graves with more weapons than the sword. Weapon combinations without swords are left out here.

In accordance with these factors, the swords can in many cases be dated to a certain century only, at best to the first or second half or the middle part of a century. Among the most common hilt types, C-type swords have been found once with a spearhead of Petersen's F-type and a shield-boss like R 562, and twice with G-type axes, indicating use throughout the 9th century.

H-type swords were likewise used from the beginning of the 9th and well into the 10th century, according to Petersen. He states that the M-type came into use in the middle of the 9th century, and was still being used in the beginning of the 10th (1919:120–21). In the Telemark finds, few were found in combinations limited to the 9th century, while the majority can be dated only to 850–950 AD. This is clear from the combinations with E, G and H-type axes and some with I and K spearheads that did not come into use before 900 AD. M and Q-type swords were partly contemporary in the 10thcentury, but the Q-type was used until the end of the century.

Finally, one must mention that the number of finds increase throughout the period, with the 10th century having the highest number, and a subsequent decrease occuring after 1,000 AD.

One can also note that there are differences in the relative numbers of M and Q-type swords in different parts of Telemark. In Grenland the M-type dominates (29 to 15), while in eastern and western Telemark the numbers are nearly equal (4 to 5 and 15 to 18 respectively). This is part of a chronological trend: late finds are more numerous in the inner parts than in Grenland.

5. EARLIER TECHNICAL INVESTIGATIONS

Numerous technical investigations of sword blades have been carried out in Europe, and it is not our intention to present a comprehensive survey of all such investigations. Our survey is selective, limited to those directly relevant to our work. This entails mainly those based on X- radiographs or metallography, or a combination of both, along with hardness measures. Investigations of swords from the Viking Age and seaxes from previous centuries are naturally central, but some relevant studies of spearheads are also included.

We have concentrated on papers dealing with a more comprehensive selection of objects, and have omitted papers presenting a single or only a small number of weapons.

Our survey of bibliographies reveals some important features: A high percentage of papers are centred on pattern welding, even when this special technique is not specified in the title. In contrast, only a few investigations of swords with ULFBERHT and other inscriptions or marks on the blade have been carried out, a fact that has not prevented researchers from rutinely repeating that such inscriptions are indicative of high quality blades. Accordingly, blades which have neither pattern welding nor inscriptions have attracted little interest from researchers. Details of pattern welding, such as the number of rods, are of little relevance to our work and will not be treated here.

We will concentrate on the following questions:

- Which investigations were carried out?
- Who carried out the investigation? What was their professional background?
- What was the purpose of the investigation?
- How were the objects selected and documented, and which timespan was covered?
- How were the investigations presented?
- The results of the investigations, including discussions of interpretation problems.
- Were the results related to archaeological problems?

Technical investigations are with few exceptions performed by metallurgists, chemists, conservators and others with backgrounds in science or technology. One exception is R. Pleiner, an archaeologist skilled in this field of archaeological science.

Next to stating what kinds of investigations were carried out, an important question is who performed them, and to what extent was there collaboration between technicians and archaeologists? This ought to include many steps in the process, starting with the archaeological problems to be elucidated through the selection of objects for analysis, their primary documentation, and the presentation of the results in a way that can be understood by archaeologists. Important concerns here entail eventual interpretative problems and the representativity of the results, not least because archaeologists tend to accept such results uncritically.

Many readers will miss important works in our survey, for example Ronald F. Tylecote's *The Prehistory of Metallurgy in the British Isles* (1986). Early medieval swords are only briefly mentioned in this work, whilst a much more detailed presentation by Brian J. J. Gilmour will be treated below. The polish metallurgist Jerzy Piaskowski has published more than 300 papers on metallurgical investigations, mostly in Polish. "The main goal of this research is the determination of the origins of early iron implements, mainly based on phosphorus" (Piaskowski 1989:407, 414). His paper from 1989 provides a survey of his long-lasting and comprehensive work, but we do not find it relevant for our context. In some cases, such as Nørgård Jørgensen's study of all Danish single-edged swords from the Late Iron Age, X-radiographs were important (Nørgård Jensen 1999). However, since they are treated only summarily and not documented, we are not able to use them.

5.1 INVESTIGATIONS OF SWORD BLADES

Norwegian investigations

As early as 1889, the archaeologist A. Lorange had chemical analyses made of three Viking Age swords (by L. Schmelk). No information apart from carbon content is given, not even the museum numbers (Lorange 1889:27).

Petersen (1919) was a pioneer in publishing chemical analyses of sword blades, carried out by the engineer

K. Refsaas. Petersen deliberately chose blades from both foreign and indigenously-made swords in order to see if there were marked differences in carbon content, but the analyses did not show significant variations.

The samples were taken by drilling through the blades, and Refsaas reported that attaining the correct average for the samples was problematic. The results were presented in a table (1919:208–212).

Thorbjørn Dannevig Hauge, a chemical engineer and head of the conservation laboratory in Oldsaksamlingen, University of Oslo for many years, published the first comprehensive study on iron extraction in Eastern Norway (1946). Here, 76 analyses were carried out, based on drilled samples taken from different kinds of tools and weapons covering a very long timespan, giving carbon content and melting point (1946:179–82). Such analyses listing average values have hardly any interest today, and are not used in modern research.

Aslak Liestøl's paper, "Blodrefill og mål" (1951), is frequently referred to in literature on pattern- welding. Liestøl was a philologist and head of the Norwegian Runic Archives at the University of Oslo. His goal was to clarify the meaning of the Norse word *blodrefill* which he connected to the pattern-welded bands on the central part of sword blades.

He demonstrated how pattern- welding could be carried out, and had one sword of Petersen's H-type (C.788 with unknown provenience) investigated metallographically by engineer Aarvik. Two sections were made, and the results presented in words and pictures (Liestøl 1951:85, Figure 3 i–k). The sections show that the blade has two pattern-welded layers without a plain layer in between.

Liestøl questioned whether X-radiographs could be useful in recognizing pattern- welding on blades, but remained uncertain. He had X-radiographs taken of C.788 and of the single-edged sword C.24217 from Hjartdal, Telemark, which has directly visible pattern- welding. On C.24217 no pattern- welding was visible on the X-radiograph. It is, however, visible on pictures taken later (Martens 2004:Figure 2). This sword is very well preserved and is one of a small number of pattern-welded single-edged swords.

British investigations

British scholars have contributed important work. Two such works will be examined here: Janet Lang and Barry Ager's *Swords of the Anglo-Saxon and Viking Periods in the British Museum: A Radiographic Study* (1989), and Gilmour's *Results of the Examination of Edged Weapons,* which is Part II of the comprehensive work *The Metallography of Early Ferrous Edge Tools and Edged Weapons* together with Tylecote (1986). The general introduction states that "some of the objects examined in this work arise from a continuous program by one of us over about 20 years". This refers to Tylecote, perhaps the most outstanding metallurgist working on a wide range of topics in the prehistory of metallurgy, as demonstrated by his other publication from 1986, *The Prehistory of Metallurgy in the British Isles*.

Lang and Ager's study was first presented at "a particularly successful conference in Oxford in January 1987". In her introduction to the conference publication "Weapons and Warfare in Anglo-Saxon England", S. Hawkes stresses the importance of X- radiographs in the study of ancient ironwork. "There has been no systematic large-scale study of Anglo-Saxon swords by this essential method until very recently" (1989:6).

Lang and Ager, scientist and archaeologist respectively, both at the British Museum, carried out the investigation at the request of the Department of Medieval and Later Antiquities in order to facilitate their studies, primarily to see if the blades were pattern-welded or have inscriptions.

In all, 142 swords were X-radiographed, though some of them were too fragile to be handled safely. 119 swords are included in their Table 7.1. Twenty-two were dated to the 9th and 10th centuries, while the majority were from an earlier period. Several X-radiographs are depicted.

The paper is mostly concerned with the pattern-welding technique, and the authors describe construction details. The results are given in several tables. Some of the corroded swords were examined visually and found to be split into two or three layers (Lang and Ager 1989:92). Pattern-welded inscriptions are described in detail, while the blade construction is not given much attention.

In their discussion (Lang and Ager 1989:107ff) they make some important statements, such as the percentages of pattern-welded blades throughout the relevant centuries, amounting to 100% in the 7th century, decreasing to 45% in the 9th and 10th centuries. No sword blades could be firmly dated to the 8th century.

A general discussion encompasses the purpose of pattern- welding, whether decorative or constructional, and the question of whether it was of English or continental production. They find the use of surface removal to vary the patterns the most obvious difference in technique. Frequently used on the continent, it is only found on one English sword, thus strongly indicating some kind of sword-making industry in England (Lang and Ager 1989:112). Socioeconomic implications are treated rather arbitrarily. These complicated problems need to be discussed on the basis of analysis of the archaeological material, not on assumptions that cost consciousness escalated a tendency towards standardisation, with reference to Hodges (1985). From a Norwegian point of view, it is interesting that many of the Viking Age swords from England have been found in river contexts, which can be tied to Viking activities.

The publication by Tylecote and Gilmour is perhaps the most comprehensive on metallurgical investigations of archaeological material. Both authors are metallurgists, and apart from names mentioned in the acknowledgements (Tylecote and Gilmour 1986:255) and references in the text, we cannot see that there was any close cooperation with archaeologists. The objects examined were divided into: I. domestic and agricultural tools, and II. edged weapons. Most of the introduction specifies the important features of edged tool making, and they find a certain overlap in the techniques of making tools and weapons. They also mention that not all artefacts found in Britain were necessarily manufactured in Britain, but there is no focus on more specific archaeological problems. The work contains a wealth of important knowledge on prehistoric smithing.

We will concentrate on the seaxes and swords examined by Gilmour. Six of the seven seaxes are of Viking Age date (see Table M, Gilmour 1986:125, which summarises the basic find information and results of the examination).

The 39 swords examined cover a long timespan, from the Early Iron Age to Late Medieval. The majority are from the 6th and 7th centuries, and only eight specimens are of Viking Age date including two from the 7th–9th centuries and one from the 11th century.

The objects are presented as contour drawings with the examined sections marked. Only two have the entire hilts preserved, others have parts of the hilts, mostly the lower guard, and some of these can be type-determined and identified through other publications. For the swords, find information and results are summarised in Table N (Tylecote and Gilmour 1986:156–158).

The analyses comprise metallurgy, X-radiographs and hardness measures. The X-radiographs were used for reconstructions of welding-patterns, presented as sketches showing surface patterns and number of rods.

The metallographic analyses are described in detail, with photos and sketches showing specifications of structures. Additionally, blade construction is shown in a three-dimensional drawing. Overall, the documentation is high quality and easily understandable for archaeologists with a minimum of training in studying such investigations.

In the final discussion on swords written by both authors, some important developments in swordsmithing throughout the centuries are presented. After stating that a high number (25 out of 33 Anglo-Saxon swords) had been pattern-welded they state: "During the Late Saxon Period, however, this technique of manufacture becomes less common for sword blades and ceases to be used for these possibly in the 11th century, although it continued to be used in scramasaxes or knives for longer" (Tylecote and Gilmour 1986:244, 247). "The observations made on eleven swords of the Late Saxon Period have been discussed in some detail in this section because of the great variety of their fabrication methods which has come to light in this study". Two main points are stressed:

> First, all of the later pattern-welded sword blades, including those ascribed to the 7th–9th centuries, show a much higher standard of overall manufacture with the more extensive use of steel, which would have made these swords much more serviceable weapons than those of the 5th–7th centuries, which as we have seen were mostly of low carbon iron … secondly the same change in the standard construction and use of steel is true of the non-pattern-welded swords … [Tylecote and Gilmour 1986:249]

The second part is about pattern welding, which will not be treated here. What is important is that metallography provides much more detailed information on blade construction and the materials used than what can be achieved by the use of X-radiographs.

German investigations

Herbert Westphal, conservator in a museum in Paderborn, has contributed two comprehensive and important papers based on X-radiographs. The first, "Untersuchungen an Saxklingen des sächsischen Stammesgebietes – Schmiedetechnik, Typologie, Dekoration" (1991), covered seax blades: 19 *Kurz und Schmalsaxe*, 82 *Langsaxe*, and 15 undeterminable ones, totalling 114 blades. His starting point was an observation during conservation that two long-seaxes had serrated welding seams between the back part and the edge, and he wanted to look for more blades with this special feature. The metallurgist D. Horstmann performed metallographic investigations of four such blades. No hardness measures were employed.

Westphal's documentation is systematic and good. A selection of objects is described in detail, while the total number is presented in tables. The presentation includes photos of the blades, including details for many of them, such as X-radiographs of several blade segments and decorations, although not all the X-radiographs depicted are of good quality. The metallographic investigations are described well.

He finds important differences between short-seaxes and long-seaxes. All the short-seaxes are made of homogeneous materials, while the long-seaxes are more varied in construction and materials. Pattern-welded blades and blades with serrated welds make up approximately one fourth of the long-seaxes. The majority are simple and technically uniform, made of homogeneous materials or more often in two parts: a back and an edge. Eleven such blades are described. Blade types vary. Five of them are described as homogeneous and three consist of two parts. Probably two and possibly a third are made in three parts, with a middle part between the back and edge sections. In his conclusions on long-seaxes he states that there is a correspondence between typological traits and special technological features of the blades. Technical developments enabled morphological changes (Westphal 1991:335). He mentions the smiths' challenge in achieving even carburisation in the edge (Westphal 1991:335), and in note 76 he has reservations about the analyses of carbon content in the edges. As hardness measures were not made, no exact information on the quality of these blades can be obtained.

Westphal's primary interest obviously lies in the pattern-welded blades and those with serrated welds. He uses English seaxes for comparison, referring to Gilmour's metallurgical investigations, but without mentioning constructions with only two layers, without a plain middle one. The number of layers is, however, not visible on radiographs.

Westphal's second work, "Franken oder Sachsen? Untersuchungen an frühmittelalterlichen Waffen" (2002), sprang out of a recurring question during the research for the exhibition, Kunst und Kultur der Karolingerzeit, concerning similarities and differences between Franks and Saxons, two groups living at a great distance from one another. His investigations were carried out in order to see if technical properties of weapons could shed light on these questions.

This work covers large areas and a vast timespan, from the mid 5th to the 10th centuries. It includes different kinds of weapons: double-edged swords, single-edged seaxes and spearheads with lugs on the socket. In addition to weapons from Westphalen and Niedersachsen, he has worked on finds from neighbouring areas. One of these is Schleswig-Holstein including Hedeby, and therefore of great interest from a Norwegian point of view. The area named Südkreis denotes a large part of southern Germany and Austria and many well-known finds, such as the swords from Mannheim and from the Bootkammergrab B in Hedeby.

The problems he intends to elucidate are indeed very complicated, and it is beyond our scope to examine them even if questions of regional traditions and differences have a general application. We have to concentrate on the use of X-radiography, and on some problems and limitations when this method is used without supplementary metallographic studies and hardness measures, with the risk of not doing justice to this comprehensive work by a very competent scholar. No doubt, the article's wealth of information is of great value for many different research projects.

In all 132 swords, 44 seaxes including some examples from the 1991 publication, and 33 spearheads with lugs on the socket are presented in detail. All the weapons presented are depicted in their entirety, either as photos or drawings. In addition, several X-radiographs, many hilts, inscriptions and marks are depicted on a scale of 1:1.

No doubt, his main interest still lies in pattern- welding, and his in-depth studies of this technique are very valuable. Twenty-five swords, of which 16 are from the 8th or the 8th–9th centuries, were not made in this complicated and time-consuming way, and though some well-known specimens with splendidly decorated hilts, such as the sword from Neuburg (Westphal 2002:144–145) are not pattern-welded, his interest is limited.

Some such swords, mostly of from the 6th century, have only a single pattern-welded rod, but most have three rods in addition to the edges. In the text he states (our translation), "So the blade consists of three rods, namely the pattern- welding and the cutting edges". From our experience one question arises: Is it always plainly visible on the X-radiographs that these blades have welded-on edges? No comments were made about interpretative problems, which on this point is not relevant for pattern-welded blades.

Of the limited number of X-radiographs depicted, one is of a non-pattern-welded blade (1.2.17 from Cleverns). Here the edges are missing or not visible in the photo.

Westphal's works prove that X-radiography is unrivalled in the volume of objects that can be treated in a non-destructive way. When X-radiography is not supplemented by metallography and hardness measures, a serious limitation is the lack of information on the steel quality and heat treatment used during forging.

Sweden: The Helgö investigations

The most important Scandinavian study in this field is Volume XV of *Excavations at Helgö: Weapon Investigations. Helgö and the Swedish Hinterland* (Arrhenius and Thålin Bergman 2005). The authors are Birgit Arrhenius and Lena Thålin Bergman. The metallurgical investigations were carried out by Helfrid Modin and Sten Modin, and the spectroanalyses by AB Analytica.

At an early stage in the excavations at Helgö, an important central place in Eastern Sweden, extensive workshop refuse from bronze casting and iron working was revealed. This last mentioned find group consists of tools, currency bars and rod-shaped blanks, as well as forging pits and slag. Unfortunately, waste from iron working does not reveal what the finished products were, or their quality and distribution, in the same way as moulds from bronze casting can.

The investigations started in the 1960s, and the Helgö research group agreed that technical investigations were a necessary approach to questions relating to the products of the Helgö smithies. They are an early example of defined archaeological problems, and of close technological collaboration between archaeologists and scientists. It was obvious from the beginning that material from several parts of Sweden had to be analysed, one reason being that weapon finds from Helgö are few and fragmentary. The archaeologist L. Thålin Bergman worked on the project for many years, and her writing shows that she acquired comprehensive knowledge of the relevant analytical methods, as well as in formulating an archaeological interpretation of the results. Conversely, the metallurgists gained valuable insights into archaeological questions relevant to their work. Such mutual understanding is indeed both necessary and valuable.

Unfortunately, it took a long time before the investigations were published, and this created several problems for the editor, B. Arrhenius (Arrhenius and Thålin Bergman 2005:7). Several chapters start with a general introduction to the applied methods and the purpose of the investigations. Thålin Bergman comments on the problems of interpreting X-radiographs of well-preserved objects (Arrhenius and Thålin Bergman 2005:35).

Altogether, more than 400 swords and spearheads were X-rayed. One unexpected result was the great number of pattern-welded weapons of both kinds. The results are shown in a number of tables presenting the combined results of archaeological documentation with blade techniques. In the tables of the publication the column "blade technology" contains a mixture of information: pattern- welding, welded-on edges, inscriptions and straight welding lines along the middle of the blade. Letters and symbols on the blades are not representative of the welding technique used, and the information is not always correct. Petersen's typology is used for Viking Age weapons, but no dates within the periods are given, and neither type determinations nor dates are given for earlier weapons (see review by Martens 2006b).

The metallographic investigations of five swords and fifteen spearheads were performed and published with excellent photos by H. and S. Modin. Three of the swords, including the Helgö blade fragment, are dated to the Vendel period, the other two as well as the spearheads are from the Viking period, among them nine spearheads from the unique deposit of approximately 500 such objects from Gudingsåkrarna on Gotland.

The brief concluding text by Arrhenius and Thålin Bergman mostly summarises the completed investigations (2005). Reluctantly, they state that no proof of weaponsmithing in Helgö was found. They emphasise the high quality of a considerable percentage of the investigated weapons, and point out that no final answer to the question of origin and production sites of Swedish weapons has been found so far.

Czech Republic: Mikulcice

The publication *Early Medieval Swords from Mikilcice* (Kosta and Hosek 2014) is very valuable for several reasons. It deals with all swords found in this important power centre of Great Moravia, sixteen complete swords from graves and fifteen fragments from the settlement, predominantly from large-scale excavations carried out between 1954 and 1992. The central location was in use for only about 100 years, from the early 9th to the early 10th century.

The swords are presented in a wide archaeological context, starting with "Miculcice in the Early Middle Ages" (Chapter 1), and "The current state of knowledge of early medieval swords" (Chapter 2). We will concentrate on the comprehensive Chapter 3: "Investigation of the Miculcice swords" (Kosta and Hosek 2014:53–237). It starts with the methodology and history of the sword investigations (3.1), typology (3.2) nomenclature and analytical methods used (3.3). Chapter 1 refers to the tragic event in 2007, when a fire broke out at the archaeological science centre in Miculcice, destroying the archives and other digital data. The majority of the swords were damaged by the fire but could fortunately be restored through conservation. All organic material, such as scabbard remains, were completely lost.

The individual investigations of the sixteen complete swords include circumstances of discovery, description and typological determination, and this wealth of information will certainly be useful for many different studies.

We will concentrate on the blades. Some of the swords were examined metallographically before the fire, but all documentation was lost. New samples could be taken from the previous cuts, and a special set was annealed at 950 ˚C followed by controlled cooling, resulting in a structure of ferrite and pearlite, whose ratio allowed the determination of both content and distribution of carbon within the samples with reasonable accuracy (Kosta and Hosek 2014:59).

The metallographic investigations are well documented by a fixed set of depictions including photos before and after the fire, with sample cuts marked. In ten cases two cuts were made on the blades, and for each sample there are depictions before and after etching with Nital and/or Oberhoffer's reagent, as well as a layout of microstructures and main welds. In addition, there are hardness distribution charts for all cuts. Colour photos of structures and welding lines in varying enlargements are very informative, especially in connection with the descriptions.

On the nine swords where two samples were taken from the blade (always one on each edge, and at a distance from each other), the samples are described separately, except for sword 438. Since taking two samples is important when studying the homogeneity of the blades, a comparison of the two samples would have been extremely helpful.

Chapter 5 deals with the internal structure and heat treatment of blades, and with the methods employed in welding semi-finished pieces together (Methods A–D, Kosta and Hosek 2014:273, Figure 142). All include welded-on edges. There are different combinations of materials used as well. The majority of the blades were quenched in some way. Only four swords were pattern-welded, and this publication is thus very important for studies of non-pattern-welded swords.

The chapter ends with a discussion of the provenance of the Mikulcice swords:

> But the question remains open as to whether local smithy workshops were able to produce high quality swords and if so, in what number … we might reasonably assume that some of these swords were produced in Great Moravia although we do not know the proportions. [Kosta and Hosek 2014:294–96]

The final chapter deals with swords as status symbols. The proportion of swords among weapons in graves is very low, and such graves were usually concentrated in groups of richly furnished graves. As expected, graves with swords were richly furnished (Kosta and Hosek 2014:298–306). This remains valid not only for Mikulcice, but for Great Moravia in general, and as the status of men buried with swords varies both in time and space, this publication forms an important contribution to the discussion of these questions.

Investigations of ULFBERHT blades from several European countries

ULFBERHT and other inscriptions on sword blades are marks of high quality blades. This statement has been repeated until it has become an accepted truth. The problem, however, is that hardly any systematic investigations of these blades have been carried out, and our knowledge of the construction and quality of ULFBERHT blades is very poor. This is only one of many problems relating to the production and distribution of these blades.

Alan Williams, a British metallurgist, has recently presented the most comprehensive metallographic investigations of ULFBERTHT blades ever performed, first in his special paper, "A Metallurgical Study of some Viking Age Swords" (2009), and as Chapter 8 "Viking Age Swords and their Inscriptions" in his book, *The Sword and the Crucible* (2012).

Williams' metallographic investigation of 44 ULFBERHT swords is thus of great interest. They were found in several European countries, the majority in Norway, Finland and Estonia. Moreover, X-radiographs were not used here nor in previous investigations (see our remarks and Williams' reply in Gladius 2011; Astrup and Martens 2011; Williams 2011).

The swords presented in the two texts are in general the same, but there are more pictures in the first one and their quality is better. The most marked difference between the two is group division. In the first one groups A and B are distinguished by the way the second + is placed in the name (+ULFBERH+T and +ULFBERHT+), groups C and D by alternative spellings on steel swords and iron swords respectively. Group E covers other Viking swords with inscriptions.

In his 2012 version groups I–V are all defined by steel quality/construction: I. Hypereutectoid steels (more than 0.8%C); II. Eutectoid steels (around 0.8%C); III and IV. Hardened and unhardened steel edges respectively (generally around 0.4%C) on an iron core; V. Iron blades (less than 0.2%C). This division is certainly an improvement, but it raises a general question about the homogeneity of the materials used. Is the carbon content in one small section of the blade representative of the blade as a whole? This cannot, as Williams does, be taken for granted (see Westphal 1991:335 and note 76).

Williams says nothing about the selection of swords for analysis, and his documentation of the swords is without hilt type references. He argues that hilt types are uninteresting because swords, especially those of high quality, could be re-hilted (Williams 2011:208). Re-hilting has certainly taken place – how frequently we do not know – but in order to study this and other questions of interest to archaeologists, hilt types are a necessary factor.

He gives very scanty information about where his samples were taken. This is basic information to readers, and we should not have to guess that most samples were taken from the edges. In his last publication, Williams states that "unless a complete section or half-section of a blade could be examined, which was not always the case …" (Williams 2008:121). Both Gilmour (1986) and Modin and Modin (2005) depict their investigated sections in ab.5x, and such informative depictions would have been very useful in Williams' works, eliminating uncertainties about his samples. They would also be useful in comparison with other investigations.

From his group division it follows that ULFBERHT blades vary considerably in composition and quality, and his most interesting result is the use of hypereutectoid/eutectoid steels in groups I and II. "This may have been ingots of crucible steels imported from the Middle East via the River Volga. In which case, this location was probably the Baltic area where this trade route terminated, and where most of these swords have been found" (Williams 2009:143, 2012:120).

This is certainly problematic, one reason being that the Latin alphabet was not in use there at the time when ULFBERHT swords were produced. Stalsberg has interpreted the crosses as connections to ecclesiastic milieus, and her opinion deserves serious consideration (Stalsberg 2008:101–103). The number of finds depend to a great extent on burial practices, in this case Christian versus heathen ones. The Norwegian swords and spearheads, which are the most numerous by far in Europe, offer several examples of high numbers of finds obviously imported from Western Europe.

Can one exclude other routes by which the crucible steel ingots reached the Carolingian realm and its successors where the ULFBERHT swords are usually supposed to be made, or the possibility that such crucible steels were produced in advanced smithies there? (Müllerin Müller-Wille et al. 1970:91). To our minds we cannot, and these are only two of the many complications connected to the ULFBERHT swords.

5.2 INVESTIGATIONS OF SPEARHEADS

Norway

The most comprehensive Norwegian study in which X-radiographs are used systematically, is the archaeologist B. Solberg's PhD dissertation "Norwegian Spearheads from the Merovingian and Viking Periods" (1984):

> The aim of the present study was to examine the typology, chronology and the geographical distribution of spearheads found in Norway from the period c.550-1100. Furthermore, it was examined whether the spearheads represented highly specialised manufacture or were derived from less specialised workshops and whether they were the results of indigenous workmanship or represented imports to the country. To pursue this object a new classification system of spearheads was developed based upon measurements of typological elements and results of X-ray examinations. [Solberg 1984:1]

She focused on three different regions in Western Norway, Mid-Norway and Eastern Norway respectively, the last one including Telemark county (see map in Solberg 1984:Figure 1, 1991:245). The total number of objects amount to 1,581. They were classified in 12 type groups, totalling 33 types and subtypes, 14 variants, and 177 non-classifiable specimens. Her classification includes types and subtypes that were not described earlier, and she corrects some misleading points in Petersen's typology. She also demonstrates that spearheads with lugs on the sockets are similar to those without this special feature, both in shape and smithing technique, and she classifies the two kinds as subtypes of the respective types. All specimens are listed with type determinations. She studied the European distribution for all type groups, and discusses their origin.

Solberg's type groups VI–XI are of Viking Age date, starting at approximately 750 AD (XII corresponding to Petersen's type L, small throwing spears). Ninety-six Viking Age spearheads were found in Telemark.

Details will be presented here only for her type group VI, corresponding to Petersen's types A–E, except for his Figure 11. This is a very important type group with a wide European distribution. Her results, in which X-radiographs of 279 spearheads played a key role, were published in a separate paper (Solberg 1991, types and subtypes Figure 4). The results are astonishing, since it turned out that some of her subtypes have a very high frequency of pattern-welded blades, while others have a very low frequency. Another difference reveals that the non-pattern-welded subtypes show greater variation in proportion details, indicating more widespread production by local blacksmiths. She also found differences in distribution, both in Norway and Europe. The numerous pattern-welded subtypes have to a great extent been found in the coastal areas of Norway and were also widely distributed in Europe, whereas the others dominated inland and were rarely found outside Norway. She interprets the differences as imported continental spearheads and indigenously-made ones respectively. As we believe that sword blades and spearheads were forged by the same blacksmiths in Norway, the basic problems of manufacturing are similar to ours, and her thesis is of great interest to our investigation. Several of her results will be taken into account in our concluding chapter.

The Baltic area

Kristina Creutz's PhD dissertation in archaeology, "Tension and Tradition. A Study of Late Iron Age Spearheads around the Baltic Sea", is a comprehensive and ambitious work, thus it is possible here to refer only briefly to some of the major questions (Creutz 2003). She has made a very detailed study of 335 11th century spearheads of Petersen's M-type found around the central part of the Baltic Sea, in Sweden, Finland, Estonia, Latvia and adjacent parts of Russia.

These spearheads have some characteristic features, such as 16 variations of facet and knob decorations on the upper part of the socket where it meets the blade. Creutz divides them into eight sub-types, partly by shape and partly by the decorations (2003:35, 37).

Creutz provides thorough documentation including measurements, as well as having had 181 specimens X-rayed, all presented in a catalogue with contour drawings. Some X-radiographs are depicted. The aim was "to penetrate the inside of the spearhead, which gives good contact with the smith, his skills and his ways of working" (Creutz 2003:43). The primary purpose was to see whether the blade was pattern-welded and which pattern was used; the secondary purpose was whether the spearhead was made in one or two parts; and the third to see the shape of the steel cone used when making the socket.

She carried out microscopic studies, especially on the socket to see if any traces of silver decoration could be revealed. Using a scanning electron microscope, 46 silver-decorated spearheads, 18 of them M-types, were analysed. The aim was to come closer to understanding how the silver had been fastened to the iron surface. The content of silver, copper, zinc and mercury was of special interest.

These analyses were carried out by several specialists and presented in appendices (Creutz 2003:492–516, 517–18). She also cooperated with a Finnish blacksmith making replicas of three spearheads, incorporating pattern welding. The problems arising during the work and the results are described in detail with pictures (Creutz 2003:129–43).

Even though she discusses several problems concerning the smiths' role in society – some of them well-known to archaeologists – we will concentrate on one important aspect: her attempt to identify individual smiths (Creutz 2003:164–200).

She maintains that the relevant Baltic smiths have been revealed through distinctive features on both the outside and inside of the spearheads. Some similarities can be measured whilst others cannot. In her mind both the general measurements and the impressionistic feeling of significant similarities are important. The recognition of different smiths has accordingly been based more on her impression and sensibility, and not as much on measurements (Creutz 2006:165).

In this way, she has identified 25 different smiths around the Baltic Sea, and she presents them all as having distinctive features. The number of spearheads ascribed to each smith ranges from 18 (two smiths) down to only two specimens (10 smiths) (Creutz 2006:166–192). With such small numbers follows great uncertainty, and this is even more pronounced by the fact that only 40% (127 out of 335) of the spearheads can be ascribed to the identified smiths.

She introduces the concept "smith-zones": defined as the outlet or working area of a craftsman, the area of a leader of some kind, or a production centre (Creutz 2006:193). These zones vary in size from one village up to a large area in southern Finland (Creutz 2003:162). Notwithstanding the uncertainties of her smith identifications, the results are convincing in showing that production was decentralised.

How interesting are such identifications of individual smiths in a wider perspective? A very relevant question is whether the smiths of, for example, Estonia have distinctive features in common, which are not found in other areas. From our point of view, ascribing production of weapon types and distinctive features to larger areas is more acceptable, but her in-depth studies of features are very relevant. Furthermore, they raise important questions relating to both weapon distribution and training of weaponsmiths. Certainly, there are no easy answers, as all factors discussed depend on the societies studied.

5.3 CONCLUSIONS

One important result of most of the investigations treated above, is the unexpectedly high number of pattern-welded sword blades and spearheads (Lang and Ager 1989; Tylecote and Gilmour 1986; Westphal 1991, 2002; Arrhenius and Thålin Bergman 2005; Solberg 1984, 1991). Their results were obtained through X-ray examinations of a large number of weapons, which is a method well suited for studying the number of rods and other details of this special smithing technique. For specific information on blade construction and steel quality, metallographic studies of blade sections, supplemented by hardness measures are necessary and rewarding. Metallography can, however, usually be carried out only on a limited number of objects, as it is laborious and requires invasive cuts into the blades.

Returning to the questions posed at the beginning of this chapter, several remain unanswered. The purpose of the investigations is often vague and general, information on selection principles are lacking and the documentation of selected objects is, in some cases, unsatisfactory. The presentation of the results is generally good, often with tables. The relation of the analytical results to archaeological problems is on a level with the information about their purpose.

The demonstration that an unexpectedly high percentage of sword blades and spearheads were pattern-welded, remains a remarkable result, and the implications for the production and distribution of such weapons remains are still unexplored. In addition, interest in pattern- welding has come to overshadow the study of blades without this feature. This one-sided focus further neglects to answer the important question of which blade constructions replaced pattern- welding on sword blades around 900 AD. Another detail clearly demonstrated by Gilmour is that not all blades have a plain layer between the two pattern-welded ones, a feature invisible on X-radiographs.

Many of the analyses treated here have been carried out by scientists or conservators who have a special interest in history and archaeology. Archaeology and the relevant sciences are indeed very different disciplines. Technological investigations are of great interest and indispensable in addressing a wide range of questions related to the connections between production, distribution and use of weapons in a particular society. However, in order to better understand and utilise the results archaeologists should collaborate closely with material scientists, and together should first specify the problems to be investigated, and then evaluate the end results.

6. THE CONSTRUCTION AND CRAFTSMANSHIP OF VIKING AGE SWORD BLADES: A METALLOGRAPHIC EXAMINATION[6]

The aim of this study is to gain information about the Norwegian Viking Age blacksmith's technical skill, and his understanding of the materials with which he was working. Thus, it is interesting to study to what degree refined smithing techniques, which could improve the quality of an object, were common knowledge in Norway in the Viking period. Did a majority of the blacksmiths know how to utilise such techniques as carburisation of iron and heat treatment of tools and weapons in a predictable and successful way? Or were such techniques mastered by only a few specialists, who produced objects demanding much from their material composition and craftsmanship? Further, we will examine the composition and different methods of construction of sword blades. The types and frequencies of techniques, such as pattern- welding, piling, or inlaid design used either to improve the quality of the object or to give a decorative appearance to the metal surface, have also been studied.

There are indications of differing social status and levels of specialisation among the blacksmiths both from archaeological finds and from the sagas. Since the use of iron for weapons and tools, needed in households by farmers, hunters, fishermen, carpenters, shoemakers, warriors, not to mention decorative smithing of different kinds, was steadily increasing in the first millennium AD, specialisation among blacksmiths must have been inevitable. Variable quality and uneven craftsmanship observed in ancient iron objects show that Viking Age blacksmiths did not form a homogeneous group of craftsmen. In rural districts it is likely that resident peasant smiths were responsible for repairs and production of simpler objects for daily use, for their own personal needs, and for the local population. More intricate smithing, like the manufacture of edged tools and weapons, was probably achieved by specialised and better qualified smiths. The blacksmith was either resident in the area, or worked as an itinerant specialist serving the inhabitants of a larger district (Straume 1986). The craftsman whose main occupation was smithing is more likely to have worked in central areas and marketplaces, where the demand for high-quality products was stable and the general financial resources among people higher. The most complex pieces of smithing, like the best and most impressive weapons, in which quality as well as appearance were of great importance, are most likely to have been produced by highly specialised weapon-smiths, either to order or in the service of kings and chieftains (see discussion in Chapter 3).

Swords have been specifically chosen for this study. Being a weapon it can be expected that the most advanced technology of the time was employed in the production of a high quality sword. The quality of the materials, as well as the craftsmanship, is of crucial importance in a long, slashing weapon. The material needs to be fairly sophisticated metallographically in order to meet the requirements of close combat. Another reason which makes the Viking Age swords well suited for examination is that pagan rituals for burial still prevailed in Scandinavia at the time. Rich and abundant grave finds and single finds make the number of swords available for sectioning sizable. The unusually large number of Viking Age swords found in Norway indicates extensive production of swords in the country.

Pure iron is too soft a material for some purposes. Cold-hammering will harden the iron, though only moderately and not to the same extent as cold-hammering bronze. It was therefore necessary to master

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[6] I should like to express my sincere thanks to Professor Robert Maddin, Harvard University, for discussion of the work and for his most valuable comments, and Helfrid and Sten Modin, Stockholm University for sharing with me their valuable knowledge of the relevant metal structures. Further, I want to thank senior engineer Przemyslaw Zagierski, Physics Department, University of Oslo, for a helping hand and permission to use the metallurgical microscope, senior engineer/metallographer Gisela Berg for cutting the sections and for letting me use the hardness apparatus, senior engineer Jens-Anton Horst for carrying out the microprobe analyses, and other staff members at Materials Technology, SINTEF, Oslo, for further help and useful discussions. I am grateful to two of the archaeologists at the Institute of Archaeology, Numismatics and History of Art, University of Oslo: Charlotte Blindheim for her comments and assistance concerning archaeological information, and Professor Irmelin Martens for discussion of this work and our further study of Viking Age weapons. Finally, I am grateful to the Research Council of Norway for a grant supporting this work when it was in its infancy. – *Eva Elisabeth Astrup*

techniques that could harden the iron further. A harder material, which would be an improvement for a number of tools and weapons, could be obtained by alloying the iron. Carbon was the most common alloy material for this purpose, turning the iron into steel. It seems likely that the aim of iron production in the Viking period was to make a supple, workable material, meaning wrought iron with a moderate carbon content (Buchwald 1993). When, and to what extent, this was achieved by deliberate choice of production conditions is difficult to tell. However, products from the bloomery furnaces had a heterogeneous, mostly low carbon content, although certain areas of the bloom could have an increased concentration of carbon. The bloom would typically be exposed to oxidising conditions in areas around the tuyère, resulting in an iron product. The part of the bloom which was in close contact with the charcoal could absorb carbon by accidental diffusion during the process. It has been suggested that the carbon-rich layers were cut off from the blooms in order to utilise the harder material for special purposes (Buchwald 1993). It is, however, difficult to understand how the ancient smith could identify the higher carbon content layers. The iron blooms, produced in a solid condition directly as a result of smelting iron ores, contained various amounts of entrapped slag. The raw material had to be refined by repeated reheating and reforging in order to reduce slag content. A high content of slag would leave the wrought iron brittle and difficult to forge. The smith or the smelter could, to some extent, test the slag content of the iron and assure adequate malleability by forging the end of an iron bar flat (e.g. currency bars)[7].

The temperature needed to melt pure iron (1,537°C) is higher than that likely to be obtained by the Viking Age iron producer. Deliberate production of steel therefore had to be done in the solid state by diffusion of carbon into the iron at a temperature in the order of 900°–1,000°C. The absorption or diffusion of carbon into the iron, carburisation, is dependent upon the temperature and conditions in the smithing hearth in order to produce a sufficient supply of carbon atoms. The process of carburisation in prehistoric times could be difficult and time-consuming to carry out. The product, steel, was therefore expensive. Experiments show that even in the presence of an energiser to facilitate the process, and at temperatures above 900°C, a carburised layer of only 1.5 mm thickness could be expected after 8 hours in the hearth (Maddin 1991). Intentional carburisation of an object was in principle carried out by two different methods: either the surface of the nearly finished iron object was carburised (case-carburisation) in order to give it a steeled coating; or a thin sheet of steel was built into or fused onto the iron body by hammer-welding before the final forging of the object. A skilled blacksmith with proper knowledge of the carburisation process was required to produce quality swords and a number of other weapons and tools, especially those with cutting edges.

After successful carburisation, a further increase in hardness can be obtained by suitable heat treatment. Pure iron cannot be hardened by quenching. The heat treatment of carburised iron was carried out by somewhat different methods. A full quench is obtained by a sufficiently fast cooling of the object from a temperature of about 900°C, depending on carbon content. If carbon content is high, the result will be a very hard, but also very brittle, material. If overall carbon content is low, the result will be a material which is less hard and brittle. A full quench is recognised by an all-martensitic metallographic structure (Figure 6.3e). If the cooling rate is not fast enough to produce an all-martensitic structure, hardness as well as brittleness would be less (slack-quench). The metallographic structure might be that of a mixture of martensite, bainite, or pearlite (Figure 6.14c). An insufficient cooling rate could also be the result if the quench was interrupted too soon. There are many instances of insufficient or interrupted quenching indicated through examinations of tools and weapons. It seems possible that this was an intentional technique used by blacksmiths to obtain a less hard and brittle material than that resulting from a full quench. In cases where the quenching produces too brittle a material, a partial softening can be achieved by tempering (re-heating at 200°–250°C), in order to produce a high-quality sword blade. Analyses of cutlery from the 10th–12th centuries AD, mainly from the eastern parts of the

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[7] It is not correct that iron made from bog ores often shows elevated phosphorus content. This misunderstanding goes back to a paper by Olof Arrhenius whose analyses of pattern-welded objects presented average values of all the material from a sample. Many of the same objects were used for more general analyses during the study of the Helgö material, and later their phosphorus content was determined, showing low phosphorus values (Bergman 2005:65 with reference and Table 19:68). In Astrup's own chemical analyses of some of the metallographically investigated swords "phosphorus was found to be present in fairly low concentrations, too low to be of importance for this examination". Chemical analyses of slag from Møsstrond also show low phosphorus content (Rosenqvist 1988:Table 5 and 7). One should rather ask how widespread phosphorus-rich bog ores were and where they were found. These questions are relevant to the problem of pattern welding carried out in Norway. – *I. Martens*

continent show that heat treatments like quenching and tempering became common (Pleiner 2007:237; Kosta and Hosek 2014:277–279).

Iron products from Central Europe in the Hallstatt period (c. 700–500 BC) (Piaskowski 1969) and the late La Tène period (c. 500 BC– 0) (Emmerling 1975), show that the carburisation treatments were often uncontrolled and accidental. A thorough study of Celtic swords (c. 500–50 BC) (Pleiner 1993) proves that carburisation was a well-known process, and that blacksmiths knew how to do this successfully. Later on, South and Central European smiths seem in general to have mastered the process of hardening iron by carburisation followed by quenching (Maddin, Hauptmann and Baatz 1991). Thus far, however, it is not known at what time carburisation and heat treatment were initially carried out in Norway, nor from what time these processes were generally used in the production of weapons and tools.

Next to carbon, phosphorus is the alloy material most commonly found in old iron objects. Like carbon, phosphorus also increases the hardness of iron. Wrought iron with an elevated phosphorus content can compete with unquenched carbon steel. However, phosphorus causes a pronounced brittleness, which would easily result in unintentional chipping and breaking of the object and render the material difficult to forge (Nosek 1991). Unlike carbon steel, phosphorus-containing iron cannot be heat treated in order to obtain a further increase in hardness. While absorption of carbon into the iron tended to be an additional process of refinement, phosphorus derives from the ores. The presence of elevated concentrations of phosphorus in iron will hamper the diffusion of carbon into the metal. Any attempt to carburise such iron will not be successful.

To build a blade from various iron and steel parts they had to be joined together by hammer welding. Such welding was carried out by heating the metal pieces in a charcoal hearth to between 1000°C and 1200°C and then joining the hot metal strips together by hammering. However, the formation of surface oxides (hammer scale) produced at such high temperatures may prevent satisfactory welding. Problematic amounts of hammer scales can be reduced by cleaning the surface of the metal while preparing the weld and minimised further by using a flux, such as salt or sand.

There were different methods of constructing sword blades. A high quality blade should have the right combination of a resilient central part and hardened steeled edges. A skilled smith would probably choose a method in which a minimum of steel was used without reducing the quality or impairing the operational purpose of the weapon. After all, steel was time-consuming and difficult to make, and consequently more expensive than iron. Accordingly, the majority of iron objects were made by "steeling" or welding pieces of steel and wrought iron together. Blacksmiths may have had their personal preferences for sword blade constructions, compositions and welding techniques. Information on such techniques was most probably not disseminated much outside the workshop. The presence of technical characteristics might therefore indicate production methods at different workshops.

Since the end of the 19th century, a recurring question has been to what extent Viking swords were produced in Norway, or whether the numerous sword finds represent mostly imported weapons (as discussed in Chapter 3). The conclusions in published papers relating to import versus domestic production are based mainly on studies of the hilts and decorations on the blades. While the shape of the sword blades was subject to few alterations during the Viking Age, the hilts went through numerous changes. However, the hilt and the blade of a sword may not necessarily have been made by the same smith – not even in the same geographical area. As new hilts may have been mounted onto old blades or vice versa, a classification of blades cannot be based on an examination of the hilts. In the present work the construction of the blades will also be related to different types of hilts.

Although Old Norse and Irish literary sources are limited in relation to the description of the general appearance of sword blades, and even more so concerning origin of production, the quality of sword blades is mentioned in many places (Davidson 1962). The sagas mention poor-quality blades that had to be straightened with the foot, indicating that soft, fairly pure iron had been used. Furthermore, qualities like cutting power and durability are frequently referred to. The sagas reveal the importance of resilience for a good sword blade. In several cases they describe outstanding swords which had been handed down through generations. For hundreds of years the working of iron was surrounded by mysticism until Theophilus (Theophilus trans. 1963) in about 1,100 AD wrote down some of these secrets. One should bear in mind that the sagas were not put down in writing until a few hundred years after the Viking Age. Literature of Arabic origin (Zeki Validi 1936) dating from the time of the Vikings argues that in Europe the Rus, as well as the Franks, also produced swords. Today, many scholars claim that the Rus consisted of Russians and Scandinavians, at least East Scandinavians. Some types of smith tools do occur frequently in male Viking graves. Also, archaeological evidence of specialised weapon blacksmiths from the Viking Age has been found in Norway (Blindheim 1963). Grave finds of smith tools accompanied by a number of spearheads and swords, like those found in Bygland (Blindheim 1963), strongly indicate local production of weapons.

The swords studied in this investigation (Table 6.1) are all from the Viking Age. According to the archaeological classification of the hilts (Petersen 1919), they belong to the period from 800 AD until around 1,050 AD, mostly from the second half of that period. They have all been found within the same district of Norway, the county of Telemark (see map in Figure 6.1). Telemark has been chosen especially for this study because there must have been sufficient supplies of iron in all parts of the area. Large amounts of iron were produced in the mountainous areas of this district for centuries, including the period of interest for this work. An extensive work by Martens (1988) deals with iron production in the mountain areas of Telemark. Martens concludes that iron production had been going on in this area for a timespan of about 800 years, starting around 550 AD. A rough estimate of the annual production is 7,000–10,000 kg, depending on the technology employed, bowl furnace or shaft furnace. Easy access to raw materials was only one condition for a smithy. Equally important was the demand for weapons in society. To judge from the grave finds in Telemark – most of which date from the mid and late Viking Age – the county experienced a fairly steady level of prosperity with a few exceptions of considerable wealth. This implies that a demand for swords must have existed. Thus, easy access to raw materials and a reasonable demand for swords most probably resulted in a positive development of the craft in the area.

Although iron was produced in large quantities, recycling of scrap iron most likely also took place. This is confirmed by the many scraps and bent pieces of iron, including a bent axe, found in the Viking Age blacksmith's tool chest from Mästermyr on the island of Gotland, Sweden (Arwidsson and Berg 1999:Plates 12, 24, 30).

6.1 THE TELEMARK SWORDS

Around 220 swords from the Viking Age have been recovered in Telemark county. Except for some preferences in choosing certain districts in Telemark, the selection of blades in this work was purely random. A selection based on hilt types, pattern weldings, inlays or any other features has not been made. Although all the swords examined in the present work have been found in this county, it is not certain that they were all manufactured there. International trade at the time was extensive, as numerous finds from the Viking Age graves show. Therefore we must see if there are certain features in the smithing techniques or other clues that would make it possible to distinguish between domestic products and imports.

In this work 21 swords, recovered from all parts of the county, have been metallographically examined (Table 6.1). This represents 10% of the Viking Age swords found in Telemark. The swords have been selected, independent of pattern- weldings, inlays or any other features. In order to study potential local characteristics and varieties, several blades have been chosen from certain districts. Nineteen of the swords have been recovered from graves, that is from datable contexts. The remaining two were found during farming or construction work. Swords that have been exposed to prolonged heating at high temperatures after manufacturing (e.g. cremation burials), have tentatively been avoided in this study, as this might have otherwise interfered with the deliberate heat treatment by the blacksmith. Judging from the lack of iron oxide scales and the presence of metallographic structures due to quenching, many objects found in graves seem to have escaped prolonged heating. In this study, a single sword was most commonly found in each of the graves, in addition to other grave goods. In some cases, two or more swords have been recovered from the same grave. This may represent particularly rich graves, several burials in the same grave, or mixed finds. Eighteen of the swords are double-edged, and three are single-edged.

All the swords studied are today in the Museum of Cultural History, University of Oslo. Sampling the swords was restricted to those that were already fragmented and broken – a fairly common condition for sword blades recovered from this period, due to burial customs and soil conditions. Swords which were still in good condition and more or less complete have so far been avoided. The fragmentary swords represent about 60–70% of the total number of swords from Telemark, but their conditions vary considerably. By sampling already broken sword blades, it has been possible to cut sections across the blade from edge to edge. Although the cross-sections of the double-edged blades seem to have an axis of symmetry, a microscopic examination in some cases reveals some deviations from such symmetry relating to composition and forging techniques.

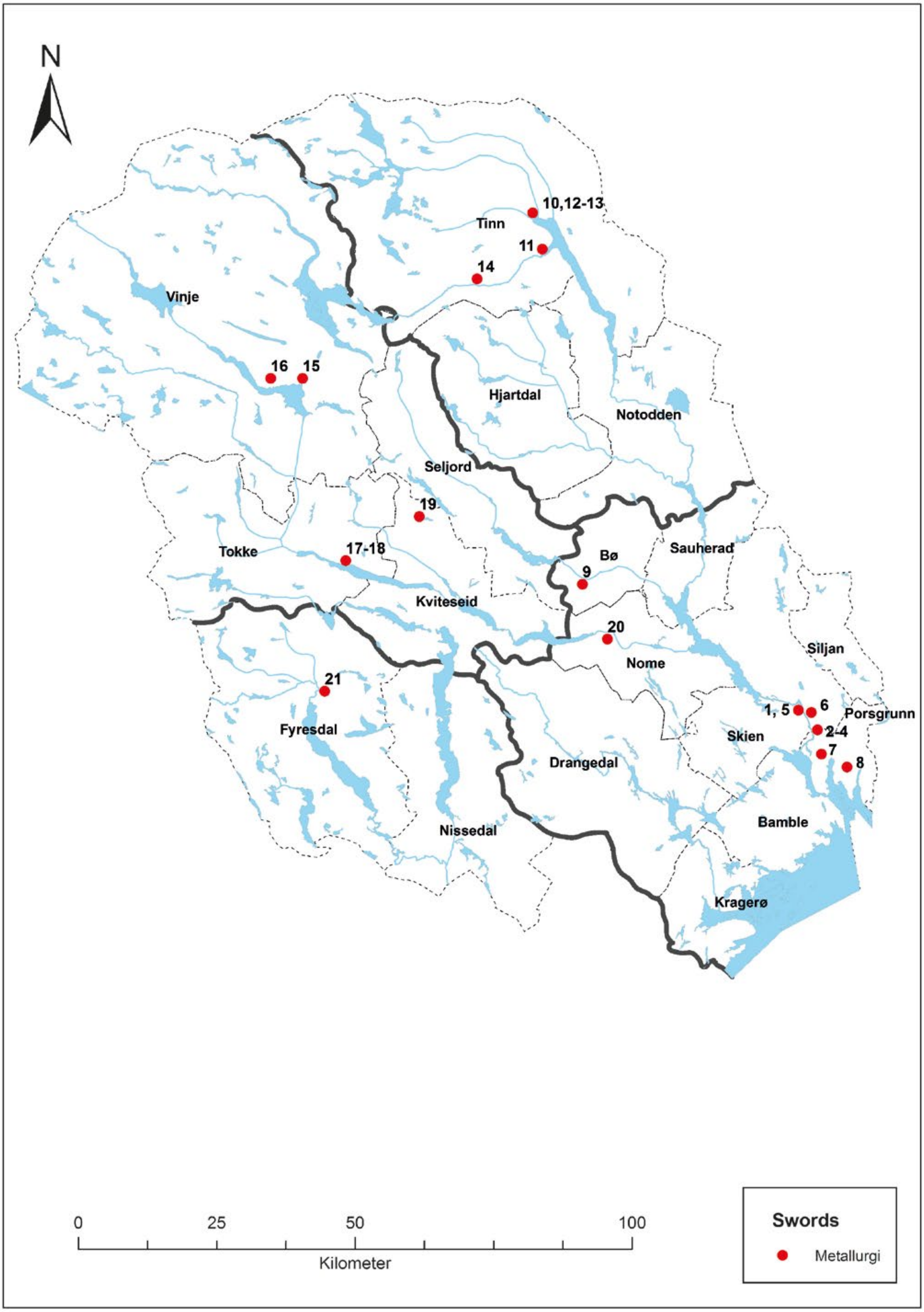


Figure 6.1. *Map showing distribution of metallographically investigated swords. Map: M. Samdal, KHM (CC BY-SA 4.0).*

***Table 6.1.** The swords metallographically examined in this work.*

SWORD/ MUSEUM		FIND PLACE	HILT TYPE*	CONDITION
1	C.30067a	Skien, Solum, Kjerringteigen	M	highly corroded
2	C.29150	Skien, Gjerpen, Ris søndre	M	acceptable
3	C.35841a	Skien, Gjerpen, Ballestad nordre	V	highly corroded
4	C.35842a	Skien, Gjerpen, Ballestad nordre	M	fairly corroded
5	C.29227a	Skien, Gimsøy, Baugeidsgt. 19	M	highly corroded
6	C.23112	Skien, Gjerpen, Frogner	M	corroded
7	C.26360a	Porsgrunn, Eidanger, Bjørnstad	H	highly corroded
8	C.28460a	Porsgrunn, Eidanger, Stamland	Q/X	highly corroded
9	C.30049	Bø, Grave	Q	fairly corroded
10	C.28239a	Tinn, Marum-Suigard	LA	fairly corroded
11	C.26828a	Tinn, Møli	Q	corroded
12	C.29700a	Tinn, Marum	Xa	very corroded
13	C.29700b	Tinn, Marum	Xa	very corroded
14	C.23364	Tinn, Dal	Xa	acceptable
15	C.25111a	Vinje, Rauland g.33 b.7	Q	acceptable
16	C.21325a	Vinje, Kjelingtveit	H	highly corroded
17	C.23018a	Tokke, Åkre	Q	highly corroded
18	C.22568a	Tokke, Kvålo	Und	highly corroded
19	C.24793c	Kviteseid, Øvre Berge	Und	fairly corroded
20	C.19575	Nome, Lunde, Røymål	Q?	acceptable
21	C.23946a	Fyresdal, Brokke	M	fairly corroded

* Hilt types:
Und = undetermined or hilt missing

Comments on typology and dating

The problem of the origin of sword hilts and blades could not be considered when the selection of swords for metallographic analysis was made. A good chronological distribution was likewise secondary to the geographic one. As the majority of Viking Age finds in Telemark belong to the second half of the period, this is also the case for the analysed swords. For instance, no C-type swords, which mostly belong within 800–850 AD, have been analysed. Another drawback is that very few of the finds can be closely dated, the common types M and Q can only be dated to between 850–950 AD and 900–1,000 AD respectively.

Three swords cannot be accurately typologically determined. Sword 8 has only the lower guard preserved, but is either a Q or X-type sword, in both cases from the 10th century. Swords 18 and 19 have no guards preserved, but sword 18 was found with an H-type axe, again indicating the 10th century. Sword 19 is from a mixed find assemblage with only a general date within the Viking Age.

The earliest analysed sword, 16, has a type H hilt inlayed with a stepladder pattern. It was found with an axe of type D that narrows the dating of the grave to 800–850 AD. The reconstructed inlay pattern on the hilt indicates that it is not one of the earliest H-type specimens. The blade fragment has the remains of an inscription, and the origin is uncertain. The blade is of construction type I. The other H-type sword, 7, has a pattern-welded blade (PW 5), which is probably not of indigenous make.

The V-type hilts (sword 3) with their Ge3-type pattern are among the most enigmatic ones in terms of places of production. The hilt and blade could have been produced separately, and as construction type III was commonly mastered by Norwegian weaponsmiths, this problem is of secondary interest here.

The very late sword, 10, the only one analysed having a whole-steel blade, construction type V, was most probably not made in Norway.

A number of metallographic investigations of European iron swords have appeared in the literature. Many analyses are either limited to blades of isolated finds, or they focus mainly on certain techniques like pattern- welding or inlaid designs. More comprehensive examinations of larger numbers of blades of general character, like Celtic swords (Pleiner 1993), Roman period swords (Kedzierski and Stepinski 1989), and Anglo-Saxon swords (Gilmour 1986), elucidate sword blade technology for more than a thousand years. Only a few swords from Norway have so far been metallographically studied (Rosenqvist 1970; Arrhenius 1982; Liestøl 1951), and no systematic approach to mapping the forging technologies based on metallographic examinations, has so far been reported (as discussed in Chapter 5).

6.2 EXPERIMENTAL METHODS OF INVESTIGATION

In this investigation full transverse sections, including both cutting edges, have been cut from all the sword blades, one from each sword, using an abrasive cut-off wheel. For one of the swords (sword 18), two sections have been studied. X-radiographs were recorded for all the blades in order to estimate the state of conservation and the best place to extract sections. Also, the X-radiographs have been used to identify pattern welding or inlays, and to record cracks and bad welds that might be present. In order to cause minimum damage to the artefacts, the sections were cut as close as possible to existing fractures in cases where the X-radiographs reveal an acceptable state of preservation for sampling. Since many of the swords are quite corroded, parts of the edges and surfaces were not well preserved and often missing. However, numerous parts including pieces of the edge are still present in most of the samples.

The sections of the blades were mounted in a cold thermosetting synthetic resin. The samples were ground on wet abrasive paper ranging from 220–1,200 grade. Fine polishing was completed on rotating pads, using 3μm and 1μm diamond spray.

The distribution and shape of slag inclusions were studied on the polished, unetched samples. The polished sections were then etched in 2–4% nital in order to make the metallographic structure visible. The microstructure has been examined at magnifications from 20× to 1,000×. In order to locate the presence of significant amounts of phosphorus, all samples have been studied after etching with Oberhoffer's reagent. Sections showing positive reactions to an elevated phosphorus content with Oberhoffer's reagent were subjected to quantitative determinations by electron probe microanalysis (EPMA). Swords 7, 16, and 20 all show piled, pattern-welded or inlaid structures. The substances phosphorus, copper, manganese, arsenic, nickel, and cobalt have been analysed in steps across the layers to create concentration profiles. For swords 4, 11, 15, 17, and 19, microprobe analyses were carried out to provide information on the chemical composition and enrichment of certain elements, especially arsenic, nickel, cobalt and phosphorus, in the welds. For sword 2, a similar analysis was carried out across an area of several pale bands. The area of each analysis, varying from 10 × 10 μm^2 to 25 × 25 μm^2 in different samples, was chosen in order to even out small heterogeneities typical for archaeological material. Step lengths differ from 20 μm/step across welding seams to 30–50 μm/step in piled structures, depending on the thickness of the layers. In sword 12 single analyses were made in order to find out if the hard ferritic material was due to significant phosphorus content.

In all samples, hardness measurements have been carried out by DPH (diamond pyramid hardness) using a 1 kg load. The figures are given as HV (Vickers Pyramid Number).

Observations of the microstructure were made using metallurgical microscopes at the Research Park, Department of Physics, and at the Research Laboratory, Museum of Cultural History, University of Oslo. The electron probe microanalyses were carried out on computer controlled Cameca Camebax Microbeam equipment at SINTEF Materials Technology in Oslo. All microphotos and drawings in this chapter are by E.E. Astrup. "The magnification given in the captions refers to the original one applied in the metallurgical microscope". The hardness measurements were made using a Zwick 3202 hardness apparatus (SINTEF Oslo).

6.3 EXAMINATION AND RESULTS

It is not always easy to unearth the intentions of the blacksmith and the working technologies of ancient metal objects. Metallographic data offer much information, but the presence of natural impurities in the raw materials and accidental combinations of steel and iron can produce confusing pictures. Moreover, prolonged heating in the hearth may smooth out or obliterate welding seams between different parts, and cause unintentional carburisation or decarburisation of the material. Uncontrolled cooling rates may render a metal structure difficult to interpret. Due to such incidental reactions the metallographic structure may indicate certain processes of manufacture, which were not intentionally carried out by the smith. For examinations of most archaeological objects, and of large objects in particular, it would be of great help if several samples could be taken from different parts of the same object. That could differentiate between intentional and unintentional processes, and show whether the craftsmanship was good enough to produce

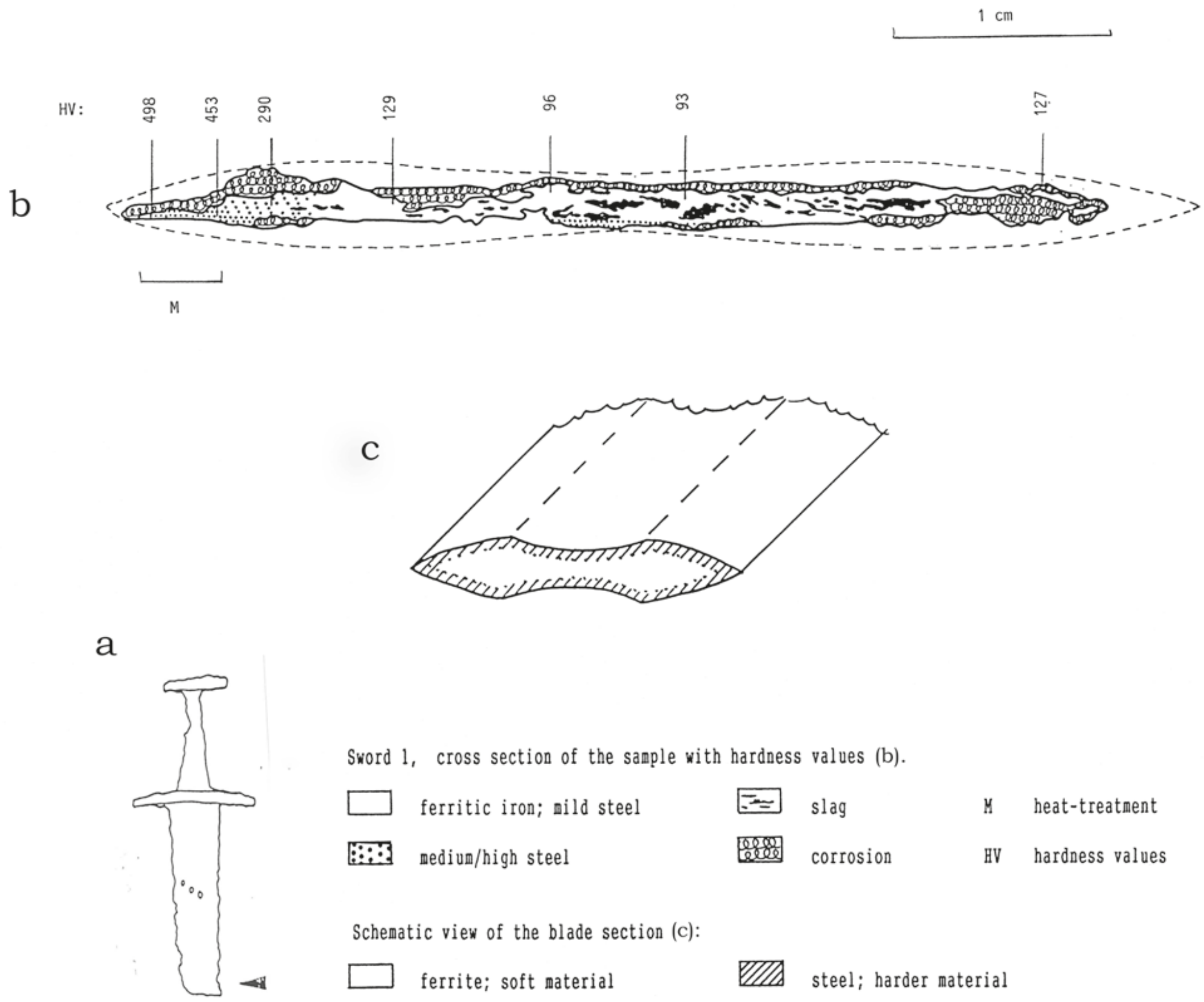


Figure 6.2a. *Sword 1. Cross-section of the sample with hardness measures (b), schematic view of the blade section (c) and outline of sword with section marked (a).*

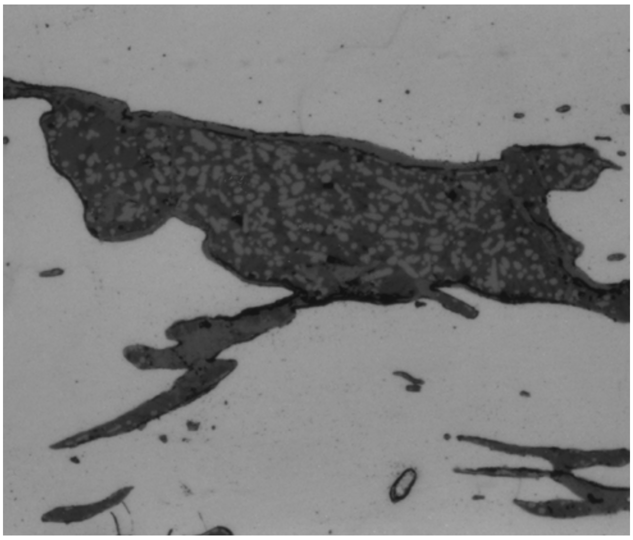


Figure 6.2b. *Sword 1. Slag consisting of a light grey spheroid phase, probably wüstite, in a dark matrix of iron silicates. (200 X).*

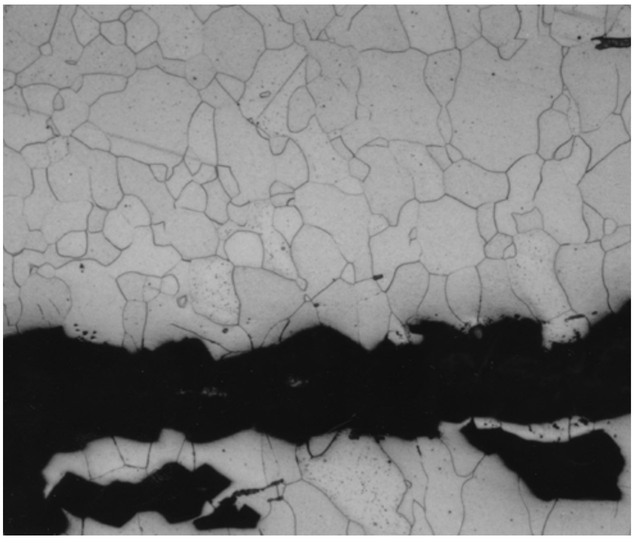


Figure 6.2c. *Sword 1. Etched. Ferritic iron with porosities and slag inclusions in a major part of the blade. (50x).*

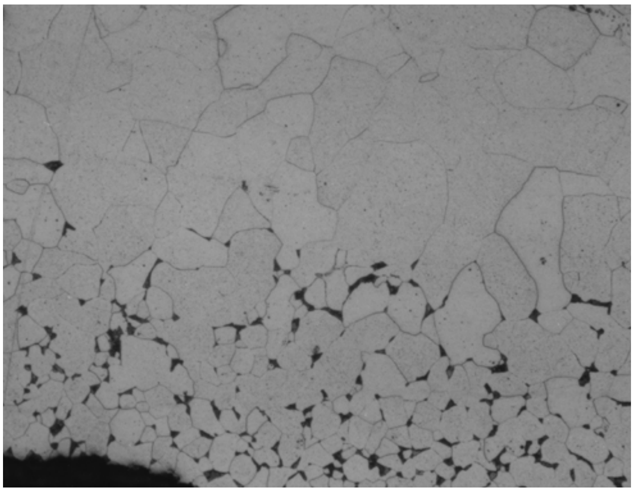


Figure 6.2d. *Sword 1. Ferrite and perlite in a small part of the section along the central surface. Carbon content is somewhat higher along the surface than in the core of the blade. (200x).*

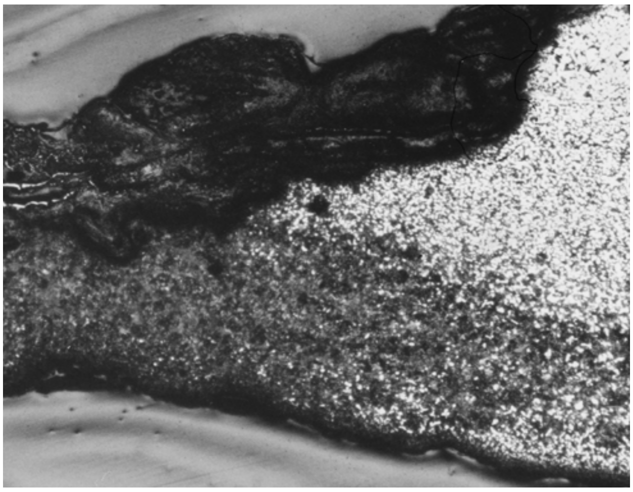


Figure 6.2e. *Sword 1. The tip of the cutting edge in the left part of the section contains high carbon content (dark). The dark part is corrosion. (50x).*

uniform quality throughout the object. However, such sampling would ruin the object completely, and can be justified only in specific cases.

To compare the quality of sword blades investigated in this study a sorting scheme of four tiers has been applied. These have been ranked as: poor, fair, decent, and high quality. The point here is to estimate the sword blades' functional quality when used in battle, disregarding aesthetic aspects. Major contributing factors when evaluating this are:

- The construction method employed in joining and welding together iron and steel elements of the blade, and whether this craftsmanship was successful.
- The presence or absence of steel/carburisation.
- Whether quenching and heat treatment had been attempted to further increase the hardness of steel components, and if it was successful. Hardness measurements will indicate levels of softness and toughness versus rigidity, edge retention and brittleness.
- The amount of slag that can be observed in the metal, and if this could be considered detrimental to the functional quality of the blade.

A blade ranked as poor quality would typically represent a somewhat random construction method and consist mainly of soft iron. A high quality blade would require steeled edges, as well as having been subjected to successful quenching and further heat treatment.

SWORD 1 (Museum No.C.30067, found at Kjerringteigen in Solum, Skien municipality close to the limit of Skien city)

The sword comes from a man's grave, in which a spearhead was also found. The sword was in a highly corroded state, only the upper part of the blade and the hilt have survived in the ground (Figure 6.2a). The hilt is an M-type. The sword is double-edged with a fuller running along both sides of the blade.

Microscopic examination of the polished, unetched section shows porosities and numerous slag inclusions, particularly in the central part and in the edge area in the right part of the section in Figure 6.2b. Although there are some large spheroid slag inclusions, most of the slag structures are more or less elongated, results of the forging process. The slag consists of a light grey, mostly spheroid phase, probably wüstite FeO, in a dark matrix of iron silicates (Figure 6.2b). The spheroid shape of the wüstite phase indicates that the sword was heated after hammering.

After etching with nital, a microscopic examination shows that most of the central part of the blade, as well as the edge area with abundant porosities and slag inclusions (right), consist of a soft ferritic iron (Figure 6.2c). In the core of the section, an average hardness value of 95 HV was measured, consistent with soft iron with a pure ferritic structure.

In one area along the surface in the central part of the blade, the carbon concentration is found to be moderately higher than in the core (Figure 6.2d), while the opposite surface shows only ferrite. However, most of the original surface layers have been lost due to corrosion.

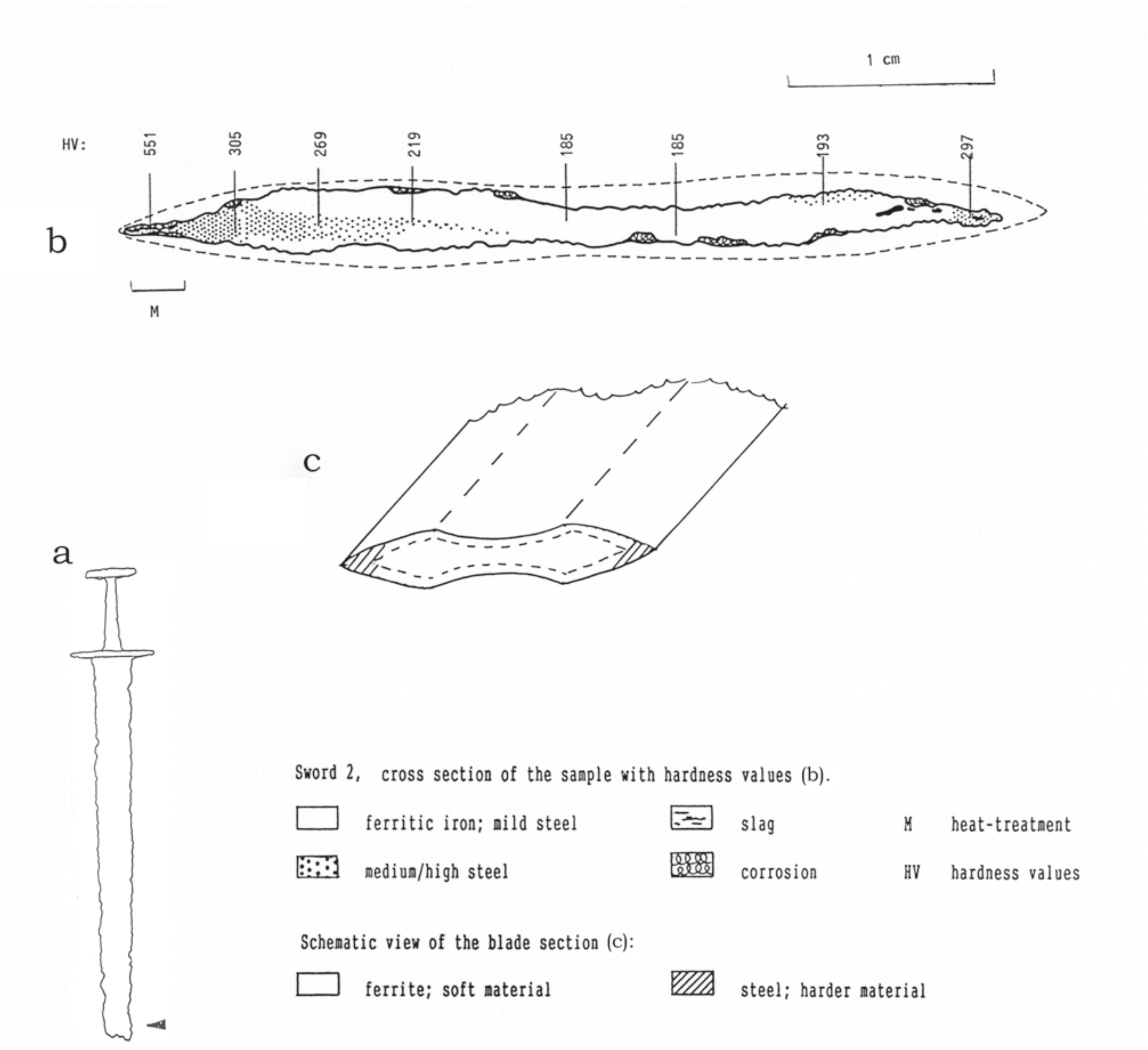


Figure 6.3a. *Sword 2. Cross-section of the sample with hardness measures (b), schematic view of the blade section (c) and outline of sword with section marked (a).*

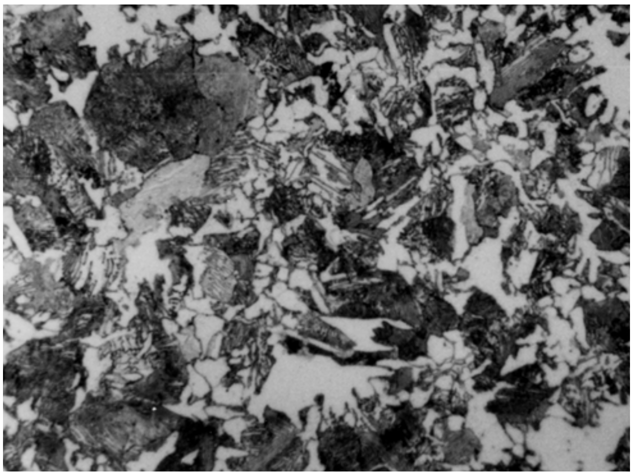


Figure 6.3b. *Sword 2. Medium carbon concentration in a generally heterogeneous structure. (1000x)*

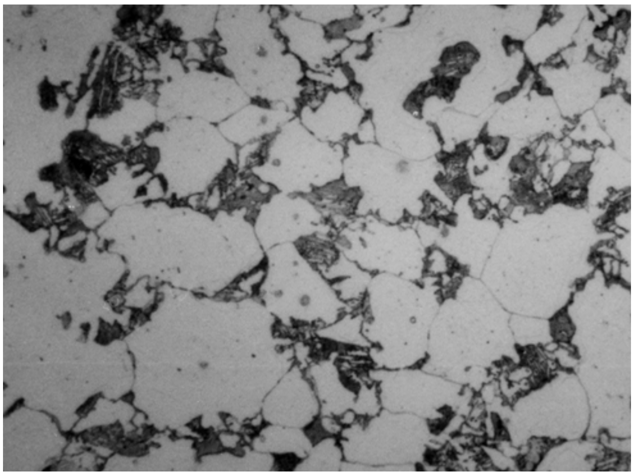


Figure 6.3c. *Sword 2. Low carbon concentration in a generally heterogeneous structure. (1000x).*

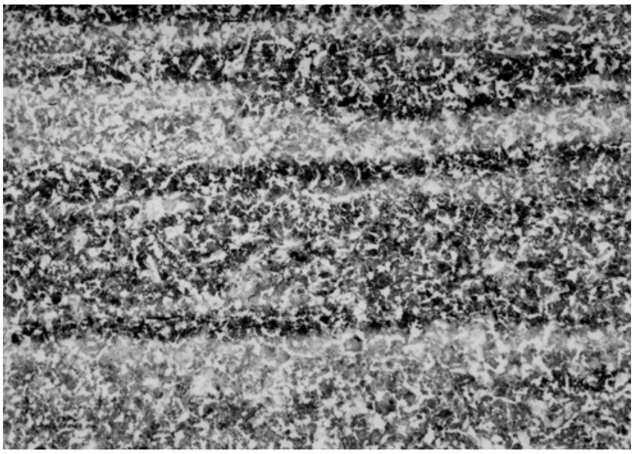


Figure 6.3d. *Sword 2. Light wavy structures, enriched with arsenic in part of the section. (1000x).*

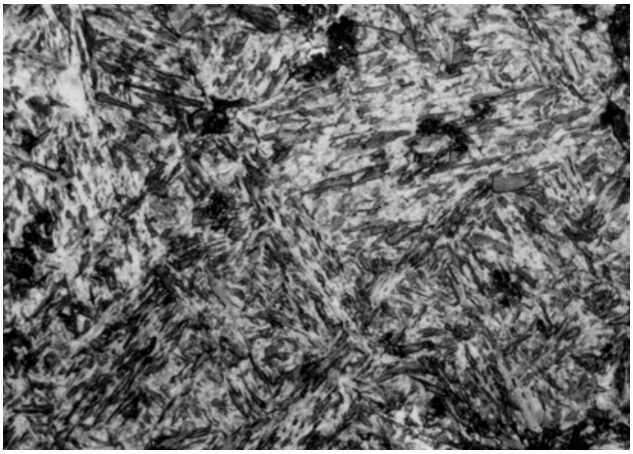


Figure 6.3e. *Sword 2. A martensitic structure due to quenching of the cutting edge in the left part of the section. (1000x).*

Part of the cutting edge on the left part of the section has been lost to corrosion. This edge, however, still consists of iron with a high carbon concentration (Figure 6.2e). The presence of a martensitic structure shows that the cutting edge has been quenched, although a full quench was not performed. This may have been done intentionally to avoid too brittle a material. The DPH hardness values (498 HV, 453 HV) show a fairly hard material.

The outer right part of the section shows only pure ferrite. To judge from the shape of the blade and the lack of carbon in this area, it seems reasonable to assume that the tip of the edge is missing due to corrosion. The hardness measured in the remaining part of this edge area is 127 HV.

Interpretation: The large amount of slag inclusions and porosities in the blade indicate poor craftsmanship or poorly refined iron, which would render the blade brittle. While the core and one of the edge areas consist of a soft uncarburised material, the other cutting edge and part of the remaining surface in the central part are harder, owing to an increased carbon concentration. Most probably a major part of the surface layers is missing, due to corrosion. It seems likely that higher carbon content might have been present in the entire surface of the blade.

In the present examination, no slag strings or weld seams were observed, which could indicate that a layer of higher carbon content had been welded to the core. Therefore, it seems that the blade had been carburised by a diffusion of carbon atoms into the iron in the last step of the forging process (case-carburisation). This conclusion is supported by the lack of a distinct gradient in the carbon concentration between the ferritic and the carburised areas. The presence of a high carbon content and a slack-quenched structure due to heat treatment in one of the edges indicate that the blacksmith was aware of the importance of hard steel in the cutting edges, and that he was able to carburise iron and to quench the steel, although the success of the process may have been somewhat accidental. Although the intentions and knowledge of the blacksmith in terms of making a good sword seem adequate, his choice of performing the heat treatment by slack-quenching indicates that a successful hardening was luck as much as skill. This sword is considered to have been of poor functional quality.

SWORD 2 (Museum No.C.29150, found at Ris in Gjerpen parish, Skien municipality)

The sword was found on a farm. As can be seen from Figure 6.3a, the blade is broken, and the outer part is missing. Otherwise the sword was in an acceptable state of preservation. The hilt is an M-type. The sword is double-edged and it has the remains of a shallow fuller along the blade.

The overall section shows only few slag inclusions. However, a couple of large, and some small, slag particles are observed close to the edges.

After etching with nital, part of the section was seen to have a heterogeneous composition of medium and low carbon content (Figures 6.3b, 6.3c). The uneven carbon concentration in the blade suggests that the material was forged together from pieces of varying carbon content in a somewhat random way, or from heterogeneous bloomery iron. In certain areas in the central part of the section there are light, wavy bands (Figure 6.3d). These bands represent an enrichment of arsenic formed by oxidation during smithing operations (Tylecote and Thomsen 1973). The elevated levels

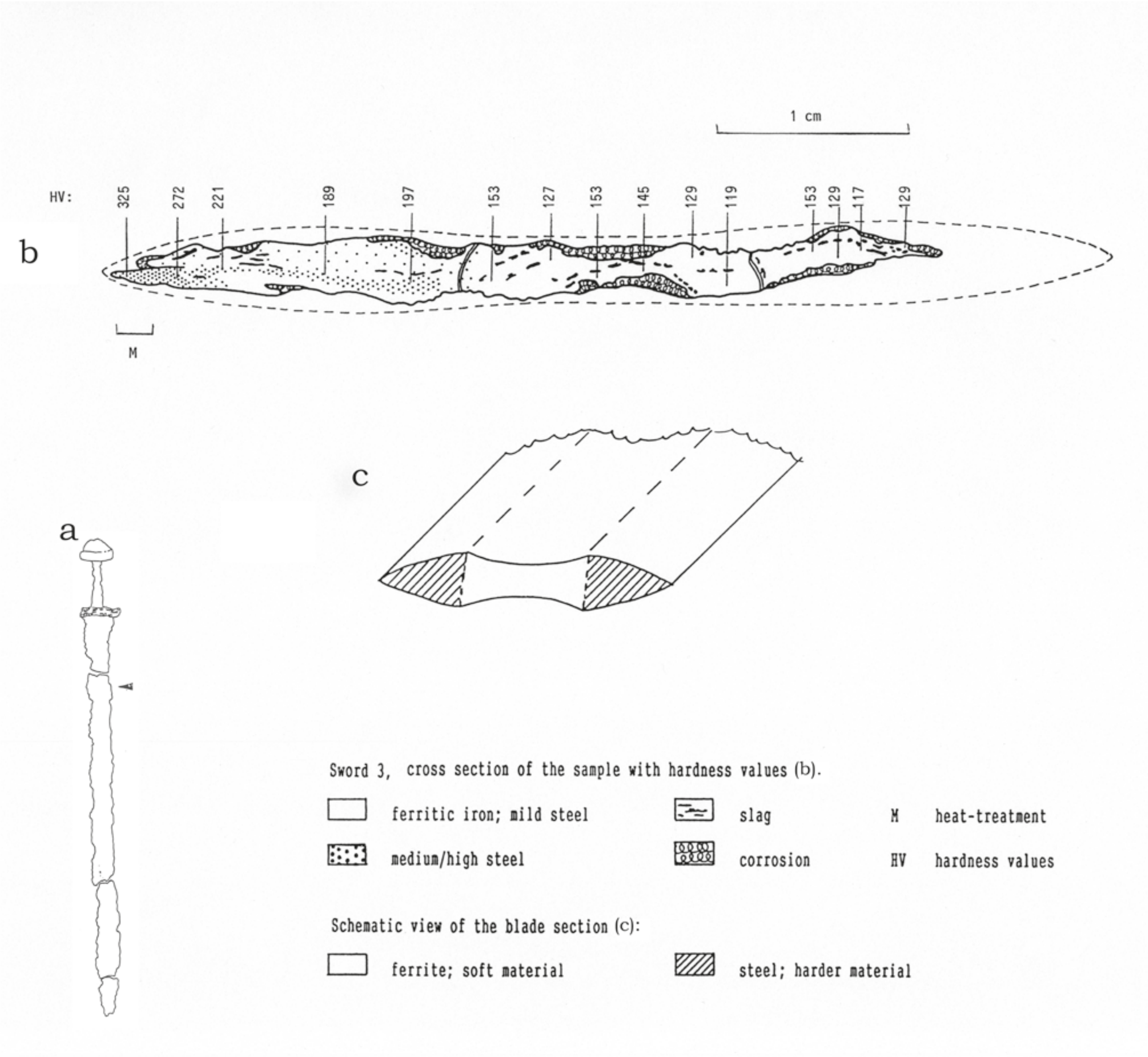


Figure 6.4a. *Sword 3. Cross-section of the sample with hardness measures (b), schematic view of the blade section (c) and outline of sword with section marked (a).*

Figure 6.4b. *Sword 3. Slag inclusions with an elongated shape due to forging throughout the section. (100x).*

Figure 6.4c. *Sword 3. The core of the blade consisting partly of areas with mostly ferritic iron. (200x).*

Figure 6.4d. *Sword 3. The core of the blade consisting partly of areas with fine grain pearlite. (200x).*

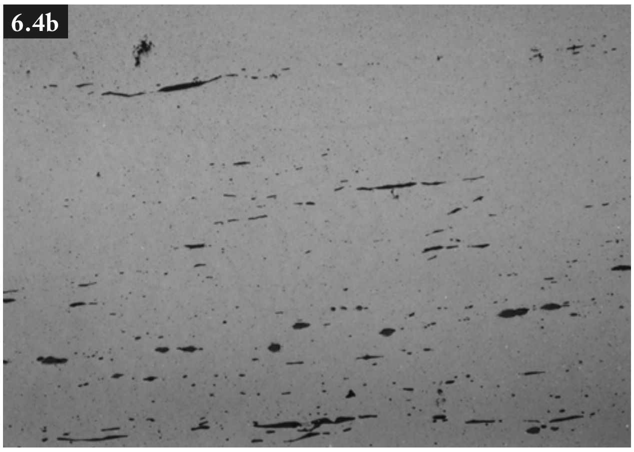
Figure 6.4e. *Sword 3. Pale line barely visible across the section, indicating welding seams between the central area (right) and the edge (left). (20x).*

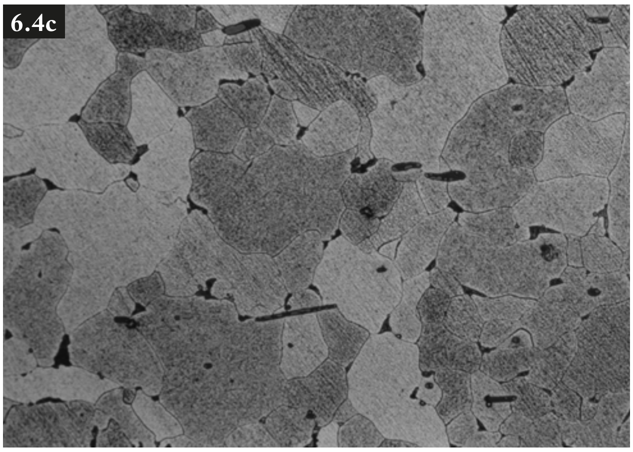
Figure 6.4f. *Sword 3. A deep crack from the surface into the left edge. (20x).*

Figure 6.4g. *Sword 3. The crack shown in 3/6. Decarburised areas on both sides of the crack resulting from lengthy heating. (100x).*

Figure 6.4h. *Sword 3. The carbon rich part of the left edge showing traces of martensite indicating quenching. (500x).*

Figure 6.4i. *Sword 3. Cutting edge of the right part of the section showing much lower carbon content than in the left edge. (100x).*


6.4b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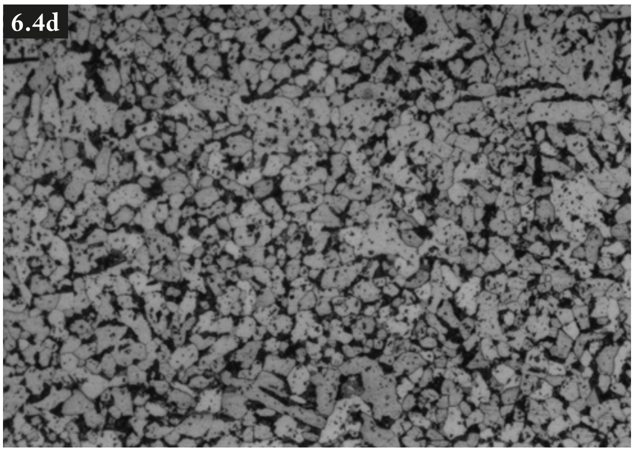
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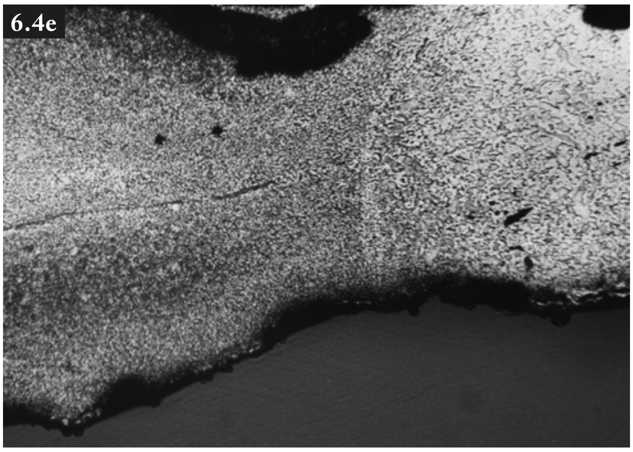
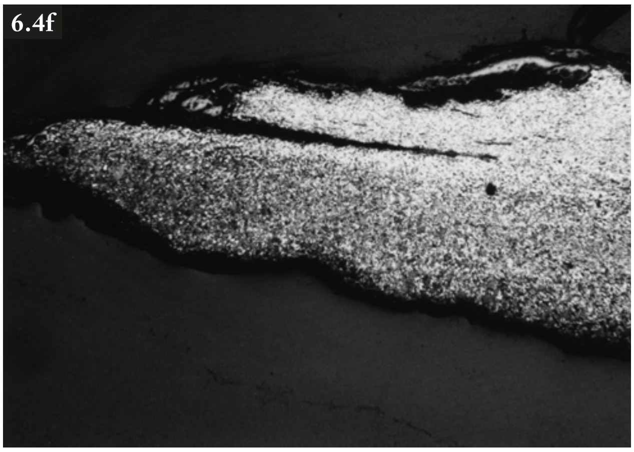
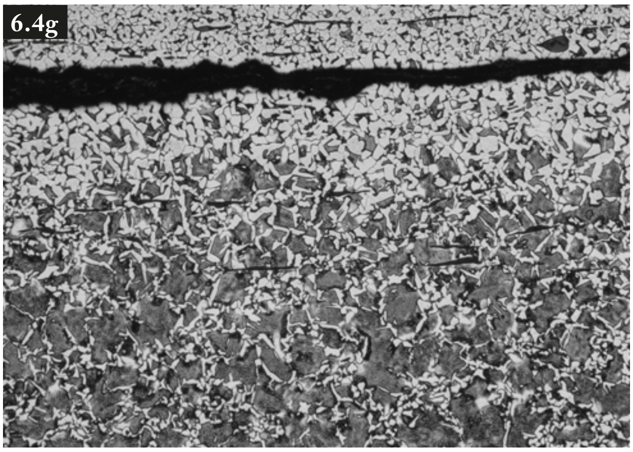
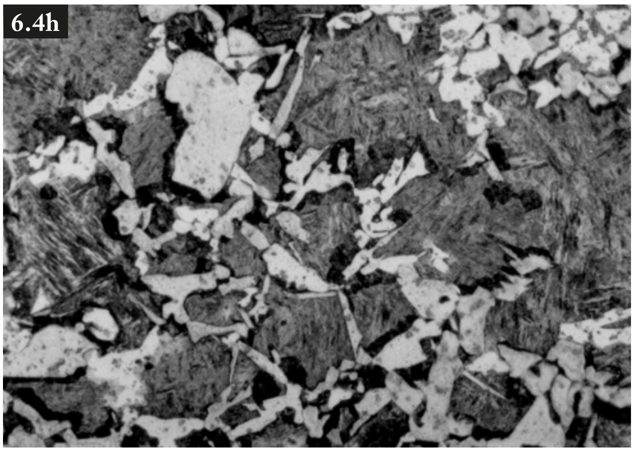
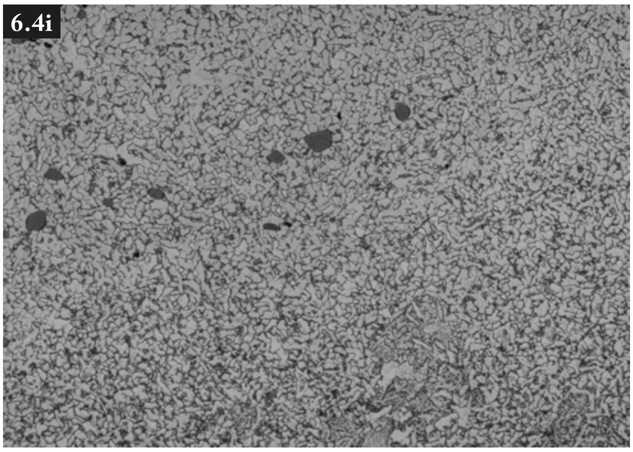

6.4e


6.4f


6.4g


6.4h


6.4i

of arsenic in the bands are confirmed by microprobe analyses. The arsenic concentrations are enriched from about 0.02 percentage by weight (hereafter wt%) in the bulk of the material to about 0.18wt% in the "pale lines". The hardness values measured in the central part of the blade range generally from 185 to 219 HV.

The cutting edge in the left part of the section shows, for the most part, fairly high carbon content. The tip of this edge has a martensitic structure due to heat treatment (Figure 6.3e). The hardness in this part is found to be 551 HV. Further away from the tip, the structure shows a mixture of martensite and bainite/pearlite, indicating incomplete quenching, possibly self-annealing. The hardness values range from 269 to 305 HV (Figure 6.3a).

A similar structure of bainite/pearlite is observed in the right edge, but there is no martensite there. This edge has a lower carbon concentration. The hardness measurements within this area average 297 HV, which is still reasonably hard steel. The indistinct transition between the carburised edge and the low-carbon core material indicates that carburisation was accomplished by direct carburisation of the finished product.

Interpretation: The blacksmith produced a sword blade with only few slag inclusions. The cutting edges were carburised, although the carbon content appears to be different in the two edges. However, judging from the shape of the blade and the width where the section was taken, a fair part of the cutting edge with lower carbon content (right) seems to have been lost due to corrosion. The structure in the outer left edge shows that the blade was hardened by quenching. Some self-annealing or incomplete quenching occurred closer to the central area. In the right edge only the incompletely quenched area is present, with the harder tip now missing. There is no indication of a carburised surface layer along the rest of the section. It is possible that only the edges were carburised, but it seems more likely that the entire blade had been carburised by case-carburisation, and that the steel layer in the blade surface has been mostly lost to corrosion. The structure shows that the blacksmith was familiar with the importance of hard cutting edges, and that he had the skill to carburise and quench the edges. This sword is considered to have been of fair quality.

SWORD 3 (Museum No.C.35841a, found at Ballestad in Gjerpen parish, Skien municipality)

The sword belongs to a grave find, which also contained a spearhead, an axe head, and a number of other iron objects. The sword is double-edged with a fuller along both sides of the blade. It was in a highly corroded state and broken into several pieces (Figure 6.4a). The hilt is a V-type.

Microscopic examination of the polished, unetched section reveals a number of slag inclusions all over the sample, with an elongated shape due to forging (Figure 6.4b). Strings of small hammer scale inclusions across the sample imply that the edges of the blade had been welded to the central part.

After etching, the core of the blade shows areas with mostly ferritic iron (Figure 6.4c), and other areas with fine grain ferrite and pearlite corresponding to a carbon content of approximately 0.3% carbon (Figure 6.4d). The hardness values in the core range from 119 to 153 HV. The latter corresponds to relatively soft pearlite. Pale decarburised lines, barely visible, across the section indicate welding seams between the low-carbon central area and the somewhat more carbon-rich edges (Figure 6.4e). Some diffusion of carbon from the edge areas across the welding seams may be observed.

The cutting edge on the left side of the section (Figure 6.4a) has a rather heterogeneous carbon content. Figure 6.4f and Figure 6.4g show a deep crack from the surface into the edge. This might be due to bad luck when hammer- welding together smaller pieces of different carbon concentrations, or it could be a fatigue crack, which was later accelerated by corrosion. The carbon-rich part of the edge shows traces of martensite indicating that quenching had taken place (Figure 6.4h). The hardness measured in this part of the cutting edge is 325 HV, while that next to the crack in the less carbon-rich area is 185 HV.

The other cutting edge (right) generally has much lower carbon content (Figure 6.4i). The hardness values range from 117 to 153 HV, with a hardness of 129 HV in the remaining outer part. This is significantly lower than in the other edge. The outer part of the right edge may originally have had a carbon concentration somewhat similar to the other cutting edge. This part of the right edge is however missing. As can be seen from Figure 6.4a, only a minor part of the edge outside the weld remains in this part of the section.

Interpretation: Strings of hammer scale inclusions and decarburised pale lines across the section indicate that the edges had been welded onto the central part. This blade section has a significantly higher carbon concentration in one edge than in the other. Although it seems reasonable to assume that the cutting edge on the right part of the section (Figure 6.4a) was lost due to corrosion, this alone can hardly account for the differences in carbon concentration in the remaining parts of the edge areas. Since a decarburisation of only one edge seems unlikely, it is possible that the original material for the two edges differed in carbon content. One of the edges clearly shows that the blade had been welded together from pieces of varying carbon content. Except for a major crack showing a weak point in one edge, the welding seams between different pieces of iron and steel were skillfully carried out. Given that the right edge also had a higher carbon concentration, this sword is considered to have been of decent quality.

SWORD 4 (Museum No.C.35842a, found at Ballestad in Gjerpen parish, Skien municipality)

The sword was found in a grave, which also contained a spearhead, a sickle, and some iron fragments. The sword is broken and quite corroded, and the outer part with the point is missing (Figure 6.5a). The blade is double-edged and has a fuller along both sides. The hilt is an M-type.

Microscopic examination of the polished, unetched sample shows a number of pores and small spheroid slag particles, particularly in the central part (Figure 6.5b). Spheroid slag particles indicate lengthy heating of the blade after the last hammering.

After etching with nital, pronounced welding seams containing small hammer scale particles (Figure 6.5c) show that the sword blade consists of a central part to which the edges had been butt-welded. Decarburisation and a pronounced enrichment of cobalt and some enrichment of arsenic and nickel appear in the welding seams. Also, some diffusion of carbon has occurred across the seams due to heating. Microprobe analyses confirm an enrichment of cobalt from a general concentration of about 0.05wt% to nearly 0.7wt% in the weld (Figure 6.24d). Also, other welds are clearly visible in both the edge areas, showing that the edge material had been welded together from several carbon-rich pieces of iron (Figure 6.5d).

The central part consists mainly of ferrite with some pearlite (Figure 6.5a). The hardness readings at different positions in this part of the blade are 145 HV and 156 HV, averaging out at 150 HV.

Both edges are thoroughly carburised, having close to a eutectoid carbon concentration in one edge and slightly lower in the other. There is a martensitic structure in both edges, due to quenching (Figure 6.5e). This is consistent with the high hardness values, averaging 587 HV and 553 HV respectively.

In the left part of the section (Figure 6.5a), there is a crack starting at the surface (Figure 6.5f). The area close to the crack has a ferritic structure, although a major part of the material in this area of the blade consists of high-carbon steel. This crack must therefore have appeared before the last heating process, which has resulted in local decarburisation of the steel around the crack.

Interpretation: Examination of this sword shows that the smith possessed great skill and demonstrated competent technical achievement in welding together pieces of different carbon content. Still, the material in the core contains too much slag and porosities. The crack at the left edge must be due to the blacksmith's bad luck during forging. The sword blade was of high quality with a flexible core and hard (too hard?), quenched edges, and should have served its purpose well.

SWORD 5 (Museum No.C.29227a, found at Gimsøy, Skien municipality)

The sword was found in a man's grave together with a spearhead. The sword is single-edged. It was found in two pieces (Figure 6.6a) that were heavily corroded, especially along the edges. The sword has an M-type hilt.

Examination of the polished, unetched sample shows that the main part of the blade contains a number of bands of small slag particles, probably along the rims of smaller iron pieces which had been hammer-welded together to make the body of the blade. The slag is partly homogeneous and elongated, and partly two-phased with a light spheroid phase, probably wüstite FeO, in a dark matrix of silicates. The edge, however, is almost without slag inclusions.

After etching, the blade appeared to consist mostly of fine grain ferrite. The blunt part is mildly carburised (Figure 6.6b) (c. 0.3%C), appearing as fine grain pearlite. This is consistent with an average hardness of 178 HV in the back. The edge area, however, consists of large ferrite grains (Figure 6.6c). Hardness in most of the section is around 119 HV (Figure 6.6a). The variation in grain size throughout the section may reflect a composition of different pieces of iron, possibly bloomery iron.

Interpretation: The blade material is composed of a large number of pieces of iron with numerous small slag particles in the welding seams. The only carbon-containing area is found in the back. Although a band of a harder material in the back would improve the strength of the blade, the cutting edge is soft, and the blade would probably still easily bend in combat. The blade was of poor quality, made of soft material.

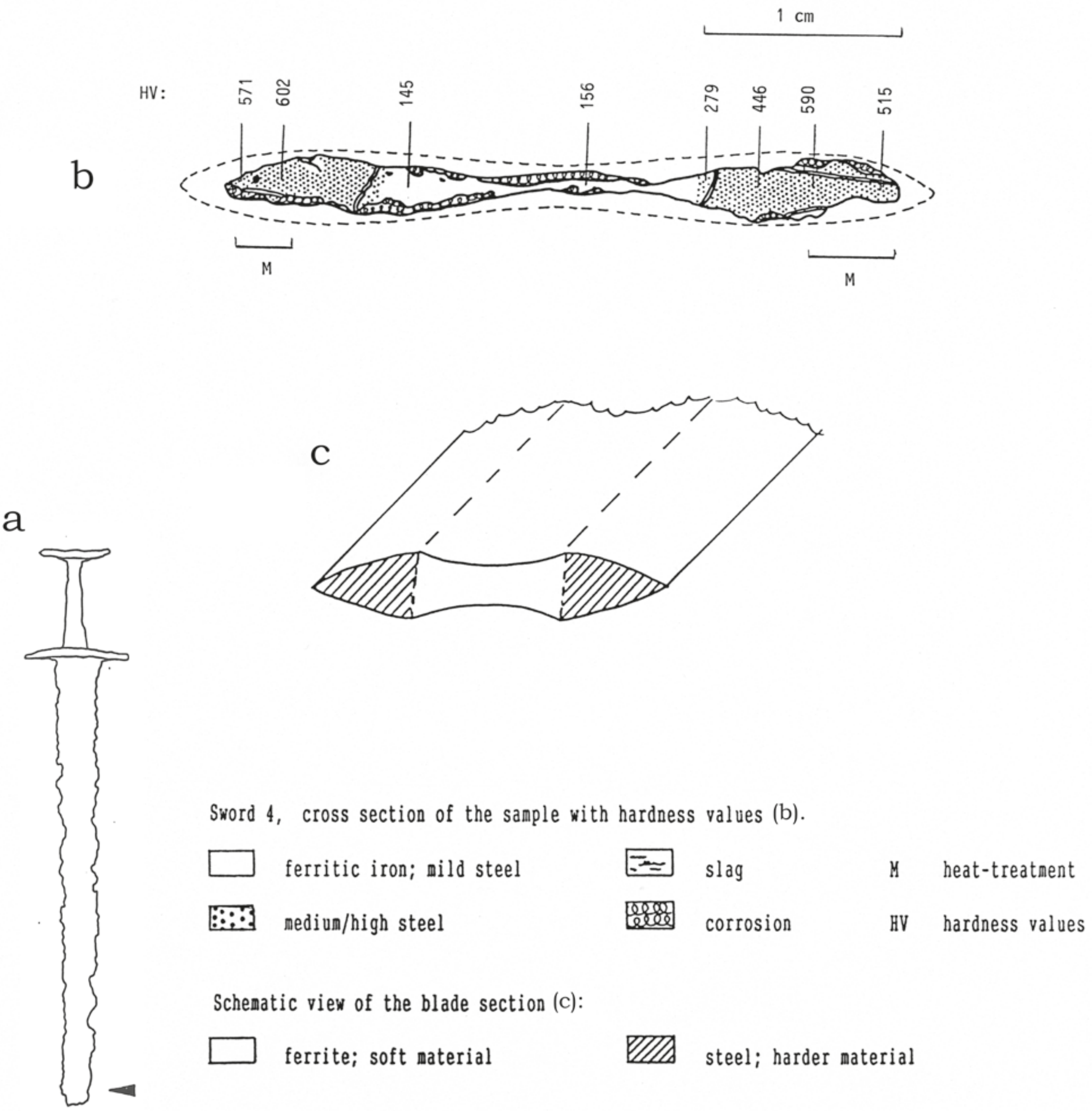


Figure 6.5a. *Sword 4. Cross-section of the sample with hardness measures (b), schematic view of the blade section (c) and outline of sword with section marked (a).*

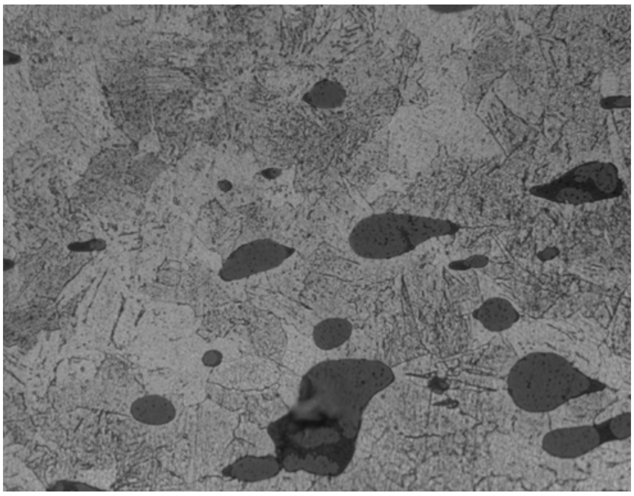


Figure 6.5b. *Sword 4. Lots of slag and pores particularly in the central part. (500x).*

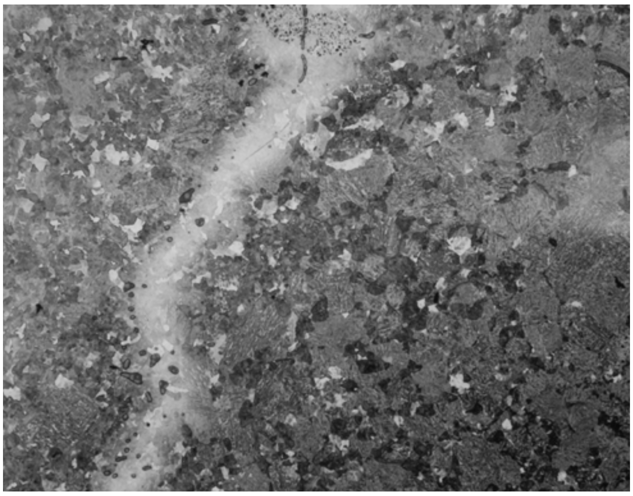


Figure 6.5c. *Sword 4. Welding- seam with small inclusions of hammer scale between the edge and the core of the blade. (100x).*

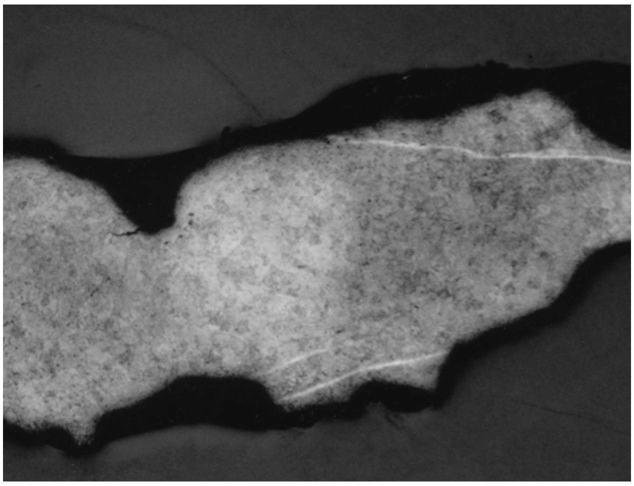


Figure 6.5d. *Sword 4. The carbon-rich (right) edge with welding seams between smaller pieces welded together. (20x).*

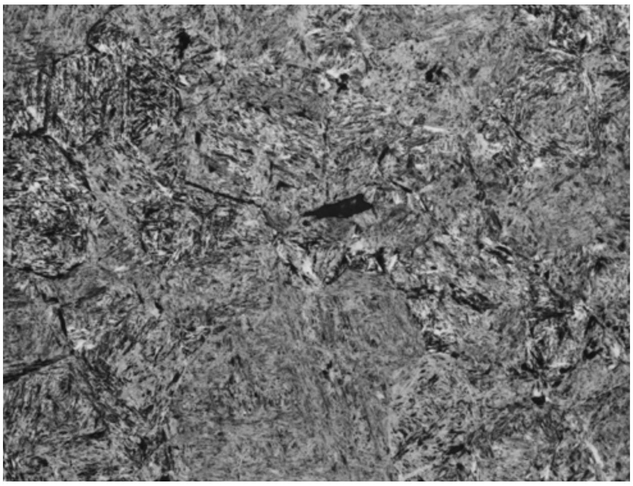


Figure 6.5e. *Sword 4. Martensitic structure in both edges due to quenching. (200x).*

Figure 6.5f. *Sword 4. A pronounced crack starting on the surface of the edge in the left part of the section. Decarburisation has occurred around the crack due to long heating time during forging. (100x).*

SWORD 6 (Museum No. C.23112, found at Frogner in Gjerpen, Skien municipality)

The sword was found in a grave together with an iron axe head and fragments of a shield boss, a spearhead, a sickle, a knife, nails and rivets, and fragments of whetstones made from slate. The sword, which is single-edged, is corroded and exists in several pieces (Figure 6.7a). The edge was significantly more corroded than the back, which is mostly in a surprisingly good state of preservation. The hilt is an M-type.

The polished, unetched sample shows only small amounts of slag. The slag inclusions are mostly elongated. Etching with nital reveals that the blade material is composed of several smaller pieces and sheets of somewhat different carbon concentrations. The pieces have been skillfully hammer-welded together, leaving hardly any hammer scale inclusions along the welding seams. The edge consists mainly of low-carbon iron with fairly large grain ferrite (Figure 6.7b), the average hardness values being 147 HV (Figure 6.7a). The back, also consisting of low-carbon iron, shows large variations in grain sizes (Figure 6.7c). A large part of the material, from the back to around the centre of the blade, is composed of longitudinal layers of different grain sizes corresponding to hardness readings ranging from 110 to 148 HV. An area in the right part of the section has somewhat higher carbon content (an average hardness value of 178 HV), and is (Figure 6.7a) the hardest part of the entire blade. Since a piece of harder material in this part of the blade has no function relating to the usability of the sword, this piece must have ended up unintentionally in the blade material. It is possible that the smith was ignorant of the properties of the individual pieces of iron and welded them together into a packet of sufficient size to make the blade.

Interpretation: The forging process had been carried out skillfully with only a few slag inclusions. An intentional carburisation of the blade does not seem likely, as the carburised parts appear to be randomly placed in the material. The edge is soft with practically no carbon. The quality of the sword was not particularly good. Since the blade is generally too soft it is considered to have been of poor quality.

SWORD 7 (Museum No. C.26360, found at Bjørnstad in Eidanger parish, Porsgrunn municipality)

The sword was found in a grave together with an iron axe head. The sword was extremely corroded with heavy incrustation and was broken into several pieces. It is a double-edged sword with a fuller along both sides of the blade. The hilt is incomplete and defective (Figure 6.8a), but can still be classified as an H- type.

Microscopic examination of the polished, unetched sample shows many elongated slag inclusions, some of which are rather large (Figure 6.8b). The slag is particularly abundant in the central part, while less plentiful in the edges.

After etching with nital, the sword was seen to be composed of a low-carbon central part, to which the two cutting edges of somewhat higher carbon content had been welded (Figure 6.8c, 6.8a). The curved shape of the welds indicates that the edges had been bent around the central part before welding. The surface layers in the central part of the blade consist of distinct sheets of alternating ferritic iron and medium carbon steel, hammer-welded together (Figure 6.8d), while the actual core consists mostly of ferrite of different grain sizes, interspersed with some pearlite. Etching with Oberhoffer's reagent suggests that the ferritic sheets in the surface, as well as parts of the core, contain a fair amount of phosphorus, which accounts for the considerable hardness of the ferrite, measured hardness values being 189-239 HV. Microprobe analyses made in steps across the layers show that phosphorus content in the low-carbon, ferritic sheets ranges between 0.25wt% and 0.40wt%, while the concentration in the medium carbon, pearlitic sheets is about 0.02wt%. The concentration of arsenic is found to follow the course of the phosphorus concentration, varying between 0.01wt% arsenic in the pearlitic sheets and 0.44wt% in the ferritic sheets.

The microstructure is consistent with a cut through a piled or pattern-welded surface layer, which has been welded onto a ferritic core. Pattern welding is also vaguely observable on the X-radiographs of the corroded sword blade. The design observed in the X-radiograph might be a "herring bone" – two piled strips twisted in opposite directions, possibly alternating with straight sections. However, the pattern is barely recognisable and impossible to interpret with any certainty. Owing to corrosion, most of the surface layers are now missing.

Both cutting edges have a heterogeneous structure of varying carbon content and grain sizes. One of the edges (Figure 6.8a, right) shows a patched structure of lamellar pearlite with a fairly high carbon concentration (Figure 6.8e). The hardness measurement of 263 HV at the tip of the edge (Figure 6.8a) indicates reasonably hard steel. Light, decarburised stripes (Figure 6.8f) in the edge area show that the edge is composed of smaller pieces of steel welded together.

The other cutting edge (left) shows mostly a somewhat lower carbon content (187 HV), except in the very tip where it is high. The original tip of this edge has been lost to corrosion.

Interpretation: This must have been an impressive looking weapon, with the pattern-welded blade surface made from sheets of mild steel and phosphorus-containing ferritic iron. The core of the blade has a lot of slag that could have been worked out. The carbon concentration of the material is adequate. In parts of the core, iron areas have a fairly high content of phosphorus. The cutting edges are harder than the core, owing to higher carbon concentrations. The two edges seem to be of somewhat different carbon content, although this may be explained by loss of material at the outermost left edge due to corrosion. There are no signs of quenching. For practical use in combat this sword blade is considered to have been of fair quality.

SWORD 8 (Museum No. C.28460a, found at Stamland in Eidanger parish, Porsgrunn municipality).

The sword was found in a grave together with a spearhead, an axe head, a rattle, and a sickle. The blade was found in two pieces which were heavily corroded. The blade is double-edged and has a fuller along the centre. The fuller was mostly corroded all the way through. The sample, taken across the blade, consists of two pieces broken along the fuller. The hilt is incomplete (Figure 6.9a). Only the lower guard remains, which makes it difficult to classify the hilt type. The slightly curved lower guard suggests a Q or possibly an X-type.

In the polished, unetched sample, small roundish slag particles are present. The section was easily etched with nital. Strings of small slag particles across the section and a slight discontinuity of the carbon concentration between the central part and the edge areas (Figure 6.9b) indicate that edges of higher carbon concentrations were welded to a less carbon-rich central part. However, welding seams are hardly visible, and the right weld especially is very corroded.

Both edges have a near eutectoid carbon concentration with retained austenite remaining from the quenching operation. In Figure 6.9c the characteristic appearance of martensite is evident. The hardness measurement values average 591 and 551 HV for the two edges respectively (Figure 6.9a).

Moreover, the scanty remains of the central part contain significant carbon content, although not quite as much as in the edges. Like the edges, the central part of the blade shows a partly martensitic structure due to quenching. The hardness values range from 339 to 439 HV.

Interpretation: The blacksmith was obviously familiar with the importance of hard edges and a somewhat softer central part. The forging had been carried out in a skillful way, and the blade had been heat treated. However, although this sword for the most part satisfies the requirements of a high-quality weapon, the central part of the blade was probably too hard and brittle, thus lacking the resilience of an excellent slashing weapon. An all-steel blade, which is rare (Tylecote 1986:2; Williams 1970:81), would also have been a waste of costly carburised material. This sword is considered to have been of high quality.

SWORD 9 (Museum No. C.30049, found at Grave, Bø municipality)

The sword was found in three pieces, in a fairly corroded state, during building activities on a farm (Figure 6.10a). Several small burial mounds were reported close by. The blade is double-edged with a double fuller running along the centre on both sides. The hilt is a Q-type.

Examination of the polished, unetched sample shows some slag particles, mostly as alignment of flat slag due to forging. The slag particles consist of two phases (Figure 6.10b), a light grey, mostly dendritic phase, probably wüstite FeO, in a dark matrix of silicates. Also, there are bands of hammer scale particles across the section, indicating welding seams for the two cutting edges.

After etching with nital, welding seams for both edges were seen to be decarburised light bands across the blade (Figure 6.10c). Both edges have carbon content close to a eutectoid concentration. The cutting edges have a martensitic structure due to quenching (Figure 6.10d). The hardness values in the cutting edges are measured as 613, 555 HV and 551, 557 HV respectively. Some diffusion of carbon is observed across the welding seams (Figure 6.10e). The edge to the right in Figure 6.10a has a somewhat heterogeneous structure. Pieces of medium carbon content have been forged into the edge material (Figure 6.10f).

The central part of the blade has medium carbon content in the areas near the welding seams (257, 321 HV), decreasing towards the centre of the blade (130–170 HV). The central area is heterogeneous with varying grain sizes and carbon concentrations. Figure 6.10g shows a coarse-grained ferrite and a fine-grained structure of higher carbon content.

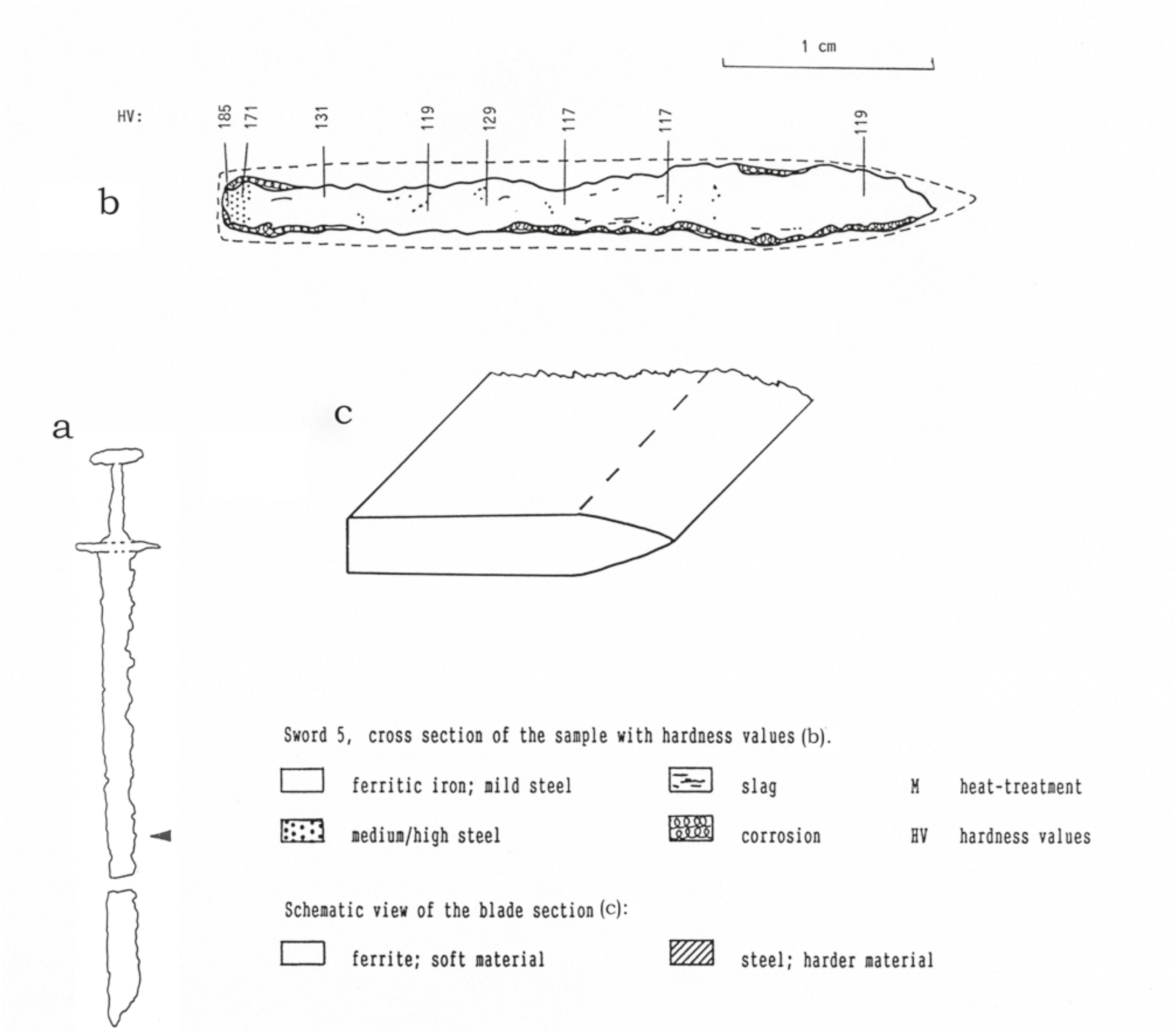


Figure 6.6a. *Sword 5. Cross-section of the sample with hardness measures (b), schematic view of the blade section (c) and outline of sword with section marked (a).*

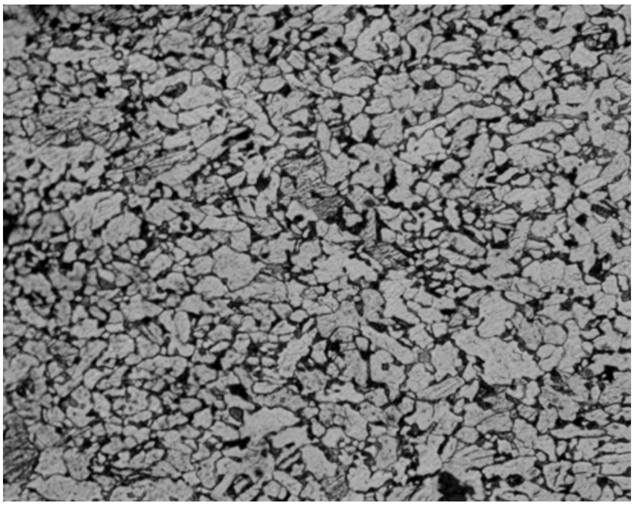


Figure 6.6b. *Sword 5. The back part is mildly carburised. (200x).*

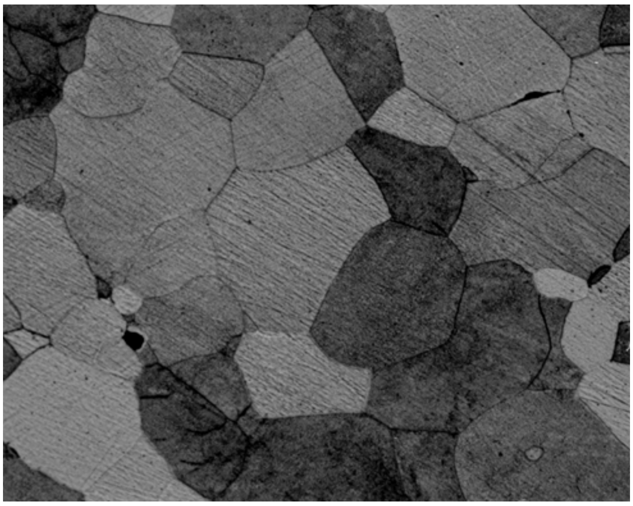


Figure 6.6c. *Sword 5. The edge consists of large ferrite grains. (200x).*

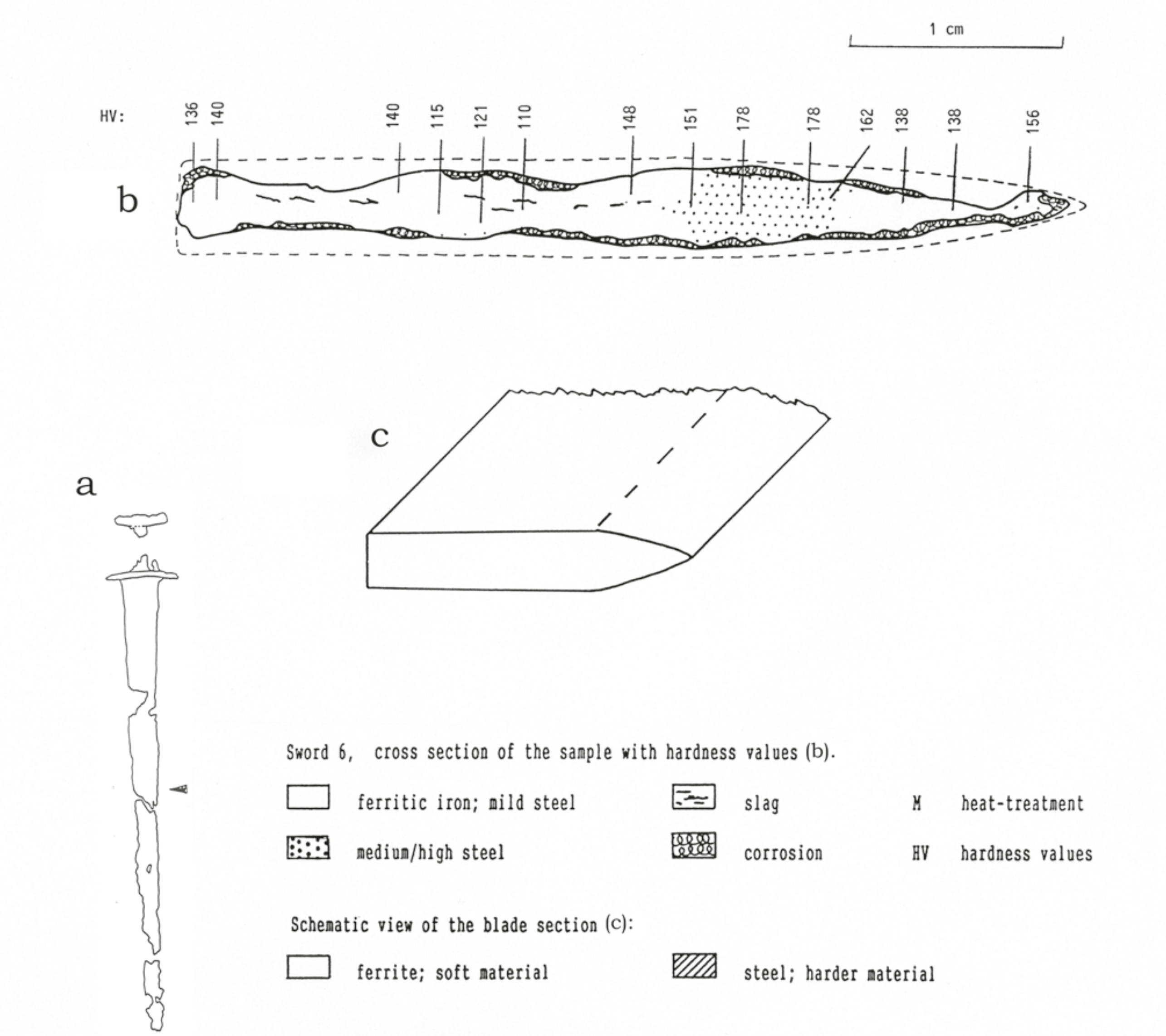


Figure 6.7a. *Sword 6. Cross-section of the sample with hardness measures (b), schematic view of the blade section (c) and outline of sword with section marked (a).*

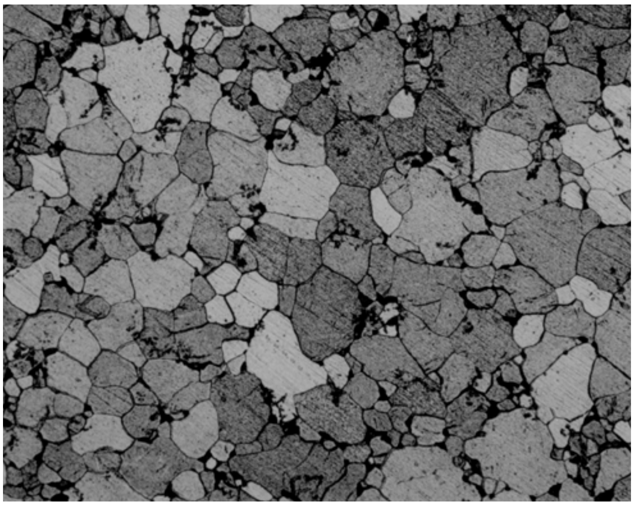


Figure 6.7b. *Sword 6. The edge has low carbon content with large grain ferrite. (200x).*

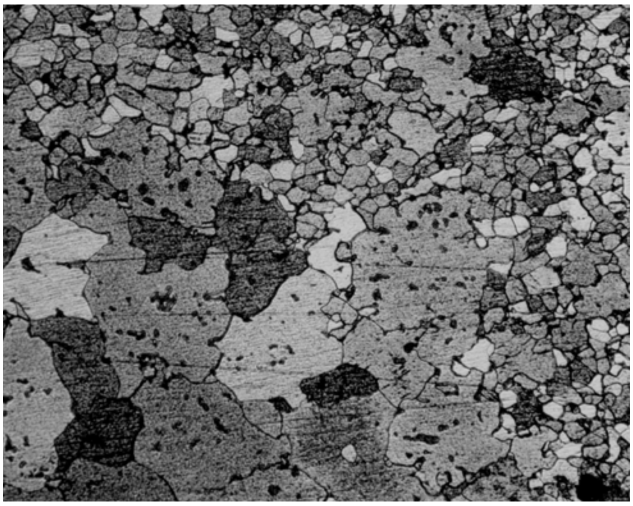


Figure 6.7c. *Sword 6. The back consists of ferrite with some pearlite showing large variations in grain size. (100x).*

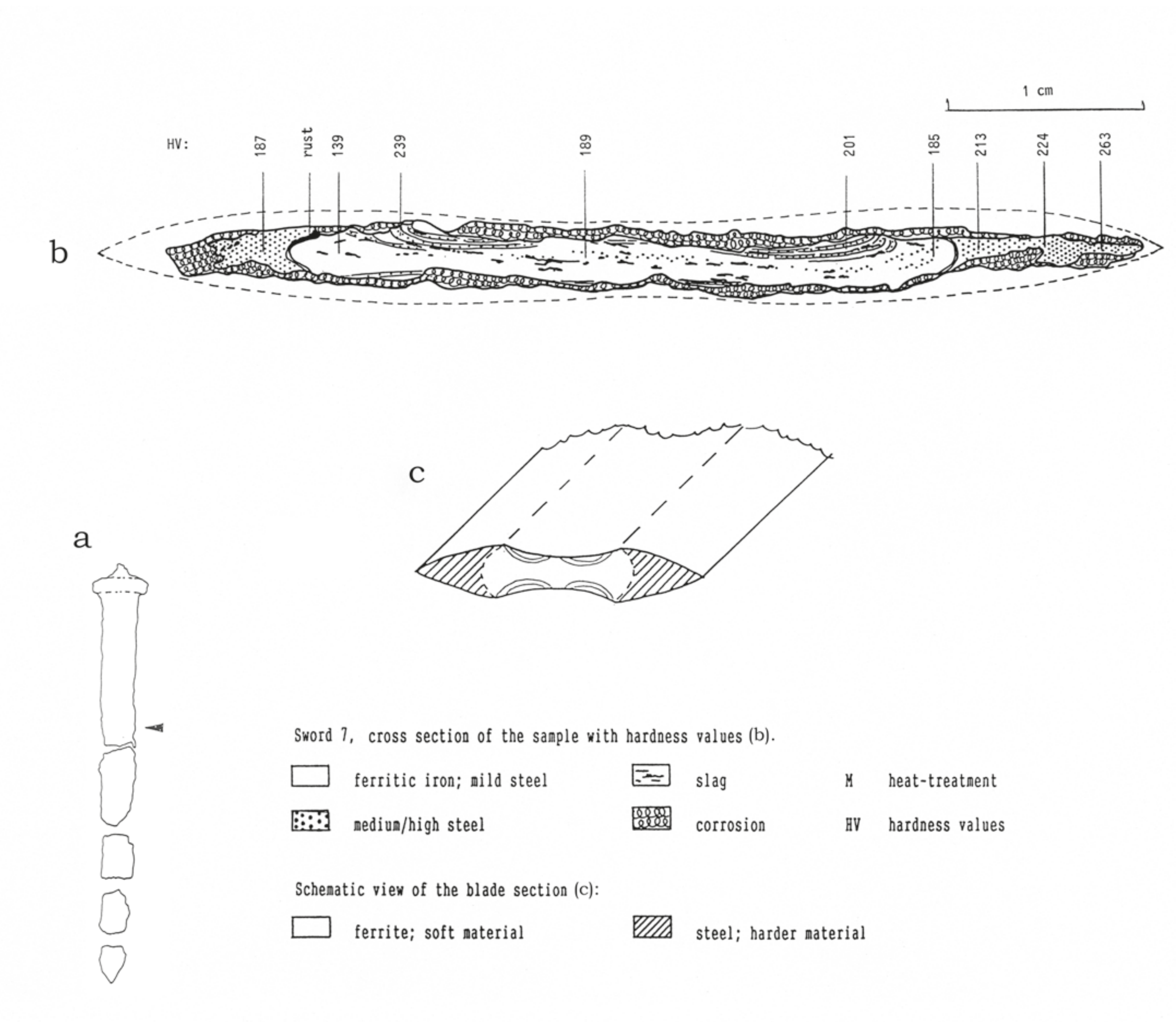


Figure 6.8a. *Sword 7. Cross-section of the sample with hardness measures (b), schematic view of the blade section (c) and outline of sword with section marked (a).*

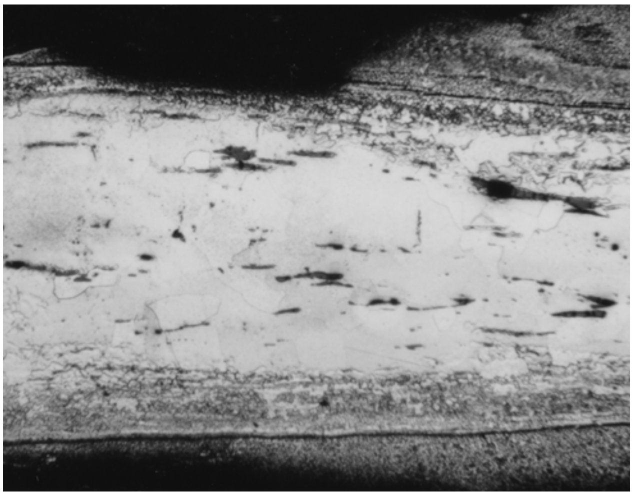


Figure 6.8b. *Sword 7. The central part has large amounts of slag inclusions. (20x).*

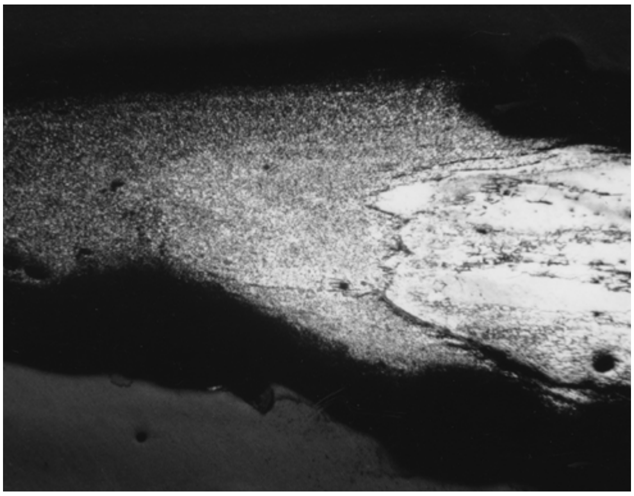


Figure 6.8c. *Sword 7. The blade is composed of a low-carbon central part (pale) onto which the cutting edges, with higher carbon content, are welded. Left part of the section. (20x).*

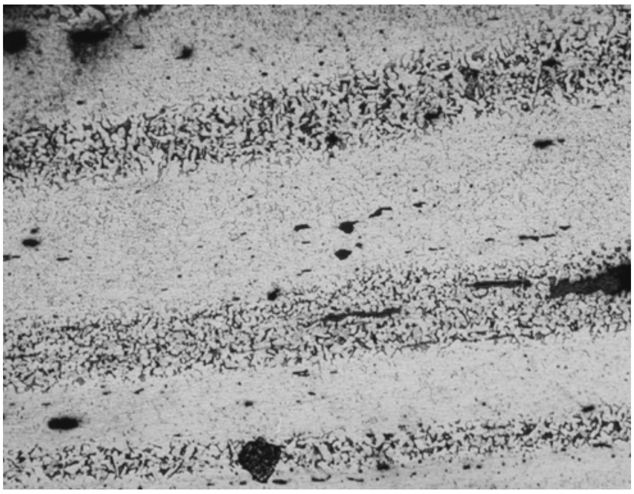


Figure 6.8d. Sword 7. Layers of varying carbon content, representing pattern-welded sheets, run along the surfaces of the central part of the blade. (100x).

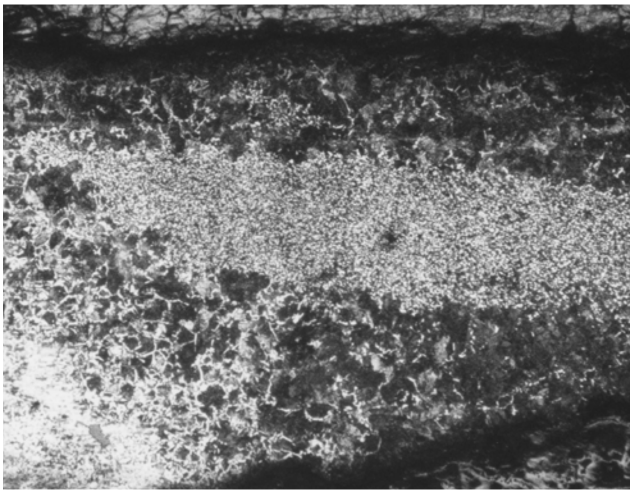


Figure 6.8e. Sword 7. Patched structure of lamellar pearlite in the cutting edge (right edge shown). (50x).

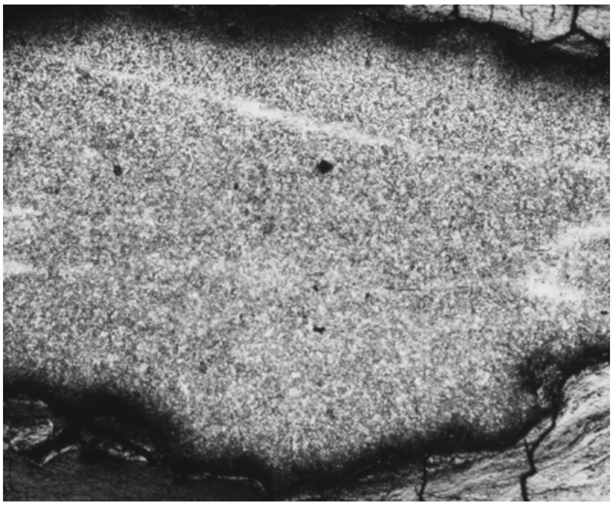


Figure 6.8f. Sword 7. Light decarburised lines in the edge area (right part) showing welding seams between smaller pieces. (50x).

Interpretation: The blacksmith had the skill to produce a sword with quenched steel edges, while the central part consists of a softer, more flexible material. The welding had, for the most part, been well done with only minor particles of hammer scale in the seams. This sword is considered to have been of high quality.

SWORD 10 (Museum No. C.28239, found in Mårem-Suigard, Tinn municipality)

The sword is probably a grave find, and was found together with a spearhead. The blade was broken and quite corroded – only the upper half with the hilt remains (Figure 6.11a). The sword is double-edged and has a fuller along both sides of the blade. The hilt is a late Anglo-Scandinavian type not included in Petersen's typology, by Martens named La, Figure 4.4.

The pommel and lower guard are decorated with silver ornaments in the Ringerike style (Fuglesang 1980). The hilt type is rare for Norwegian sword material, though one other item has been found at Såem, also in Tinn. Further, thin twisted silver wires remain around the grip. Stereoradiographs by Caroline Murstad (1996) revealed inlays shaped like two omega-like symbols with a cross potent in between on one side of the blade. On the reverse side a scroll or roundish symbol can be seen (Figure 6.11b). While the cross potent appears on the X-radiographs as twisted rods, a similar twist is not visible in the omega symbols or the scroll. Most likely the actual inlays in the latter two are missing, and only the prints of the inlays are left in the corroded layers of the blade. Similar designs are known from other swords (Figure 6.11c). A comparison between the present inscription and particularly those of swords 5 and 6 in Figure 6.11c, suggests that further figures could be present on the blade, next to the scroll. This was, however, not observed.

Regardless, the present sword must once have been an impressive looking weapon, though the quality of the weapon can only be judged from the metallographic structure of the blade.

Microscopic studies of the polished, unetched sample show a fair amount of small slag inclusions with a light spheroid phase, probably of wüstite FeO, in a dark matrix of silicates.

The section was easily etched with nital. The microscopic examination of the metallic structure shows that the entire blade has high carbon content, near a eutectoid concentration. The blade has a martensitic structure throughout, due to quenching (Figure 6.11d). Several welding seams are observed as light, slanting

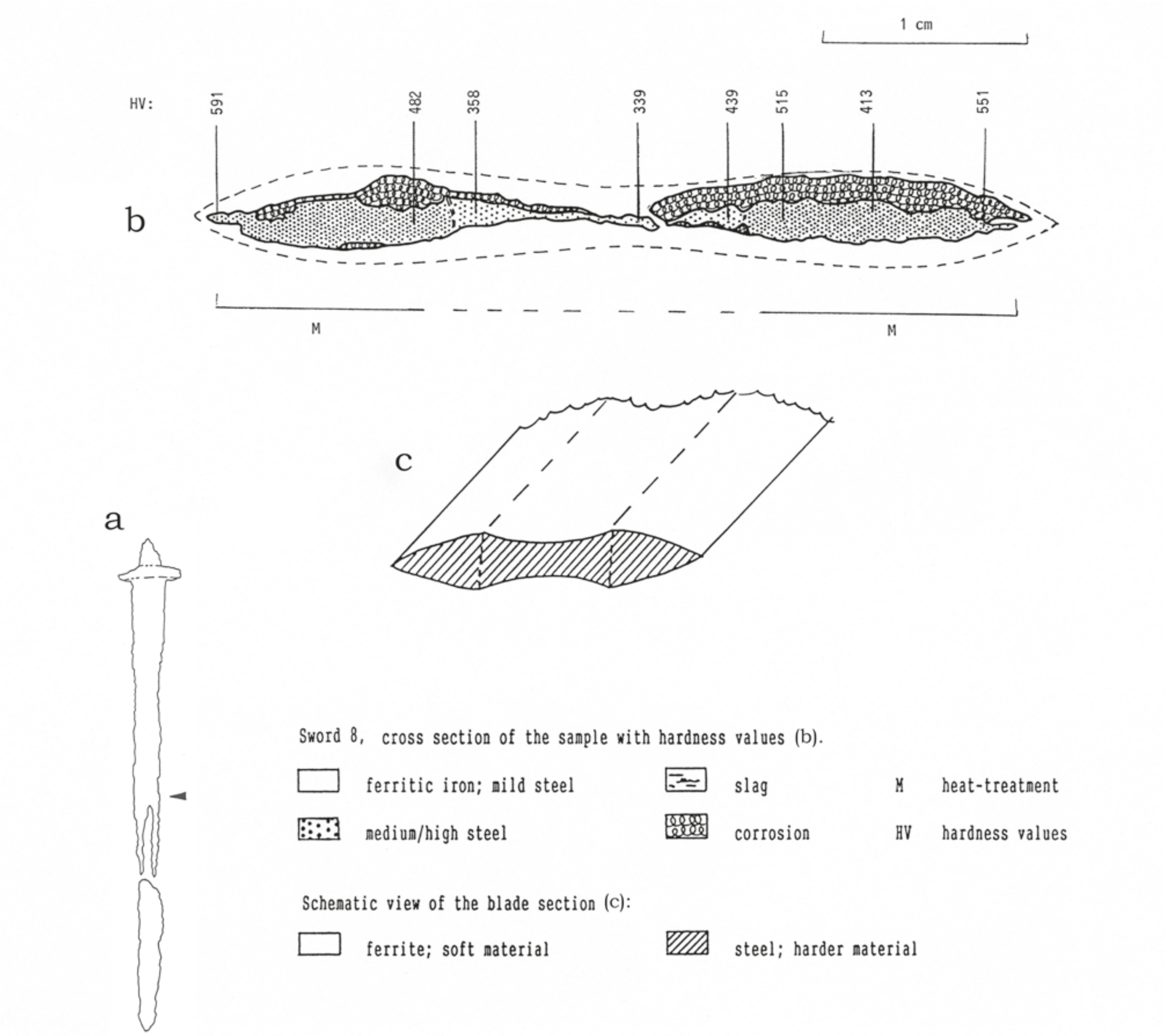


Figure 6.9a. *Sword 8. Cross-section of the sample with hardness measures (b), schematic view of the blade section (c) and outline of sword with section marked (a).*

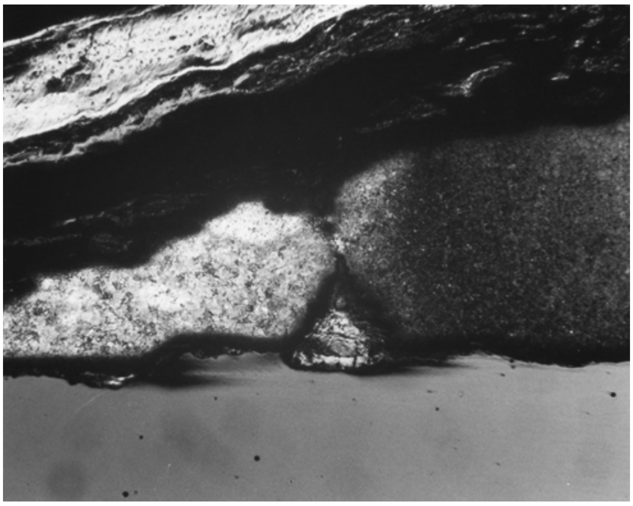


Figure 6.9b. *Sword 8. Corrosion almost separates the carbon-rich edge (right) from the less carbon-rich central part along the welding seam. (Light area top left is the surface corrosion layer). (20x).*

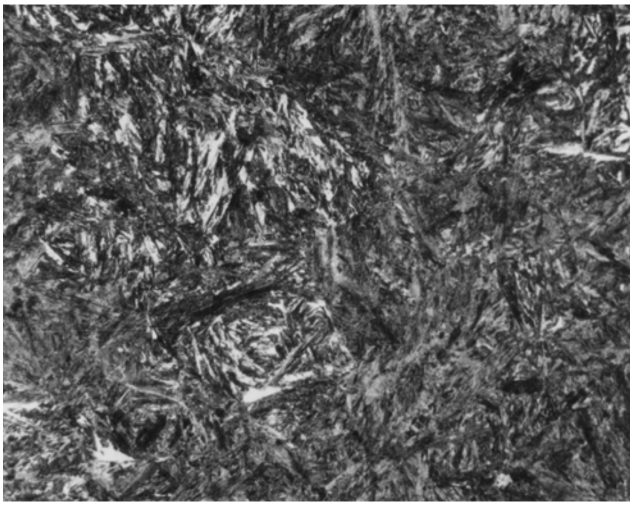


Figure 6.9c. *Sword 8. Both edges have a near eutectoid carbon concentration with a martensitic structure due to quenching. (500x).*

stripes running across the section in different places (Figure 6.11e). These lines show that the blade material is composed of several smaller pieces of carbon-rich iron. A crack, which seems to be the result of corrosion, runs through the central part (Figure 6.11a). The hardness values measured across the blade show a predominantly hard material, 636 and 446 HV were measured in the two edge areas respectively. Hardness values ranging from 515 to 571 HV were measured in the central part of the blade.

Interpretation: This fine-looking sword with a decorated hilt and inlays in the blade surface was made of carbon-rich material, which had been quenched. The material in the blade is fairly uniform with high carbon content throughout. The blacksmith mastered the technique of quenching. The edges were of excellent quality. The central part, however, must have been too hard. Blades made entirely of carbon-rich iron were not common (Tylecote 1986:2; Williams 1970:81). In the hardened state – as found here – this blade is brittle.

The blacksmith knew how to make inlays in the blade. The combination of omega symbols, scrolls and different kinds of crosses is known from other 9th –11th century swords found in England and Ireland (Lang and Ager 1989:101; Wilson 1965:42; Bruce-Mitford 1953:321; Read 1915), in Finland (Leppäaho 1964; Evison 1968) and in Russia (Kirpichnikov 1966:Figure18, 308; Stalsberg 1981) (Figure 6.11c). One of the English blades has a spiral scroll between the omega symbols and three crosses on the reverse side of the blade (Figure 6.11c, blade 5). The other English blade has a plain, equal-armed cross between the omega symbols and two transverse bars on the reverse (Figure 6.11c, blade 3). One of the Finnish swords features a cross potent between omega symbols on one side and a spiral scroll between two similar crosses on the other (Figure 6.11c, blade 6). Similar symbols can be seen on the Russian sword blade (Figure 6.11c, blade 4). A second blade found in Finland also has a cross potent between two omega symbols, while the reverse side has a different design, unlike those found on the other blades mentioned (Figure 6.11c, blade 7). The Irish blade and the third Finnish blade show very similar designs on both sides of the blade. The omega-like symbols on those blades are different from those on the other blades (Figure 6.11c, blades 1 and 2). The design on the present sword blade is most closely related to the English and the Finnish blades (Figure 6.11c, blades 5 and 6 respectively).

Normally, one would think that the elaborate design on the decorated hilt was the work of a specialised silversmith, while the steel blade with the inscriptions was more likely to have been made by a swordsmith or weaponsmith. The present sword differs from the others in this study with regard to the decoration on the hilt, its construction and composition, and the inlays in the blade. Ignoring the decorative aspects, this sword is functionally considered to have been of decent quality.

SWORD 11 (Museum No. C.26828a, found at Møli, Tinn municipality)

The sword was found in a grave together with some iron fragments and a few animal bones. The blade was broken into two pieces, but only a small part of the blade is missing (Figure 6.12a). Although the surface layers are missing due to corrosion, the sword is generally in stable condition. The blade is double-edged with a fuller running down the centre on either side. The hilt is a Q-type.

When viewed unetched, the overall slag content appears fairly low. In the left and the right parts of the section, there are a few slag bands running along the rims of small pieces of metal, which have been forged together. The central part of the blade is practically without slag. Only indistinct bands of tiny slag particles across this section indicate welding seams between the cutting edges and the core.

In the etched condition, however, welding seams are clearly seen between a low-carbon central part and the carburised edges (Figure 6.12b). The welding seams are clearly marked as pale lines. Microprobe analyses carried out in steps across the welds show that there is a considerable enrichment of cobalt (1.2wt%), and some enrichment of nickel and arsenic (0.16wt%) in the weld (Figure 6.24b). The general concentration levels of all three elements in the bulk of the material is about 0.03wt%. Phosphorus content is typically less than 0.01wt%.

The central part is mostly ferritic with small grains. The hardness values in the centre and the left parts of the core range from 152 to 162 HV. The right part of the core consists of ferrite of varying grain size. The corresponding hardness values are in the range of 104–129 HV. The ferrite crystals (Figure 6.12c) are seen to be more acicular than those observed for the more common equiaxed ferrite. Acicular ferrite is found to be superior in strength and toughness (Tither, Kewell and Frost 1971). The formation of acicular ferrite depends generally on composition, temperature and cooling rate, and was hardly intentionally produced in the Viking Age. The structure observed close to the welding seams shows that the blade had undergone prolonged heating during forging,

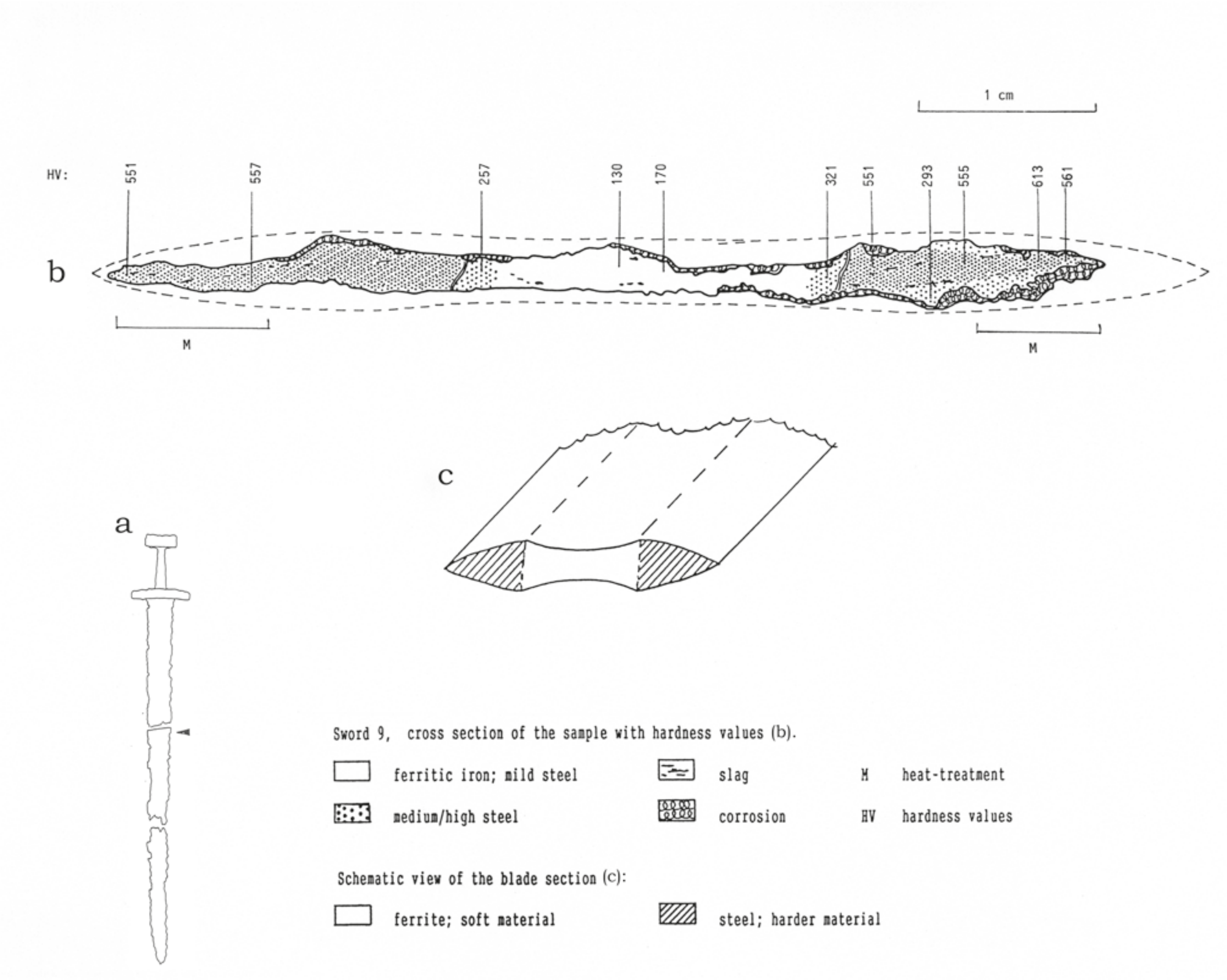


Figure 6.10a. *Sword 9. Cross-section of the sample with hardness measures (b), schematic view of the blade section (c) and outline of sword with section marked (a).*

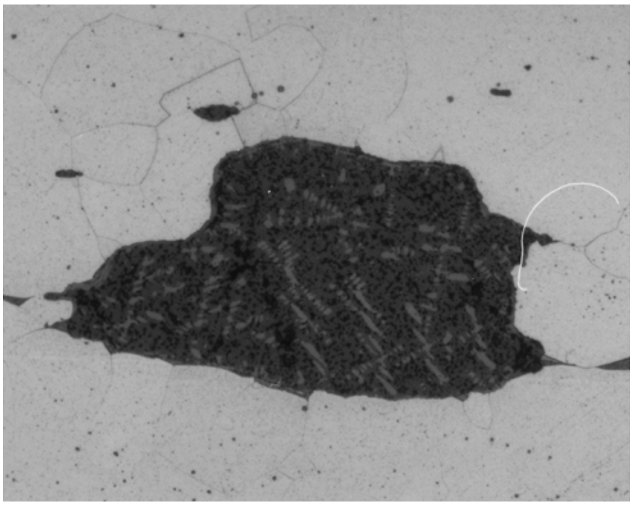


Figure 6.10b. *Sword 9. The slag consists of a light grey mostly dendritic phase (wüstite) in a dark matrix of silicates. (200x).*

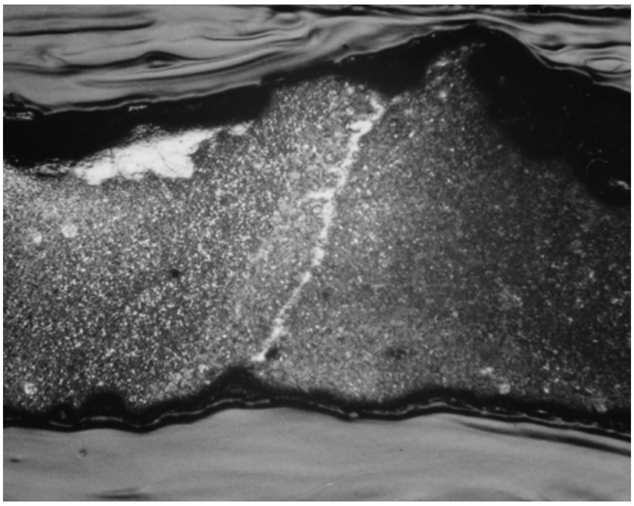


Figure 6.10c. *Sword 9. Welding seams for the edges are seen as pale decarburised lines across the sample. Right part shown. (20x).*

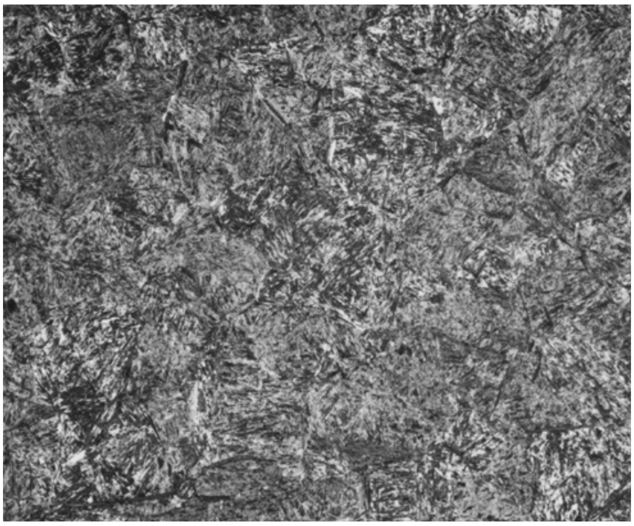


***Figure 6.10d.** Sword 9. A martensitic structure in the edges due to quenching. Left part of the section shown. (200x).*

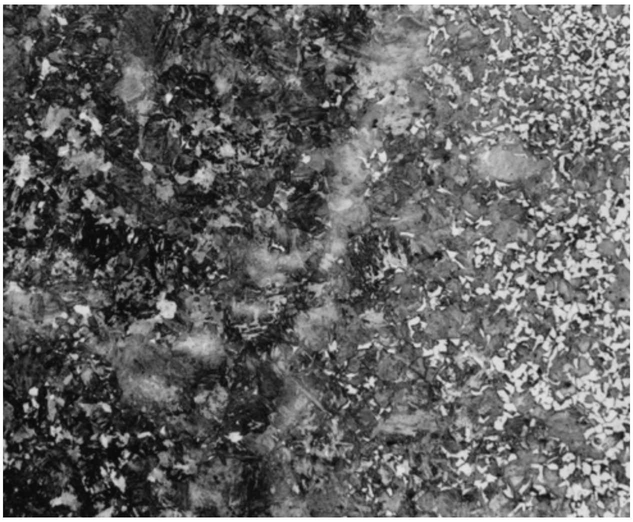


***Figure 6.10e.** Sword 9. Some diffusion of carbon from the carbon-rich dark edge (dark part) across the welding seam. Left edge shown. (100x).*

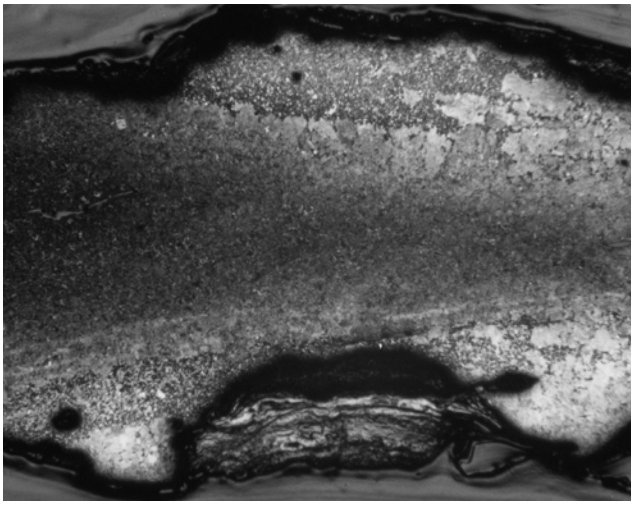


***Figure 6.10f.** Sword 9. Pieces with medium carbon content have been forged onto the material in one of the edges (right). Pale welding seams are easily visible. (20x).*

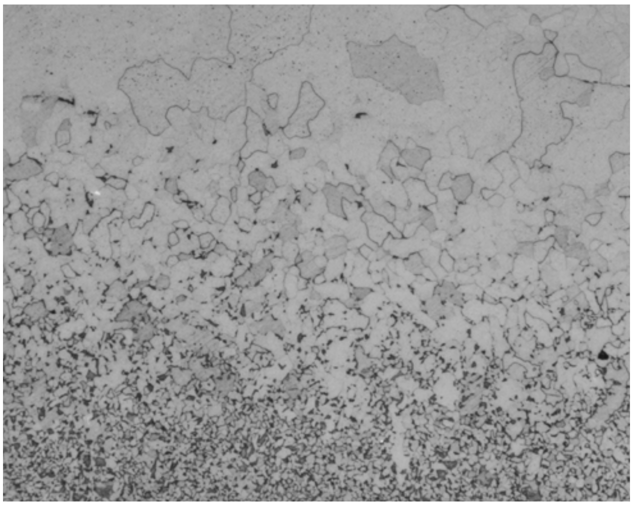


***Figure 6.10g.** Sword 9. The central part is heterogeneous with some coarse-grained ferrite, and some fine-grained structure of higher carbon content. (50x)*

which caused a fairly extensive carbon diffusion across the welding junctions from the edges to the central part (Figure 6.12b). Hardness values measured in the diffusion zones along the seams are 167 and 175 HV, in the right and left part respectively.

The edge in the left part of the section (Figure 6.12a) shows mostly medium carbon content and a somewhat heterogeneous structure of ferrite and pearlite. Part of the surface area of this edge appears to have a lower carbon concentration than the rest (Figure 6.12d). Pale lines, probably oxidation enrichment bands in the welding seams, divide the lower-carbon from the more carbon-rich areas. The latter constitute the predominant part of the edge. The hardness values measured in the low-carbon area are 182 and 184 HV. In the higher carbon area, the hardness readings at three different positions are 201, 210, and 257 HV, averaging 223 HV. These hardness numbers are indicative of iron with significant carbon content quickly cooled (most likely air-cooled), but not quenched.

The edge in the right part of the sample (Figure 6.12a) appears to have a somewhat more homogeneous carbon content. The hardness values in the greater part of this edge are consistent with those in the left edge – 205, 219, 219, and 229 HV, averaging 218 HV. However, the tip of this edge shows somewhat higher hardness readings – 245-283 HV. Judging from the shapes of the remaining parts of the two edges, a significant portion of the surface layers of the left edge

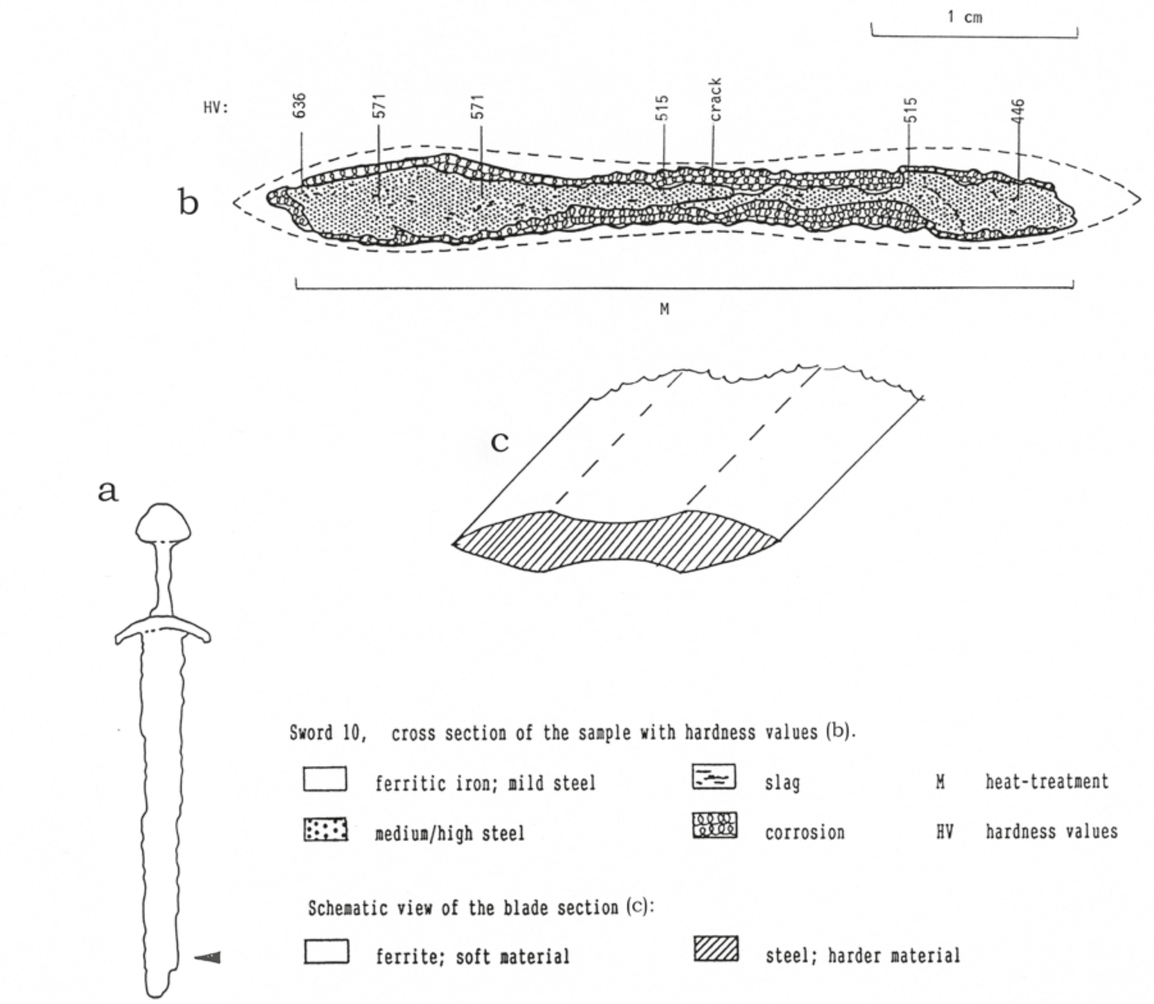


Figure 6.11a. *Sword 10. Cross-section of the sample with hardness measures (b), schematic view of the blade section (c) and outline of sword with section marked (a).*

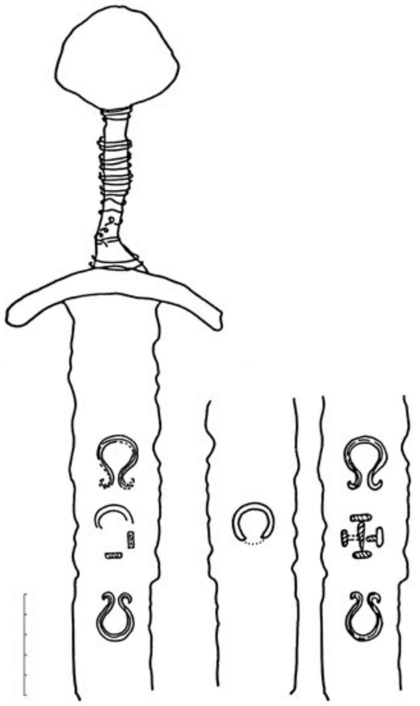


Figure 6.11b. *Sword 10. Outline of inlays in the blade as seen on stereoradiographs.*

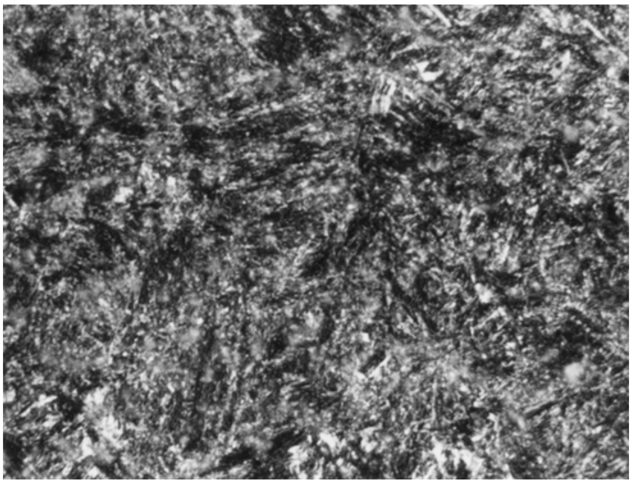


Figure 6.11d. *Sword 10. The entire blade is very hard and has a martensitic structure due to quenching. (1000x).*

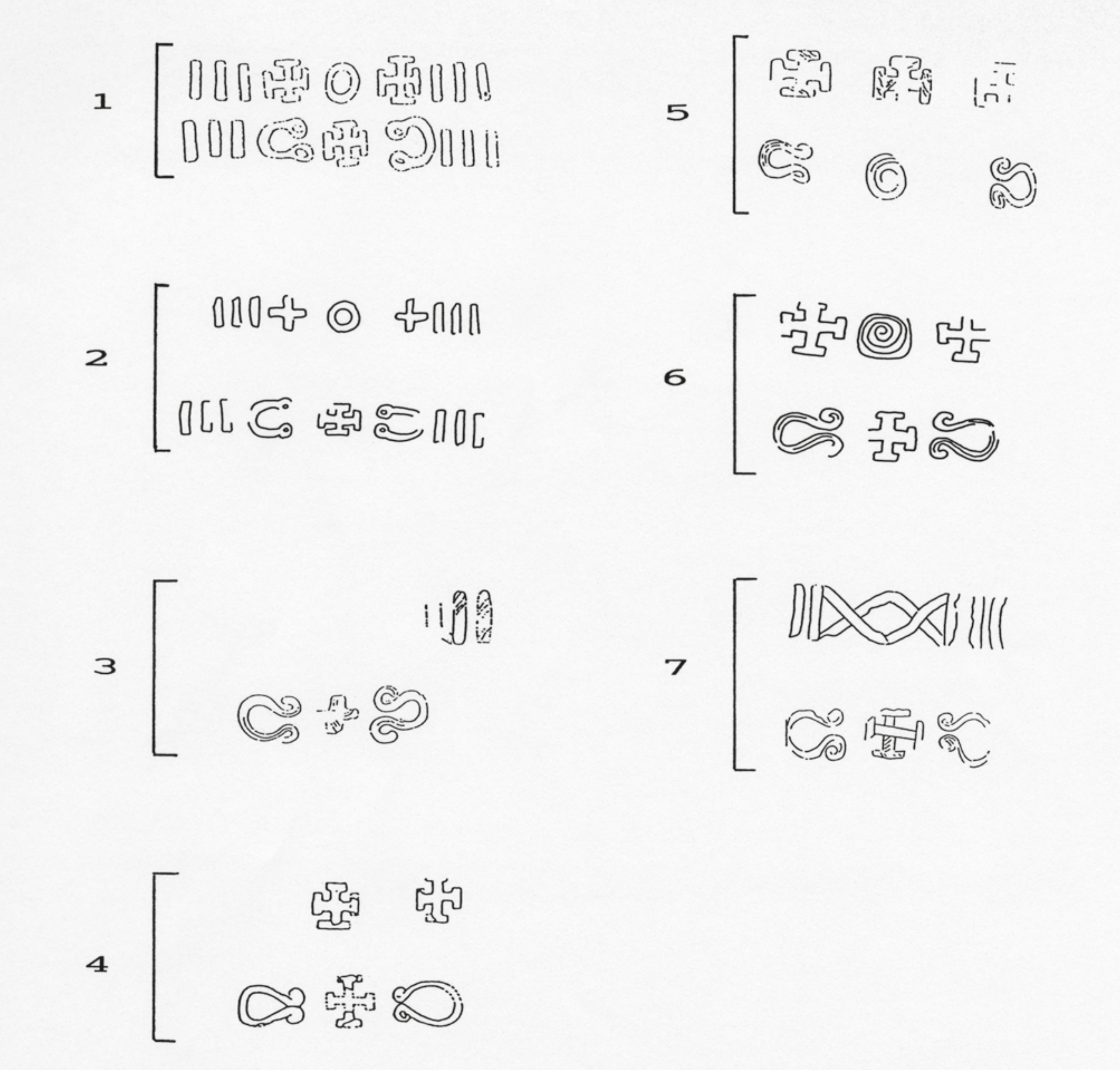


Figure 6.11c. *Sword blade inlays comparable to sword 10: 1 Ireland; 2, 6, 7 Finland; 3 England; 4 Russia; 5 England.*

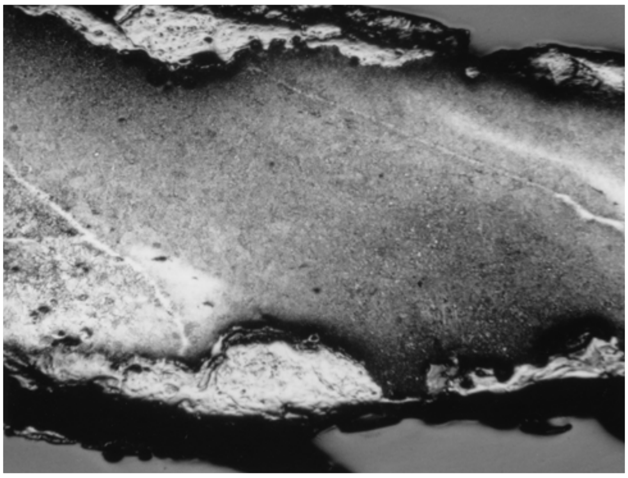


Figure 6.11e. *Sword 10. The blade material has been made of several pieces of steel. A number of decarburised pale lines indicate the welding seams. (20x).*

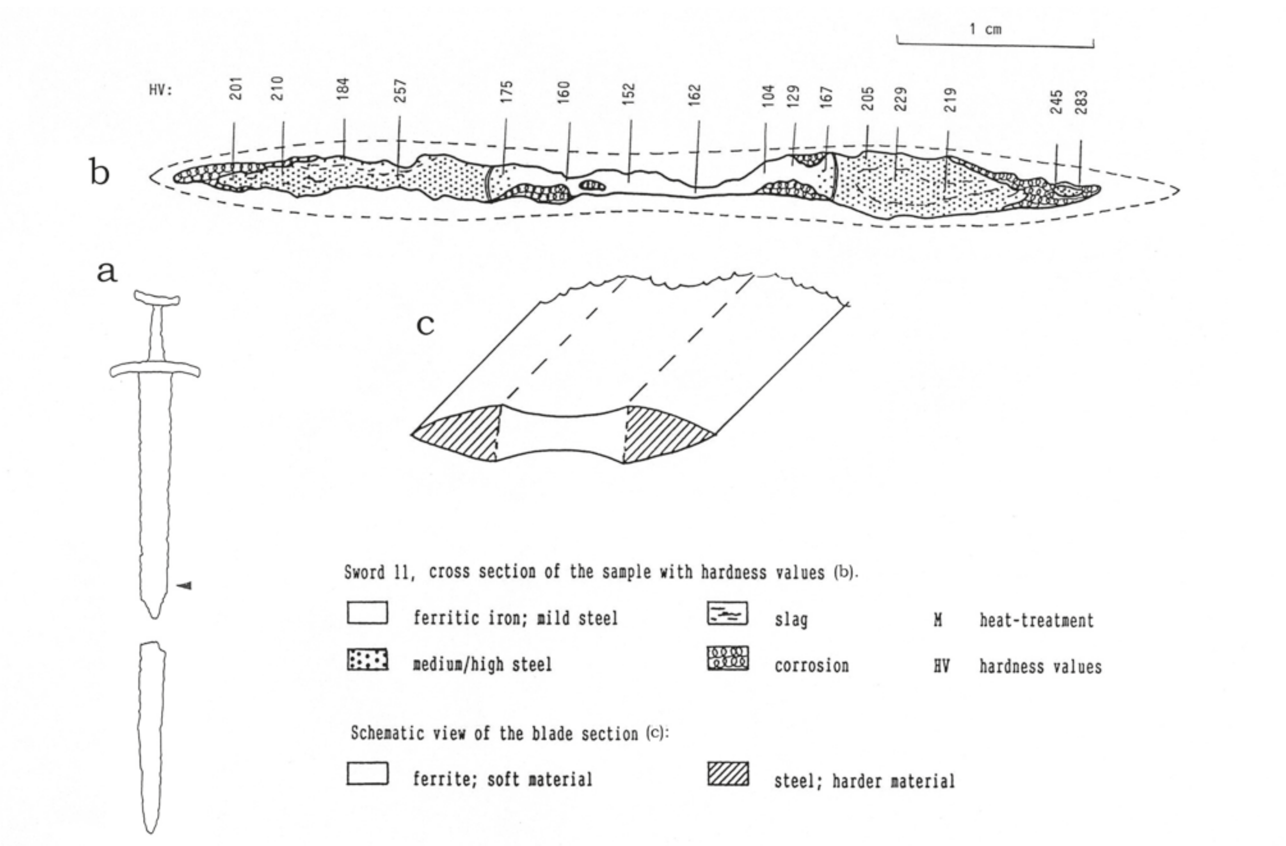
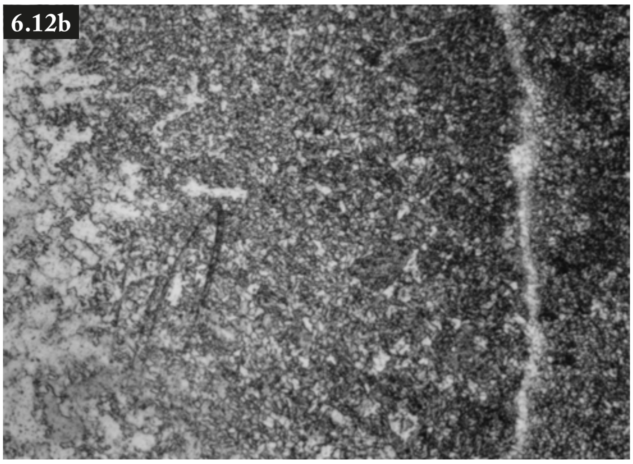
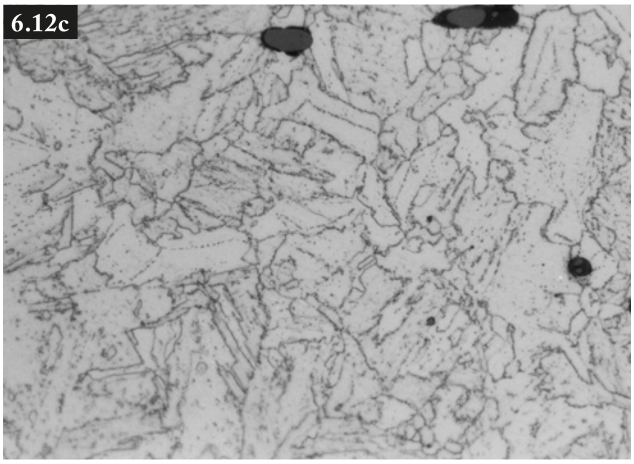


Figure 6.12a. *Sword 11. Cross-section of the sample with hardness measures (b), schematic view of the blade section (c) and outline of sword with section marked (a).*

6.12b



6.12c



6.12d

Figure 6.12b. *Sword 11. The weld- line between the core and the edge is clearly marked by a pale line. Diffusion of carbon has taken place across the weld (right edge). (100x).*

Figure 6.12c. *Sword 11. The central part is mostly ferritic with an acicular grain structure. (500x).*

Figure 6.12d. *Sword 11. The left edge with heterogeneous carbon content. Pale lines divide the lower-carbon (white) from the higher-carbon (dark) area. (100x).*

is missing. The outermost, and probably harder, parts of both cutting edges have been lost to corrosion.

Interpretation: The iron and steel materials in this sword have been worked well, with only a few slag inclusions. There are almost no slag or hammer scale particles in the welding seams. Carburised and harder edges were welded to a softer core. However, the blacksmith had not performed any quenching to obtain harder edges, possibly lacking the skill or knowledge to carry it out. Quenching and tempering would have made this sword even more serviceable. This sword is considered to have been of decent quality.

SWORD 12 and SWORD 13 were both found in Mårem, Tinn municipality, in a grave where two spearheads, two axe heads, a sickle, 21 arrowheads, two knife blades, a fire steel and some iron fragments, were also found. Further, some glass beads and a slate whetstone were found in the same grave. The types and number of artefacts in the find suggest that it may represent two burials in the same grave.

SWORD 12 (Museum No.C.29700a)

The sword (Figure 6.13a), which is double-edged, was extremely corroded. The fuller was corroded right through. The section taken for examination broke into two fragments when cut from the blade (Figure 6.13a). The core, as well as the tip of the edges, consists entirely of corrosion products. The hilt is categorised as an Xa-type.

Examination of the polished, unetched sample shows very large amounts of slag inclusions (Figure 6.13b). The slag is partly elongated, consisting mostly of silicates, entirely from corrosion products. The blade was broken, and the point missing.

The sample was not easily etched with nital, indicating that the carbon concentration is low. The whole sample is ferritic (Figure 6.13c) with a mixture of large and small grains. Etching with Oberhoffer's reagent indicates that phosphorus is present throughout the section. Microprobe analyses confirm that phosphorus content is somewhat variable, but mostly at an elevated level of 0.15wt%. This accounts for the comparatively high hardness values measured in the sample (153-178 HV, Figure 15/1), which are greater than expected for ferritic iron.

There is no evidence of pearlite in the micrographs. An attempt to carburise the material would have been hampered by the high phosphorous content. Generally, an increase in carbon content is most easily obtained in the austenitic phase of iron, where carbon dissolves tolerably well. However, if phosphorus is present, this will inhibit the iron from forming austenite, and only small amounts of carbon will dissolve.

Interpretation: If the blacksmith intended to carburise this sword, he was unfortunate in his choice of raw material, which contained too much phosphorus. Consequently, he would not have been able to introduce significant amounts of carbon. The choice of a phosphorus-containing raw material could also have been deliberate, as this makes the ferritic iron harder. The hardness values in this blade can be explained by the presence of considerable amounts of phosphorus. The substantial amount of slag indicates an unskilled smith, who probably did not know how to work the material, nor how to make a serviceable weapon. Due to the high phosphorus concentration and pronounced slag content, the blade was too weak and brittle to be classified as a good sword. This sword is considered to have been of poor quality.

SWORD 13 (Museum No. C.29700b)

The sword is double-edged with a fuller along each side of the blade, which was severely corroded. The actual point is missing (Figure 6.14a). Only part of the section, mainly the central part, still contains metallic iron. The sword is considered to have an Xa-type hilt.

Microscopic examination of the polished, unetched sample shows some flat slag, hammer scale inclusions and strings of slag particles, probably trapped in welding seams between pieces of iron. The slag consists of a light grey spheroid phase, probably wüstite, in a dark matrix of iron silicates.

After etching with nital, high carbon concentrations were observed along the remaining surfaces in parts of the blade (Figure 6.14b). The structure of the carbon-rich surface layers shows that the sword was quenched (Figure 6.14c). A mixture of martensite, bainite and pearlite indicates that the blade was not fully quenched. The hardness measurements in the carburised areas vary from 283 to 413 HV (Figure 6.14a), depending on the heterogeneous nature of the carburisation and the incomplete quenching. Carbon content shows a distinct drop between the surface layers and the core of the blade (Figure 6.14d). The core is made from almost pure ferrite or bloomery iron, which corresponds to the low hardness measurements ranging from 96 to 140 HV in the ferritic area (Figure 6.14e). This suggests that the iron is practically without phosphorus. The lack of phosphorus was confirmed by examining the structure after etching with Oberhoffer's reagent.

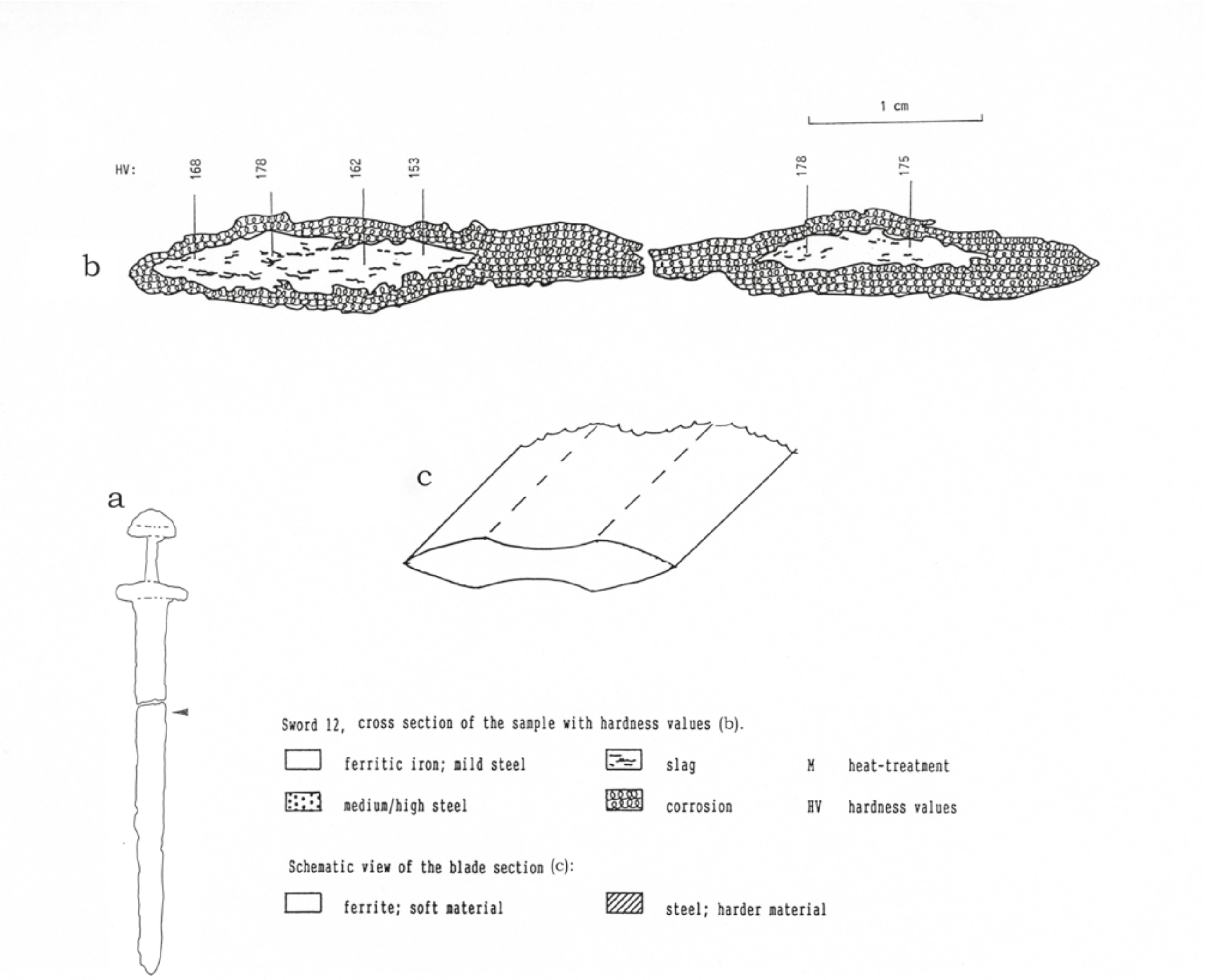


Figure 6.13a. *Sword 12. Cross-section of the sample with hardness measures (b), schematic view of the blade section (c) and outline of sword with section marked (a).*

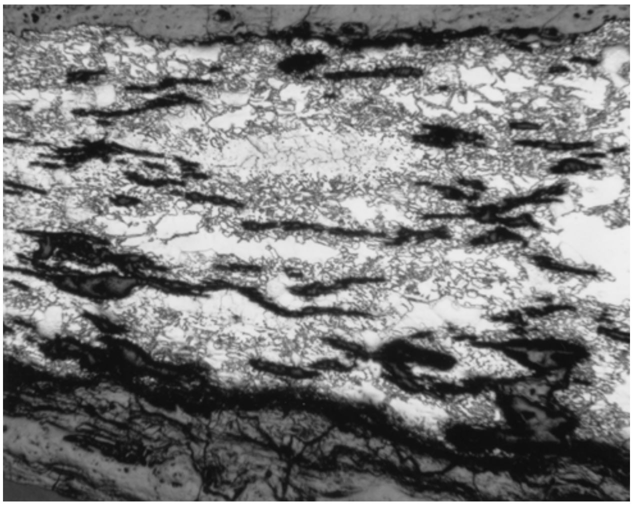


Figure 6.13b. *Sword 12. Large amounts of slag inclusions in most of the section. (20x).*

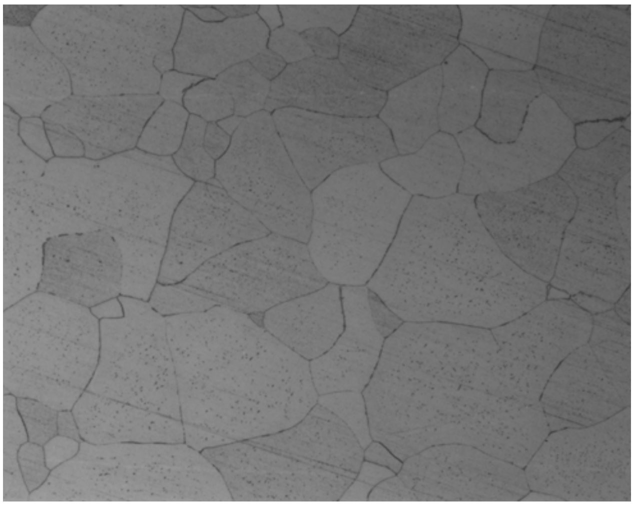


Figure 6.13c. *Sword 12. The entire sample consists mostly of pure ferrite. (200x).*

Interpretation: Although only a small part of the transverse section of the blade remains uncorroded, it may be assumed that this sword has been forged from a low-carbon material reinforced with a thin carburised surface layer. A distinct change in carbon concentration and strings of hammer scale particles in the transition zone point to a pre-made steel sheet welded onto an iron core. The blade has been quenched, but not fast enough to produce an all-martensite structure, which would have been harder and more brittle. Because the edges were lost to corrosion it is not possible to determine their quality. Judging from the scanty remains the sword was probably of decent quality.

SWORD 14 (Museum No. C.23364, found at Bøen in Dal parish, Tinn municipality)

The sword appeared during construction work. The blade was broken into two pieces, which represent more or less the complete blade (Figure 6.15a). The sword was in a fairly good state of conservation. The blade is double-edged with a fuller along each side. The hilt is an Xa-type from the late 10th century.

Examination of the polished, unetched section shows numerous small, mostly roundish slag and hammer scale particles running in parallel, wavy bands along the main axis of the section. There are also a few larger slag inclusions.

After etching in nital, the section appears to have a wavy structure of layers of low carbon content of somewhat different grain sizes running from edge to edge, suggesting that the blade material is composed of many sheets of similar composition welded together.

There is no indication of welded-on edges or any other welding seams across the section. Although parts of the blade surface are missing due to corrosion, the remaining surfaces on both sides of the blade appear to have dark etched layers of pronounced higher carbon content than the core. The core shows a mild steeled structure of ferrite and some pearlite, the hardness values being in the range of 151, 162, 169, 187 HV (Figure 6.15a). The welds between the high-carbon surface layers and the lower carbon core area are well indicated by bands of hammer scale inclusions (Figure 6.15b). This indicates that sheets of carbon-rich steel were welded onto the surface of the less carbon-rich core.

Both cutting edges show high carbon content. The edges show a martensitic structure (Figure 6.15c) due to heat treatment, the hardness values being 356, 371, 402, 420 HV. The carburised areas further away from the edges have the structure of martensite and bainite (Figure 6.15d), indicative of an insufficient cooling rate for a full quench, possibly deliberately so. The somewhat acicular nature of the ferrite in the pearlite areas also indicates relatively fast cooling, but the partly spheroidised ferrite near the centre may point to some self-annealing.

Interpretation: This sword has hardened steel edges and a core made from a layered material of low carbon content. A distinct gradient between the low-carbon core and the high-carbon surface suggests that a carbon-rich steel sheet had been welded onto the core. The blacksmith knew how to quench the steel. The low-carbon core had been worked competently, and the welding seams between the layers were done well. The slag and hammer scale particles are mostly small, resulting in no particular weak points in the material. This sword is considered to have been of decent quality.

SWORD 15 (Museum No. C.25111a, found at Rauland farm, in Vinje municipality)

The sword is a grave find, found together with the lower hilt and a fragment of another sword, two axe heads, five arrowheads, a knife blade, an iron bell, and three iron fragments. Judging from these finds, it seems reasonable to assume that the objects belong to two different burials in the same mound. Despite a corroded surface, the sword was in fairly good condition. The blade was broken into two pieces, which represent most of the weapon (Figure 6.16a). There is a fuller along each side of the blade, which is double-edged. The sword has a Q-type hilt.

Unetched, the slag content appears to be very low in the central part of the blade, and only some short ribbons of small slag inclusions, some flattened and some spheroid, were observed in the edge areas. A distinct crack is found in the edge area in the left part of the section (Figure 6.16a).

Etching of the section with nital reveals pronounced welding seams between the edges and the central part (Figure 6.16b). The two welds run as pale bands across the section, enriched with cobalt and arsenic. Microprobe analyses show an enrichment of cobalt from about 0.04wt% in the bulk of the material to about 1.0wt% in the welds. The enrichment of arsenic is somewhat less, from 0.04wt% to 0.7wt%. There is only a slight enrichment of nickel in the weld. The content of phosphorus is mostly low, around 0.01wt% (Figure 6.24a).

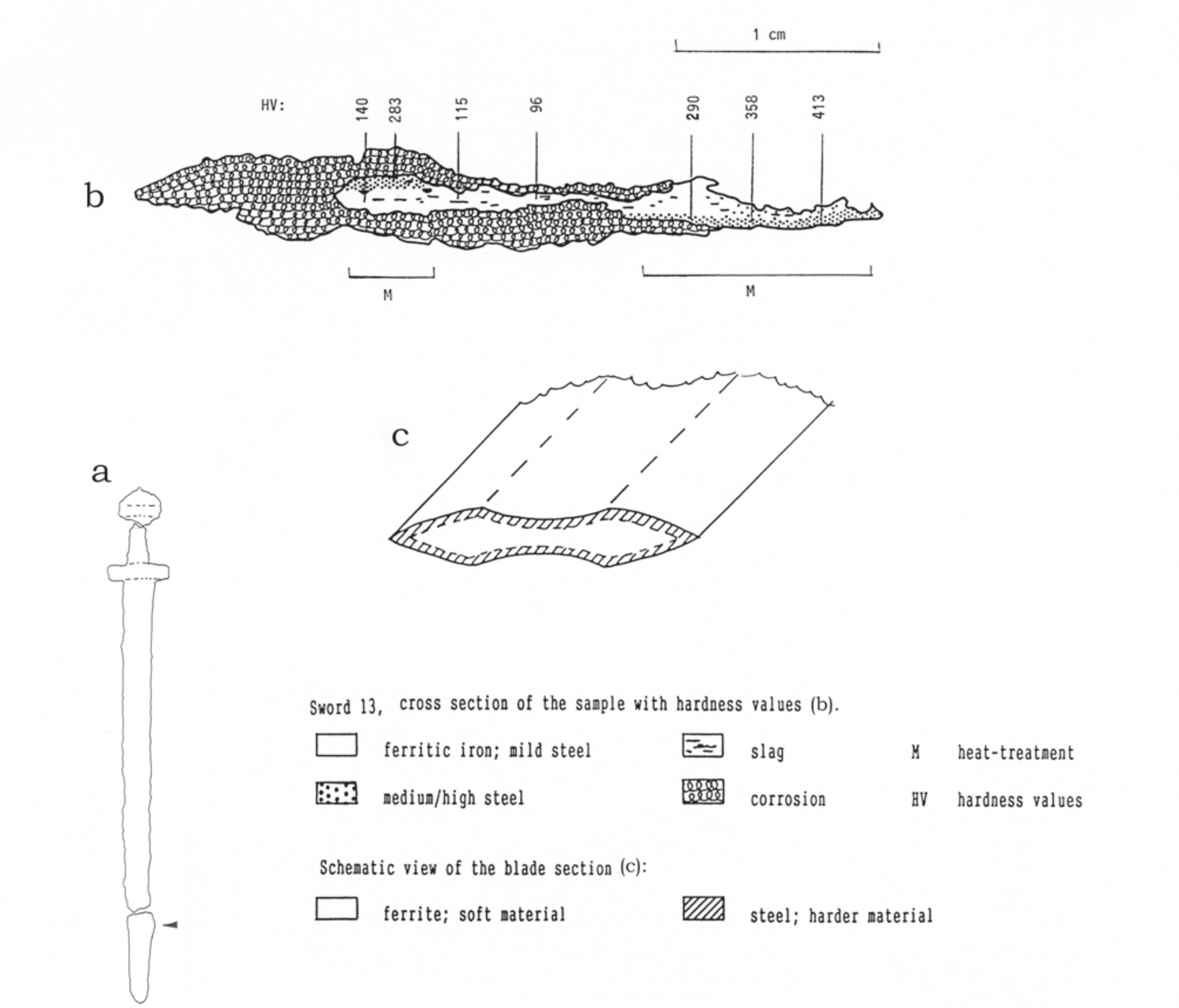


Figure 6.14a. *Sword 13. Cross-section of the sample with hardness measures (b), schematic view of the blade section (c) and outline of sword with section marked (a).*

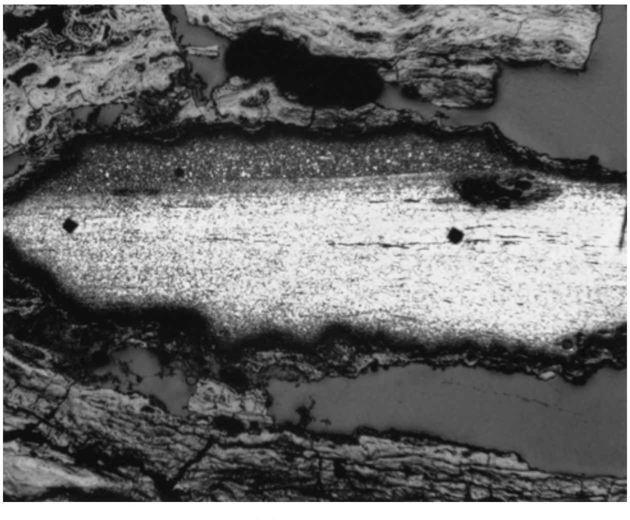


Figure 6.14b. *Sword 13. The blade has a surface layer of high carbon content and a mostly ferritic core. (Grayish corrosion products detached from the blade surface. Hardness impressions shown as two dark spots). (20x).*

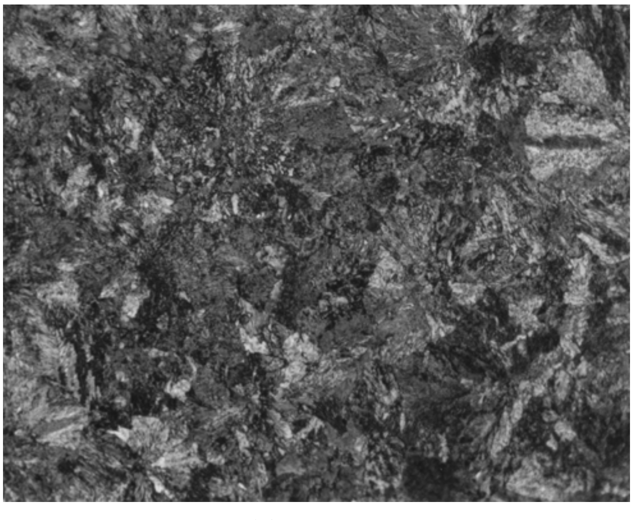


Figure 6.14c. *Sword 13. The carbon-rich area along the central part of the blade shows a mixture of martensite and bainite/ pearlite, indicating incomplete quenching. (500x).*

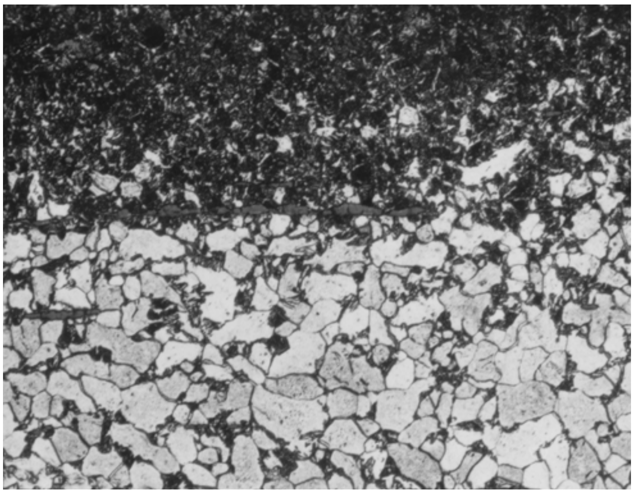


Figure 6.14d. *Sword 13. The carbon content shows a distinct drop between the surface and the core. A number of small hammer scale particles (grey) suggest a welding seam. (200x).*

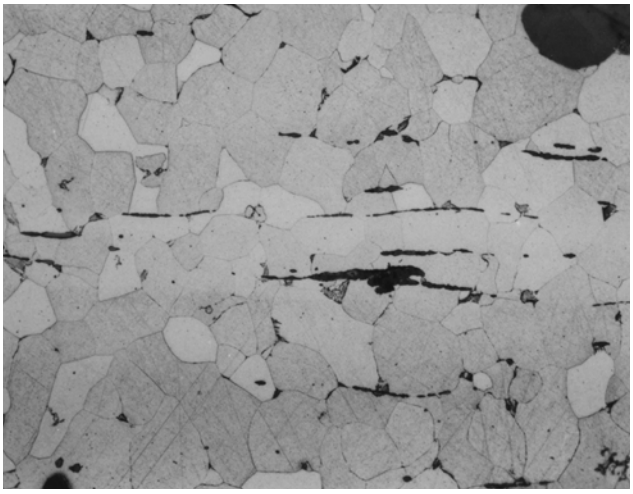


Figure 6.14e. *Sword 13. The core is mostly ferritic. (200x).*

The central part is largely composed of pure ferrite of mostly small grain sizes (Figure 6.16c). The hardness values are 86 and 91 HV, typical of a soft, fairly pure wrought iron. The zones close to the welding seams have slightly higher carbon concentrations. The hardness readings in the central part close to both welds are 119 HV. A small area with hardness values of 136 HV was observed in the core close to the weld for the right edge (Figure 6.16a). This piece was probably forged into the material unintentionally, or it is due to heterogeneous bloomery iron. This is probably also the case for a smaller piece in the middle of the core.

The material in the edges is composed of several pieces of fairly pure ferrite and mildly carburised iron. The highest carbon contents were observed in the actual cutting edges. The tip of the left edge has hardness values of 138 and 153 HV, and a structure of ferrite with some lamellar pearlite (Figure 6.16d). The major part of this edge area has a low and somewhat heterogeneous carbon content and some variation in grain sizes (Figure 6.16e), corresponding to hardness values in the range of 108–125 HV. A pronounced crack in the middle of this edge area may, to some extent, have formed a weak part of the blade.

The right edge shows mostly small grain ferrite with some pearlite. The hardness values range from 110 to 121 HV, about the same carbon concentration found in the left edge. The hardness values measured at the tip of this edge average 136 HV, which also corresponds quite well to the left edge.

Interpretation: It seems that the blacksmith knew the importance of having a soft, flexible central part and carburised harder edges in order to make a good sword. However, in the present sword the core would have been too soft and pliable, and the carbon content in the cutting edges only slightly higher than in the core. This sword would have been prone to bending in combat. It is possible that some decarburisation took place while welding the edges onto the core. There are no indications of quenching. Although some carburised iron is observed at the edges and the intention of the smith may have been the best, this sword is made up of materials too soft to make a quality sword blade. However, the blade shows good welding with very few hammer scale inclusions. This sword is considered to have been of poor quality.

SWORD 16 (Museum No. C.21325a, found in Killingtveit, Vinje municipality).

This sword was found under a large stone heap, probably a burial cairn, together with an axe head and an adze. The preserved part of the sword consists of the hilt and a small part of the upper blade (Figure 6.17a). The surface of the sword was very corroded. The blade is double-edged and has a fuller along the centre on each side. The hilt is an H-type. A close look at the blade surface indicates vague remains of inlays on both sides. This is confirmed by X-radiographs. However, there is so little left of the inlays that the reconstruction (drawing) is uncertain.

The unetched section shows mostly low slag content, except for a few small parallel slag bands along the axis of the sample, and some major slag inclusions in the welds for the inlaid designs observed in the blade surface (see below) (Figure 6.17a).

After etching with nital, the cross-sections of three inlays, two on one side and one on the other, are clearly defined (Figure 6.17b). There are no indications of

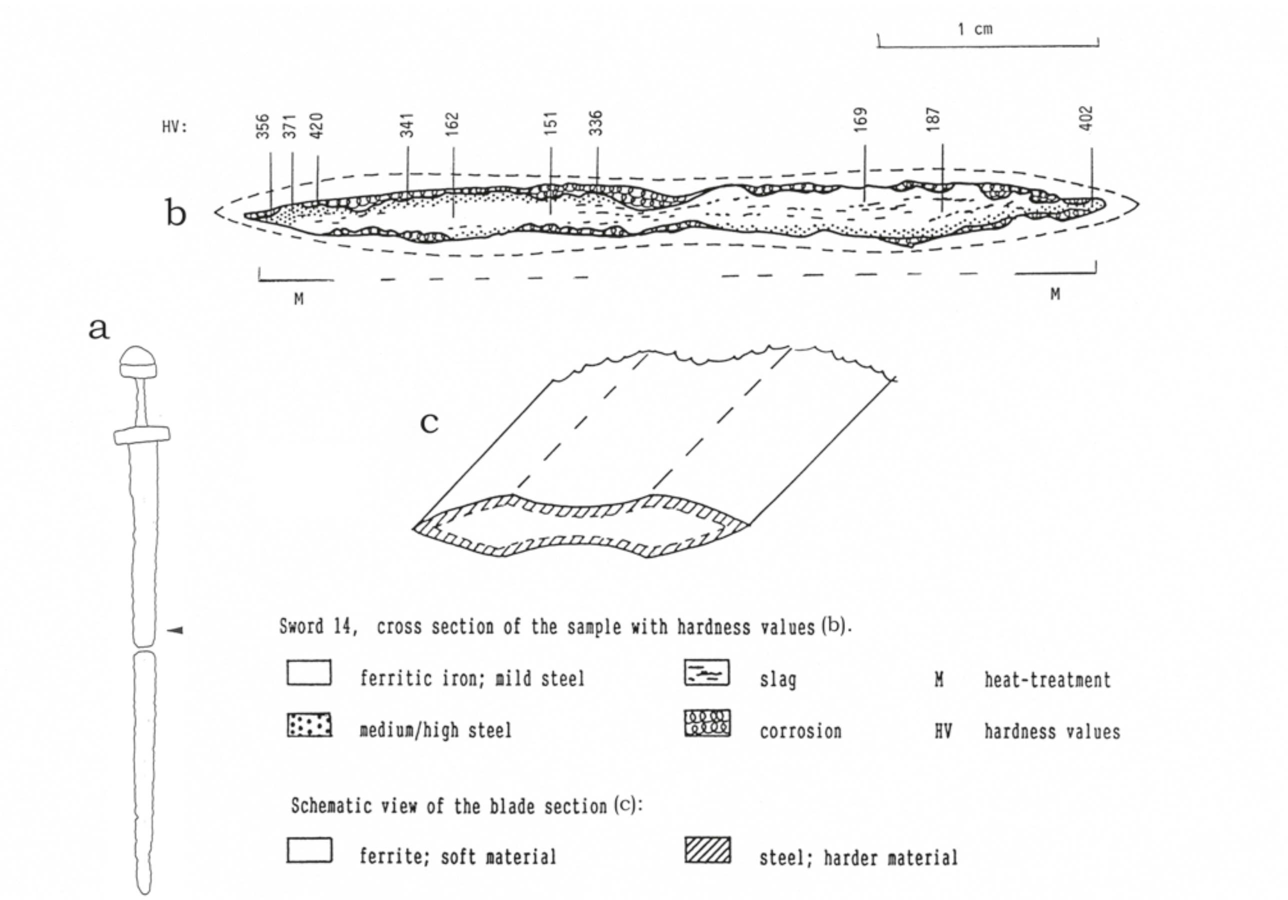
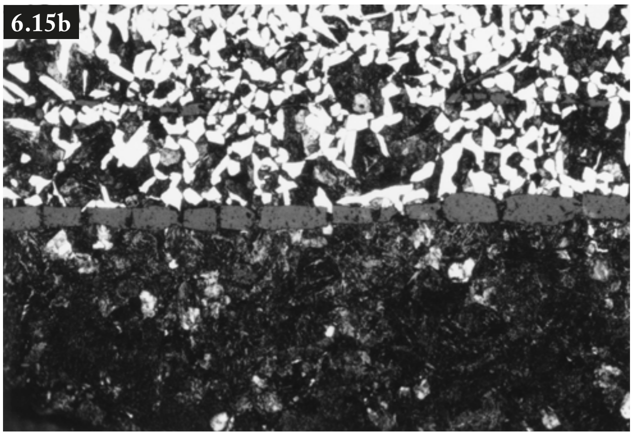
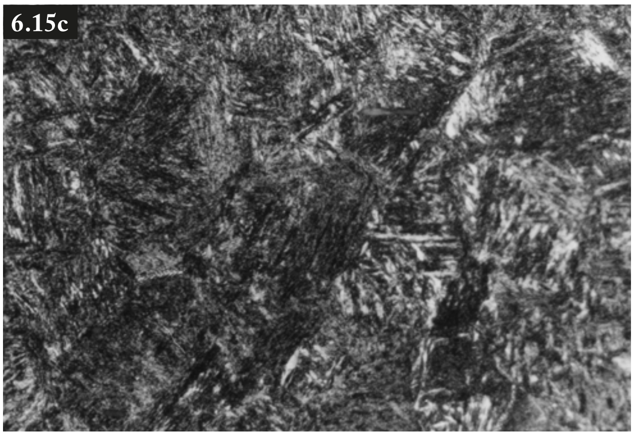


Figure 6.15a. *Sword 14. Cross-section of the sample with hardness measures (b), schematic view of the blade section (c) and outline of sword with section marked (a).*

6.15b



6.15c



6.15d

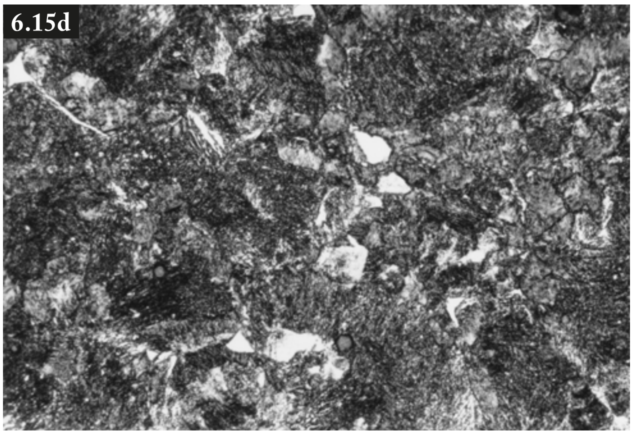


Figure 6.15b. *Sword 14. A carbon-rich steel layer has been welded onto a low-to-medium steel core. The welds are marked by slag bands. (200x).*

Figure 6.15c. *Sword 14. Both cutting edges show a martensitic structure due to quenching. (500x).*

Figure 6.15d. *Sword 14. The structure of the carbon-rich surface areas along the center of the blade indicate some heat treatment. (500x).*

welded-on edges of a harder material. Apart from the inlays, the structure of the entire section is almost pure ferrite (Figure 6.17c). Hardness values typically range from 103 to 143 HV, showing a soft material. The remaining outer part of the left edge, also of a ferritic structure, shows a slightly harder material – 153, 162, 165 HV, averaging 160 HV, possibly due to the elemental composition. The hardness values of the right edge average 119 HV. There is no indication of cold-working the edges. Large parts of both edges seem to have been lost as a result of corrosion.

The three inlays observed in the section show the cross-sections of a twisted structure of alternating layers of large grain ferrite and a darker, smaller grain low-carbon pearlite (Figures 6.17d). Etching with Oberhoffer's reagent (Figure 6.17e) reveals that the ferritic part of the inlays contains phosphorus, while a major part of the ferritic blade material is practically without it. Microprobe analyses of the different layers of the inlays show the phosphorus content in the ferritic layers to be about 0.25wt%, while that in the low-carbon layers is about 0.05wt%. The phosphorus content in the blade material is only 0.01wt% (Figure 6.25). Hardness measurements in the ferritic layers are 143, 162 and 171 HV in the three inlays respectively, while the carburised parts of the inlays show values between 189 and 193 HV. The inlays were produced by first twisting together a number of thin wires of low-carbon iron and phosphorus-containing iron. Then the composite wires were shaped into the preferred designs before they were placed, along with flux, on the surface of the already hot and consequently softer blade. A further heating, followed by hammer welding, would flatten and push the wire inlay into the blade surface at the same time as the metal surfaces bonded together. This technique has been shown by Kasper Andresen (1993) to be relatively easy to carry out and did not demand chased channels in the sword blades to hold the inlays, nor a punch to drive them into position (East, Larkin and Winsor 1985; Lang and Ager 1989:101). By hammer welding the inlays into the blade, the shape of their cross-sections has been somewhat distorted and flattened.

Interpretation: The material throughout the section of this sword is too soft. The edges would not last in battle and the blade would be easily bent. This once visually wonderful sword with inlays along the blade seems to have been designed and valued more as a prestige weapon than for its usefulness in combat. According to reconstructions, the forging of inlays is not particularly difficult to accomplish and does not prove outstanding skill. So, if the blacksmith had the skill to produce a high-quality weapon, he has certainly not exhibited that skill in this sword. Nevertheless, the inlays of mild steel and phosphorus-rich iron, in order to improve the appearance, indicate that the blacksmith had adequate knowledge of the materials. Most likely the simple blade was intentionally made in that manner in order to save steel and elaborate work. (See Chapter 7: The Hedesunda sword.) This sword is considered to have been of poor functional quality if used as a weapon in combat.

SWORD 17 (Museum No. C.23018a, found in Åkre, Tokke municipality)

The sword was found in a grave together with a spearhead, an axe head and a fragment of another axe head, a flat iron ring and an oval bronze brooch. The blade is double-edged and has a fuller along both sides. The sword was broken into two parts at about the middle of the blade (Figure 6.18a). The blade was very corroded, particularly in the area where it was broken. Due to corrosion, part of the blade is split along the fuller. Moreover, a large part of at least one of the edges has been lost (Figure 6.18a). The hilt is a Q-type.

Examination of the section before etching shows traces of hammer scale bands across the blade. This indicates welded-on edges. Only a few slag particles were observed in the central part. In the left part of the section (Figure 6.18a), there are some slag inclusions, particularly in the more carbon-rich areas. In the right part slag particles are abundant except in the outer tip.

After etching with nital, the section appears to have carburised cutting edges welded onto the central part. Both welding seams for the edges are clearly marked as light, decarburised lines across the section. Microprobe analyses carried out stepwise across the welding seam show a significant enrichment of cobalt from about 0.02wt% in the body of the blade to almost 0.5wt% in the weld, and only a minor enrichment of arsenic from c. 0.02wt% to 0.07wt% (Figure 6.24c).

The structure of the central part of the sword has mostly small grains and low carbon content (Figure 6.18b). Hardness measurements show an average value of 131 HV. Exceptions are the areas along the welding seams for the edges, where some diffusion of carbon across the welds has taken place (153, 164 HV). Also, in the thinner part of the core, a small piece of higher carbon content seems to have accidentally ended up in the core material.

Both edge areas are composed of several pieces of mild to medium carburised iron. The structure in the tip of the cutting edge in the left part of the section

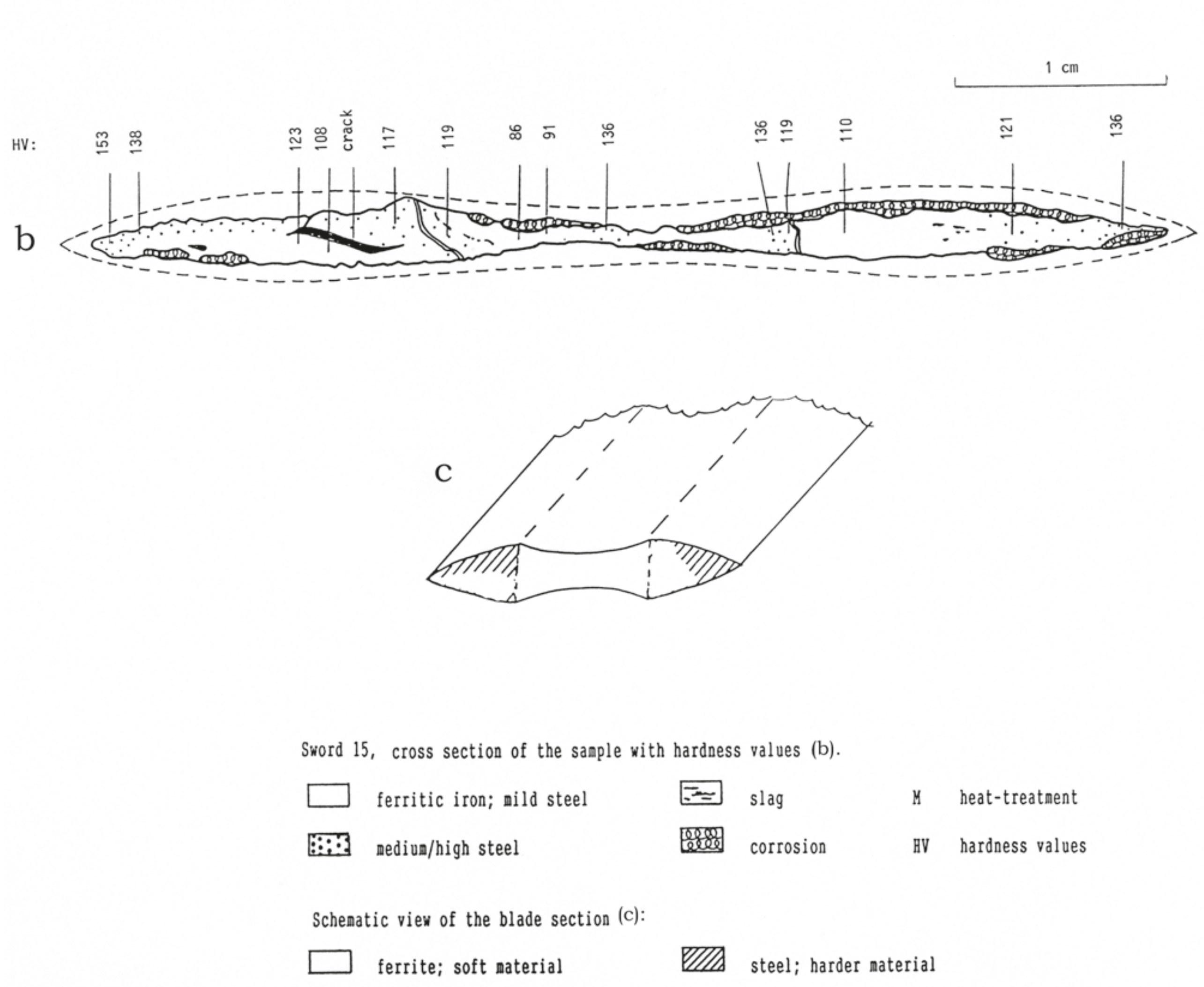


Figure 6.16a. *Sword 15. Cross-section of the sample with hardness measures (b) and schematic view of the blade section (c).*

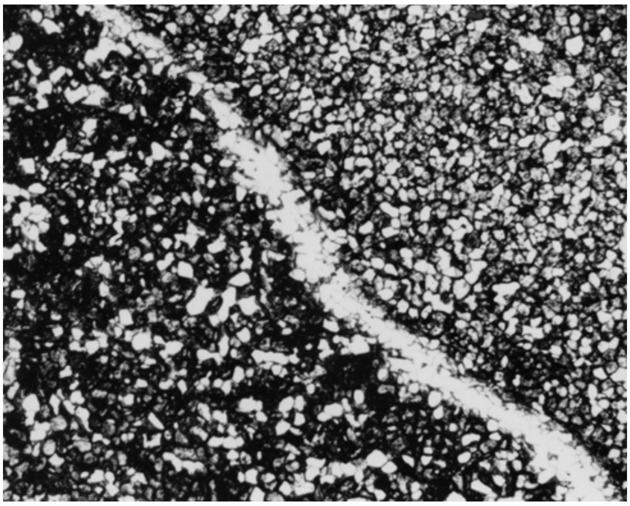


Figure 6.16b. *Sword 15. Pale bands across the section indicate welding seams between the central part and the edges. (100x).*

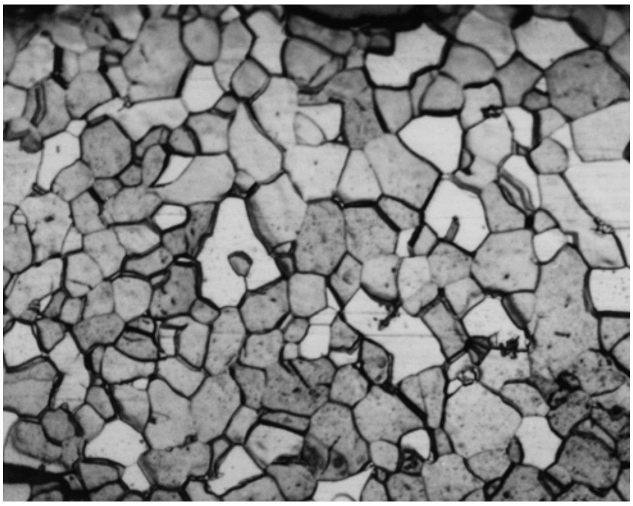


Figure 6.16c. *Sword 15. The core consists mostly of pure ferrite. (200x).*

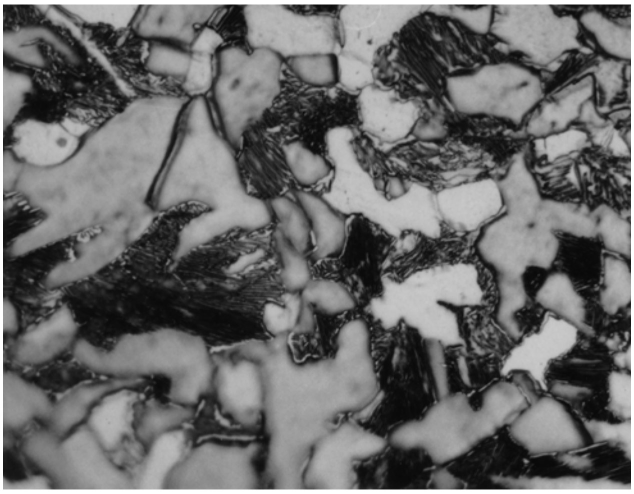


Figure 6.16d. *Sword 15. The tip of the left cutting edge with lamellar pearlite. (500x).*

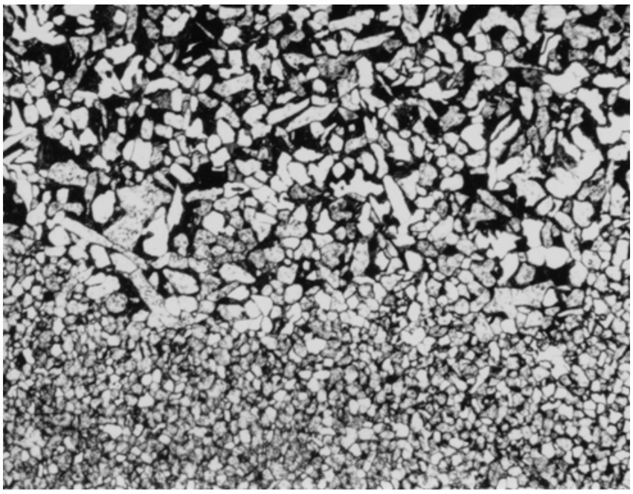


Figure 6.16e. *Sword 15. The left edge area shows a heterogeneous grain size. (100x).*

shows lamellar pearlite with a somewhat higher carbon content (Figure 6.18c), corresponding to an average hardness of 201 HV. The major part of this edge shows ferrite-pearlite with mostly medium carbon concentration (178 HV), while the area close to and along the welding seam shows increased carbon content and hardness values averaging 193 HV.

The right edge also shows lamellar pearlite with somewhat varying concentrations of carbon corresponding to hardness values in the range of 167 HV and 203 HV, and a hardness of 171 HV in the tip. As was the case with the left edge, increased carbon content is observed in a zone parallel to the welding seam (203 HV). There is no indication of quenching.

Interpretation: The blacksmith was aware of the importance of having harder edges and a softer central part. The welding seams between the edges and the core were well made. The edges have mostly medium carbon concentrations, but the blacksmith was not familiar with the technique of heat treating, which would have improved the hardness of the cutting edges and the quality of the weapon. This sword is considered to have been of decent quality.

SWORD 18 (Museum No. C.22568a, found in Kvålo, Lårdal parish, Tokke municipality).

The sword was found under a stone mound, probably a burial cairn, during farm work. An axe head and part of a sickle blade were also found with the sword. The extant parts of the sword consist of two pieces of the blade, which were very corroded. The hilt is missing (Figure 6.19a). There is a fuller along both sides of the blade. Since it was unclear whether the two pieces of the blade really were parts of the same sword, one section from each fragment has been studied (section A and B in Figure 6.19a).

Microscopic examination of the unetched sections shows quite a few slag inclusions. A few bent structures of hammer scale appear in the left part of section A shows that pieces of iron were folded and forged together (Figure 6.19b). The central and right parts of both sections show flat, parallel inclusions of slag and hammer scale, mostly as a long band through the section.

Etching with nital reveals a composition of distinct layers of soft iron and medium carbon steel running in a slightly oblique direction from one edge area to the other. A major part of section A has medium carbon content corresponding to hardness measurements in the range of 201–207 HV. The tip of the edge in the left part of the section (Figure 6.19a) shows higher hardness values, averaging 241 HV (Figure 6.19c), indicative of fairly high-carbon steel quickly cooled but not quenched. There is a pronounced distinction between the low and the higher carbon areas (Figure 6.19d), with some bands of hammer scale indicating welds. The ferritic or low carbon layer running through the section (Figure 6.19a) shows hardness values of about 120–179 HV. This is higher than expected for almost pure ferrite (Figure 6.19e). Perhaps the elemental composition could explain these high values. Etching with Oberhoffer's reagent showed no evidence of elevated phosphorus content. The grain sizes vary throughout the section.

The second section (B) cut from the other piece of the blade shows virtually the same structure and hardness measurements as section A. However, in this section the ferrite layer has a slightly lateral displacement such that both edges have increased carbon

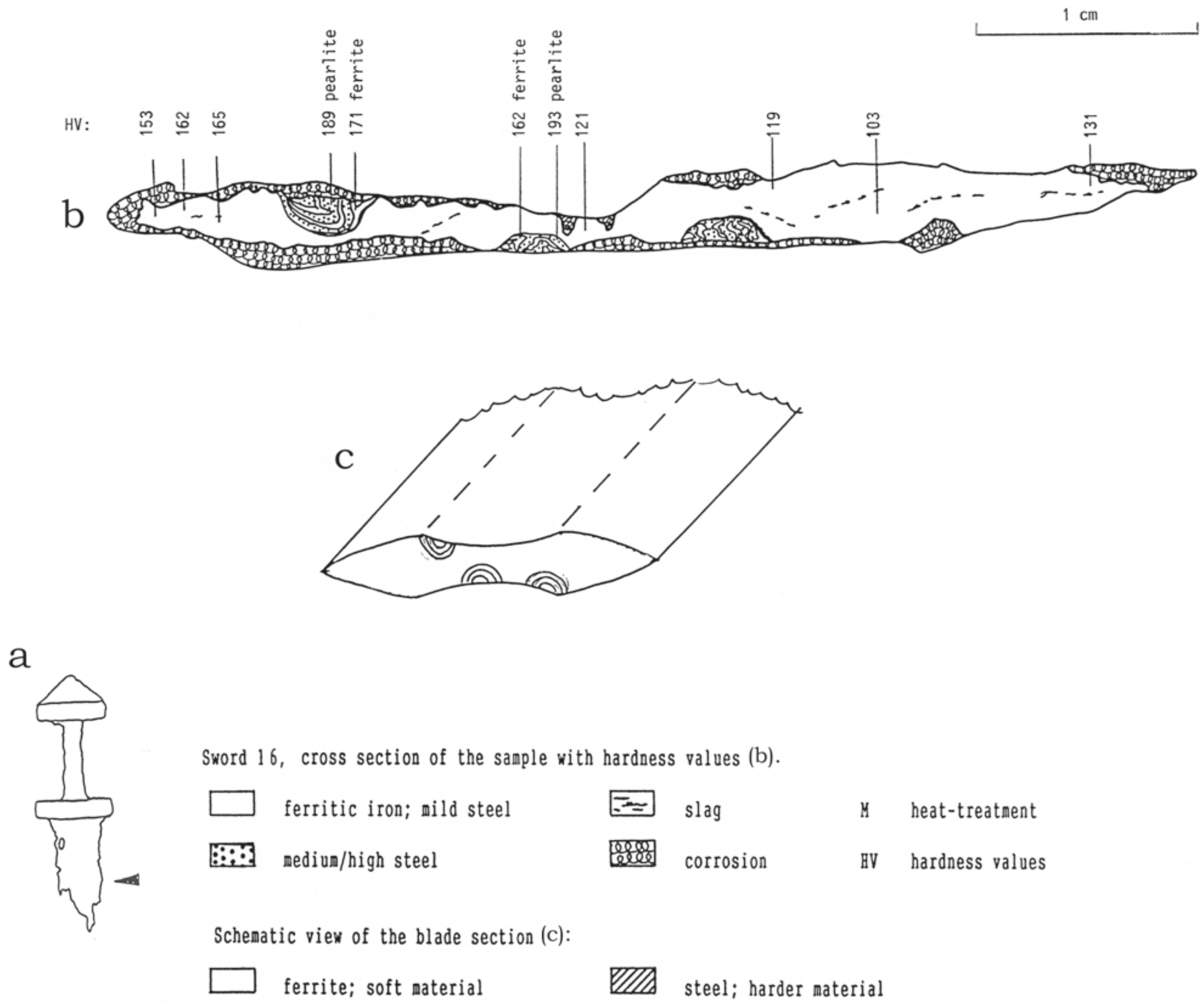


Figure 6.17a. *Sword 16. Cross-section of the sample with hardness measures (b), schematic view of the blade section (c) and outline of sword with section marked (a).*

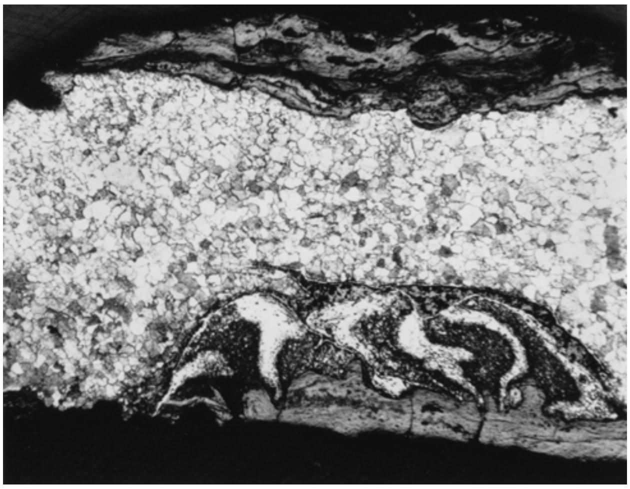


Figure 6.17b. *Sword 16. Cross-section of one of the inlays consisting of medium steel (dark) and phosphorus-containing wrought iron (white). The main constituent of the blade is almost pure ferrite. (20x).*

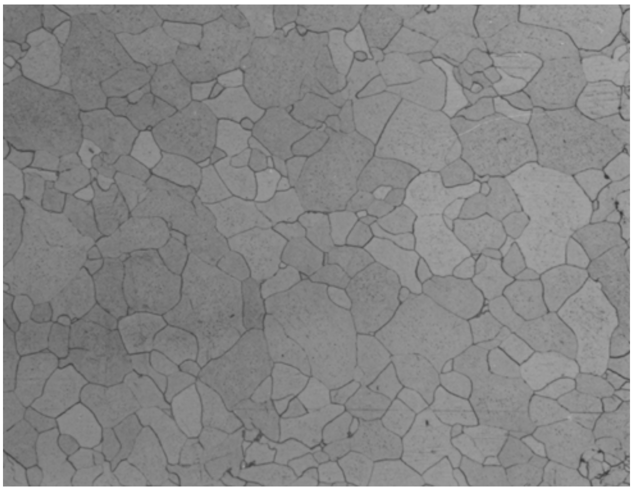


Figure 6.17c. *Sword 16. The blade is made of more or less pure ferrite. (100x).*

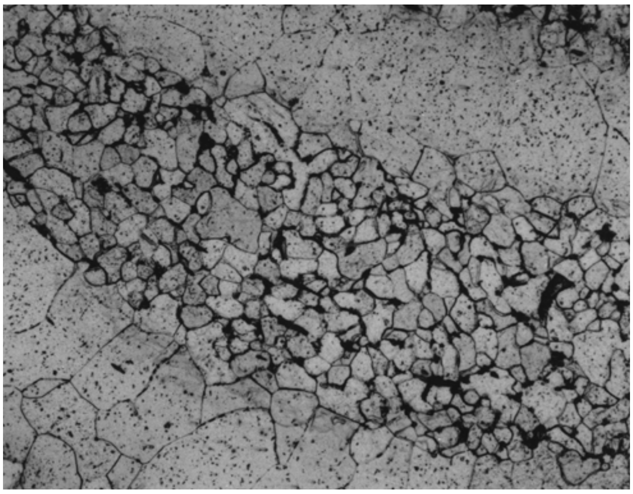


Figure 6.17d. *Sword 16. The inlays consist of layers of large-grain ferrite and small-grain ferrite/pearlite. (200x).*

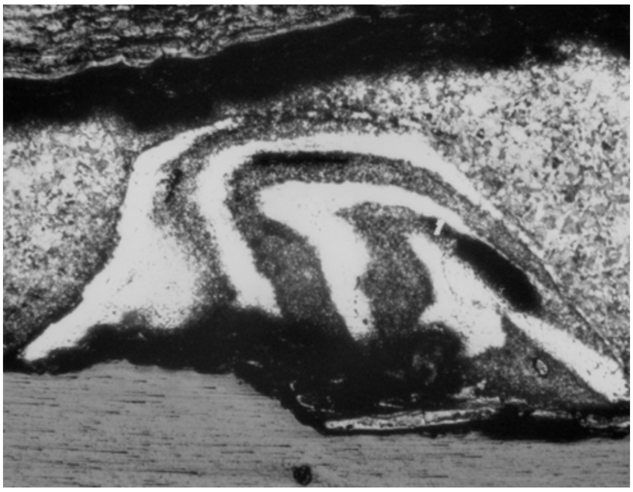


Figure 6.17e. *Sword 16. One of the inlays after etching with Oberhoffer's reagent, shows phosphorus-rich ferrite (pale) and mild steel (dark). (50x).*

content (Figure 6.19a). The ferritic layer appears to run somewhat obliquely through the centre of the blade.

Interpretation: Judging from the construction, the microstructure and the hardness values of the two sections, it seems clear that they belong to the same sword. It is difficult to form a definite opinion about the construction of this blade and the intention of the blacksmith. The blade could be the result of a body welded together randomly from pieces of harder steel and softer iron. However, the fact that two sections taken quite a distance apart in the blade show in principle the same construction and composition, may indicate that layered blade material could have been deliberately arranged from three flat bars – a wrought iron bar between two mild steel bars – with some lateral displacement (Figure 6.19a).

Both edges have been carburised in section B, while section A has only one carburised edge. This might be the result of corrosion of the other edge and loss of the carburised part, or it may be due to a certain displacement of the three bars during forging. The fact that the hardest parts of the sections were found at the very edges might indicate that the blacksmith performed a secondary carburisation of the tips of the edges intentionally, and that he had the knowledge of how to make an adequate sword. The blade has not been quenched. This sword is considered to have been of decent quality.

SWORD 19 (Museum No. C.24793c, found in Øvre Berge, in Kviteseid municipality)

The grave mound in which the sword was found probably contained at least three burials. The sword was found together with another double-edged and a single-edged sword, three axe heads of somewhat different types, an iron shield boss, a knife blade, three horse bits, an iron ring, a pair of scissors, a small bell, the lock of a chest, a fork-shaped tool, two fragments of some kind of iron blade, and some iron fragments. The sword blade was broken into two pieces and the hilt was missing (Figure 6.20a). The blade is double-edged and has a fuller running down either side.

Examination of the unetched section shows some slag inclusions. A few bands of slag or hammer scale particles in the left part of the section (Figure 6.20a) are parallel to each other and also to a major crack, slanting from the surface through a large part of the edge area. The hammer scale bands indicate welding seams between different sheets of metal forged together to make the edge material. A few parallel bands of scale or slag can also be seen in the right edge area. Some tortuous ribbons of hammer scale across the section suggest welding seams between the edges and the central part.

Etching the sample with nital reveals the blade to consist of a low-carbon central part with welded-on medium carbon edges. The hardness readings in the central part, consisting of practically pure ferrite (Figure 6.20b), are 96, 103 and 104 HV, an average of 101 HV. Higher carbon content was found close to the welding seams, where some diffusion of carbon had taken place. The welding seams for both edges are visible as three tortuous light lines across the section (Figure 6.20c). These welds are unlike other welds in this study. It is difficult to explain what kind of process could produce such welds. Microprobe analyses in steps across one of the welding seams show an enrichment in cobalt from about 0.03wt% in the blade body to about 0.18wt% in the weld, some enrichment of arsenic and only a slight enrichment of nickel (Figure 6.24e). The phosphorus content is mainly low (less than 0.01wt%), and at a constant level.

The cutting edge in the left part of the section appears to be composed of several parallel layers of mildly steeled iron of somewhat varying carbon content (Figure 6.20d). The hardness values in the main part of the edge are in the range of 163 to 185 HV. Between the layers there are pale lines representing the welds between the layers. Microprobe analyses across the layers of this edge reveal some enrichment of cobalt in the welds between the layers, which are approximately 0.3 mm thick. Further, the contents of arsenic, phosphorus and nickel were found to fluctuate around 0.02wt% in the layers as well as in the welds. A crack through the material runs between two layers. As can be seen from Figure 6.20e, the crack is surrounded by a decarburised ferritic layer. This indicates that the crack was present before the last heating of the blade, during which decarburisation occurred. The outer edge in the left part of the section, the area outside the crack, has a somewhat higher carbon concentration than the rest of the section. Hardness values average 201 HV. The structure in this part is quite uniform and shows a prior austenite grain size outlined by ferrite (Figure 6.20f).

In the right edge area, the carbon concentration is mostly homogeneous (hardness values of 178, 178, 185 HV). The tip of this edge has a hardness value of 182 HV, which is somewhat lower than that in the left edge. Piling of layers like those observed in the left part was not observed here, although a few slag bands running parallel to the blade surface through most of this edge may be indicative of welding seams.

Interpretation: The edges of this sword could have benefited from being somewhat harder. The blacksmith placed the harder material at the edges while the central part is more flexible, perhaps too soft. The left edge shows a structure produced by piling and welding together thin pieces or sheets of steeled iron to make up the necessary thickness of the body required for the edge. Although a similar structure is not clearly seen in the right edge, this may be due to extensive heating of the material, which evened out the variations in carbon content. There are no indications of quenching. This sword is considered to have been of fair quality.

SWORD 20 (Museum No. C.19575, found in Røymål, Lunde, Nome municipality).

The sword was found in a mound which probably contained several burials. Associated finds include a second double-edged and two single-edged swords, a spearhead, three axe heads, a number of arrow heads and knife blades, one or two shield bosses, one or two sickle blades, two horse bits, a whetstone and five beads. The blade was broken, and only the upper part with the hilt remained (Figure 6.21a). The surface layers were missing due to corrosion. The remaining part is in an acceptable state of preservation. The hilt is probably a Q-type.

Microscopic studies of the unetched section show lots of flat forged slag and hammer scale inclusions (Figure 6.21b), running in bands parallel to the blade surfaces indicating a piled structure.

Etching with nital shows that the blade has medium to high carbon content edges, which were welded onto a layered central part. The layers are partly ferritic, and made partly from low-carbon iron (Figure 6.21c). The ferritic layers, separated by lines of pearlite as well as hammer scale bands, run parallel along the section in the edge-to-edge direction (Figure 6.21e). Etching with Oberhoffer's reagent indicates that some of the ferritic layers have a considerable concentration of phosphorus (Figure 6.21d). Phosphorus content of about 0.3wt% was measured in some of the layers, while the others have about 0.05wt% according to microprobe analyses. The layers show hardness values partly in the range of 117–148 HV, and partly 173–197 HV due to variations in the phosphorus as well as the carbon concentrations. Some of the layers, mostly along the surface, were made from low-carbon steeled iron.

Compared to the other swords in this investigation, the edges of this particular sword are narrow and constitute only a smaller part of the section (Figure 6.21a). The central part makes up almost 80% of the entire section.

The welding seam of the left cutting edge appears as a pale decarburised line across the section, while a band of corrosion across the sample has replaced most of the weld between the right edge and the core. The welds between the edges and the core are somewhat curved. This may indicate that the edges were bent around the central part rather than being butt-welded.

Carbon content in the edges was considerably higher than in the central part. The cutting edge in the left part of the section shows a somewhat heterogeneous, patched structure of ferrite and pearlite. The hardness values measured at the very outer left edge are 245, 260 HV, averaging 253 HV. In the rest of this edge, the hardness measurements average 200 HV. The structure appears to be lamellar pearlite with medium carbon content (Figure 6.21f).

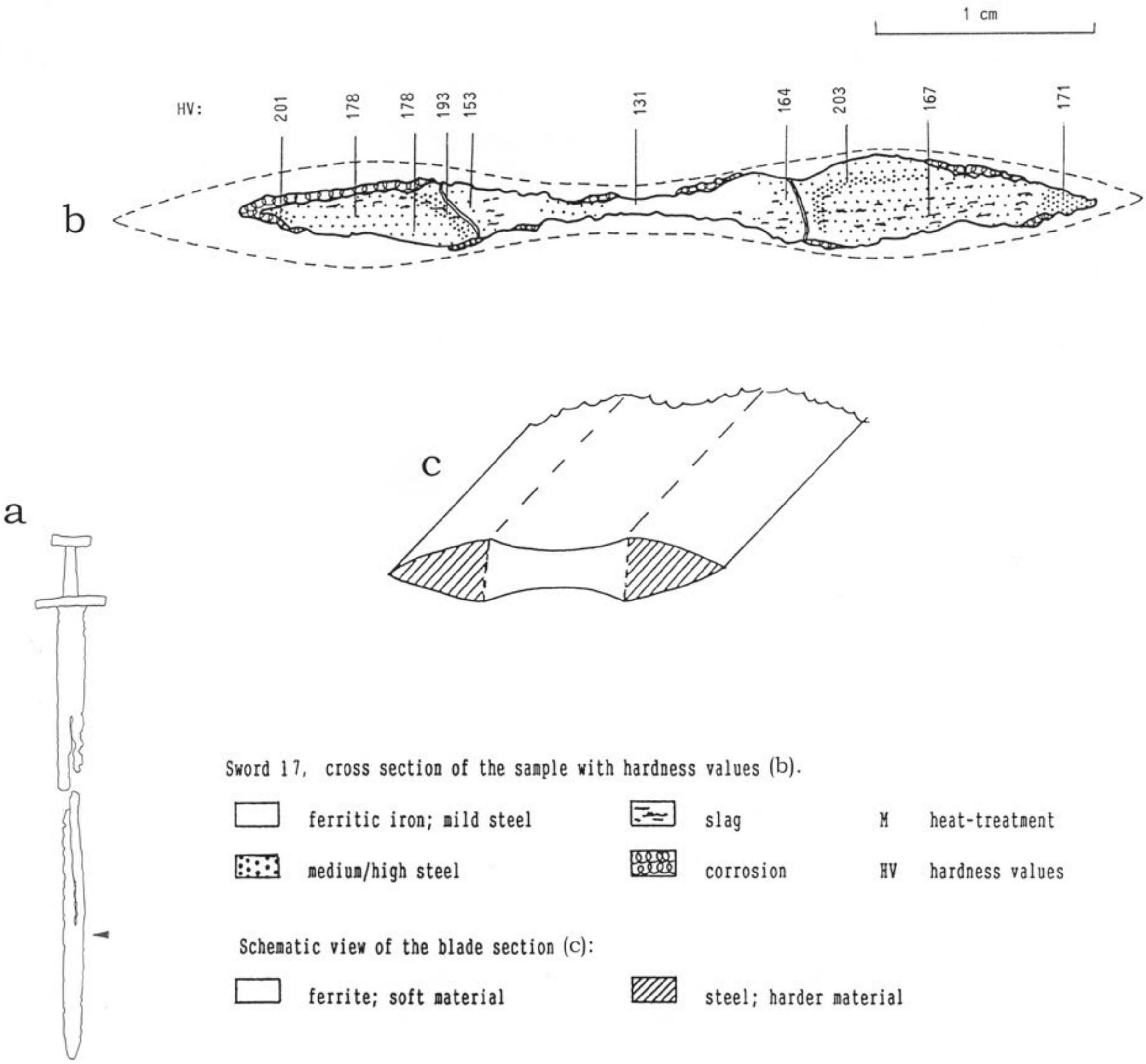


Figure 6.18a. *Sword 17. Cross-section of the sample with hardness measures (b), schematic view of the blade section (c) and outline of sword with section marked (a).*

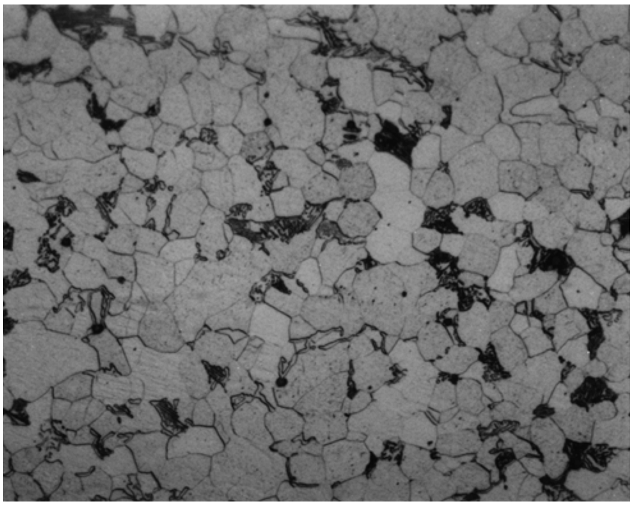


Figure 6.18b. *Sword 17. The central part has mostly small grains and low carbon content. (500x).*

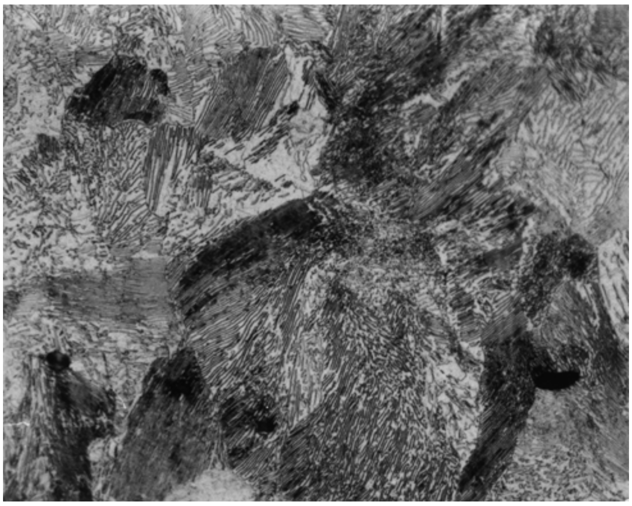


Figure 6.18c. *Sword 17. The tips of the cutting edges show lamellar pearlite and mostly high carbon content. (500x).*

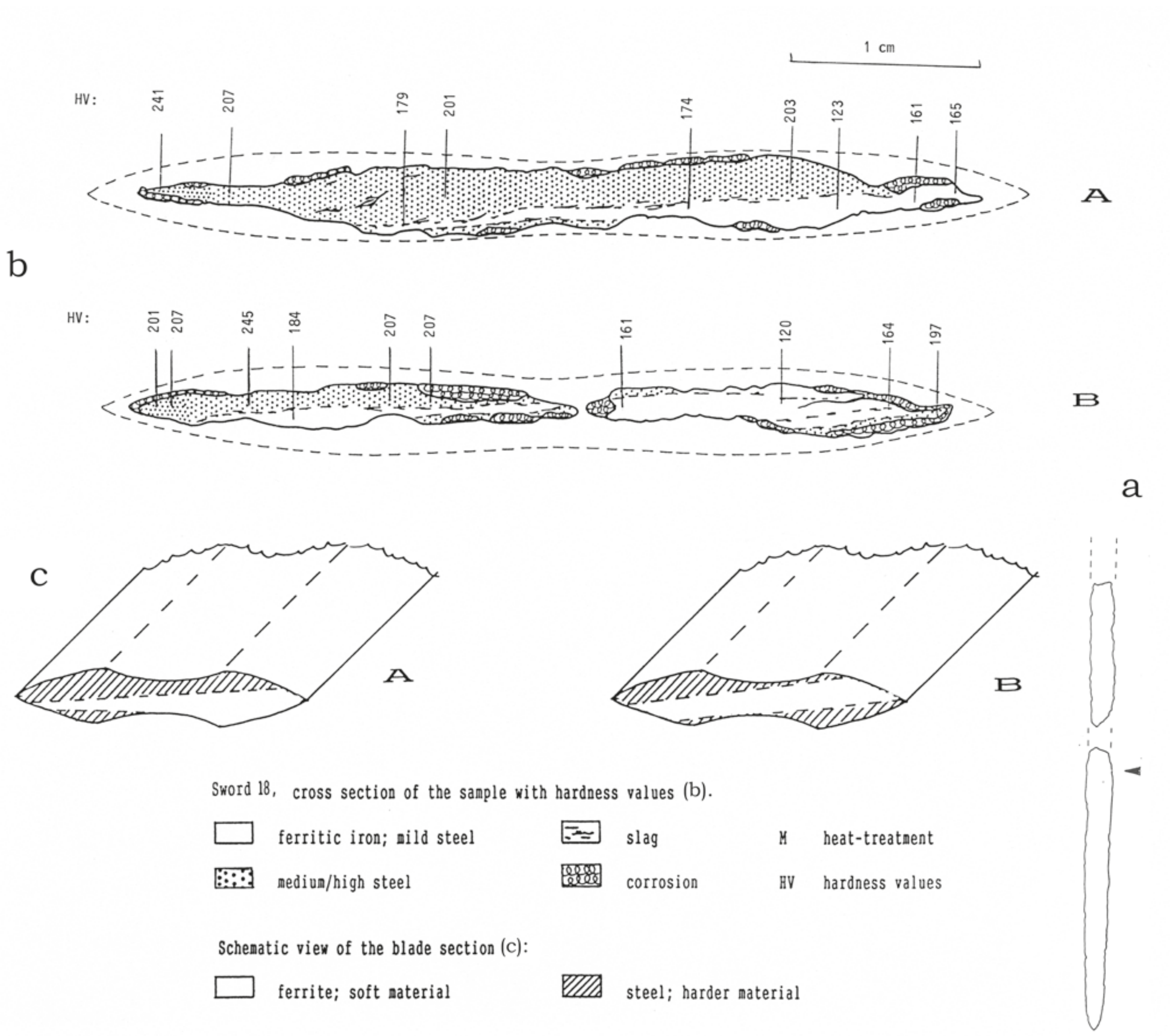


Figure 6.19a. *Sword 18. Cross-section of the sample with hardness measures (b), schematic view of the blade section (c) and outline of sword with section marked (a).*

Figure 6.19b. *Sword 18. Unetched. A few bent hammer scale structures in the left part of the section indicate that pieces of iron were folded and forged together. (50x).*

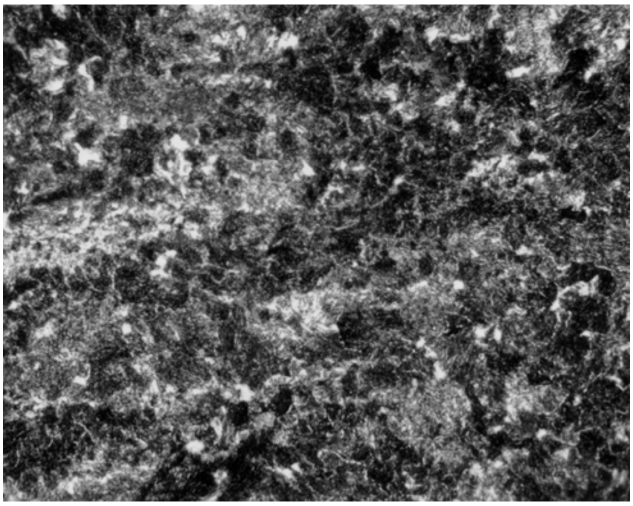


Figure 6.19c. *Sword 18. The outer left edge shows fairly high carbon content. It has been cooled quickly, but not quenched. (500x).*

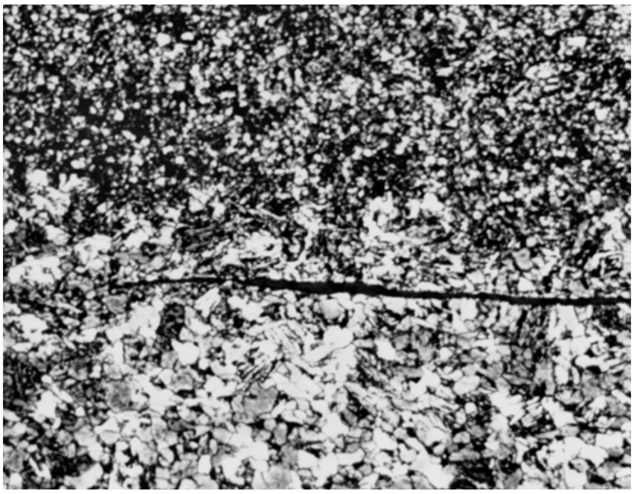


Figure 6.19d. *Sword 18. The blade is composed of sheets of low (pale) and high (dark) carbon content. A distinct border runs obliquely from one edge area to the other. (100x).*

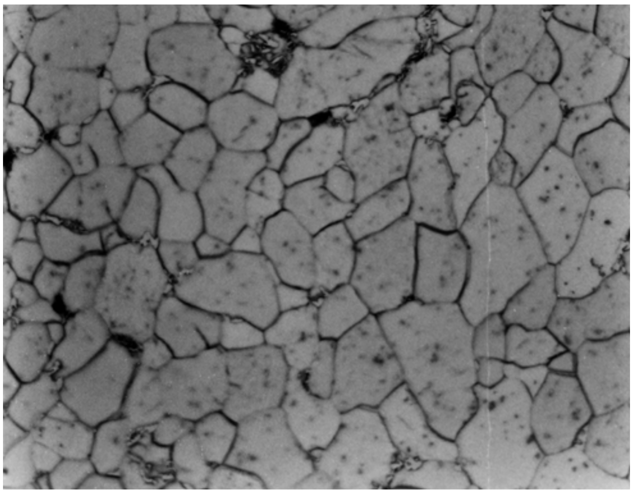


Figure 6.19e. *Sword 18. A ferritic layer runs obliquely in an edge-to-edge direction. (500x).*

The right cutting edge is somewhat harder than the left. Hardness values vary from 224, 250, 251 HV close to the weld, to 289 HV at the very edge. The edge consists of medium to high carbon content with cementite in the prior austenite grain boundaries (Figure 6.21g). None of the edges show any signs of quenching.

Interpretation: The central part is ductile. The amount of slag and hammer scale is somewhat high. The edges are considerably harder than the core. Quenching may not have been a technique familiar to the blacksmith. This sword is considered to have been of no more than decent quality.

SWORD 21 (Museum No.23946a, found at Brokke, Fyresdal municipality)

The sword is a grave find. An axe head, an iron reed and a frying pan were found together with it. Only a part of the blade and the lower guard of the hilt have survived (Figure 6.22a). The sword is single-edged. The remaining parts were quite corroded, particularly the sharp edge. The hilt is an M-type.

Unetched, the section shows some long, flat slag bands mostly along the central part.

When etched in nital, the sample reveals mostly low carbon content with typical hardness values in the range of 100–123 HV (Figure 6.22b). The hardness measured in the back part is 123 HV. Higher carbon content (Figure 6.22c) was observed along one surface of the blade, as well as in a band running along the axis of the section from near the back, slanting towards the surfaces near the cutting edge area (Figure 6.22a). Typical hardness values in the carburised areas are 159, 180, 182 HV. The remaining part of the edge consists partly of a ferritic area, and partly of a carburised area (Figure 6.22d). The hardness in the actual edge is 226 HV (Figure 6.22a).

The material in this sword blade seems to have been forged together from sheets or pieces of soft iron and mildly carburised iron. This may have been done intentionally in order to give some stiffness to the blade. Although a large part of the blade consists of nearly pure ferrite, examination shows that the actual cutting edge is carburised. There is no indication of quenching.

Interpretation: The question remains whether the blade was made from random pieces of ferritic iron and mildly carburised iron, or if it was deliberately piled from a few alternating sheets of different carbon content in order to increase its strength. There is no sheet of steel running through the tip of the cutting edge. Still, carbon content increases in the cutting edge, which may be due to a secondary carburisation of this part. The blacksmith seems to have been aware of the advantage of carburised iron in the cutting edge, and he knew how to carry out the process. However, it seems he did not have knowledge of quenching. This sword is considered to have been of decent quality.

6.4 DISCUSSION

In order to make a sword blade of high functional quality in relation to actual combat, it was necessary for the smith to have extensive knowledge of the materials with which he was working, and of the techniques for improving the strength and resilience of the materials by carburisation and heat treatment. He must also possess the adequate skill to perform these processes.

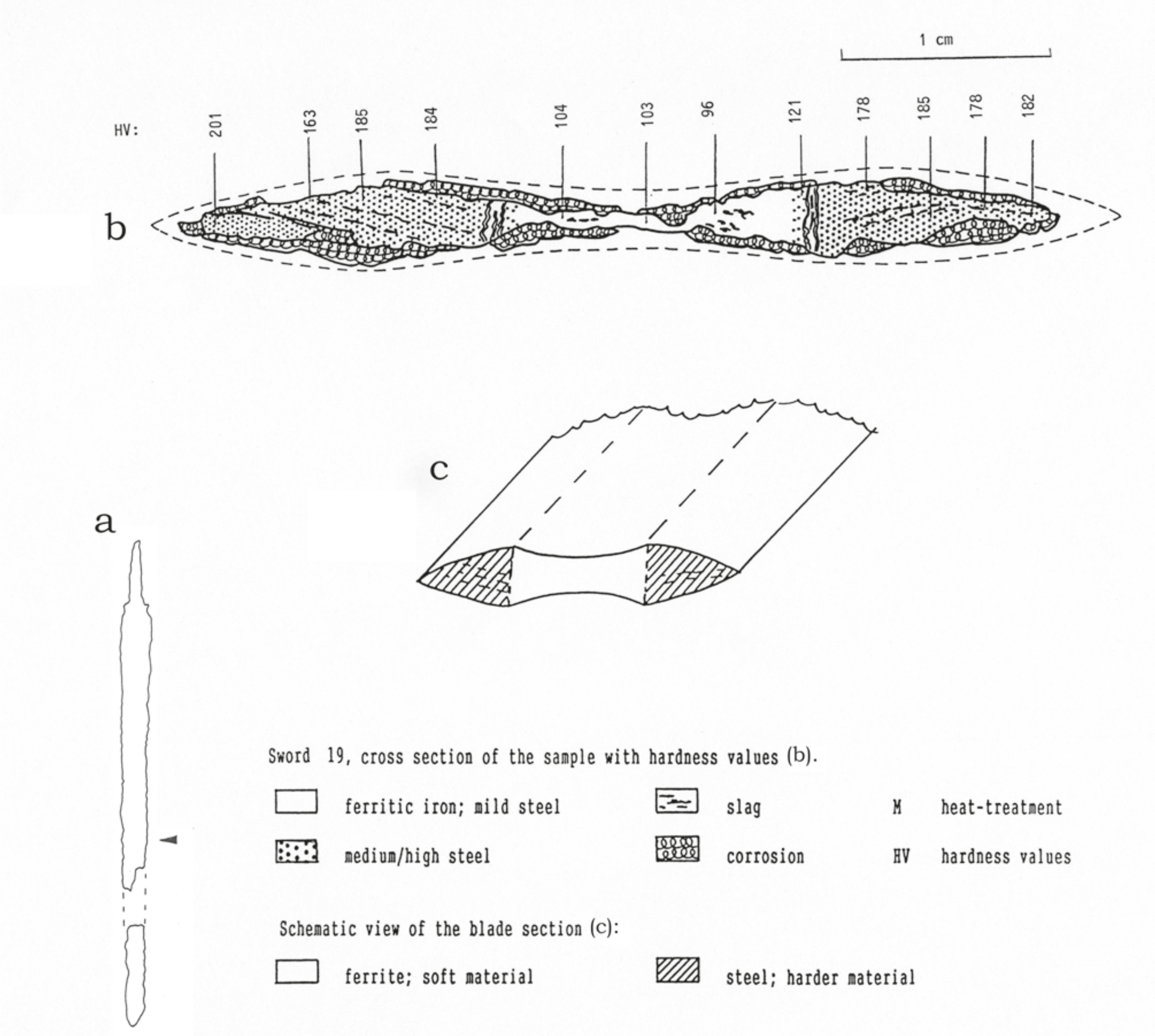


Figure 6.20a. *Sword 19. Cross-section of the sample with hardness measures (b), schematic view of the blade section (c) and outline of sword with section marked (a).*

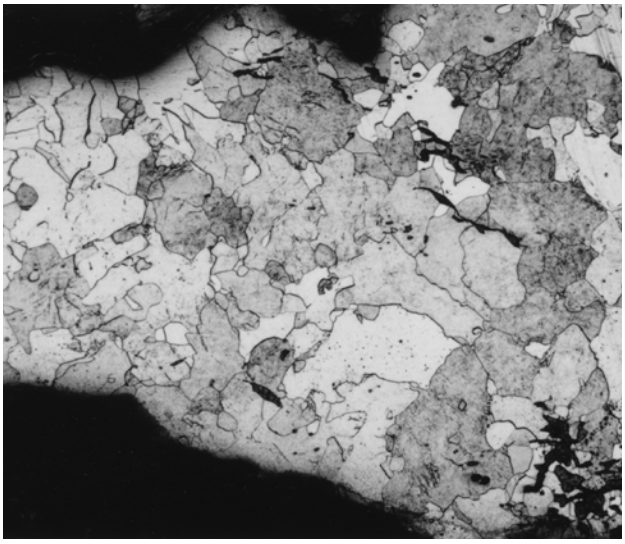


Figure 6.20b. *Sword 19. The central part is soft and consists of almost pure ferrite. (50x).*

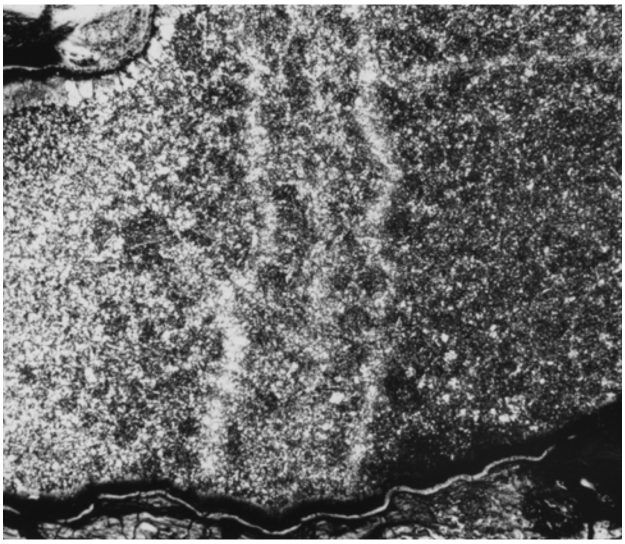


Figure 6.20c. *Sword 19. The welding seams for both edges are seen as three tortuous pale lines across the section. (50x).*

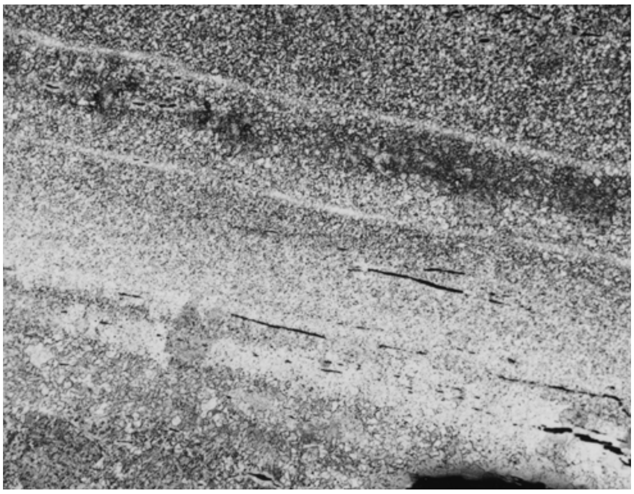


Figure 6.20d. *Sword 19. The left cutting edge is composed of several parallel layers as indicated by light welding seams. (50x).*

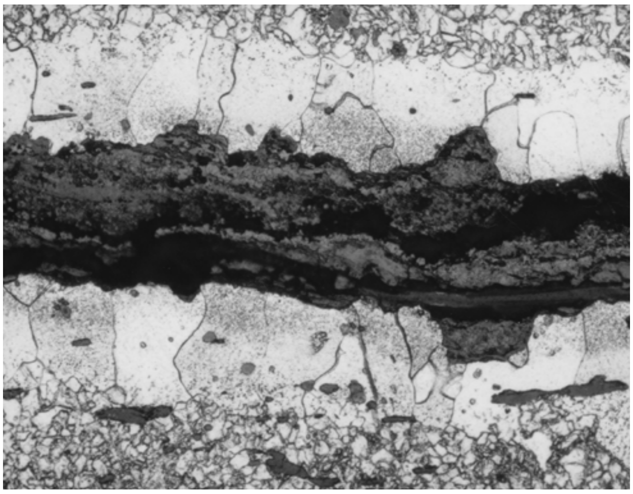


Figure 6.20e. *Sword 19. A crack through the material runs between two layers of mild steel. The decarburisation along the crack must have developed during the last heating of the blade. (200x).*

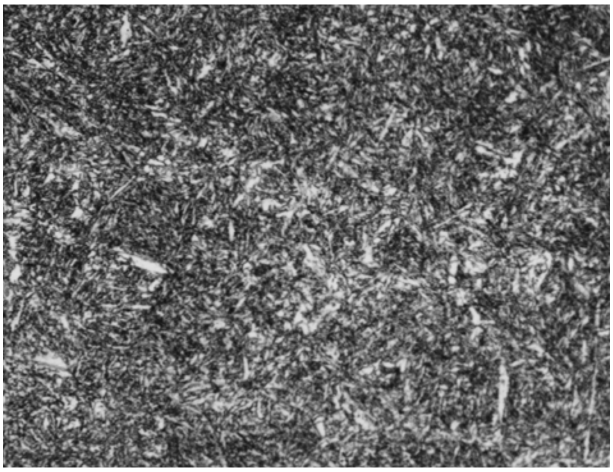


Figure 6.20f. *Sword 19. The highest carbon concentration is observed in the edge on the left part of the section. The structure is quite uniform. (200x).*

This along with other observations show that several different construction schemes were employed in the production of sword blades. Various sword blades may have similar constructions but still be remarkably different in terms of the composition of materials, and hence in the quality of the blades. Such differences have been revealed in the microstructure of the metal. The degree of heterogeneity of the raw material, the distribution and concentration of carbon and phosphorus, grain sizes, heat treatment, and hardness all affect the quality of the sword, independent of construction.

The blade material

Iron production methods in the Viking Age resulted in blooms consisting of a mixture of slag and pieces of metallic iron[8]. Hammering the blooms released pieces of iron which were welded together to form the necessary structure for further smithing and shaping. Currency bars occur frequently in Norway. Ancient iron objects were found to differ considerably in the amount of slag. Small slag inclusions can hardly be avoided, and they are usually not harmful to the quality of the objects. Some authors (Lang and Ager 1989:86) maintain that as long as the slag particles are small, they might even provide a certain strength and stiffness to the iron. Large inclusions, however, have an embrittling effect on the material. The quality of the object required that the blacksmith or smelter worked the material well enough to reduce the amount of slag to an acceptable level. The amount of slag in iron objects can therefore serve as an indication of the quality of the craftsmanship.

In the parts of the bloom that were in close contact with charcoal, some carburisation was likely to appear. However, most of the bloom consisted of iron low in carbon. Such bloomery iron is soft and ductile and needs to be hardened to serve the different purposes of many tools and weapons.

Although the carburised parts of the bloom may have been cut off and used where a harder material

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[8] Blooms found in Norway consist of iron without many slag inclusions. A.M Rosenqvist investigated two blooms and two lightly wrought blooms metallographically. One of the blooms was found at Møsstrond, and Rosenqvist states that this bloom is remarkably free of slag inclusions in the inner part, and the other three are not very different. The shape of the blooms attest to their being formed in shaft furnaces with slag-tapping from the side, which was the dominant furnace type in Norway in the Viking and Medieval periods. Rosenqvist also states that their phosphorus content is low. (Rosenqvist 1979) – *I. Martens*

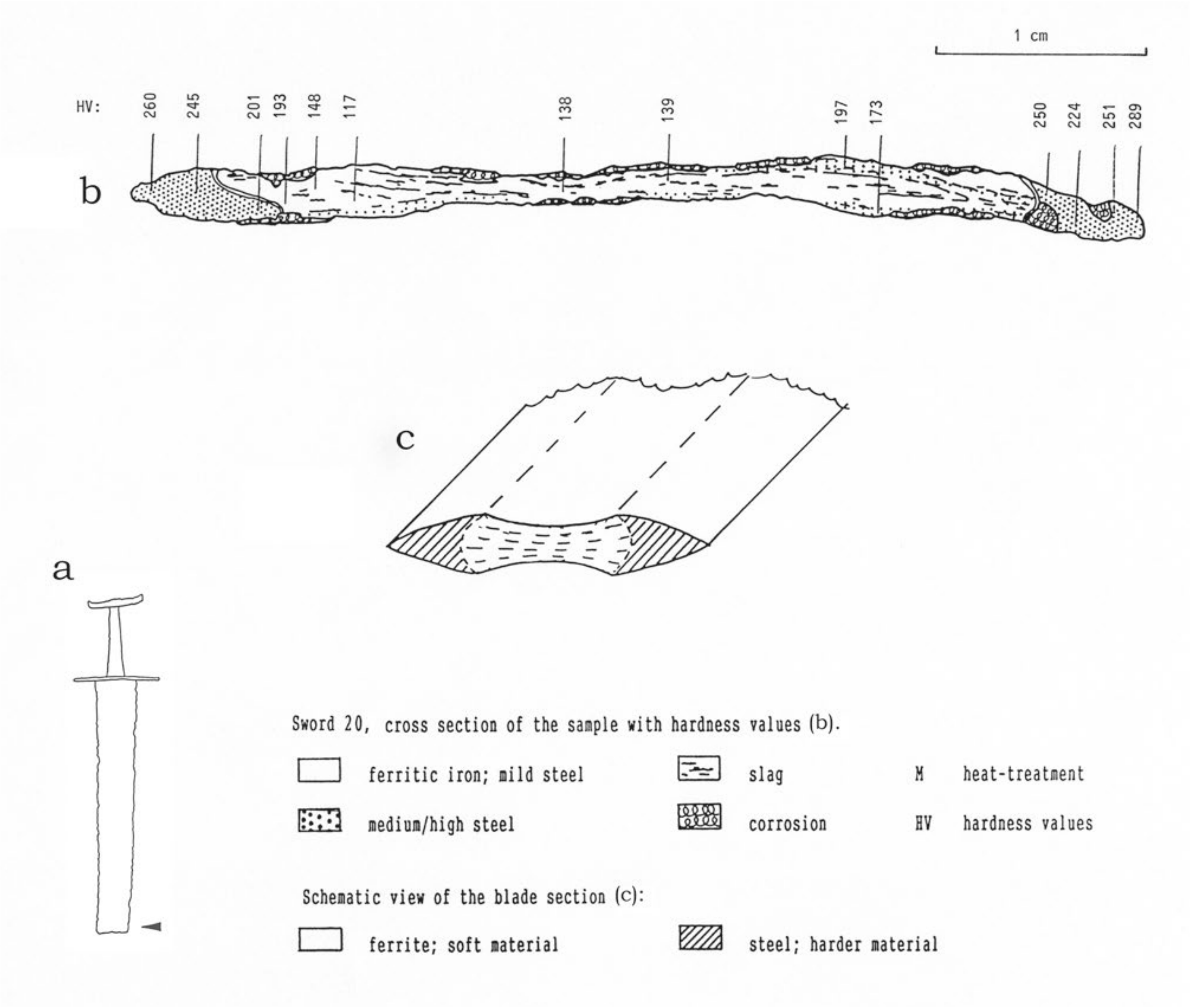


Figure 6.21a. *Sword 20. Cross-section of the sample with hardness measures (b), schematic view of the blade section (c) and outline of sword with section marked (a).*

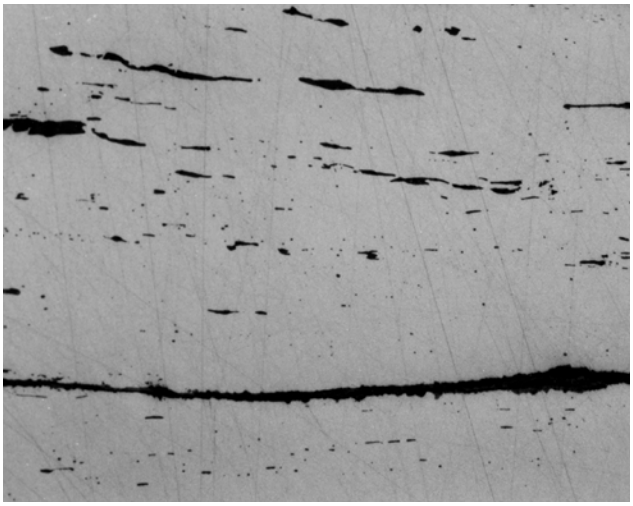


Figure 6.21b. *Sword 20. Unetched. Parallel, flat-forged slag and hammer scale inclusions all over the section indicate that the blade is composed of several layers piled and forged together. (50x).*

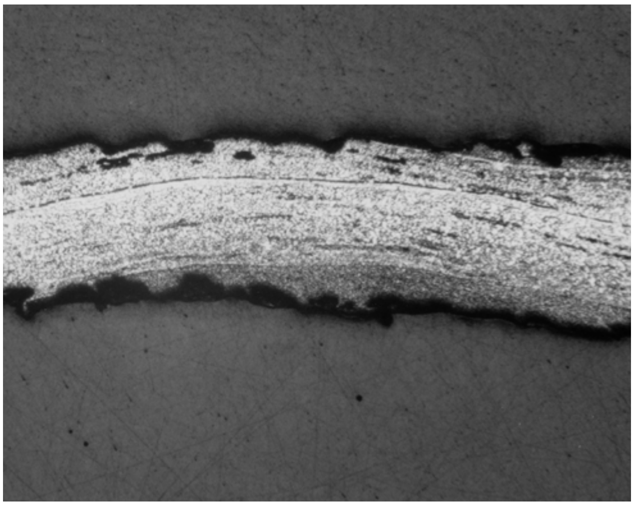


Figure 6.21c. *Sword 20. Most of the central part consists of layers of ferrite separated by numerous lines of pearlite and bands of slag and hammer scale running parallel from edge to edge. Etched in nital. (20x).*

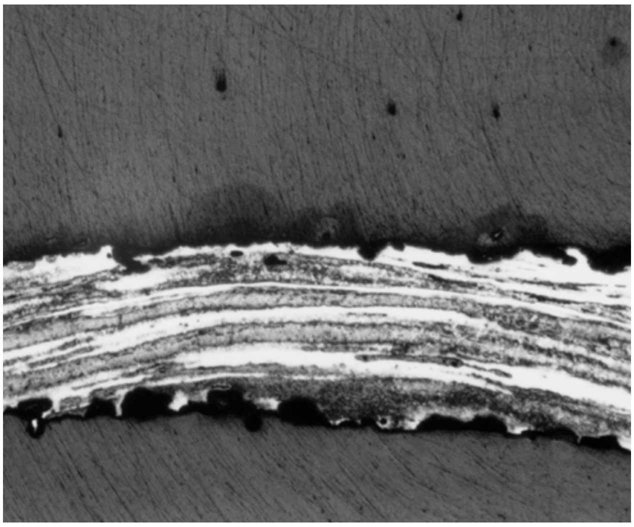


Figure 6.21d. *Sword 20. Same as 6.21c 20/3 etched in Oberhoffer's reagent. Pale layers of phosphorus- rich ferrite. (20x).*

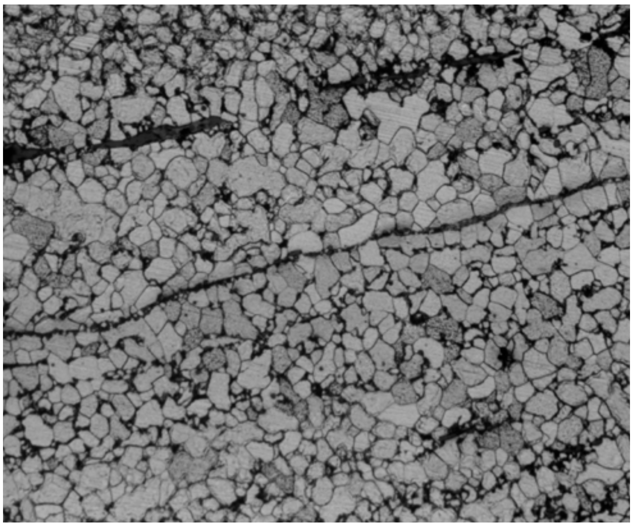


Figure 6.21e. *Sword 20. Ferrite layers separated by lines of pearlite and slag and hammer scale bands running across the entire central part. (100x).*

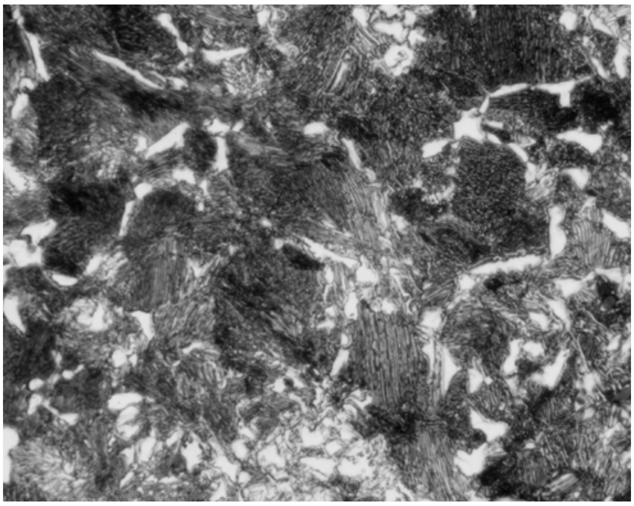


Figure 6.21f. *Sword 20. The left edge consists of lamellar pearlite with medium to high carbon content. (500x).*

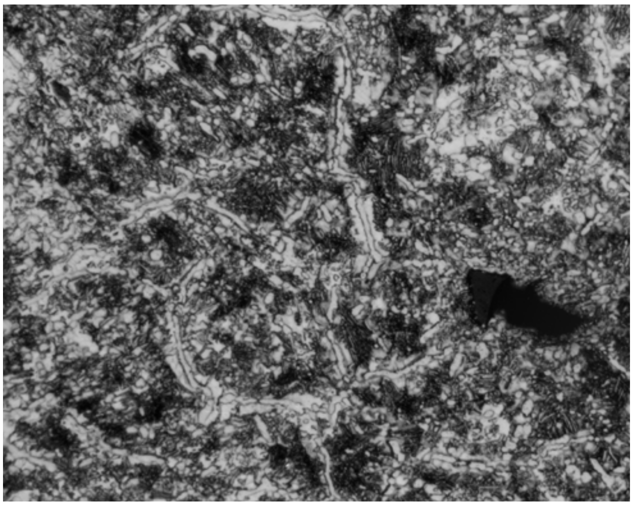


Figure 6.21g. *Sword 20. The right edge consists of medium to high carbon steel with cementite in the prior austenite grain boundaries. (500x).*

was needed, this alone could hardly account for the amount of steel that was used in the Viking Age.

When studying the prehistoric development of the use of iron and steel, and the skill of the blacksmiths, it is essential to examine to what degree hardening iron through carburisation and heat treatment occurred, and whether the harder materials were deliberately incorporated into the objects in places where their specific mechanical properties were most needed. Even if the blacksmith knew that carburisation and heat treatment would improve the hardness of the iron, and hence the quality of the object, he might still not have mastered a technique that was precarious and difficult to carry out successfully.

The presence of elements other than carbon can also increase hardness in iron. Ancient iron objects often show increased hardness as a result of elevated phosphorus content. Phosphorus makes the iron not only harder, but also brittle and difficult to work. Elements like arsenic, nickel and manganese are similar to carbon in their hardening effect on iron, but concentrations need to be several times higher than those of carbon in order to obtain the same level of hardness. Microprobe analyses of several of the blades in this investigation have shown that some of them have high phosphorus content. Except for one blade (sword 12), which is made mainly of phosphorus-rich iron, phosphorus is primarily connected to surface decorations, such as inlays and pattern-welded structures in a part of the blade where some increase in brittleness would not affect the quality of the weapon. The phosphorus-rich iron in these cases must have

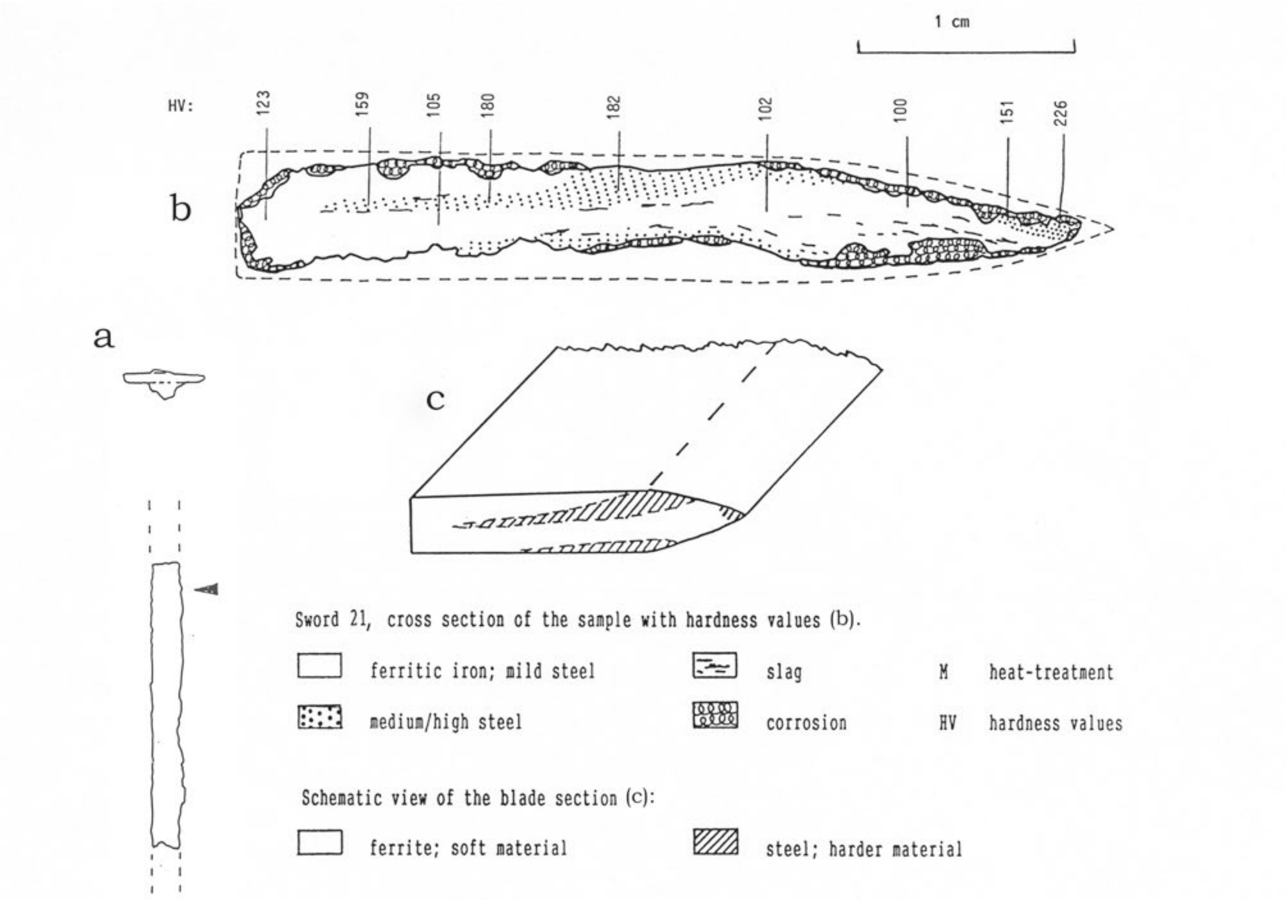
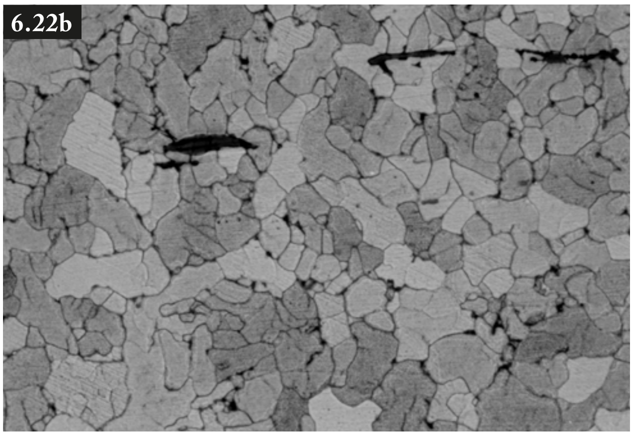
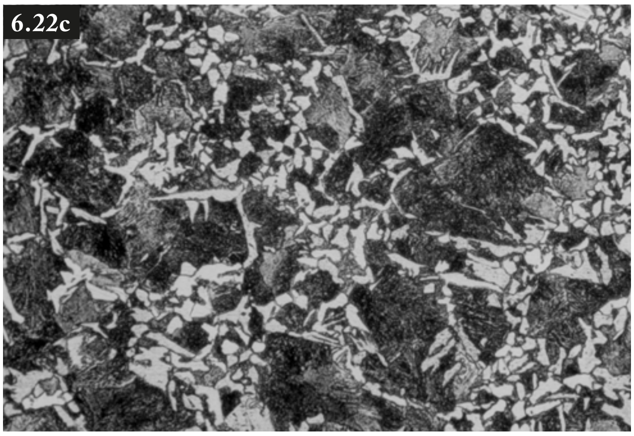


Figure 6.22a. *Sword 21. Cross-section of the sample with hardness measures (b), schematic view of the blade section (c) and outline of sword with section marked (a).*


6.22b


6.22c

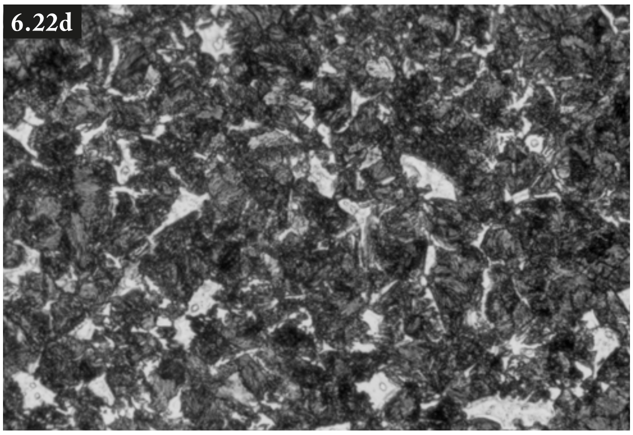

6.22d

Figure 6.22b. *Sword 21. The sample reveals mostly low carbon content. The back is soft and consists of pure ferrite. (100x).*

Figure 6.22c. *Sword 21. A wide band with higher carbon content runs through a large part of the section and bends towards the surface as it approaches the edge. Pearlite (dark) with ferrite (light) grown/precipitated from the austenite grain boundaries. (200x).*

Figure 6.22d. *Sword 21. The highest carbon content is observed at the very edge. (500x).*

been used intentionally to improve appearance, and, after etching, show a distinct difference in carburised iron and iron rich in phosphorus. The levels of arsenic, nickel and manganese measured in this study are too low to have any significant effect on the material.

The construction and composition of sword blades

The different types of blades studied in this work are shown in Figure 6.23, based on their construction and the composition of steel and iron. Three of the blades are single-edged (swords 5, 6, and 21), the remaining 18 are double-edged. All the double-edged blades have a fuller or groove along the centre on both sides of the blade. The literature describes fullers that were cut into the blade (Bennett et al. 1982), and fullers that were forged (Lang 1984). Although the surfaces of most of the blades in the present work were damaged by corrosion, it is obvious from the slightly curved shape of slag bands in the central part that these fullers were produced by forging. Of the 21 swords that have been examined 19 can be described by one of the construction types I, II, III, V, defined in Figure 6.23. The construction of the remaining two blades are difficult to explain (construction type I or IV).

Construction type I. A blacksmith who had insufficient knowledge of materials and inadequate knowledge of carburisation was likely to make his products from bloomery iron, which was worked more or less adequately to get rid of slag, or he probably produced new objects by reusing pieces of old scrap iron of random hardness and elemental composition. The less skilled smith no doubt used whatever material was at hand.

In the present work such simple sword blades are ascribed to construction type I (Figure 6.23), blades made from a single bar where the central part as well as the cutting edges are made from a bloomery iron, or from a fairly uniform material, mostly from soft, ferritic iron, or from iron or mildly steeled pieces forged together randomly. The ferritic blades would be too soft and ductile for a good weapon, while blades of arbitrary composition would not utilise the specific mechanical properties of the materials in order to improve quality. The blacksmiths who produced such blades were not familiar with the properties of steel and how to make it. This kind of construction is represented by the two single-edged blades of swords 5 and 6 (Skien), and by the double-edged sword 12 (Tinn).

Moreover, the blade of sword 16 (Vinje) is a simple construction of soft, fairly pure ferritic iron throughout resulting in inferior functional quality. The blade is well worked. It has an inlaid design, made from twisted wires of mildly carburised iron and phosphorus-rich iron, indicating that the blacksmith had adequate knowledge of the materials. In this case it seems the main purpose was the fine appearance of the blade. In this particular sword this simple construction was most likely intentional, in order to save steel and intricate work (see Chapter 7, the Hedesunda sword).

A high quality sword blade should be constructed in such a way that the core is resilient – not so hard that it would easily break, not so soft that it would easily bend – and the edges should be hard, but not so hard that pieces would easily chip or break in combat.

It has been suggested that soft iron edges might be more advantageous than steel, because the notches acquired in combat could be easily repaired by the warrior himself simply by hammering. However, a soft-edged sword blade would work efficiently for only a short time compared with a steel-edged sword. Some increase in iron hardness can also be obtained by cold-hammering the material. However, such treatment would not improve the overall quality of the sword blade to any great extent.

Significant improvement of the simple iron sword blade was attained by introducing harder, carburised iron in the cutting edges. Metallographic examinations showing different ways in which this was done have been documented in the literature (Tylecote and Gilmour 1986; Kedzierski and Stepinski 1989; Pleiner 1993).

Construction type II. One method of creating steeled cutting edges is to carburise the entire surface of the blade to give it a harder “shell” around a softer core: construction type II (Figure 6.23). In principle this was done through different methods since the Celts (Pleiner 1993:134). Lengthy heating in the presence of charcoal will, under the right conditions in the hearth, result in a thin layer of increased carbon content due to the diffusion of carbon atoms into the surface of the iron blade (case-carburisation) (construction type IIa). However, as already mentioned, the diffusion process is slow, and the carburised steel layer will penetrate only a short way into the surface. It has been assumed by several authors that there might have been difficulties connected to heating the entire sword blade continuously for many hours at a constant temperature. However, judging from examinations of sword blades it seems that at least the specialised smiths had their ways of doing this successfully. Another method that would achieve a carburised surface layer was by hammer-welding a successfully pre-made carburised sheet of steel onto the iron core before finishing the forging of the blade (construction type IIb). The latter method probably produced more reliable results since good quality steel was produced before welding the sheet onto the core. The gradient between the carbon-rich layer and the low-carbon core can be used mostly to distinguish between the two methods of surface carburisation. The carbon concentration gradient is much more distinct, often with hammer scale bands, when a steel layer has been welded onto the core (Figure 6.15b). In case-carburisation the transition is recognised by a more gradual increase in carbon concentration (Figure 6.2d).

In the present work, type II constructions consist of blades forged mainly from fairly pure, soft iron or moderately carburised iron. In sword 1 (Skien), the steeled layer was attained by diffusion of carbon into the surface of the nearly finished blade (case-carburisation) (construction type IIa). In swords 13 (Tinn) and 14 (Tinn), a steel sheet was welded onto an iron core (construction type IIb). This investigation demonstrates that the blacksmiths not only accomplished successful carburisation of these blades, but that they also knew how to quench in order to harden the edges further. All three blades show a structure consistent with heat treatment. However, the result of the heat treatment did not always end up as successfully as was probably planned. Figures 6.14d (sword 13 (Tinn)) and 6.15d (sword 14 (Tinn)) show the steel layers of high carbon content welded onto the low-carbon core, where bands of small hammer scale particles between the steel surface and the iron core indicate welding seams.

Because of corrosion, it is difficult to interpret the construction of sword 2 (Skien) with any certainty. It is obvious that the edges had been carburised, and the tip of the left edge also shows heat treatment (Figure 6.3e). The transition between the carburised zone and the core is more diffuse than would be expected for a welded-on steel sheet, a fact indicating case-carburisation. There are, however, no traces of carburisation along the remaining surface of the blade section. Whether only the edges were carburised, or the whole blade, cannot be ascertained. It is possible that this blade originally had a fully case-carburised surface (construction type IIa), most of which has been lost as a result of corrosion.

The importance of good resilience in a sword blade can hardly be overstated. Thorough descriptions of the springiness of sword blades in Old Norse literature (Davison 1962:164) can only mean that the right combination of iron and steel in the core of the sword blade was well known and highly appreciated. Whether producing a core from more or less homogeneous medium carbon material, or producing piled or laminated core material from alternating sheets of steel and iron, sufficient springiness in the core could be achieved (Ypey 1984).

Construction type III. The superior combination of a resilient core and sharp edges necessitated producing steel edges and a more flexible central part, as shown in Figure 6.23, construction type III. Direct carburisation of the edges in an almost finished iron blade is possible, but the steeled material would be thin and could not survive many resharpenings. Forging techniques in which steel edges were welded onto a medium carbon core or onto a piled iron-steel core were easier to control, and produced more solid and long lasting steel. The steel edges were usually either butt-welded onto the core (Figure 6.23, construction type IIIa) or a steel sheet was bent and welded around the end of the core (Figure 6.23, construction type IIIb). In certain cases, a sheet of steel was welded to only one side of the edge in such a way that there was always steel in the tip, even after resharpenings (Figure 6.23, construction type IIIc). This method would require less of the costly steel.

All the blades with welded-on edges have been classified as construction type III, although the composition of the materials may range from fairly pure iron to high steel. The welded-on edges indicate that the blacksmith was familiar with the importance of having harder carburised edges and a more flexible central part. Otherwise there would not have been any incentive to implement this construction. However, the blacksmith may not have always had the skill to prepare the right materials and to produce an excellent blade.

From the present investigation, it is apparent that blacksmiths were familiar with the superior quality of this type of sword blade construction. Half the blades examined have this type of construction, including all of the best ones. Also, all the blades with this construction were found to have carburised edges. Only fairly small amounts of hammer scales were observed in the welds of most sword blades examined here. It also appears from the X-radiographs that the blacksmiths most often mastered the difficult technique of skillfully welding the edges to the central part all along the blade. Moreover, the technique of quenching appears to have been known to many Viking Age smiths, although not to all of them. In this work about

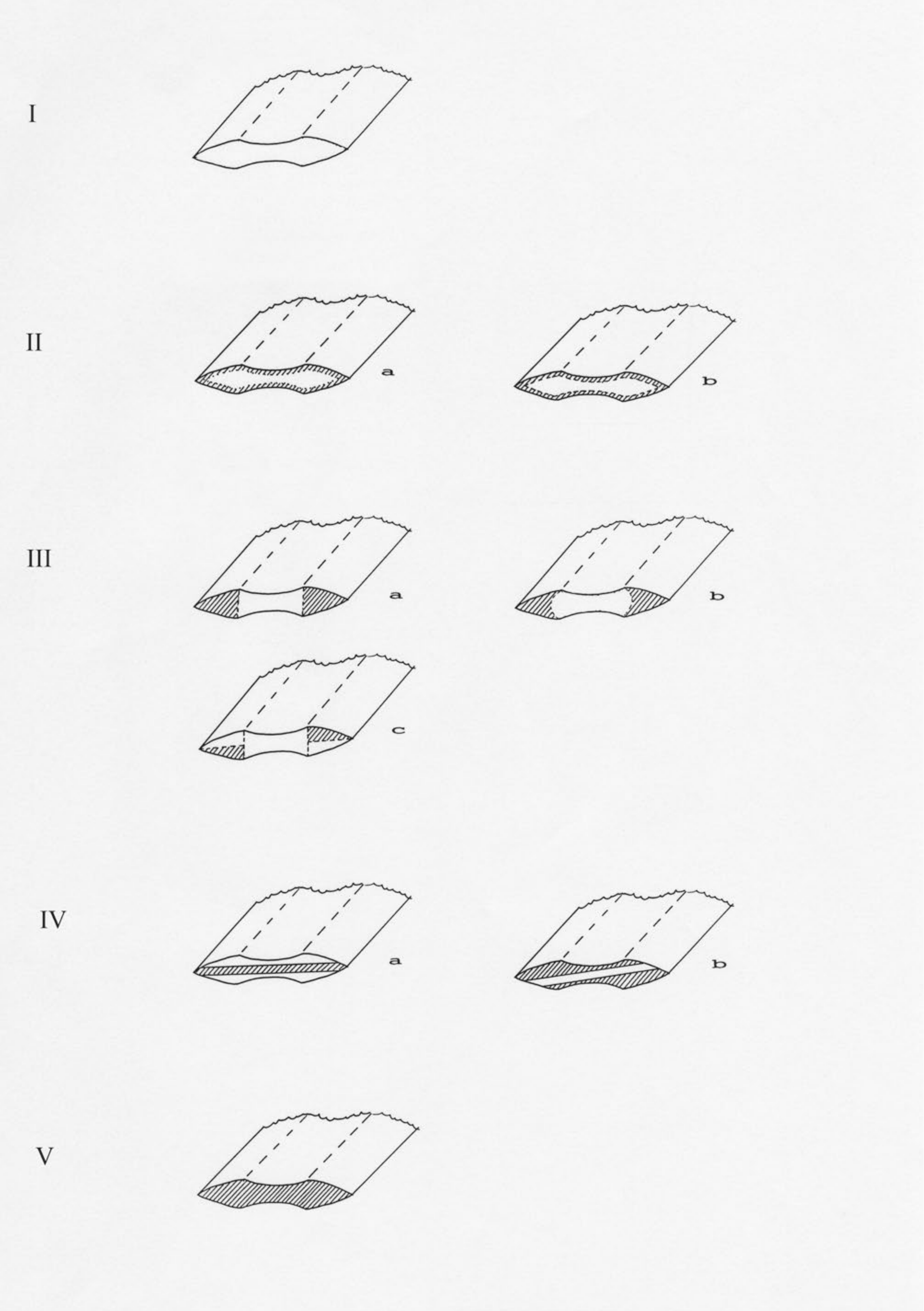


Figure 6.23. Construction types for Viking Age sword blades from Telemark.

40% of the blades of type III construction show more or less successfully quenched edges (Table 6.2).

This construction seems to have become well-known and fairly widespread in Telemark in the Viking Age, at least in the parts of the county covered by this study. This includes coastal zones, inland, valley and mountain areas (Kaland 1972; Martens 1995). Nine of the 21 blades found in eight of the nine municipalities studied have edges welded onto the core (Table 6.2: swords 3 and 4 (Skien), swords 7 and 8 (Porsgrunn), sword 9 (Bø), sword 11 (Tinn), sword 15 (Vinje), sword 17 (Tokke), sword 19 (Kviteseid), and sword 20 (Nome)). Nine of the 11 blades show butt-welded edges (construction type IIIa), one has the steel bent around the edge of the core (sword 7, Porsgrunn) (construction type IIIb). Also, sword 20 (Nome) probably has the latter construction. However, sword 20 deviates somewhat from the other swords in construction type III. The welded-on steel edges are unusually narrow, and the core has a piled, laminated structure throughout, the materials being soft iron and phosphorus-rich iron with bands of pearlite in between.

The obvious advantages of welding on pre-made steel sheets or steel edges to a core were: first, that the steel could be thicker and consequently longer lasting; second, that the smith knew he had a good piece of steel before it was introduced into the sword blade. The chance of bad luck during carburisation would be minimised.

In construction type III, only swords 3, 4, 8, and 9 had been heat treated.

Construction type IV. Another construction type which, according to the literature (Gilmour 1986), was fairly common in the Viking Age is the "sandwich" type, in which layers of steel and iron are piled and welded together in an edge-to-edge direction, so that there is always a steel layer running through the cutting edge (Figure 6.23, construction type IVa). This kind of construction would assure a varying degree of resilience to the blade, as well as providing the sword with harder, quenchable steel edges using a minimum amount of steel.

Different types of sandwich constructions are well known from swords, as well as from other cutting objects from the European continent and Britain (Tylecote and Gilmour 1986), and it is assumed that this method of producing sword blades developed from making knife blades.

The sandwich constructions may consist of one or more parallel steel layers piled alternately onto layers of iron. Steel layers may run either all the way from edge to edge (Figure 6.23, construction type IV) or they may be found only in the edge areas, which are then welded onto a separate core. In the latter case they would be classified as construction type III in this work.

It is not evident that any of the sword blades in this investigation have the edge-to-edge sandwich construction with a steel layer running through the actual tip.

Two of the examined blades cannot be easily placed within any of the mentioned types of construction. Sword 18 (Tokke) and sword 21 (Fyresdal), being double-edged and single-edged respectively, both have some kind of layered structures of fairly pure iron and mild steel.

Sword 18 (Tokke) has a kind of layered structure with a ferritic iron layer between two moderately carburised layers (possibly like Figure 6.23, construction type IVb). This may well be an intentional composition of alternating bars of steel and iron welded together in a somewhat oblique way. However, in one of the two examined sections of this blade only one of the edges coincides with the steel layer, while the other edge has fairly low carbon content. In the second section, carburised layers run through both edges (Figure 6.19a). The lack of steel in one of the edges in one section may have simply been due to somewhat unsuccessful forging. Similar structures of slanting layers of a softer material embedded between harder materials have been reported by Pleiner for Celtic swords (Pleiner 1993:136, 148). This construction, however, has not been reported in later sword blades from the Roman (Kedzierski and Stepinski 1989), the Anglo-Saxon and the Viking periods (Gilmour 1986). It therefore appears that the construction of this sword may be an accidental combination of sheets of steel and iron, or possibly a local construction type. This obliquely piled structure, when properly done, would have steel edges and some flexibility in the core. However, it does need more steel than necessary in a traditional sandwich construction, where one layer of steel running from edge to edge is sufficient.

The single-edged sword from Fyresdal (sword 21) has a different kind of layered structure, which may have been an unsuccessful attempt at making a sandwich welded together from layers of fairly pure iron and two layers of low-carbon iron (Figure 6.22a). The main purpose of a sandwich structure is to produce steel edges and adequate flexibility in the core using a minimum of steel. In sword 21 a carburised layer runs through the centre of most of the section, but ends up at the surface next to the edge. This may be due to bad luck during forging. The layers of carburised iron may also have been welded into the soft material just to stiffen the blade. A completely random composition of pieces of iron of differing carbon content is less likely, since the presence of a carburised tip of the edge shows that the blacksmith was far from unskilled. However, a random construction (construction type I) cannot be ruled out.

Construction type V, consisting of sword blades made entirely of steel, was not commonly found (Tylecote and Gilmour 1986:2; Pleiner 1993:138). After all, steel was time-consuming and costly to make. Also, the quality of the blade would not be improved compared to blades made of laminated sheets of alternating ferritic and steeled iron.

Sword 10 – the blade as well as the hilt – is clearly different from all other swords studied here. The blade material was made from a bar composed of several pieces of high-carbon steel. The blade has been quenched. The material is the same throughout the section, and the hardness values are high. This sword is, however, not indigenously made (see Chapter 4). Further, sword 8 (Porsgrunn) consists of a steeled material of medium to high carbon content throughout the section. However, as this sword has welded-on edges it has been classified as construction type III. It is assumed that the steel core, which is hard but softer than the edges, represents an attempt to make a flexible but not too soft material. It did not quite end up as such.

Chemical analyses. When etching the sections with nital, pronounced welding seams – particularly between the edges and the central parts in blades of construction type III – become visible as “pale lines”. It was important to analyse such “pale lines” in order to find out to what extent reactions other than decarburisation, took place when welding the pieces together.

One weld in each of the following swords has been examined by microprobe analyses in steps across the “pale lines”: swords 4, 11, 15, 17, and 19. The concentrations of arsenic, cobalt, nickel, manganese, copper and phosphorus have been determined. In these blades, phosphorus, copper and manganese were found to be present in fairly constant concentrations, too low to be of importance here. For all the examined sections the enrichment of cobalt is pronounced (Figure 6.24 a-e). Some arsenic enrichment was detected, but to a lesser degree than cobalt, while the enrichment of nickel is little or none. The general concentrations of cobalt, arsenic, and nickel in the bulk of the materials were quite low and typically less than 0.03wt% for all three elements. Enrichment of elements like cobalt, arsenic, and nickel in the welds was expected on the basis of results from other investigations of early iron (Tylecote and Thomsen 1973; Tylecote 1990; Modin and Modin 1988; Becher 1961; Thomsen 1971; Rosenqvist 1970). The suggestion in some of these papers, that an interlayer of high arsenic content had been introduced to facilitate the joining of iron and steel, has been questioned by Tylecote and Thomsen (1973). Arsenic-rich iron, in the same way as phosphorus-rich iron, suffers from severe hot-shortness, which would make forging down to thin sheets difficult. More probably, Tylecote and Thomsen suggest, the high-arsenic layers observed in the welds are due to the formation of arsenic segregates during forging. All three elements, cobalt, arsenic and nickel, oxidise slower than iron (Modin and Modin 1988; Tylecote and Thomsen 1973). During heating in the welding process the iron is oxidised, while cobalt, arsenic, and nickel are enriched in the surface layers. Phosphorus, being slightly less noble than iron, oxidises faster. Therefore, it does not accumulate in the weld during oxidation, but enters the oxide film (hammer scale) in the metal-oxide interface during forging.

The widths of the welds as estimated by the concentration profiles of cobalt enrichment are seen to be in the order of 0.07–0.12 mm (=70–120µm) in all the sections.

The structure of certain areas in the central part of sword 2 shows several parallel, light, wavy bands (Figure 6.3d). There are no other indications of welds, such as hammer scale particles or bands. Microprobe analyses across the pale bands confirm the presence of significant arsenic enrichment, and a slight enrichment of cobalt in the light bands (Tylecote 1990).

While the microstructures of the ferritic areas in some of the blades (swords 7, 16, 19, and 20) indicate fairly soft materials, hardness values show unexpectedly high readings. This was assumed to be due to the elemental composition of the materials, most likely the presence of phosphorus. As described in the experimental part, etching with Oberhoffer’s reagent has been carried out on all the blade sections in order to map the presence of phosphorus in the iron. The blade sections which showed positive reactions to phosphorus segregations were further subjected to quantitative microprobe analyses. The presence of phosphorus-rich wrought iron was found to be connected mostly to surface decorations, such as inlays and piled structures where distinct and pleasing patterns were essential. Phosphorus-rich iron is found in the inlays of sword 16 (c. 0.27wt%, Figure 6.25) and in the piled structure of sword 7 (0.24–0.41wt%). Also, the layered structure observed in almost the entire central part of sword 20 was found to have elevated phosphorus content in the wrought iron layers (c. 0.28wt%). While the phosphorus-rich iron in the piled and pattern-welded parts of sword 7 and sword 16 must have been used deliberately, the use of phosphorus-rich iron in sword 20 is more difficult to explain. In this case the appearance cannot have been the intention, since the different layers are not visible on the blade surface. However, the presence of phosphorus not only influences the appearance, but also the hardness (and brittleness) of the material. It is therefore possible that this was used intentionally in the central part to produce a somewhat harder material. An accidental use of phosphorus-rich iron cannot be disregarded, but a skilled blacksmith would notice the difference between pure and phosphorus-containing iron during forging. The overall quality of sword 20 is decent. The smith was most probably a skilled specialist.

Only one blade (sword 12) is made almost entirely of phosphorus-containing iron. The material is somewhat heterogeneous with variable phosphorus content around 0.15wt%. This accounts for the increased hardness appearing in the ferritic materials.

In sword 19, one edge appears to be made from a layered material, while such layering is not observed in the other edge. Microprobe analyses across the layers indicate some enrichment of cobalt between the layers. However, the concentration is low, less than 0.05wt%. The concentrations of phosphorus, arsenic, and nickel are less than 0.03wt%, with no typical enrichment of arsenic and nickel in the welds. The presence of this layered structure must be due to some decarburisation in the welds of the material.

Surface decoration of the sword blades

A large number of Viking Age swords have been reported to have pattern-welded or inlaid blades. Lang and Ager (1989) and Kirpicnikov (1970) report that about half of the examined sword blades were made this way.

The characteristic decorative appearance of pattern-welded sword blades is usually due to a combination of sheets or rods of different materials such as pure iron, carburised iron, or phosphorus-rich iron. These materials react differently to etching, through which different patterns appear determined by cutting, twisting and forging the rods. Also, piled layers of the same material may produce the desired pattern when twisted and welded together (Anstee and Biek 1961), due to bands of trapped slag in the welds generating contours in the layers.

Whether the piled structures were twisted or just running parallel would probably not affect the properties of the core, though twisting the strips before polishing and etching the blade would certainly add to the fine appearance of the weapon.

Pattern welding has been considered to be a procedure used mainly to improve the flexibility and resilience of the blade. However, in recent years several authors seem to agree that pattern weldings served mostly as decorative elements (Tylecote and Gilmour 1986:1; Pleiner 1993:143). This opinion is based on the fact that extensive use of the pattern welding technique in sword blades began with wholly pattern-welded core materials around the 3rd century AD. On the continent, it developed into only thinly pattern-welded surface layers covering the blade core around the 5th century AD (Williams 1970; Lang and Ager 1989; Anteins 1968; Müller-Wille et al. 1970, 1982; Thomsen 1989; Thålin 1967). In the latter case it had no functional value, but the weapon still retained its impressive appearance. Later on, at the end of the 9th century AD, pattern welding becomes less common and is usually found only as inlaid letters and designs on blade surfaces (Müller-Wille et al. 1970:82, 1982:147,149). At this stage one realised that the same mechanical properties of the blade could be achieved through simpler methods. Sword blades of the 9th–11th centuries AD were frequently made by piling alternate pieces of iron and steel into a bar and forging them together without twisting (Williams 1970:75).

The blades in this study represent a selection of swords from within a certain geographic region, the county of Telemark (Figure 6.1). The presence of decorative elements such as pattern weldings and inlays is quite accidental. Only three of the 21 swords in this investigation have some kind of surface design (swords 7 (Porsgrunn), 10 (Tinn), 16 (Vinje)). The observed designs, whether inlays or pattern welding, are barely visible on the X-radiographs.

The piled structure of the pattern weldings in sword 7 (Porsgrunn) shows up in the micrographs as parallel layers of phosphorus and arsenic containing wrought iron and medium carbon steel respectively. The piled structures are present as thin sheets welded onto the surface of each side of the ferritic central part of the blade. Due to surface corrosion, the piled layers are partly discontinuous. Neither from the X-radiographs nor from the micrographs is it possible to recognise

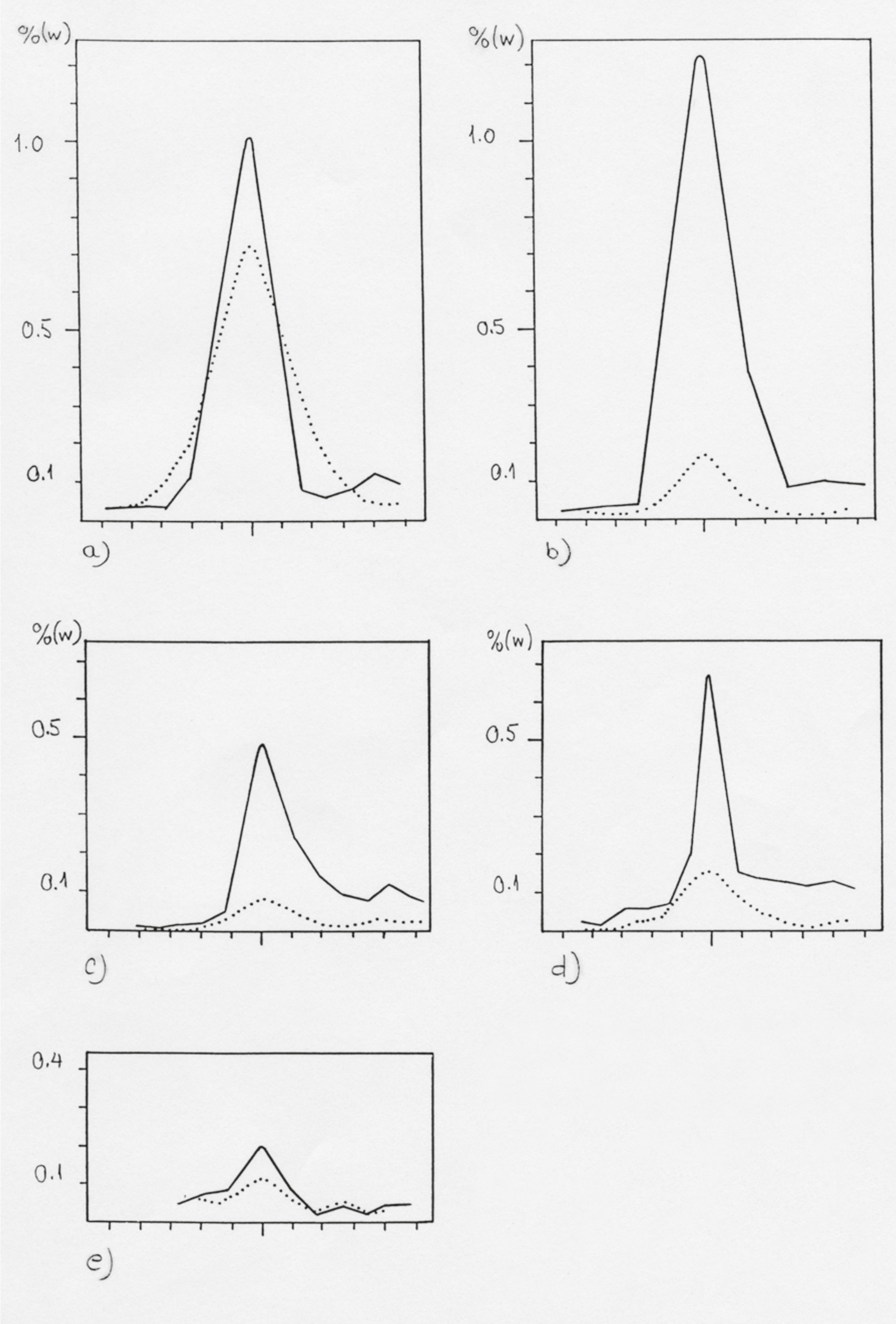


Figure 6.24. *Concentrations of cobalt – seen as a coherent line, and arsenic …? measured by electron probe microanalysis across the edge-to-core weld in: a. sword 15; b. sword 11; c. sword 17; d. sword 4; e. sword 19 (across one of the pale lines); and f. sword 16. The concentrations, shown on the ordinate, are measured in % (w); each step across the weld shows none.*

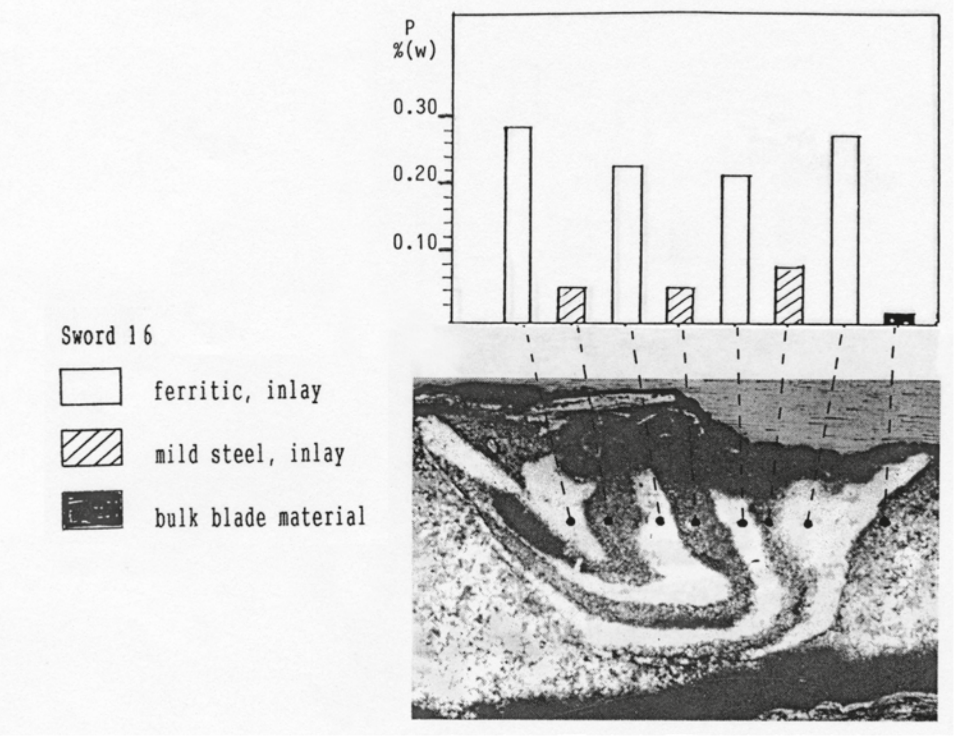


Figure 6.25. *Sword 16. The diagram (top) shows the phosphorus content in each layer of one of the inlays (bottom).*

the pattern with any certainty. However, parts of the X-radiographs seem to indicate two rods forming a "herring bone" pattern, i.e. two piled rods twisted in opposite directions.

Swords 10 (Tinn) and 16 (Vinje) both have inlaid designs in the blades. This is confirmed by X-radiographs. Stereoradiographs of sword 10 show two "omegashaped" inlays with a cross potent in between on one side of the blade. On the reverse, a roundish character is observed (Figure 6.11b).

Only the hilt and a small part of the upper blade remain of sword 16 (Vinje). Vague traces of an inlaid inscription on the surface can be seen, and also confirmed by X-radiograph. However, it is impossible to identify the characters. The section cut for the metallographic study runs right through some of the inscriptions on each side of the blade. This provides a good opportunity to study how the inlays were produced. Chemical analyses revealed that the inlaid characters were made from several wires of fairly pure iron, and iron with significant phosphorus content (0.27wt%, Figure 6.25). The wires were twisted, forged together and shaped prior to insertion into the soft, ferritic blade surface as described above.

6.5 CRAFTSMANSHIP AND THE QUALITY OF THE BLADES

A blacksmith who could produce high quality sword blades must have had solid and extensive practical knowledge of the specific mechanical properties of the materials with which he was working. During forging, he would notice the difference between wrought iron and steel. Moreover, phosphorus-rich iron would be recognisable because of its hot-shortness during forging and the brittleness of the finished product. Many of the same properties would appear in the case of high arsenic content, as phosphorus and arsenic have many common properties. However, such high arsenic content appears less frequently than phosphorus. Further, the presence of other elements in the iron may influence its material properties, but most likely this was not noticed by the blacksmith, since that would require an inconceivably high concentration of the elements. A competent smith obviously had the knowledge and ability to make good steeled iron through carburisation, and to harden the carburised iron sufficiently through heat treatment. Presumably he also had the practical skill to work the materials well enough to minimise the amount of slag and to avoid serious cracks, as well as to produce strong and solid welds between iron and iron alloys of different melting points. Further, he must have had adequate experience in how to combine the materials in order to attain good resilience in the core and the required hardness in the edges.

Based on the above, one can conclude that the blades examined in this work range from poor to high quality (Table 6.2). The table shows the quality of the sword blades from different find sites. A few of the blade sections in this work show remarkably high amounts of slag inclusions. Assuming that the sections are representative of the whole blade from which they were cut, such blades must have been weak and likely to break. High slag content, typical of materials having been insufficiently worked by the blacksmith, can be found in sword 1 (Skien) and sword 12 (Tinn). Sword 1 otherwise shows carburised surface layers (construction type IIa) which have been quenched. This indicates that the smith had fair knowledge of the production of sword blades, but that he did not practice his craft skillfully. The other blade rich in slag, sword 12, is made of phosphorus-containing iron throughout, which would improve the hardness of wrought iron but also increase brittleness significantly.

Those sword blades, which seem to be composed of random pieces of iron of varying composition, would be generally inferior in combat. The single-edged swords 5 and 6 (both from Skien) are typical examples of random composition (construction type I), soft materials, and poor functional combat capability. In addition, sword 15 (Vinje) must be classified as a relatively poor weapon. Although the blade has welded-on edges (construction type III) and a slightly higher carbon concentration in the edges, it is made from materials that are too soft throughout. This blacksmith obviously had some knowledge of the principles of making steel and of blade construction, which would normally result in a high quality blade. Unfortunately, he does not seem to have had the skill to carburise the iron sufficiently. As a combat weapon, sword 16 (Vinje) must also be classified as poor, since it was made from soft wrought iron throughout. As mentioned, the advantage of soft iron, which could be repaired by the warrior himself simply by hammering, can hardly compensate for the disadvantage of a sword that would serve its purpose for only a fairly short time in combat, due to bending and notching. However, the combination of soft blade material and inlays in the blade indicates

Table 6.2. *Features and Qualities of Metallurgically Investigated Blades.*

Sword No	Municipality	Hilt-type	Edges	Construction	Carburised	Quenched	Edge hardness (HV)		Slag content	Functional quality	Blade decoration
1	Skien	M	2	III(c?)	X	X	498		++	Poor	
2	Skien	M	2	IIa ?	X	X	551		0	Fair	
3	Skien	V	2	IIIa	X	X	325		+	Decent	
4	Skien	M	2	IIIa	X	X	590		+	High	
5	Skien	M	1	I			119	Soft	+	Poor	
6	Skien	M	1	I			156	Soft	0	Poor	
7	Porsgrunn	H	2	IIIa	X		263		+	Fair	Pattern-welded
8	Porsgrunn	Q/X	2	IIIa	X	X	591		0	High	
9	Bø	Q	2	IIIa	X	X	613		0	High	
10	Tinn	LA	2	V	X	X	636	Brittle	+	Decent	Inlayed signs
11	Tinn	Q	2	IIIa	X		283		0	Decent	
12	Tinn	Xa	2	I	Phos		178		++	Poor	
13	Tinn	Xa	2	IIb	X	X	413		0	Decent	
14	Tinn	Xa	2	IIb	X	X	420		+	Decent	
15	Vinje	Q	2	IIIa	X		153	Soft	0	Poor	
16	Vinje	H	2	I			165	Soft	0	Poor	Inscription
17	Tokke	Q	2	IIIa	X		201		0	Fair	
18	Tokke	Und	2	IV?	X		245		+	Decent	
19	Kviteseid	Und	2	IIIa	X		201		0	Fair	
20	Nome	Q	2	IIIb	X		289		+	Decent	
21	Fyresdal	M	1	IV (I?)	X		226		0	Decent	

Phos= phosphorus-rich iron.

that such swords might have been produced more as prestige weapons than for combat purposes. The nicely decorated hilt supports this assumption. A qualified smith would probably not have wasted precious steel where it was not needed.

The slag inclusions are denoted by 0; small amount and particles by +; moderate amount or numerous small, flat particles, ++; large amount, large particles, probably weakening the product.

LA = Late

Three of the four swords classified as fair quality have carburised edges. Three have welded-on edges (construction type III: sword 7 (Porsgrunn), sword 17 (Tokke), sword 19 (Kviteseid)), and one has edges that were carburised by direct carburisation of the nearly finished blade (construction type IIa: sword 2 (Skien)). Sword 7 shows a pattern-welded surface layer in the central part of the blade. Since the layers are only surface elements, they did not particularly improve the sword's mechanical properties as a weapon. Examination of these blades reveals that the smith had a fair understanding of sword blade constructions. However, these blades still cannot be classified as decent or high quality weapons, either because the degree of carburisation was too low or because heat treatment was lacking or insufficient.

Eight blades qualify as decent combat weapons, namely: swords 3 (Skien), 10 (Tinn), 11 (Tinn), 13 (Tinn), 14 (Tinn), 18 (Tokke), 20 (Nome) and 21 (Fyresdal). The makers of these blades were skilled craftsmen. The materials were worked well: the welds were carried out skillfully, and no severe cracks from the forging process were observed on the X-radiographs. The construction types of these blades (II, III, IV, Figure 6.23) and their compositions suggest that the blacksmiths also had adequate knowledge of the carburisation process and of sword blade constructions. All the blades have been carburised to an adequate level. However, five of the blades have not been heat treated. Still, the hardness in the edges of all these blades was measured to be above 220 HV, which is a fairly satisfactory material for a sword blade. Swords 13 and 14 have been heat treated. Both blades are type II constructions. The hardness measured in the steel layers, including the edges, is adequate, but especially in sword 13 the core is very soft and could easily bend in combat. It seems reasonable to assume that type II constructions are generally somewhat inferior to construction type III. Construction type II has a hard steel layer covering a softer inner iron core. This would provide less flexibility to the blade body. Most likely, a hard blow to the blade would easily result in cracking the thin steel layer.

Sword 10 (Tinn) is also classified as a decent weapon (construction type V). Despite the fact that this blade was highly carburised and successfully quenched, it was hardly an excellent weapon. Being made of highly carburised iron throughout, the core was also quenched to a hardness that makes the blade very hard and brittle. It lacks the resilience which is so important in sword blades.

The best blades examined in this work are sword 4 (Skien), sword 8 (Porsgrunn), and sword 9 (Bø). These blades show a favourable combination of high skill, solid knowledge, and an understanding of the importance of carburisation, heat treatment, blade constructions and craftsmanship. These blades are all type III constructions. The edges have satisfactory carbon content. In the case of sword 8, the core may perhaps be somewhat too hard and to some extent brittle. The heat treatments of swords 4 and 9 were found to achieve the right hardness of the edges and a suitable resilience of the core.

The significance of the sword in Viking Age society

Although the purpose of the sword must originally have been to serve as a weapon, it seems obvious that it has also served as a symbol of social status. This can be clearly seen from the time-consuming and elaborate work invested in many blades and hilts, which in no way improved the functional quality or combat capability of the sword. Indeed, a solid pattern-welded core in a sword blade contributed both to the marvellous appearance and to the resilience of the blade. However, comparable quality could still have been achieved through simpler but less visible and impressive techniques, like piling of the materials. For the large number of sword blades reported in the literature, in which inlays and pattern weldings are only surface features, such adornments had no influence on functional quality. As demonstrated in the present work (sword 16) and also pointed out by other authors (Gilmour 1986; Lang and Ager 1989), there are even beautifully decorated sword blades of poor functional quality. Therefore, it seems reasonable to suggest that such swords were made more as weapons of prestige than for combat purposes. On the other hand, the present work also shows that sword blades of high quality frequently appear without any decoration (swords 4, 8, 9). Thus, it cannot be concluded that swords with a pleasing appearance were necessarily high quality weapons or vice versa.

The difference in combat capability between poor and high quality sword blades is considerable, and the poor-quality swords would surely have performed badly in combat under otherwise equal conditions. Still, the number of poor blades appears to be significant. There may be several reasons for this. Poor blades produced by less skilled smiths were probably cheaper and easier to obtain. In order to handle a sword effectively in combat it was necessary to have had adequate training. It seems reasonable to assume that not every free man could handle a sword properly, and consequently did not invest in an expensive one. Or he simply could not afford the best that was available. Good weapons training was probably reserved mostly for men from the more prosperous segments of society. Especially in marginal areas, where society was less well organised than in central districts, one can easily imagine that a sword was handled and appreciated as a weapon to a lesser degree, but much more as a symbol of status. It was the privilege of the free man to bear weapons. Simply to own a sword – independent of quality and decorations – probably gave a man of lower social rank a highly appreciated status among equals.

However, men who first and foremost used their swords as weapons must have been able to distinguish differing quality, a fact also chronicled in Old Norse literature. These men would hardly run the risk of ill-matched combat due to a poor sword. Most probably, they would prefer a high-quality blade rather than a striking appearance, if they could not afford both.

6.6 CONCLUSION

Viking Age sword blades from Telemark have been analysed in order to gather comprehensive information on the construction and composition of sword blades, as well as acquire knowledge about iron manipulation and the craftsmanship of blacksmiths.

The study includes 21 sword blades recovered from coastal and central areas, from inland valley districts, and from sparsely and more densely populated areas. For certain districts, several swords have been studied in order to see if there were typical local features and variations in smithing techniques. The metal structures of the blade sections have been studied using metallographic analyses and hardness measurements. The elemental compositions of pattern welding, inlays and piled structures, as well as welding seams have been determined through electron probe microanalyses. This examination leads to the following conclusions:

1. The analyses show that the carburisation process became well-known to most blacksmiths, enabling this kind of weapon production during the Viking Age. Carburised iron and steel were deliberately incorporated into most of the blades in ways that improved the quality of the weapon. Eighteen of the blades were carburised, although a few of them not quite successfully. Successfully carburised sword blades have been found in every district included in this work (Table 6.2). This is hardly surprising, since carburisation of iron had already been successfully practiced for more than 2,000 years in the eastern Mediterranean by the time of the Vikings. Although dissemination of this technology was slow – probably intentionally so – the need for processes by which soft wrought iron could be hardened would nevertheless have been an incentive in the development of iron manipulation.

2. The metallographic structures and hardness measurements of the blades demonstrate that heat treatment or quenching of the blades was found in swords in the districts of Skien, Porsgrunn, Bø and Tinn, all of which were active and central areas in Telemark in the Viking Age. However, this technique was far from familiar to every smith. No heat treatment was observed in blades found in other districts included in this work (Table 6.2). Nine of the swords in this investigation (40%) indicate some degree of heat treatment. Some of the swords show a metallographic structure corresponding to a more or less full quench, while several swords underwent incomplete quenching. This may be due either to an unintentionally slow cooling rate, or to a skilled blacksmith who, on purpose, discontinued the cooling before a full quench was attained (slack quenching) in order to prevent the material from being too hard and brittle. The fact that quenched steel appears be present in the coastal and central areas, and absent in more remote districts, may indicate that the development of iron manipulation and the influence of foreign technical improvements were more pronounced in areas of higher activity and heightened contact with other countries. However, the lack of this more "sophisticated" technique in certain areas of Telemark may also reflect the limited number of swords examined so far.

3. The metallographic analyses demonstrate different ways in which sword blades were constructed (defined by construction types I, II, III, IV, V, Figure 6.23). Twenty of the blades can be ascribed to four different construction types (I, II, III, V). For two of the blades it is difficult to distinguish a deliberate construction from an accidental one. There is, however, some support for a deliberate, but not quite successful handling of both blades (construction type IV, Figure 6.23).

Ten blades (50%) were constructed with harder (steeled) edges welded onto a softer, more resilient core (construction type III). However, the attempts of the blacksmith to produce harder materials for the edges and resilient materials for the core were not always successful. One can deduce that this represents the most common blade construction observed in this work. This construction type is present in eight of the nine municipalities encompassed by this study (Table 6.2). However, with only one sword sample from the ninth (Fyresdal) one cannot conclude anything meaningful. Blade constructions in which a softer core is overlaid with a thin steel layer appear in four of the swords (construction type II). In two of these blades, the carburised surface layer was produced by direct diffusion of carbon into the nearly finished sword blade, case-carburisation (construction type IIa). In the other two, a pre-made steel layer has been welded onto the surface of a softer core (construction type IIb). Only one of the blades has a fairly homogeneous all-steel composition, forged from a single bar of high carbon content (construction type V), and possibly two blades seem to have some kind of "sandwich" structure (construction type IV). From this study the "sandwich" construction does appear to be typical for sword blades in Telemark in the Viking Age. A group of simpler blades (construction type I), considered to be inferior in battle to the construction types mentioned above, consisted of either random pieces of iron and mild steel, a fairly homogeneous material of phosphorus-rich wrought iron, or an almost pure soft wrought iron.

4. The craftsmanship demonstrated in the 21 blades in this work is mostly good. A few sword sections show minor cracks in the material. The X-radiographs of whole blades indicate generally good welding. Most blacksmiths exhibit fair knowledge of blade constructions and understanding of the specific properties of iron and steel. In a few cases, the blacksmith seemed to have had bad luck or insufficient skill to perform the carburisation and heat treatment as he intended. A few blades demonstrate a lack of knowledge and understanding of sword blade production (construction type I). An unacceptably high amount of relatively large slag inclusions in some sections indicates a less qualified blacksmith.

It is often assumed that blades with inlaid designs reflect particularly skilled smiths. However, recent reconstructions (Andresen 1993) show that this technique is not very difficult to execute. Consequently, no conlusions about the skill of the smith can be drawn from such decorations alone. Williams's metallographical investigations of 44 ULFBERHT swords demonstrated that these swords were made of very different materials and varied greatly in quality (Williams 2009).

Beautifully decorated sword blades often create the deceptive impression of also being of high quality. As is shown in the present study, this is not necessarily the case. Decorations that are only surface features, such as inlays and sheets of pattern weldings welded onto the surface of the core, do not influence the quality whether good or poor. Solid pattern-welded cores produce generally good resilience and strength to the blade. However, pattern-welded sheets cannot easily be distinguished from solid pattern-welded materials through visual examination of the surfaces.

5. While the general shapes of double-edged and single-edged sword blades were subject to few alterations during the Viking Age, the appearance of sword hilts underwent repeated changes – as a result of fashion and of the competence of the smith. However, blade dimensions do vary. The various blade construction types seem to have existed contemporaneously for several hundred years. Nevertheless, this and other investigations of Viking Age sword blades confirm the fact that different blade constructions display pronounced variations in composition, and hence in the quality of the blades.

Generally, there is no apparent correspondence between hilt types and types of blade construction. Yet it is striking that in this investigation all the swords with Q-hilts have the same blade construction, type III. However, the quality of the blades varies. The M and Q-hilts were the most common in Telemark in the Viking Age. Simpler blade constructions of inferior quality seem to predominate the M-hilts. All three single-edged blades in this work have M-hilts, and at least two of them are poor quality, owing to random composition and soft materials. The construction scheme of the third single-edged blade is difficult to interpret, but the quality is considerably better than the other two. Moreover, one of the double-edged blades with an M-hilt is fairly poor quality due to too much slag. The connection between Q-hilts and blade construction type III, and between M-hilts and inferior blade quality found in this work, may result from an insufficient number of blades examined. More reliable results will be available when further analyses have been carried out.

6. The observations in this investigation indicate that pattern-welded sword blades were not particularly common in the county of Telemark in the Viking

Age. The rare occurrence of pattern-welded blades in Telemark is further supported by X-radiographs of all the Viking Age swords from this county.

Only three of the 21 blades show some kind of surface decoration: one blade has a pattern-welded central part, and two blades have pattern-welded inlaid designs. Based on the results from other studies (Lang and Ager 1989; Kirpichnikov 1970) it was surprising to find so few swords with pattern weldings. However, the fact that there are many swords in Telemark in the Viking Age, but few decorated blades, may reveal a general impression, based on grave finds, of a steady level of prosperity with only few exceptions of great wealth in the county.

Elemental analyses of the materials responsible for the contrasts in the pattern-welded rods and in the inlaid characters in all three blades show that the design consists of alternating sheets or wires of phosphorus-rich iron and mildly carburised iron.

7. It is difficult to see special technical characteristics, which might distinguish clearly between different workshops. Further, it is difficult to point out any distinctive features, which can differentiate between domestic production and imports. Similar construction types were obviously present on the continent, in England, and in Norway for several hundred years. The skill or success of carburisation can only distinguish between individual blacksmiths, not between different regions.

It seems that only one blade can be clearly determined to be an import: the combination of an all-steeled blade (construction type V) with inlays that are closely related to "foreign design" strongly indicates an imported blade. This assumption is further supported by the type of decorations on the hilt, although in principle the hilt could have been a later addition.

It is, however, noteworthy that both blades of construction type IIa have been found in the Skien area, while both blades of category IIb were found in Tinn. In addition, the compositions and craftsmanship were comparable. As mentioned, the layered blade construction in which an iron sheet was welded in between two steel sheets (construction type IVb) was not common. Could this be a local construction, or just an accidental one, welded together from different sheets? The structure of the two blade sections of this sword suggests a deliberate construction.

The number of sword blades examined in this work includes only about 10% of the total known Viking Age sword material from the county of Telemark. The volume of Viking Age swords found in Norway offers an excellent opportunity to study blades on a larger scale. To ensure a solid foundation for conclusions relating to production techniques, quality and craftsmanship, and also to search for additional evidence for specific workshop traditions, this work needs to be followed by additional analyses of sword blades from other districts of Norway.

6.7 INTERPRETATION OF RADIOGRAPHS

Radiography is a fairly simple process to perform when facilities are available. Unlike metallographic analysis, radiography is non-invasive and much less time consuming. This makes utilising it on a large number of objects possible. There is also little need for specialised equipment to study traditional radiographs. The downside of radiography is that it cannot be trusted to reveal all welds and construction elements, elements that could easily be observed in a metallographic cross-section. Radiography allows some indication of the internal structures of the blades, though understanding the limitations of the method is paramount.

This study employed traditional two-dimensional radiography, mostly with analogue film. Some of the later batches of radiographs were acquired through a semi-digital system. The digital system had lower resolution (50 micron), but achieved better contrast than the analogue images. To get some sense of three-dimensionality, stereoscopic imaging was attempted during this project. The results here were limited. In the near future, extensive access to industrial strength microtomography (3D x-ray) could make systematic studies of radiographic cross-sections feasible.

The goal of doing radiography was to identify weld lines. Such lines were created when steel edges had been forge-welded onto an iron core, or some other variety of a composite blade construction. Not all weld lines are observable on radiographs, especially when limited to two-dimensions. The main factors affecting a possible positive identification are: the orientation or angle of the weld; how faulty the weld is; and how corroded the metal is. If the plane of the weld is parallel to the direction of the x-rays, then there is a good chance the weld will be visible in the images (a butt-welded edge, blade construction III). If the plane of the weld is oriented at a steep angle or 90 degrees to the direction of the x-rays, then the weld will usually not be possible to observe in traditional radiographs (welds oriented in the plane of the blade, blade construction II and IV).

Faulty welds are more visible in the radiographs, as these exhibit gaps and cracks. If such faults repeat along a line at a uniform distance from the edge, this is a good indication of a butt-welded edge. The state of degradation is also important, since heavy corrosion will "etch" lines or voids into the structures of the blade. Steel elements corrode more than areas of iron, differentiating them on the radiographs. Corrosion will also exacerbate gaps and cracks in faulty welds, making them wider and more discernible.

One should also be aware of the fact that somewhat haphazard weld lines observed in radiographs may represent earlier phases of forging. Such an early phase would be the refining of raw iron and patching together of iron pieces to construct a rough iron bar. Such an iron bar would then later be used either by itself to form a homogenous blade, or welded together with other bars of iron and steel to form a more composite blade construction.

6.8 RESULTS AND PRESENTATION

The total number of swords in this investigation is 221, including 15 items with only the hilts preserved. Of the total number of swords, 174 have been radiographed, and of these 167 are on film, 10 digital. Also, an additional 23 films have been digitalised, preferably those with uncertain (B) interpretations. Six swords have undergone all three procedures, and one sword was recorded on both a film and a digital radiograph. The digitalisation of films was done to find out if there were more welding lines to be seen, but the only result was that features we saw on the films became more distinct.

The remaining swords were either too badly preserved or not available to have radiographs taken, including the thirteen swords in Skien museum.

As our investigations relate to Norwegian blacksmiths' knowledge and skills, it is important to determine which of the metallographically investigated swords were indigenously made. There is no reason to doubt this for the M and Q-type swords, nor for sword 8, a Q/X-type, and sword 19. Of the indigenously made swords, no C-types are included, and none can be dated earlier than c. 850 AD. Sword 10, from the 11th century, is undoubtedly a foreign product (see Chapter 4). Swords 3, 7, 12, and 20 are of uncertain provenance.

Metallographic investigations have been instrumental in interpreting the radiographs. Firstly, we can compare the two methods on the metallographically investigated swords. Secondly, we can use this knowledge on the other radiographs. Of the five construction types found, categories I, II and V will not be visible on radiographs. Construction type IV is problematic. However, this construction type cannot be assumed to be numerous, based on our material.

Construction type III, with butt-welded edges, is the one most easily detected on radiographs. On several blades there are only vague indications of welding lines on very short parts of the blades (interpretation B). Two of the metallographically investigated swords, 15 and 17, have welded-on edges, but the welds are hardly detectable on the radiographs with only two 1 cm long lines on each. This proves that the majority of the swords with uncertain (B) interpretations most probably have welded-on edges, and that on other blades the welds can be invisible.

The radiographs demonstrate that the frequency of welded-on edges increased throughout the Viking Age, as did the frequency of double-edged blades. There are, however, a small number (four items) of single-edged blades of the Q-type, but none with X-type hilts.

Also, according to the metallographic results, hardly any single-edged blades have welded-on edges, independent of hilt types. Mostly they were equipped with indigenous hilt types, C, M and Q, though five of 15 radiographed specimens have H-type hilts. Of the double-edged H-type swords, two have certain, and two uncertain welded-on edges, including swords 7 and 16, with pattern welding and inscriptions respectively. The radiographs also confirm that few of the Telemark swords were pattern-welded or have inscriptions on the blade, but it is important to note that sword C.28352 from Fyresdal has the blade inscriptions +INGERIIIFECIT and CONSNVIIINS, which were not visible on any of the other four radiographs on film, but are visible on recently taken digital ones.

7. DISCUSSIONS AND CONCLUSIONS[9]

The swords have been examined using X-radiographs and metallography, as well as hardness measurements. This, along with a detailed archaeological study of the weapons their context have provided new insights of the swords of Telemark. However, these investigations have, for several reasons, continued for many years. During this time research interest in, and general knowledge about, societal conditions for specialised craft production have developed significantly. One basic assumption is that all swords were forged by trained blacksmiths even though their skills and knowledge of materials varied considerably, not least depending on their social relations and attachments. It is also assumed that such knowledge, as well as more advanced smithing techniques, were spread from blacksmiths working in centres to others working farther away. The small number of swords and spearheads, not classifiable as ordinary types, strongly indicates that the number of weaponsmiths was never very great, and that there was some level of contact among them.

One premise is that indigenously made weapons at the beginning of the Viking Age in general were of simple construction. The radiographs indicate a certain amount of technical development during this period.

What is meant by more advanced smithing techniques? As stated in Chapter 1, a good point of departure is Pleiner's division into simple, advanced and top techniques (Pleiner 2006:Chapter XI). His division is his answer to the problem of how to arrange a selection of extensive data in order to illustrate the technical level of early and ancient smiths (2006:196).

Simple techniques include the working of low carbon and heterogeneous wrought iron, either by forming one piece of material or by forge welding carbon-poor iron (2006:196–200).

Advanced techniques were commonly used to make critical parts of tools effective by increasing the hardness of cutting edges and points. Such techniques consist of additional carburising and forge welding of iron and hardenable steel, for example into an iron-steel-iron "sandwich". The methods employed were steel shells, scarf welding and butt welding (2006:200–212).

Top techniques required a perfect empirical differentiating of various ferrous materials, and an extraordinary mastery in performing minute-scale processes, as well as managing work with larger pieces of material.

One relevant process produced striped blades, achieved by joining iron bands or wires by means of butt welding. Another applicable process requiring the mastery of top techniques was pattern welding with twisted iron and steel rods. Also, yet another speciality was locksmithing, although making plate armour and clocks first occurred after the Viking Age, and thus is not very pertinent here.

It is important to note that unlike Selirand and Solberg, Pleiner distinguishes between strip welding and pattern welding (strips are patterns 1–3 by Selirand and Solberg, 3 being a serrated strip). Pattern welding means the twisting of iron and steel rods or wires. Both are categorised as top techniques. This distinction is interesting to our work as some spearhead types (Petersen 1919, types I,K, D,J; Solberg 1984:165–170, types VII.2, IX and some variants) have such strips on the blade, among them 16 out of 18 K-type spearheads from Telemark (Solberg 1984:107). Strips were found only on 10th century and later spearheads and were widely distributed in Scandinavia, Finland and the Baltic countries, on the same spearhead types (Selirand 1975:174; Solberg 1984:108). In addition, the serrated strip on a pattern-welded spearhead from Haithabu was made from a twisted rod, a feature also described by Selirand. Such strips were often parts of more complicated patterns (Thomsen 1971:79 and Figure 5; Pleiner 2006:3–4, Plate XXXVI). Their origin is uncertain.

Moreover, we stress the importance of considering forging techniques, and inlays of other metals, for spearheads as well as for swords when discussing the knowledge and skills of Norwegian weaponsmiths. Solberg only discusses pattern welding in her thesis on spearheads, and does not consider welded-on edges on

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[9] Although written by Martens, many of the insights are the result of long-lasting collaboration and numerous discussions with Astrup.

non pattern-welded items. These questions depend on the societal position of practicing specialist craftsmen, and thus the technical skill of Norwegian weaponsmiths at the beginning of the period is important.

7.1 NORWEGIAN SWORD TYPES C, M AND Q+ X: DEVELOPMENT THROUGHOUT THE PERIOD

No technically advanced features like welded-on edges, pattern welding or heat treatment were observed through the X-ray investigations of Danish single-edged swords from the Merovingian and early Viking periods (Nørgård Jørgensen 1999). They have a straight back, and the edge curves to the tip without metal hilts, similar to the Norwegian type R 498. Our premise is that such Norwegian swords were of the same technical standard, in accordance with Solberg's results for spearheads of her type groups V.2 and 3 from the 8th century, which she sees as indigenous (1984:47–51).

The radiographs of C-type swords, the earliest indigenous hilt type, are generally in accordance with this. Eleven C-type swords were single-edged, and of these nine specimens show no signs of advanced techniques; one has a distinct and one an uncertain welded-on edge. The former is C.24217, which is pattern-welded. Only three have double-edged blades, one with and two without welded-on edges (Table 7.1).

The pattern-welded C-type swords

Before discussing the development of welded-on edges based on the radiographs, the pattern-welded single-edged swords deserve special attention. A few more are known from Eastern Norway, another four from Sogn and Fjordane in Western Norway, and five in Trøndelag (Moberg 1992:145, Stalsberg 1988:16ff). It is likely that more will be discovered through radiograph examination.

Of the Sogn examples, one blade is not a usual blade type with a straight back, and is probably not indigenous (B 1184), which may be the case for other items too. Of the others, two have C-type, and one E-type hilts. Of the Trøndelag specimens, three have H and one H/I-type hilts, while the last one has a Norwegian F-type hilt. Pattern-welded single-edged swords have emerged over a large part of Southern Norway, indicating that a small number of Norwegian weaponsmiths mastered this technique in the 9th century, although more precise dating is not possible. The Trøndelag finds are not from the earliest part of the century. Internal production is supported by a very small number of pattern-welded type group VI.2 spearheads, interpreted by Solberg as indigenous (1991:250–252). Moreover, some pattern-welded double-edged swords were also probably indigenous.

The most interesting question arising from this is how this technique came to be practiced in a society that most likely was unfamiliar with advanced smithing techniques. It can be learned only through practice under the tutorship of an experienced person. One possible answer is that such experienced and attractive weaponsmiths were brought to Norway by Vikings, perhaps as hostages. Another possibility is that weaponsmiths who took part in Viking raids had the opportunity to learn advanced techniques abroad.

In order to study the development of advanced smithing techniques, we will start with the increase in welded-on edges (construction type III) detected on radiographs. Table 7.1 summarises the results for swords with the indigenous hilt-types C, M, Q, X and Æ, split into single and double-edged blades, and including H/I types as a contrast. In Table 7.2 we have separated the four Telemark regions to find differences between them. The numbers are, however, too small for more than indications.

Table 7.1. *Interpretations According to Types*

Hilt type	**Single-edged**				**Double-edged**			
	Number	**Interpretation**			**Number**	**Interpretation**		
C-type	11	1 A	1 B	9 0	3	1A		2 0
H/I-type	5			5 0	10	2 A	2B	6 0
M-type	21		1 B	20 0	29	4 A	7 B	18 0 + x
Q-type	4		1 B	3 0	22	9 A	2 B	11 0
X-type	0				7	3 A		4 0
Æ-type					2	1 A		1 0
Total	**41**	**1 A**	**3 B**	**37**	**73**	**20 A**	**11 B**	**42 + x**

***Table 7.2.** Interpretations According to Types and Regions*

Region	**Number**	**1A**	**1B**	**0**	**Number**	**1A**	**1B**	**0**
C-type								
Grenland	3			3	1	1		
Øst-Telem	6	1		5	0			
V-Telem	1			1	2			2
SV-Telem	1		1		0			
Total	**11**	**1**	**1**	**9**	**3**	**1**		**0**
H/I type								
Grenland	3			3	6	1	2	3
Øst-Telem	0			0	2	1		1
V-Telem	2			2	1			1
Sv-Telem	0				1			1
Total	**5**	**0**	**0**	**5**	**10**	**2**	**2**	**6**
M-type								
Grenland	10			10	18	4	4	9+ (1un)
Øst-Telem	2			2	1			1
V-Telem	8		1	7	8		3	5
SV-Telem	1				2			2
Total	**21**		**1**	**19**	**29**	**4**	**7**	**17 +1un**
Q-type								
Grenland	1			1	5	1		4
Øst-Telem	2		1	1	2	1		1
V-Telem	0				15	7	2	6
SV-Telem	1			1				
Total	**4**		**1**	**3**	**22**	**9**	**2**	**11**
X-type								
Grenland	0							
Øst-Telem	0				3			3
V-Telem	0				4	3		1
SV-Telem								
Total	**0**				**7**	**3**		**4**
Æ-type								
Øst-Telem	**0**				**2**	**1**		**1**

In order to measure the influence of the practice of pattern welding found on single-edged C-type swords on indigenous blacksmithing, the M-type swords are important. Their production started around 850 AD, while C-type swords were still in use, and it is natural to see the M-type as their immediate successor. None of the 50 M-type swords from Telemark were pattern-welded, and this corresponds to Moberg's results for the 19 M-swords from Sogn and Fjordane (Moberg 1992:105). However, it ought to be remembered that only a small part of the Norwegian M-type swords have been X-radiographed.

The majority of the Telemark M-type swords are most likely from the 10th century, and the pattern welding technique with twisted rods went out of use c. 900 AD, a change that was not sudden over a large area. If the pattern welding technique was spread to many Norwegian weaponsmiths in the 9th century, one would expect to find it on some of the 69 X-radiographed M-type swords.

Welded-on edges do appear on several M-Type swords, possibly as the earliest indigenous sword type (Table 7.1). All four with a certain interpretation (A) were found in the Grenland area, and Astrup found that one of them was also carburised and quenched. Four out of seven with uncertain (B) interpretations were also found in Grenland. Three more out of seven with uncertain interpretations are from western Telemark, such as the single-edged specimen.

Grenland is a large area, and the swords with A and B interpretations were widely distributed within the area. Of those from western Telemark, three were found in the Lårdal concentration and one in Seljord.

The M and Q-type swords were contemporaneous, the Q-type coming into use c. 900 AD and lasting throughout the century. The variant P 110 was developed directly from the M-type (see Chapter 4), while P 111 was influenced by hilts like the R and S-types.

When the M and Q-types are seen together, a development in blade types and construction can be plainly observed. Single-edged blades went out of use during the 10th century, and even though welded-on edges are rare on these blades, this does not necessarily mean that all such blades were of construction type I. One must always make allowances for which construction types can be detected on radiographs.

On the other hand, the frequency of welded-on edges increased markedly from M to Q-type blades, as did carburisation and quenching. This is the case for the Q/X type sword from Porsgrunn, and the Q-type sword from Bø. One blade from Vinje (15) and one from Tokke (17) with welded-on edges were carburised, but not quenched.

7.2 COMPARISONS OF SWORDS WITH OTHER HILT-TYPES

It is interesting to compare the C and M-type swords to the H/I ones. The earliest H-type hilts were made before 800 AD, but they lasted into the 10th century, and the I-type is a later development of the H-type.

The H-type had a wide distribution outside Norway and was certainly not of Norwegian origin. It is the most numerous type found in Norway. Out of 194 specimens, 73% are double-edged and 27% single-edged (Petersen 1919:89 and 94). Most likely, many of the sword blades of both kinds were produced indigenously. Even inlay decoration, which is common on these hilts, can be made locally, but no conclusions on this point can be drawn without special investigation.

In Telemark, the number of finds has doubled from eight to 20 during the last hundred years. Only five are single-edged and 14 double-edged; on the last one only the hilt was preserved. Of these, four single-edged and ten double-edged have been X-rayed. None of the single-edged objects had welded-on edges, and of the double-edged objects, one has distinct and two have uncertain welded-on edges. The other six, including the one with the remains of an inscription on the blade, showed no traces of welded-on edges.

We have compared our observations to Swedish ones. Interpretations of the large number of radiographed H/I-type swords from different parts of the country for the Helgö investigations are presented (see Tables 3, 6, 9 and 10 in Thålin-Bergman 2005). All the Swedish swords were double-edged. One such sword was selected for metallography, SHM 8974, Hedesunda (Thålin Bergman 2005:92–94). The blade structure is of great interest to our investigation.

> The illustrations show that the same type of material was used throughout the whole blade. There is no pattern welding … Figures 3–15 show the microstructure. The dark areas consist of a very fine pearlite in which individual plates of cementite in ferritic matrix do not show up at this magnification. The light areas consist of ferrite.
>
> Figures 3–15 show the rather uneven distribution of the pearlite. The microstructure did not indicate any obvious differences in alloy content … In Figures 5–8 clear streaks of non-metallic inclusions show up as dark, almost ribbon-shaped areas.
>
> Figures 13 and 14 show the cutting edges. They do not appear to have been treated in any special way. Testing with a 5 kg weight gives the following Vickers hardness values: HV 78, 74 100 and 101. HV 101is from very near to one edge. The hardness is evidently not very high. [Modin and Modin in Thålin Bergman 2005:92–94]

The sword belongs to construction type I, like the H-type sword Met.No. 16, with the remains of an inscription on the blade. Another important point to be gained from the Swedish tables is that quite a few swords with inscriptions did not show any traces of welded-on edges or other advanced techniques. Other H/I-type swords have welded-on edges and some are pattern-welded. X-ray photographs of a greater number of Norwegian H/I-type swords would probably reveal the same variations.

The most distinct difference between the C-type and the H/I-type swords from Telemark is the number of single-edged and double-edged blades. This is due partly to the H/I swords being in use for a longer period, since the frequency of double-edged blades increased during the period, and due partly to their different origins.

7.3 OTHER BLADE CONSTRUCTIONS

The other blade construction verified on metallographically investigated swords is construction type II a–b with an outer steel coating. IIa was found on two M-type swords from Skien (1 and 2); none were more precisely datable. Construction II is not detectable on X-rays, and so there are probably more M and Q-type swords with this construction.

Construction type IIb was found on two, possibly three, blades with X-type hilts (Met. Nos. 13, 14 and possibly 12), all from Tinn. The X-type swords were widespread in Europe, and certainly not of Norwegian origin. Outside Norway, several blades have ULFBERHT inscriptions (Stalsberg 2008). In Telemark, there are few X-type swords, only six or eight. Some of them have very high lower guards.

The Tinn specimens are of special interest. Swords 12 and 13 are part of the Mårem find C.29700 with two sets of weapons, and both spearheads have fishbone inlay patterns (Ge 1) on the socket. Sword 14, from Vestfjorddalen in Tinn, has an inlay pattern on the hilt, forming open rhombi, a pattern which was found only on this sword (Figure 3.4). Taken together, these swords and spearheads are most likely of indigenous fabrication.

The two metallographically examined swords with possible type IV construction were too few in number, with insufficient information for further comment. Also sword 10, construction type V, was not of Norwegian origin.

With the introduction of Solberg's VII.2A spearheads (Petersen's type I), a new set of fully developed elements appears on the blades: patterns consisting of plain and serrated V-shaped strips between the centre and the edges of the blades, and cross-sections with concave sides meeting in a marked keel. VII.2B, a very numerous type, contains the same elements, and both subtypes, as well as VII.2C can have inlay decorations on the socket. These spearheads were very widely distributed in Northern Europe and were not Norwegian in origin, but they were very likely produced in highly specialised workshops in Norway (Solberg 1984:112–13).

Solberg's X-radiograph studies revealed that the three decorated spearheads from Byggland were forged with plain or serrated strips (PW1 and PW3), and she used them as support for indigenous mastering of this advanced technique (see figure 3.5). We can add to this that six or seven of the other decorated items from Telemark were made with such strips, and they are in fact very common on Norwegian spearheads (Solberg 1984:Table 11).

In summary, we find that at the beginning of the Viking Age the majority of weaponsmiths most probably mastered only simple techniques, working with low carbon and heterogeneous wrought iron during most of the 9th century. The pattern-welded single-edged blades contradict this viewpoint, but they do not seem to have had any long-lasting impact on development, and may be examples of "production secrets" dying with their creators. The H-type swords are also intriguing, having partly imported and partly indigenously made blades. A special investigation of these factors, as well as of the inlay decorations on the hilts, is necessary.

Another interesting feature is the decoration on 9th century F-type (Solberg VII.1A–C) spearhead sockets. A large part of this indigenous type was decorated with horizontal circles in elevated areas on the socket. Solberg believed the decoration to be have been made on a lathe, thus in specialised workshops. Based on detailed studies of such sockets, another technique, drop forging, is more likely (personal comment V. Vike). This also a specialised technique.

Several more advanced blade constructions (II and III), as well as smithing techniques, came into use in Telemark in the Viking Age. Exact dating is difficult, and they were not necessarily introduced together. Most likely, the innovations took place shortly before or around 900 AD, or during the 10th century.

Pleiner categorises all the techniques found within construction types II and III: carburisation, forge welding of iron and hardenable steel, steel shells, and heat treatment as advanced smithing. On the basis of this definition we can conclude that advanced techniques were commonly utilised by weaponsmiths in Grenland, eastern and western Telemark, from the 10th century onwards, while not found in the southwestern region. The number of finds there is too small to draw any conclusions. The distribution of construction types II and III within Telemark indicate that the innovations came into use first in Grenland, but were subsequently spread to other parts of the county.

Strip welding, pattern welding and locksmithing are ranked among top techniques. Strip-welded spearheads, several with inlay decorations on the socket, were frequently found by Solberg on her spearhead types VII.2 (Petersen I and K), and she states that they represent highly specialised manufacturing (1984:170). Locksmithing is also interesting, since remains of keys and caskets, including padlocks, have been found in several Norwegian Viking Age graves, including the Byggland find (Petersen 1951:448ff; Kaland 1972:125ff). Some top technique elements were most probably practiced in Telemark by a limited number of blacksmiths, and it is likely that the standard in Telemark was representative for other parts of Norway.

Placing our results into Pleiner's divisions of simple, advanced and top techniques is not a straightforward task. Pleiner only considers iron smithing, while inlay decoration techniques are not dealt with. These certainly required specialised skills, though the degree of advanced techniques needed lies beyond our competence to judge. The patterns vary so much in fineness as to indicate that a diversity of skills may be needed.

7.4 LOCATION OF SMITHIES

Efforts to locate smithies must be limited to those where top technical procedures and inlay decorations were employed. The more numerous ones where advanced techniques were used cannot, at least at this stage of research, be located.

The most specialised ones were attached to centres/central farms. Even though blacksmith graves have often been found outside such places (as discussed in Chapter 3), no centres have been excavated or localised in Telemark, though some probable ones have been pointed out in Chapter 2. The location of smithies is thus part of a much wider set of challenges. However, our results can still help to identify one localisation feature: a concentration of probably indigenously made weapons using top techniques within a limited area.

Our results enable the identification of three areas: Grenland, Tinn and western Telemark. All basic finds belong to the 10th century, but no attempt was made to look for long-lasting traditions.

In the large area of Grenland, there were certainly several centres/central farms, though archaeological finds are not very numerous, except for Gjerpen in Skien, bordering on and formerly a part of Vestfold. In the Telemark material, Grenland stands out as an innovation area, and in spite of a lack of any distinct weapon finds, several relevant finds in Gjerpen close to the border area of Vestfold (Larvik) suggest the existence of a specialised smithy.

The situation in Tinn is different. Swords number 25 in total, including in some cases only a guard or small fragments of the blade. The stock comprises an unusual number of swords of various types with hilt decorations (Martens 2009).

Astrup's investigations consist of five swords from Tinn (swords 10–14), and except for sword 10, they are interpreted as indigenous products. Notably, two of them have blade construction IIb (swords 13 and 14), while sword 12, which is from the same grave as sword 13, is the only one made of iron rich in phosphorus.

Two swords with decorated P-type hilts, not a numerous type, were found in Tinn. The type lacks a pommel and usually has vertical fishbone pattern (Ge 1) inlays on the guards, a pattern which, as far as we know, is unique to P-type sword hilts. Sword 14 also has an unusual (reconstructed) inlay pattern with open rhombi (Figure 3.4) on the hilt.

Type group VII.2 (Petersen I and K) spearheads from Tinn number only five, but all have plain or serrated strips in the blade. Two of them, from the large find C.29700 have the inlay pattern Ge 1 on the socket, and a third find with such inlays came from the same farm as sword C.23364 (Met.No. 14). A fourth spearhead, a mountain find, has a Ge 2/3 decoration.

Taken together these features are strong indications of specialised smithing traditions in Tinn in the 10th century. Two farms had central positions: Mårem by Lake Tinnsjø is strategically placed in relation to mountain hunting grounds; and Såem-Bøen, in Vestfjorddalen, is similarly placed in relation to iron extraction sites in side valleys and at Møsstrond. There is also a soapstone quarry, Bøuri, very close by. Tinn certainly had the economic basis for an advanced smithy with top-level knowledge and skills.

Again, the situation in western Telemark is different from the other two areas. Here sword types M and Q dominate, with 16 and 18 specimens respectively. Only two Q-type swords were subjected to metallographic examination, and both blades were construction type IIIa, but without quenching.

The many spearheads with inlay decorated sockets, in the area centred around the Byggland find, lead Blindheim to conclude that they were all made in the same workshop, or at least within the same tradition (Blindheim 1963:51). Solberg found through radiographs that plain and serrated strips on spearheads were very common, mostly of her type group VII.2 (Petersen I and K), and also that they appear to have been produced by Norwegian smiths. Her strongest proof was the Byggland find containing three spearheads with such strips and inlay decorated sockets (Solberg 1984:179). The studies carried out here, showing that inlay decoration patterns reveal regional variations, further support the idea of indigenous mastering of strip welding and inlay decorations in the 10th century. The premise is that a specialised smithy with top technical skills was located in the central part of either Seljord or Kviteseid (see Chapter 2). The distinct differences between Tinn and western Telemark were probably caused by differences in geographical, economic and social conditions.

7.5 FOREIGN INFLUENCES

The advanced smithing techniques employed in Norway in the Viking Age were widely distributed throughout Europe, and thus were certainly due to foreign influence. Construction type III with butt-welded-on edges were commonly used on pattern-welded swords in the previous period, thus tracing the origin of this construction is not relevant here.

There are very few metallographic investigations available to compare non-pattern-welded blades, prohibiting a detailed discussion. The most interesting one includes 16 swords from graves in Mikulcice, one of the main centres of Great Moravia, the first Slavic state north of the Danube, covering approximately one hundred years in the 9th and beginning of the 10th century (see Chapter 5). Except for one sword lacking guards, the rest fit into Petersen's typology very well. Four swords are pattern-welded, types K (2), H/I and X respectively. The other ones, types H (1), N (2) and X (8), have butt-welded-on edges, but varying constructions of the central parts. The last sword, X-type, consists mostly of iron with some steel along the edges. Most of the blades show traces of quenching.

Another pertinent investigation is Gilmour's study of Viking Age swords from England. The number is small and type determinations problematic, but some belong to well-known types. Of the 13 relevant swords, seven are pattern-welded. Remarkably, most of the blades, independent of whether they are pattern-welded or not, show blade constructions differing from the usual butt-welded-on edges. One sword, possibly with an X-type hilt, has an all-steel blade like the one (Met.No. 10) from Tinn (Gilmour 1986).

These two investigations indicate – not surprisingly – that there were several distinct smithing traditions in Europe, and that they probably were of long duration. One cannot draw any conclusions from just two investigations, but they certainly raise some interesting questions, including a challenge to the "well-established truth" repeated over and over again that the Carolingian Empire was the central area for advanced swordsmithing.

The problems relating to the origin and production of Viking Age swords are relevant for all European countries where such swords were found. The problems are complex, since production places were far more widespread than places of origin. Differences in blade constructions and smithing techniques can add valuable information to the discussion, and highlight the necessity of analysing smithing techniques for both blades and decorations.

Jiří Kosta and Jiří Hosek are cautious when discussing the technical skills of great Moravian weaponsmiths, and question whether they were capable of producing high quality swords. Pleiner, on the other hand, states that the blacksmiths in Great Moravia learned to apply advanced techniques involving iron and steel welding in various construction schemes and heat treatment (Kosta and Hosek 2014:294ff; Pleiner 2006:237).

There are good reasons to question the place of origin for several hilt-types. There is a strong tendency – one may even call it a well-established truth – that inlay-decorated hilts from the 9th and 10th centuries are Carolingian, taking for granted that they originated and were spread from the Carolingian realm and its successors.

Studying pattern types in combination with the distribution of the their hilt-types has convinced me that it is high time to question this. There is no doubt that the geographical area of the Carolingian realm had a central position in advanced weapon production in the 8th and 9th centuries. Inlay patterns were varied, comprising tendrils, often in combination with vertical stripes as well as geometric patterns (Menghin 1980; Müller-Wille 1976, 1982).

When and where were the inlay techniques embraced in other parts of Central and Northern Europe, and were they spread along with top blade-smithing techniques? Fully answering these complicated questions lies beyond the scope of this study, and only some brief arguments are presented here, starting with the distribution of 10th century decorated hilt types.

Starting with Geibig (1991), he leaves out several of Petersen's types because they are not found in former West Germany. They are D, E, T, V and Z. He puts R and S together in his combination type 10, but the inlay patterns are very different (Martens 2004:Figure 8). His distribution map Abb.44 shows that the few R and S swords from West Germany were found near Hedeby (and the one in Hamburg, Müller-Wille et al. 1970, 1973). Geibig states that "… lässt sich im Gegensatz dazu feststellen, dass bei im fränkischen Raum gefertigten Gefässen offenbar recht früh, d.h.im Laufe des 9. Jahrhunderts, gänzlicher auf Dekor verzichtet wurde" (1991:138).

This is in accordance with Stalsberg (2008, Table 1), who includes all ULFBERHT swords she has managed to trace. The German specimens have mostly X and Y hilts, while decorated hilts of the types relevant here are lacking. Considering the five Hulterstad sword blades (Thålin-Bergman 2005:49–51), there are strong indications that ULFBERHT blades could have been distributed without hilts, and that such blades cannot be used in discussions of the origin and production sites of 10th century decorated hilts.

The relevant hilt types were widely distributed in Central and Northern Europe (Chapters 3 and 4) and their origins must be sought outside the Carolingian Empire. In addition, this is a relevant problem for some earlier hilt types too, among them the H-type, which is the most numerous one in Sweden and Finland (Androshchuk 2014: List 1; Kivikoski 1973:112 and text Tafel 94: 831–32). One can also mention that the 9th century types also include the E-type, which developed into the T-type (pattern Ge 5). The E-type has a pommel with a rounded top, while the T-type, as well as the R, S and Z types, have nearly globular sections (see above Chapter 4).

The D-type is in several ways an enigmatic one. The hilts are made by means of a special technique, normally with two pattern layers: a lower one with bronze or copper, and an upper one with silver decoration. The cross-section of the pommel is convex with a rounded top.

These features are good indications that these types originated outside, probably east of, the Carolingian Empire. Political units with strong centres such as Great Moravia were potential areas for innovation of new types and for adapting technical skills.

7.6 CONCLUDING REMARKS

Weapons are only one category of items, but certainly an important one, in the research on European culture and relationships in the Viking Age. The development of weapon production in Norway relied on a combination of indigenous conditions and foreign influences. The great number of swords and spearheads found in a country with generally sparse settlement and few centres compared to most European countries, can illuminate production conditions in other countries as well.

The collaboration of two researchers from such different disciplines as chemistry and archaeology has been a continuous learning process for both of us. From the very beginning, the technical investigations attempted to elucidate archaeological problems, but during this process our mutual understanding of the broader elements inherent in detailed technical investigations developed considerably. Looking back, one very important lesson is that collaboration should start with a specified project plan, a necessity for enabling the selection of items for metallographic and other technical investigations. If our investigation can trigger new, advanced research on Viking Age weapons in Europe, then one principal aim of our study has been achieved.

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ABBREVIATIONS:

Ab: Aarsberetning fra foreningen til norske fortidsminnesmerkers bevaring.
JONAS: Journal of Nordic Archaeological Science.
KVHAA: Kungliga Vitterhets Historie och Antikvitets Akademien
KHM: University Museum of Cultural Heritage, Oslo
NO: Norske Oldfunn.
UO Skrifter: Universitetets Oldsaksamlings Skrifter.
UOÅ: Universitetets Oldsaksamling Årbok.
ØK: Records for the Economic Map Series.

APPENDIX 1

The swords' archaeological and technical data

ARCHAEOLOGICAL DATA										TECHNICAL DATA						
GENERAL		TYPE		GRAVE CONTENT				DATING	REMARKS							
Mus.no	Municipality	Type JP +	Fig.No	Spearhead JP/BS	Axe JP	Shield R	Other		Remarks	Edges	Condi-tion	Welded-on edges	Constr.	PW/Inscr.	Met.no	Mus.no
1878	Skien	Sp.1			B	X	X	8 II--	Martens 2006	2	1	A				1878
25396a	Skien	Ma/S	*Ma 2*			564	X	9 I	Martens 2006	2	1	0				25396a
1120	Nome	S3	73					9		1	1	0				1120
8402	Kragerø	Car	*74*					9 I		2	2	A		PW		8402
54840/1,10	Tinn	Car						9 I	Only guards	X	X	X				54840/1,10
1500	Seljord	B	53					8 II-9 I		2	1	0				1500
10082	Nome	C	57-8					9 I--		1	1	0				10082
12596	Sauherad	C	57					9 I--		2	1	A				12596
12696	Bamble	C	57-8	F/VII. 1A	E	562	X	9 I--		1	1	0				12696
36368	Nome	C	57-8					9 I--		1	2	0				36368
S 4379	Bamble	C	57-8				X	9 I--		1	X	X				S 4379
18168	Hjartdal	C	57-8			564	X	9 I--		1	1	0				18168
24217a	Hjartdal	C	58		2G		X	9 I--	Mixed finds	1	1	A		PW 5		24217a
27618	Hjartdal	C	58					**9 I--**		1	1	0				27618
27978	Hjartdal	C	57-8					9 I--		1	1	0				27978
54805/1	Notodden	C	57-8					9 I--		1	1	0				54805/1
54844/1	Tinn	C	57-8					9 I--	54844/1-2	1	1	0				54844/1
1163	Tokke	C	58	Un/V.3	D		X	8 II-9 I	Dep. Iceland	1	X	X				1163
2505	Tokke	C	58					9 I--		2	1	0				2505
12903	Kviteseid	C	57-8		G		X	9 I--	Mixed finds	1	2	0				12903
27272	Tokke	C	57-8					9 I--		2	2	0				27272
S 3269	Kviteseid	C	58					9 I--		Us	1	X				S 3269
28412a	Fyresdal	C	57-8		E		X	9 I--		1	2	B				28412a
8095	Telemark	D	59					9		2	1	0		Inscr.		8095
29090a	Skien	E	61				X	9--		2	1	0				29090a
S 33/82	Seljord	E	65	A/VI.1A			X	9	Only guards	X	X	X				S 33/82
3601	Skien	H	79		B			9--		1	2	0				3601
5621	Nome	H	79					9--	Too much curved	1	1	X				5621
21379a	Kragerø	H	79					9--		2	3	B				21379a
26360a	Porsgrunn	H	79		E			9 II-10 I		2	3	A	IIIa/b	PW	7	26360a
28238	Porsgrunn	H						9-10 I	Type uncertain	2	3	0				28238
28280	Nome	H	79					9 10 I		2	1	B				28280
28429a	Porsgrunn	H	79		D	562	X	9 II-10 I		1	3	0				28429a
29511a	Porsgrunn	H			G	562	X	9 II-10 I		2	2	0				29511a
32026a	Kragerø	H	79					9-10 I	Only guards	X	X	X				32026a
36370	Skien	H	79					9-10 I		1	1	0		PW		36370
53463/1	Nome	H	79					9-10 I	Type uncertain	2	3	0				53463/1
S 1220	Skien	H	79					9-10 I		1	X	X				S 1220
22508a	Hjartdal	H	79	F/VII.1A	E		X	9 II--	Dep. Iceland	2	X	X				22508a
24305a	Tinn	H	79		E		X	9 II--		2	2	0				24305a
20583a	Kviteseid	H						9-10 I	Uncertain identification	2	3	X				20583a
21325a	Vinje	H	79		D		X	9- 10 I		2	3	0	I	Inscr.	16	21325a
24793b	Kviteseid	H?						9- 10 I	Mixed finds	1	1	0				24793b
S 3145	Kviteseid	H			D,G		X	9-10 I	Mixed finds	2	3	X				S 3145
21383a	Nissedal	H		Un	D			9 I--		2	2	0				21383a
10815	Telemark	H						9-10 I		2	1	0				10815

ARCHAEOLOGICAL DATA										TECHNICAL DATA						
GENERAL		TYPE		GRAVE CONTENT				DATING	REMARKS							
Mus.no	Municipality	Type JP +	Fig.No	Spearhead JP/BS	Axe JP	Shield R	Other		Remarks	Edges	Condi-tion	Welded-on edges	Constr.	PW/Inscr.	Met.no	Mus.no
10203	Hjartdal	I	87				X	10 I		2	2	A				10203
20130a	Seljord	I	86-7	K/VII.2B	G		X	10 I	Mixed finds	1	1	0				20130a
20528a	Siljan	L	94		G		X	9 II-10 I		2	3	A		PW 5		20528a
2208	Porsgrunn	M	99					9 II-10 I		2	1	0				2208
8473	Bamble	M						9 II-10 I		2	1	A				8473
9451	Sauherad	M	98	K/VII.2B	H		X	10 I--		2	1	A				9451
11814	Nome	M	98		E		X	9 II-10 I		1	1	0				11814
14529	Porsgrunn	M			I		X	10 I	Much corroded	2	3	B?	NB!			14529
16558	Bø	M	98		G,H		X	9 II-10 I	Mixed finds, 2 axes	2	1	B				16558
19336	Bø	M	98		Und		X	9 II-10 I	Mixed finds	2	1	0				19336
19576	Nome	M	98		I			9 II-10 I	Mixed finds	1	2	0				19576
19578	Nome	M	98		2M			9 II-10 I	Mixed finds	2	2	A				19578
23083a	Skien	M			G			9 II-10 I	Much corroded	1	3	0				23083a
25156a	Skien	M	98		E		X	9 II-10 I		2	3	0				25156a
27133a	Skien	M	98	K/VII.2B				10 I	2 spears	1	2	0				27133a
27176a	Porsgrunn	M	98	/Var 14				10 I		1	1	0				27176a
27351a	Porsgrunn	M	98	Und	K+E	562	X	9 II-10 I	Possibly mixed	2	3	0				27351a
27821a	Skien	M*	98**	/VII	K+G			10 I	*M/Q 98/110	1	1	0				27821a
28281	Nome	M*	98**					10 I	*M/Q ** 98/110	2	2	0				28281
28339	Nome	M	98					9 II-10 I		2	3	B		Inscr.		28339
29150	Skien	M	98					9 II-10 I		2	2	0	IIa		2	29150
29151	Skien	M	98					9 II-10 I		2	1	0				29151
29227a	Skien	M	98	C/VI.2A				9 II-10 I		1	2	0	I		5	29227a
30067a	Skien	M		Und				9 II-10 I		2	3	0	IIa		1	30067
33155a	Sauherad	M						9 II-10 I		2	3	0				33155a
33574a	Bø	M	98		G			9 II--		1	3	0				33574a
34018a	Skien	M	98	K/VII.2B				10 I		1	1	0				34018
35842a	Skien	M		/VII.2			X	10 I		2	3	A	IIIa		4	35842a
35843a	Skien	M	99	/VII.1A*	G	562	X	9 II--	*Socket rivets. 563?	2	2	0	IV ???			35843a
52343	Siljan	M	98					9 II-10 I		2	2	B				52343
54615/3	Nome	M	98					9 II-10 I		1	1	0				54615/3
54803/1	Nome	M	98		G			9 II--		2	3	?				54803/1
S 1225	Skien	M	98	D/VI.3B			X	9 II	Uncertain combination	1	X	X				S 1225
S 44/A5	Nome	M	98					9 II-10 I		1	X	X				S 44/A5
S 45/9	Nome	M		K?	I			10 I		2	X	X				S 45/9
1955	Hjartdal	M	98					9 II-10 I		2	1	0				1955
20643a	Tinn	M	99		H	562	X	10 I		1	1	0				20643a
27075a	Hjartdal	M	98					9 II-10 I		1	2	0				27075a
29162a	Hjartdal	M	98					9 II-10 I	Not preserved	2	X	X				29162
54823/8	Notodden	M	98					9 II-10 I	Only upper guard	X	X	X				54823/8
1753	Tokke	M	98		G	562	X	9 II-10 I	Mixed finds?	2	1	0				1753
1851	Tokke	M	98	I/VII.2A	E			10 I	Uncertain combination	2	3	B				1851
3175	Tokke	M			Und			9 II-10 I	3175-78 possibly mixed	2	1	0				3175
3176	Tokke	M			Und			9 II-10 I		1	2	0				3176
11502	Tokke	M/Q		/Var.9	E		X	10 I--	Mixed finds	1	1	0				11502
11799	Kviteseid	M	98	/VII.2C				10 I--	Axe etc. lost	1	1	0				11799

ARCHAEOLOGICAL DATA										TECHNICAL DATA						
GENERAL		**TYPE**		**GRAVE CONTENT**				**DATING**	**REMARKS**							
Mus.no	**Municipality**	**Type JP +**	**Fig.No**	**Spearhead JP/BS**	**Axe JP**	**Shield R**	**Other**		**Remarks**	**Edges**	**Condi-tion**	**Welded-on edges**	**Constr.**	**PW/Inscr.**	**Met.no**	**Mus.no**
14651	Kviteseid	M			2	562	X	9 II-10 I	Mixed finds	1	1	0				14651
19663	Vinje	M	98					9 II-10 I		2	2	0				19663
21113a	Kviteseid	M		/VII.2C		562	X	9 II-10 I	Mixed finds	2	3	B				21113a
21113b	Kviteseid	M	98					9 II-10 I	Mixed finds	2	2	B				21113b
22372a	Tokke	M		/VII.2C	G		X	10 I		1	1	0				22372a
24244a	Vinje	M	99	F/VII.1B			X	9 II-10 I		2	1	0				24244a
24439	Seljord	M?						9 II-10 I		1	2	B				24439
28786a	Kviteseid	M	98					9 II-10 I		1	1	0				28786a
35304	Kviteseid	M	98					9 II-10 I		1	2	0				35304
54817/1	Vinje	M						9 II-10 I		2	1	0				54817/1
6859	Fyresdal	M	99?					9 II-10 I		2	1	0				6859
23946a	Fyresdal	M			G		X	9 II-10 I		1	3	0	IV (I)		21	23946a
34271	Nissedal	M	98		H			10 I	Axe 36363	2	1	0				34271
53462	Telemark	M						9 II-10 I		2	3	0				53462
54503/1	Hjartdal	O 3						10 I	Indigenous imitation	2	2	0				54503/1
54833/1	Hjartdal	O	105					10 I	Indigenous imitation	2	1	A				54833/1
10313	Hjartdal	O?	105					10 I		2	2	0				10313
36841	Tinn	P	109					10 I		2	1	A				36841
54843/1	Tinn	P	109					10 I	Mixed finds	2	1	A				54843/1
8141	Sauherad	Q	110	/IX.2				10 --	Mixed finds?	2	1	0				8141
9809	Skien	Q?X						10		2	1	0				9809
19575	Nome	Q	110					10	Mixed finds	2	1	0	IIIb		20	19575
23112a	Skien	Q			M	562		10 II	Boat grave	1	3	0	I		6	23112
24236	Skien	Q	111					10		2	2	0				24236
30049	Bø	Q	110					10		2	2	A	IIIa		9	30049
54760/1	Skien	Q	110					10		2	2	X				54760/1
21039a	Tinn	Q						10	Only guards	2	3	X				21039a
21039b	Tinn	Q			K			10	Mixed with 21038	1	2	B				21039b
21050a	Hjartdal	Q	110		K	562	X	10 I		2	2	0		Inscr.		21050a
25770a	Tinn	Q	110					10		1	1	0				25770a
26828a	Tinn	Q	110					10		2	2	A	IIIa		11	26828a
1455	Vinje	Q	110			565		10 II		2	2	0				1455
1603	Tokke	Q	110					10		2	1	A				1603
2781	Seljord	Q	110					10	2781-91 Mixed	2	3	0				2781
2782-83	Seljord	Q	110					10		2	3	0				2782-83
4559	Vinje	Q	110		I		X	10		2	3	X				4559
6522	Kviteseid	Q						10		2	2	A				6522
9134	Kviteseid	Q			2	562	X	10 I		2	2	0				9134
19477	Seljord	Q		Und	H/K		X	10		2	2	A				19477
19820	Kviteseid	Q	111	K/VII.2B	M	563	X	10 II--		2	3	A				19820
23018a	Tokke	Q	110		H		X	10 I--?	Oval brooch	2	3	0?	IIIa		17	23018a
24793a	Kviteseid	Q	110					10		2	2	B				24793a
25111a	Vinje	Q	111					10		2	2	0	IIIa		15	25111a
25551a	Tokke	Q	110		I		X	10		2	2	A				25551a
27454a	Kviteseid	Q	110	4	7	2	X	10 middle	Byggland grave	2	3	A				27454a
27454b	Kviteseid	Q	110					10 middle	Blindheim 1963	2	2	B				27454b
27454c	Kviteseid	Q	110					10 middle	Martens 2002	2	3	A				27454c
27454d	Kviteseid	Q						10 middle	Only guards	X	X	X				27454d
S 2687	Seljord	Q	110		K			10		2	1	X				S 2687

ARCHAEOLOGICAL DATA										TECHNICAL DATA						
GENERAL		**TYPE**		**GRAVE CONTENT**				**DATING**	**REMARKS**							
Mus.no	Municipality	Type JP +	Fig.No	Spearhead JP/BS	Axe JP	Shield R	Other		Remarks	Edges	Condi-tion	Welded-on edges	Constr.	PW/Inscr.	Met.no	Mus.no
23548a	Nissedal	Q			H			10 I--		1	1	0				23548a
21633d	Telemark	Q						10	Only upper guard	X	X	X				21633d
21210a	Tinn	R	113	K/VII.2B	H,G		X	10	Mixed finds	2	2	A		In-scr?		21210a
29878a	Notodden	S	114	M/VII.3A	K		X	10 II-11 I	Fuglesang 1980, 3B	2	2	0				29878a
53631	Tinn	S	115		Un			10 II	Only guards	X	X	X				53631
17656	Vinje	S?	114-5					10 II	Only guards	UN	X	X				17656
25111b	Vinje	S?						10 II	Only lower guard	?	X	X				25111b
11451	Fyresdal	S	114					10 II		2	1	0				11451
52806/1	Tinn	T	121	G/IX.1A	K,G		X	10 II--	Possibly mixed	2	2	0				52806/1
1648	Seljord	T	121				X	10 II--		2	1	0		Inscr.		1648
28352a	Fyresdal	T	121		H			10 II--		2	1	0		Inscr.		28352a
17958	Bø	T/V			H		X	10 II	Mixed finds +2 axes	2	2	A				17958
35841a	Skien	V	Pl.III	G/IX.1A	H		X	10 II--		2	3	A	IIIa		3	35841a
17404	Seljord	V?						10	Only pommel	X	?	X				17404
S 3231	Skien	X?								0	X	X				S 3231
23364	Tinn	X	125					10		2	1	0	IIb	In-scr?	14	23364
29700a	Tinn	X	125	K/VII.2B	I		X	10		2	2	0	IIa		12	29700a
29700b	Tinn	X	125	K/VII.2B	I		X	10		2	3	0	IIb		13	29700b
1610	Tokke	X	125					10	Mixed finds	2	3	0				1610
17401	Seljord	X	125					10		2	3	A				17401
21900	Tokke	X?Q						10		2	2	A				21900
24739a	Kviteseid	X			I		X	10 I--	NB! Type. Foto?	2	1	A				24739a
21038a	Tinn	Y	130		K	565	X	10 II		2	2	0				21038a
28738a	Vinje	Y	131-2	K/VII.2B	M			10 II	Only upper guard	X	0	X				28738a
21633c	Telemark	Y	131-2					10 II	Only upper guard	X	X	X				21633
5544	Notodden	Z	137		L		X	11 I		2	3	0				5544
54500/1	Tinn	Z						11 I	Only guards	X	X	X				54500/1
23921	Tokke	Z	136-7					11 I	Only drawing	X	X	X				23921
39278a	Fyresdal	Z			M			11 I		2	1	0				39278a
39281a	Tinn	Æ	138	M/VII.3A				11 I		2	2	A				39281a
39281b	Tinn	Æ		-«-				11 I		2	1	0				39281b
21211a	Tinn	LA	*Ka 78*		L		X	11	Kaland 1969	2	3	0				21211a
28239a	Tinn	LA	*Ka 78*	M/VII.3A		565		11	Uncertain combination	2	1	0	V	Inscr	10	28239a
S 4043	Skien	S16	R.495							2	X	X				S 4043
16559	Bø	S 17			3		X		Mixed finds	1	1	0				16559
2201	Porsgrunn	Un								2	2	0				2201
8706	Kragerø	Un								2	2	A				8706
19577	Nome	Un								1	2	0				19577
21716a	Skien	Un							Guards like M	2	2	0				21716a
23418a	Bamble	Un							Small fragments	Unc	3	X				23418a
26410a	Kragerø	Un							Only lower guard	Unc	3	X				26410a

ARCHAEOLOGICAL DATA										TECHNICAL DATA						
GENERAL		TYPE		GRAVE CONTENT				DATING	REMARKS							
Mus.no	Municipality	Type JP +	Fig.No	Spearhead JP/BS	Axe JP	Shield R	Other		Remarks	Edges	Condi-tion	Welded-on edges	Constr.	PW/Inscr.	Met.no	Mus.no
27351 o	Porsgrunn	Un			G	565			Much corr. Mixed	2	3	?				27351o
28460a	Porsgrunn	Evt.X		G/IX.1A	I			10 II	Much corroded, HK type X	2	3	A	IIIa		8	28460a
30848a	Porsgrunn	Un							Much corroded	2	3	0				30848a
54615/1	Nome	Un								Un	3	0				54615/1
54615/4	Nome	Un							V-type? Old drawing	2	3	0		Inscr		54615/4
54621/1	Nome	Un								2	3	B				54621/1
54846/1	Bø	Un								2	3	0				54846/1
S 1219	Skien	Un							JP O?	X	X	X				S 1219
S 32/103	Skien	Un								X	X	X				S 32/103
11310	Notodden	Un								2	2	B				11310
24305b	Tinn	Un							Small fragments	1	X	X				24305b
24349	Tinn	Und							Small fragments	1						24349
27602b	Hjartdal	Und								2	1	A				27602b
34000	Notodden	Und							Only lower guard	X	X	X				34000
54842/1	Tinn	Und							Cfr.21211, 28239	2	3	0				54842/1
8073	Kviteseid	Und								2	1	0				8073
12340	Kviteseid	Und							Small fragments	2	3	X				12340
14652	Kviteseid	Und								1	2	B				14652
17401	Seljord	Und								2	2	A				17401
17655	Vinje	Und								2	3	X				17655
17899	Seljord	Und								1	3	X				17899
20584	Kviteseid	Und								X	3	X				20584
20589a	Kviteseid	Und								1	1	0				20589a
22281	Tokke	Und								2	3	0				22281a
22546	Tokke	Und		K/VII.2B				10 I--		2	1	0				22546
22568a	Tokke	Und			H			10-11 I		2	2	A	IV?		18	22568a
24394	Tokke	Und								2	3	0				24394
24435	Seljord	Und								1	1	0				24435
24527	Seljord	Und								2	2	B				24527
24793b	Kviteseid	Und								2	2	0	IIIa		19	24793b
24793c	Kviteseid	Und								2	3	X				24793c
26484	Vinje	Und								2	2	0				26484
26551a	Tokke	Und							Small fragments	2	3	X				26551a
26637a	Tokke	Und					x		Many smith’s tools	2	3	0				26637a
26800a	Seljord	Und								2	2	A		PW 5		26800a
30110	Vinje	Und								2	2	A	IIIc			30110
33157v	Tokke	Und							Small fragments	2	X	X				33157v
13933	Fyresdal	Und							Uncertain provenance	1	2	B				13933
21383b	Nissedal	Und								2	2	0				21383b
No	Com	TY	Fig	Spear	Axe	Shi	Ot	Date	Remarks							

APPENDIX 2

Find list. Swords found in concentrations and other sword finds.

Municipality	**Concentrations**		**Number**	**Other locations**	**Mus.no**	**Find place**
GRENLAND	No	Name				
Porsgrunn	1	Porsgrunn	6		26360a	Bjørntvedt
					27176a	Herøya
					27351a	Valler
					27351o	Valler
					28429a	Valler
					29511a	Eidanger vicarage
	2	Eidanger	3		28238	Lerstang
					28460a	Stamland
					30848a	Oksum
	3	Brevik	2		2201	Brevik
					2208	Brevik
			1	●	14529	Kvestad
Skien	1	Gjerpen	9		1878	Mæla
					21716a	Frogner
					23112a	Frogner
					24236	Falkum (uncertain)
					25396a	Grini
					27133a	Rising
					27821a	Gjerpen vicarage
					34018a	Gjerpen vicarage
					S 4043	Brekke
	2	Bø/Ås	2		S 1220	Bø
					S 1225	Ås
	3	Ballestad	6		35841a	Ballestad
					35842a	Ballestad
					35843a	Ballestad
					36370	Ballestad
					29150	Ris
					29151	Ris
	4	Gimsøy	4		3601	Faret
					29227a	Gimsøy
					30067a	Kjærringteigen
					S 3231	Gimsøy
			6	●	29090a	Vale
				●	S32:103	Bakken
				●	S 1219	Fjellvannet area
				●	9809	Stavdal, Solum
				●	23083a	Bjørntvedt
				●	25156a	Dalane, Solum
Siljan			2	●	20528a	Gonsholt
				●	52343	Hogstad
Bamble	1	Bamble	2		12696	Tegdal
					23418a	Valle

Municipality	**Concentrations**		**Number**	**Other locations**	**Mus.no**	**Find place**
GRENLAND	No	Name				
			2	●	8473	Fosstveit
				●	SM 4379	Tråk
Kragerø	1	Låkasken	2		26410a	Låkasken
					32026a	Låkasken
			3	●	8402	Kalstad
				●	8706	Frøvik
				●	21379a	Støle
Nome	1	Ytre Flåbygd	8		1120	Røymål
					19575	Røymål
					19576	Røymål
					19577	Røymål
					19578	Røymål
					28281	Ovenstrøm
					54621/1	Nes
					S 1945:9	Nes
	2	Lunde	5		10082	Hvåla (Kvålo)
					28280	Ytterbø
					54615/1	Helgetveit
					54615/3	Helgetveit
					54615/4	Helgetveit
	3	Holla	2		28339	Søve
					54803/1	Heisholt
			9	●	5621	Tinholt
				●	36368	Skårdal
				●	53463/1	Verpe
				●	11814	Lunde kirke
				●	S 1944 A5	Ullevik
Sauherad				●	8141	Kise
				●	33155a	Gunheim
				●	9451	Vestgarden
				●	12596	Sunde
Bø	1	Øvrebø	3		17985	Øvrebø
					19336	Verpe
					30049a	Grave
	2	Erikstein	3		16558	Erikstein
					16559	Erikstein
					54846/1	Tveitan
			1	●	33574a	Li
EASTERN TELEMARK						
Notodden	1	Gransherad	3		29878a	Bøen
					54805/1	Nisi
					54823/8	Li
			3	●	5544	Hafsten
				●	34000	Sauar
				●	11310	Tveitan
Tinn	1	Rjukan	7		21038a	Bøen
					21039a	Bøen
					21039b	Bøen

Municipality	**Concentrations**		**Number**	**Other locations**	**Mus.no**	**Find place**
GRENLAND	No	Name				
					21210a	Såem
					21211a	Såem
					23364	Bøen
					54843/1	Bøen
	2	Dale	3		20643a	Moen
					24349	Moen
					25770	Dale
	3	Mæl	3		26828a	Møli
					39281a	Ørnes
					39281b	Ørnes
	4	Gøystdal	2		24305a	Gøystdal
					24305b	Gøystdal
	5	Mårem	5		28239a	Mårem
					29700a	Mårem
					29700b	Mårem
					52806/1	Mårem
					53631	Mårem
	6	Austbygdi	3		36841	Åpålen
					54840/10	Bøen /10-11
					54842/1	Bøen
			1	●	54844/1-	Gausta /1-2
Hjartdal	1	Kirkebygda	2		24217a	Risvoll (Århus)
					27618	Holm
	2	Sauland	9		1955	Leine
					10203	Mosbø
					10313	Mosbø
					18168	Landsverk
					27075a	Bø
					27602b	Bø
					27978	Øvstebø
					54833/1	Skeie (Skoye)
			4	●	22508a	To
				●	54503/1	Hjartsjå
				●	29162a	Lonar
				●	21050a	Fosse
WESTERN TELEMARK						
Seljord	1	Flatdal	4		2781	Skeie
					2782-3	Skeie
					19477	Haugstuen
					S 2687	Sundbø
	2	Centre area	9		1500	Nordgarden
					1648	Utgarden
					17401	Nordgarden
					17401	Nordgarden
					17404	Loftsgarden
					17899	Midtbøen
					24435	Grave
					24439	Grave

Municipality	**Concentrations**		**Number**	**Other locations**	**Mus.no**	**Find place**
GRENLAND	No	Name				
					26800a	Bjørge
			2	●	20130a	Strond
				●	S 33/82	Vasstveit
Kviteseid	1	Morgedal	9		6522	Berge
					8073	Berge
					20583a	Bjåland
					20584a	Bjåland
					24793a	Berge
					24793b	Berge
					24793c	Berge
					35304	Berge
					S 3145	Bjåland
	2	Byggland	4		27454a	Byggland
					27454b	Byggland
					27454c	Byggland
					27454d-e	Byggland
	2	Svanejord	2		9134	Svanejord
					11799	Midtbøen
Kviteseid	3	Dalane	2		19820	Dalane
					24739a	Dalane
	4	Tveit	3		21113a	Tveit
					21113b	Tveit
					21113k	Tveit
	5	Sundbygda	5		12340	Utsund
					12903	Midtsund
					14651	Midtsund
					14652	Midtsund
					S 3269	Kyrkjebø
			2	●	20589a	Gjershvam
				●	28786a	Flatland
Tokke	1	Åmdal	2		1163	Åmdal
					26637a	Skredtveit
	2	Høydalsmo	3		24394	Haukom
					26551a	Kvåle
					33157v	Kvåle
	3	Lårdal	10		1603	Åkre
					1610	Åkre
					1753	Åkre
	3				1851	Bjåland
					2505	Åkre
					22281a	Tveito
					22372	Tveito
					22568a	Kvåle
	3				23018a	Åkre
					25551a	Åkre
	4	Kolkjønn	3		11502	Kolkjønn
					21900	Kolkjønn

Municipality	Concentrations		Number	Other locations	Mus.no	Find place
GRENLAND	No	Name				
					23921	Kolkjønn
	5	Klauvreid	2		3175	Midtgarden
					3176	Klauvreid
Tokke			2	●	22546a	Groven
				●	27272	Lofthus
Vinje	1	Rauland	2		25111a	Nystog
					25111b	Nystog
	2	Særen	2		17655	Særen
					17656	Særen
	3	Åbø	3		4559	Midtbø
					19663	Hylland
					28738a	Midtbø
			5	●	1455	Klypa
				●	21325	Killingtveit
				●	24244a	Hellegjuvsberget
				●	26484	Nordgarden
				●	30110	Vinje vicarage
SOUTHWEST						
(Nidelv watercourse)						
Fyresdal	1	Veum	2		13933	Veum (uncertain)
					28412a	Veum
	2	Moland	3		6859	Moghus
		(Kyrkjebygdi)			11451	Århus
					39278a	Århus
			2	●	23946a	Brokke
				●	28352a	Momrak
Nissedal	1	Homme	2		21383a	Homme
					21383b	Homme
			1	●	34271	Fjalestad

Finds only registered to municipality.

Nissedal	23548a
Seljord	24527
Tinn	54000
Tinn	54500
Skien	54760/1
Vinje	54817/1