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 Clevерns). 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.