Technological aspects of the Viking age gold treasure from Hiddensee, Germany

Barbara Armbruster with H Eilbracht

ABSTRACT: This paper deals with the study of ancient gold jewellery manufacture, in particular the techniques and tools used during the Viking age. It discusses the Hiddensee-style, named after the gold hoard found at the end of the 19th century on the shores of Hiddensee. This kind of jewellery is generally dated to the 10th and early 11th century AD, when Christianization of the north is beginning. It is characterized by a hollow body made of thin gold sheet with a typical relief decorated with filigree and granulation. The hoard also contains a twisted neck ring, made of several hammered rods and a clasp. Twisted neck and arm rings were in fashion in the Viking world and also with the Slavs, their eastern neighbours, and were worn during the entire Viking period, from about 800–1050 AD.

Introduction

What is now known as the 'Hiddensee Treasure' is a collection of jewellery, dated to the last quarter of the 10th century, consisting of sixteen gold items: ten cross-shaped pendants, four small pendants, a disc-shaped brooch and a neck ring, with a total weight of 598g (Fig 1 and Table 1). The hoard appears to be incomplete. It probably originally consisted of more than one collar, as there are several cross-shaped pendants of different shapes and sizes which do not all form proper pairs. Several groups of gold objects were found between 1872 and 1874 along about 60 metres of the beach of the small isle of Hiddensee, which is situated to the west of the island of Rügen, off the Baltic coast of Germany (Fig 2). It appears that the items were uncovered by heavy storms. Hiddensee faces the continental coast, outside the Viking heartland of the Danish kingdom, but on the sea route towards the central and eastern Baltic.

The Hiddensee hoard was first mentioned in an exhibition catalogue shortly after its discovery (Baier 1880, 38–40) and the original monograph devoted to it was published by Paulsen (1936). In 1979 the detailed cataloguing of archaeological finds from the former German Democratic Republic produced the first good quality illustrations of the objects (Herrmann and Donat 1979, no 44/221). Recent works have studied the characteristics of the filigree and granulation (Eilbracht 1999), the tools implied by its manufacture (Armbruster 2002a), and the art historical and cultural implications of the Hiddensee-style ornaments (Kleingärtner 2003). A recent interdisciplinary study of the gold items from Hiddensee revealed new information on gold technology (Armbruster *et al* 2005). A full publication is in preparation (Armbruster *et al* in prep).

The origin of the treasure is still unclear as details of its discovery remain unknown. Legend has linked it with the first baptized Viking king, Harald Blauzahn [Bluetooth] (Paulsen 1936; Duczko 1992). It was thought that during the reign of Harald Blauzahn and Sven Gabelbart [Forkbeard] in Denmark, at the turn of the 10th and 11th centuries, Slav pirates took possession of the treasure and lost it while sailing east (Filipowiak 1998, 341). There are many other fanciful hypotheses: that the gold had been part of the cargo of a long-distance trading ship that was wrecked, that it had been an offering to pagan deities, or that the jewellery was the dowry of a Danish woman (Paulsen 1936; Schulze-Dörrlamm 1999). However, whatever its origin, this

Figure 1: The Hiddensee hoard

hoard of complete gold ornaments appears to have had a different function from that of the numerous large silver hoards (hack-silver) of the Viking Age that were buried for their metal value (Hårdh 1996).

Table 1: Details of the Hiddensee treasure (numbered as on Figure 1)

Item	Weight (g)	Size (mm)
1	114.0	diam 80
2	152.8	125 x 135
3	5.0	19.0 x 23.0
4	5.6	20.0 x 23.2
5	5.4	20.9 x 22.8
6	5.0	18.6 x 22.7
7	20.2	51.3 x 47.0
8	20.3	51.7 x 48.0
9	21.5	51.6 x 48.3
10	22.5	51.5 x 48.6
11	40.4	67.9 x 64.2
12	39.1	69.0 x 64.9
13	38.0	68.2 x 63.6
14	35.0	65.5 x 64.3
15	34.5	65.8 x 64.9
16	36.2	64.4 x 64.6

Viking precious metal jewellery

Gold jewellery is among the rarest archaeological evidence from the Viking Age. Viking precious metal ornaments were predominantly manufactured in silver, as shown by over a thousand rich silver hoards, the so called 'hack-silver', consisting of personal ornaments,

Figure 2: Location map showing Hiddensee and areas of Viking settlement (after Willemsen 2004)

ingots and coins, both complete items and fragments (Hårdh 1996). Nonetheless, important archaeological finds of goldwork and goldsmiths' tools demonstrate its appreciation. Viking jewellery attests the richness of its owners and is clearly a symbol of status and wealth. However, the use of amulets proves it also had a spiritual dimension. Cross-shaped pendants, such as those from Hiddensee or from the Tolstrup hoard from Jutland, evidently have a religious character (Koktvedgaard Zeiten 1997, 28, fig 38).

The Hiddensee Treasure is arguably the most significant discovery of its kind from Germany and one of the most important ensembles of gold objects to have survived from the Viking period. Nevertheless, the outstanding hoard of Hon (Haug, Buskerud) from SE Norway, with a total weight of about 2.5kg, is the heaviest and most magnificent gold treasure buried in Scandinavia (Grieg 1929). This hoard from the early Viking period (9th century) consists predominantly of goldwork, including heavy neck rings and bracelets, of several twisted rods, filigree pendants and some silver and glass beads of various origins (Duczko 1985, 106–8). Coins mounted as pendants are of several provenances, *eg* Frankish, Roman, Byzantine, Arabic and Anglo-Saxon. This numismatic mixture reflects the wide range of contacts of the Scandinavians and informs us about a part of their continental and insular precious metal resources. A large trefoil-shaped brooch from the Hon hoard is of Carolingian origin. Other hoards such as that from Vester Vedsted, Denmark (Skovmand 1942), or large and heavy neck rings from Sigtuna, Sweden, and Tissø, Denmark, the heaviest of its kind, are also among the outstanding gold finds of the Viking Age (Kann Rasmussen 1970).

It is recorded by Arabic writers that twisted rings made up of several precious metal bars were a very common type of jewellery worn by Nordic men and women (Graham-Campbell 2001, 118). They are typical of Viking precious metal working and represent the most frequent jewellery items. Twisted neck rings exist in many technical and stylistic varieties (Hårdh 1976; 1996, 191–208). The different technological aspects of twisted Viking ring jewellery and their close relationship to eastern European rings have been studied in detail (Stenberger 1947, 270–88). The four-rod examples of such rings are related to the Hiddensee neck ring (*ibid*, 278-80; Lønborg 1998, 75).

The Hiddensee neck ring

The Hiddensee neck ring was found coiled up, indicating that the hoard was deposited in a small container of perishable material or in a ceramic vessel, as are known from other precious metal hoards (Paulsen 1936, pl 16; Wiechmann 1996, 193–5). Today the neck ring has been restored to its circular form (Fig 1.2). It is made of four equal cylindrical rods, each tapering towards the ends, and fastens with a hook and loop. Although separately manufactured, the component parts are joined together so expertly as to seem physically a single piece.

The rods of varying diameter were hammered on an anvil, starting with a quadrangular section, passing through a polygonal section to reach to a round one. Hammers and anvils which could be used for the manufacture of such rods are known from tool hoards, *eg* the Mästermyr hoard (Arwidsson and Berg 1983), graves, *eg* the Bygland find (Blindheim 1963), and from settlement sites (Armbruster 2002b, 147; Fig 26). In Hedeby, a specialised tool for rod and wire production, a stake formed as a swage block bearing a linear depression of semi-circular section, was found (Fig 26, 5). Rods and wires of circular section could be made by hammering the work piece in this depression while it was continuously turned. Another way of obtaining polygonal or circular-sectioned bars is the use of a double swage block. Such a tool was used by Stapley, who reproduced rods of polygonal section, characteristic of the Iron Age Ipswich torcs (Brailsford and Stapley 1972).

After annealing the hammered rods, two cords were twisted, using two rods for each. Twisting of massive rods must be done while one end is fixed in an immobile vice and the other end in a mobile hand vice. During twisting the work piece must be annealed several times to assure a regular twist. The two cords were then twisted around each other (Figs 1.2 and 3a).

The next step consisted of joining the ends of the four rods by casting on, which was presumably executed by lost wax casting. For that, each extremity was covered by a wax model with an added runner and sprue, and then covered by several layers of tempered clay to form the mould. After drying, the wax was melted out and the hollow form was filled with gold melted in a crucible. Tool marks show clearly that the cast-on gold was then hammered into a strip. On one end this hammered part was split with a chisel to make a loop (Fig 3b), while the other one was bent and formed into a hook (Fig 3c). Both cast-on strips were decorated with imprints of a lozenge-form punch with a central point.

Experimental work directly concerning the Hiddensee torc was done by a local goldsmith in Schleswig, who produced a replica of the Hiddensee jewellery (Links 1997,

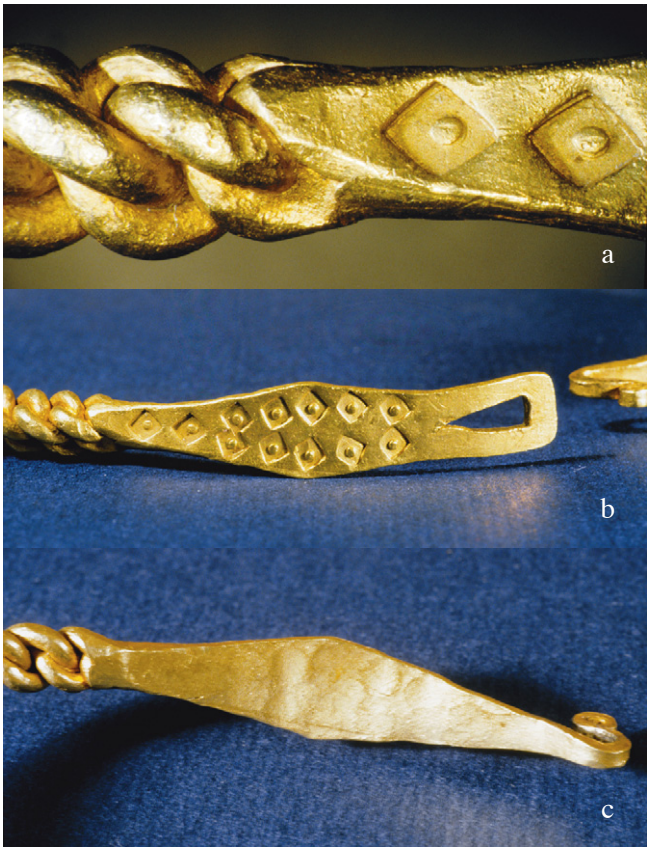

Figure 3: Details of the torc. a: a cast-on end piece, b: loop end with punched decoration, c: back of hook with tool marks from punching.

Figure 4: Terslev-type silver pendant from the Terslev hoard. Diameter 35.2 mm. [see also Plate 20]

137). The experiment contributed to our knowledge of the complex twisting and annealing process, and the production of the fastener. It also included the manufacture of the four rods, which the goldsmith mistakenly thought had been made by a rolling mill (Links 1997, 129–38). This kind of precise mechanical tool which modern goldsmiths use was not known during the Viking Age. Replication experiments that employ modern methods produce technically incorrect details. Maryon was right to say 'Therein lies the root of trouble. Archaeologists, relying on their acquaintance with modern methods, or misunderstanding the ancient methods, have attributed to the ancient workers power which, with their primitive furnaces, they could never have attained' (Maryon 1949, 103).

Hiddensee filigree art

Apart from the heavy neck and arm rings, two Viking jewellery types predominated during the 10th century and the beginning of the 11th century: the Terslev-type (Fig 4), named after a Danish silver hoard (Friis Johansen 1912), and the Hiddensee-style, named after the hoard under consideration (Fig 1). Duczko (1993, 187–9) includes the Terslev-type in what he has named Hiddensee filigree art or Hiddensee-style. He states that the set of dies from the harbour at Hedeby (Fig 5), comprising about 14 different motifs, is representative of the Hiddensee-style. This die hoard includes two Terslev-type examples, and the isolated die finds from the settlement area of the site contain at least three more Terslev-type dies (Armbruster 2002a, pls 5 and 12). The bulk of Viking age dies correspond to Duczko's Hiddensee-style. Eilbracht (1999, 133) instead separates the two types, demonstrating an earlier date for the Terslev-type pattern, and a later one for the animal ornament of the Hiddensee-style brooches.

Ornaments of both styles are abundantly decorated with filigree and granulation, and are hollow, worked using dies. Consequently they have little weight in relation to their volume, and were designed for serial production. The Terlev-type are strictly disc-shaped pendants and brooches with four volutes (Fig 4); in some variations three volutes occur. The volutes are symmetrically arranged in a square or lozenge, the openings facing outwards (Duczko 1985, 82–86); the centre of the brooch forms a cross. The Hiddensee-style comprises disc-shaped brooches, and pendants which vary from cross-shaped to leaf-shaped with characteristic combinations of local animal style and western-European interlace motifs (Duczko 1993, 185). The principal patterns are four or three interlaced animal bodies for the brooches (Figs 1.1 and 16), and animal head suspension loops and

Figure 5: Dies from the Hedeby tool set. a: die for a disc-shaped brooch like the Hiddensee brooch; b: dies for cross-shaped pendants like the two styles of Hiddensee pendants, with interlaced tendrils (left), with plain surface for granulation (right).

interlaced tendrils for the pendants (Figs 1.3–1.16 and 20). Viking filigree ornaments of this kind are renowned for the fine quality of wire work and interlaced figural and floral motifs which are characteristic for this period of Scandinavian history.

The technical examination of the Hiddensee jewellery reveals details of soldering, wire production, filigree, granulation and the use of dies for the pendants and the brooch. All objects from the Hiddensee hoard are composed of several elements, the component parts manufactured individually and then joined. Brooch and pendants are constructed of worked sheet gold, forming a hollow body, and wire and granules outlining interlaced tendrils and stylized animals.

Worked sheet gold

The worked gold sheet was obtained from a cast ingot by hammering, interrupted by repeated annealing. After

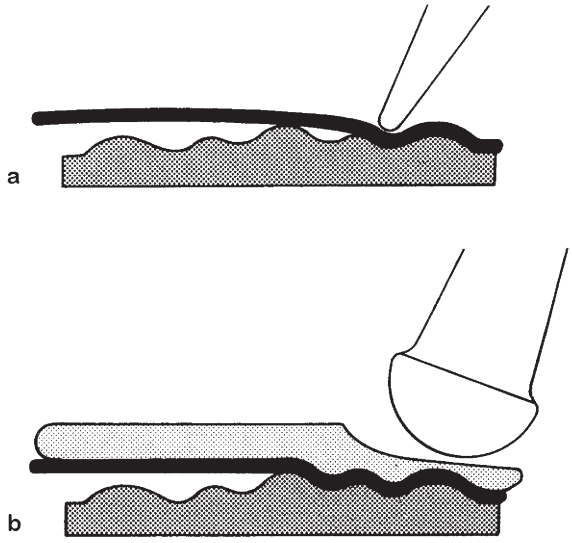

Figure 6: Pressed sheet production. a: pressing the sheet (black) into the raised relief (grey) of the die with a point or punch; b: pressing the sheet (black) into the relief (grey) using a lead sheet (light grey) and a round-faced hammer.

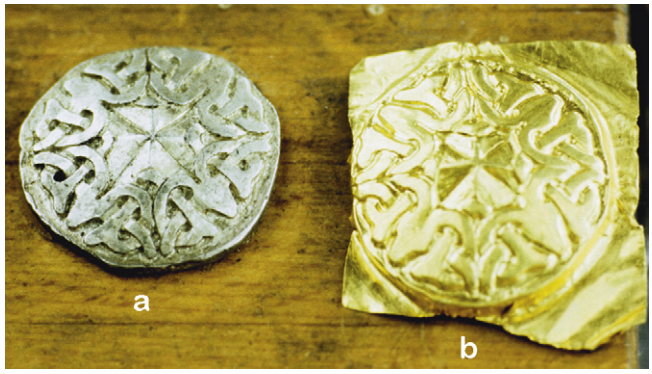

Figure 7: Experimental production of pressed sheet using a pointed tool. a: die; b: pressed sheet.

achieving the desired thickness, the sheet had to be transformed on a die. The deep relief of the Hiddensee ornaments has been worked with copper alloy dies and a pointed tool, such as a metal point, punch, chisel etc (Figs 6–7; Armbruster 2002a, fig 11). The dies have a flat back, which lies on a support during work. Experimental archaeology showed that the manufacture of pressed sheet is not a matter of one stroke on the die as has been proposed on several occasions. The work with the die and the point was carried out in several steps, including annealing phases.

When the relief sheet is finished, its outline is cut out of the larger sheet with the help of a sharp chisel. It is then placed on a flat back plate and soldered on. In the case of the cross-shaped pendants this includes also soldering in

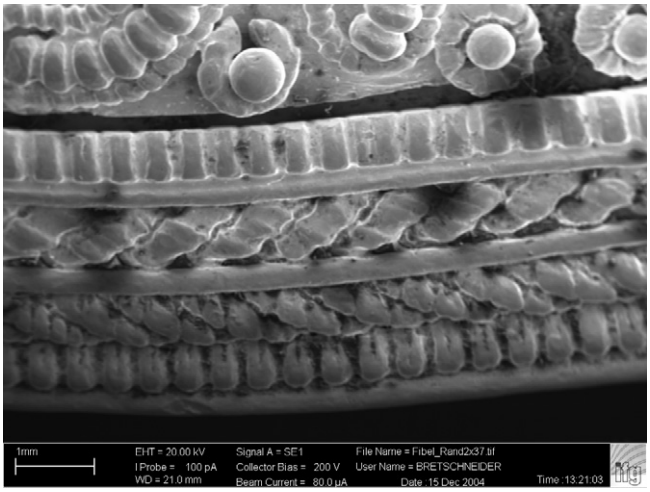

Figure 8: SEM image of the Hiddensee brooch showing varied wire profiles and single granules in a wire ring. (Institute for Scientific Instruments, Berlin, project Armbruster/Eilbracht)

the round openings between the arms of the cross. After that the surplus metal of the back plate is cut off with a chisel, working around the pressed relief sheet and in the circular openings. The relief sheet is subsequently decorated with filigree and granulation. For that, the goldsmith has to produce wire and small granules.

Filigree

The filigree ornaments from the Hiddensee treasure have predominantly beaded wire of various shapes as well as some twisted wires (Fig 8; Wolters 1987, figs 1, 2 and 5). Bands of three or more wires of different profile soldered onto the upstanding parts of the pressed sheet give an optical illusion of interlaced bands (Fig 18). Only the small pendants are manufactured exclusively in filigree and their motifs do not include any animal style elements (Figs 1.3–1.6 and 21).

Viking wire production was based on hammering a wire from a cast ingot, followed by the use of a draw-plate in order to get a fine round-sectioned wire (Figs 9–10; Whitfield 1990; Armbruster 2005). Draw plates are documented from various Viking sites, amongst them Staraja Ladoga, Russia (Davidan 1982), Hedeby, Germany (Armbruster 2002b), By and Bygland, Norway, and Mästermyr, Sweden (Lønborg 1998; Martens 2002). Except for one example from Staraja Ladoga which is made out of a high-zinc brass (Fig 11), the others appear to be of iron (Armbruster 2005, 290). A radiographic study showing dense metal remains in the conical holes, and analyses of the metal composition confirmed that silver wire was drawn with the Hedeby drawplate (Armbruster 2005, fig 3). Beaded wire was produced from round-sectioned wire by means of an 'organarium', a double swage block with beaded negative forms, or

Figure 9: Depiction of wire drawing, from the Mendelsche Zwölfbrüder-Stiftung, Nürnberg 1425 (after Treue et al 1965, Fig 229). [see also front cover]

with a 'file' for beaded wire (Fig 12) (Armbruster 2002b, 171, fig 40; Whitfield 2004). Such tools were described in detail by Theophilus in the 12th century (Dodwell 1961). Only one tool for beaded wire production, a beading file with its wooden handle, has been found in archaeological context – in the 3rd century bog find of Illerup-Ådal in Denmark (Carnap-Bornheim and Ilkjaer 1996, 81, fig 58a).

On cross-shaped pendant 13 a length of beaded wire on the suspension loop still has part of its initial plain round form (Fig 13). The same technical detail is recorded from a gold bead with filigree and granulation from Hedeby (Armbruster 2002b, 129, fig 19). These details demonstrate that the goldsmith used all the small bits of wire available in his workshop, even unfinished ones.

Granulation

Granulation is used in combination with filigree on the cross-shaped pendants and on the brooch from Hiddensee. There are different kinds of granulation: granules filling spaces (Fig 14), a single granule in a wire ring (Fig 8), which occurs singly and in groups, or scattered granulation as on two of the cross-shaped pendants.

Figure 10: Wire drawing in Mali; the draw plate is held between the feet.

Figure 11: Draw plates from Staraja Ladoga, made of brass (below) and iron.

The small gold spheres used in Viking granulation are very heterogeneous in size and form (Fig 14a). However, the granules were most probably made from small pieces cut from wire or sheet, and melted in a crucible, as it is described for ancient granulation (Wolters 1986; Nestler and Formigli 1993). To do that, a crucible is filled with alternating layers of charcoal powder and pieces of gold, the charcoal used as separating material. Once heated in the furnace, the melted metal tends to form spheres.

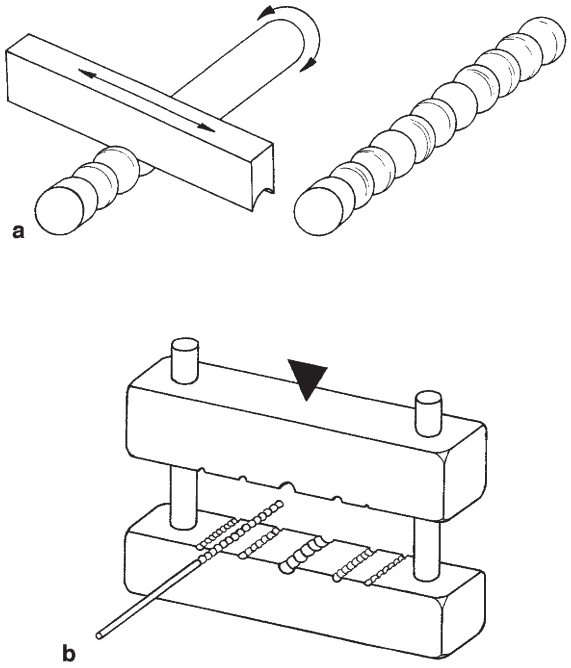

Figure 12: Beaded wire manufacture. a: using a beading file (after Williams and Ogden 1994, Fig 24); b: using an organarium (after Drescher 1986, Fig 31a).

After cooling, they are removed from the charcoal by washing them out. The small spheres are then placed on the worked sheet together with the wire segments and soldered in the furnace by means of metallic solder, presumably applied as a powder, obtained by using a file or other abrasive (Armbruster 2002b, 172–5). There is a large amount of metallic solder between the granules.

The disc-shaped brooch

The disc-shaped brooch is large compared with other contemporary gold ornaments (Fig 1.1). It is constructed

Figure 13: Detail of pendant 13, showing beaded wire with one end having the original round section. [see also Plate 24]

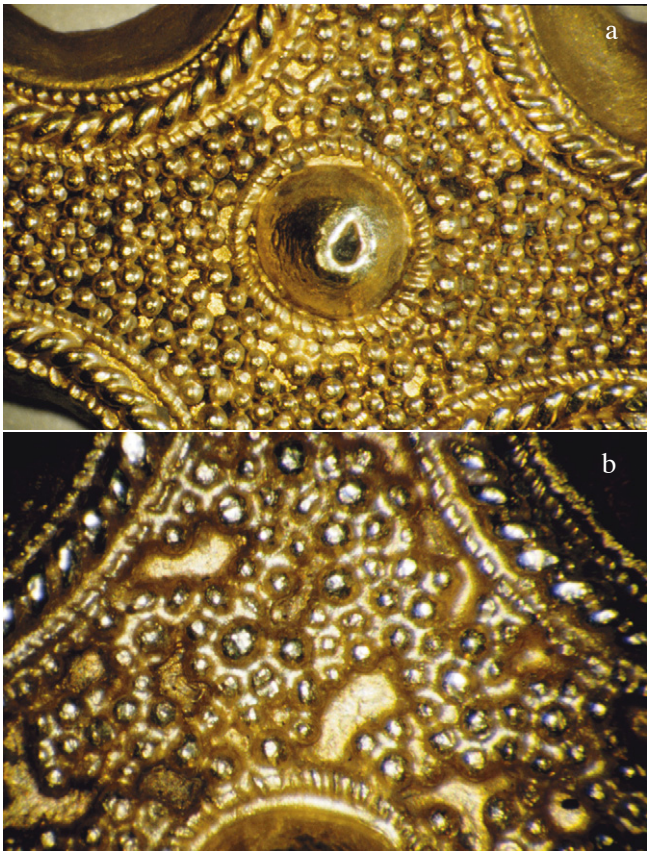

Figure 14: Details of pendants 7 and 8 showing granulation. a: varied granule size [see also Plate 25]; b: large amounts of metallic solder.

Figure 15: Deformed back of the disc-shaped brooch. Note the three rivets repairing the pin attachment (at the right). The head of one of these rivets can be seen at the bottom of Figure 16.

of a flat base plate and a domed relief plate. The brooch originally had a hollow body but now the back plate is deformed (Fig 15), apparently due to the weight of the beach sand. The catch, the attachment for the pin, and a suspension loop for decorative elements, all fashioned out of ribbed and bent strips survive on the back though

Figure 16: Detail of the four animal heads and the cross-shaped setting in the centre of the Hiddensee brooch. Compare this with the die from Hedeby (Figure 5a). [see also Plate 21]

the pin itself is missing. The pin was fixed and hinged on a rivet. The position of the attachment points for the pin indicate that the brooch was worn by somebody who was right-handed. Some fine lines and spirals of beaded wire decorate the back, following the outline of the soldered strips, one of which was repaired by riveting (Figs 15 and 16).

The relief is richly decorated with filigree and granulation in animal style (so-called Borre style). Four stylised interlaced animal bodies cover the relief plate. In the centre four animal heads come together, leaving space for a small cloisonné cross inlaid with coloured glass (Fig 16). A double frame outlines the cross and a single gold band forms the inner setting. The back plate is larger than the front one, whose edge is covered with a wide band of decorative wires.

The cross-shaped pendants

The ten cross-shaped pendants are heterogeneous in size and design details (Fig 1.7-1.16). All are made of a back plate, a worked relief plate and rich filigree and granulation. All have a large barrel-shaped suspension loop in the form of a bird head, the beak pointing towards the cross-shaped body (Fig 17). Although the design is very stylised, eyes, ears and beak are clear. The pendants can be classified in four groups, all but the last having interlaced filigree tendrils on the relief sheet.

- Nos 9 and 10 have elaborate bird heads, basic interlace ornament and plain backs (Fig 17a).
- Nos 11, 12 and 13 are larger and have elaborate bird heads and complex interlace, the back decorated with the addition of a loop on two pieces (Figs 18 and 19).
- Nos 14 and 15 are also larger and have more elaborate bird heads, complex interlace and a plain back (Fig 17b).
- Nos 7 and 8 are decorated with granulation on a

Figure 17: Details of the bird head suspension loops on cross-shaped pendants. a: no 9 [see also Plate 24]; b: no 15. Compare with the die from Hedeby (Fig 5b, left)

Figure 18: Pendant 12 with interlaced tendrils, beaded wire, granulation and open work.

flat surface outlined by a wire, with decoration on the back (Fig 14).

On several pendants the back plate has a thick beaded wire along the vertical axis with a thin beaded wire on both sides ending in small spirals (Fig 19).

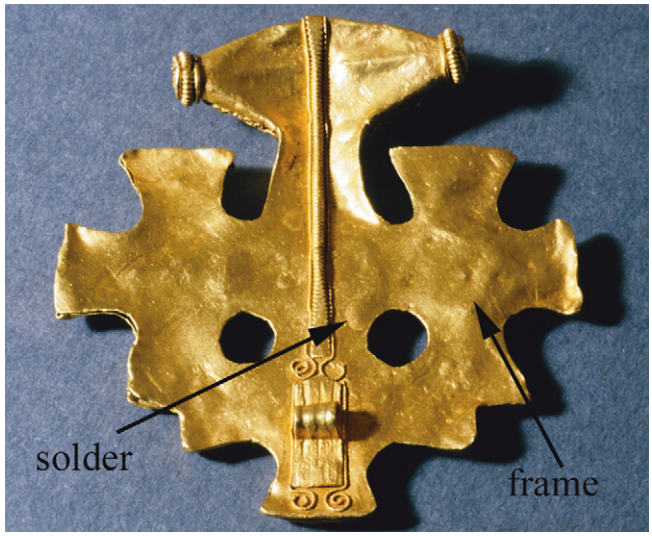

Figure 19: Back of pendant 13 showing the added loop, traces of the rectangular strengthening frames inside and remains of metallic solder.

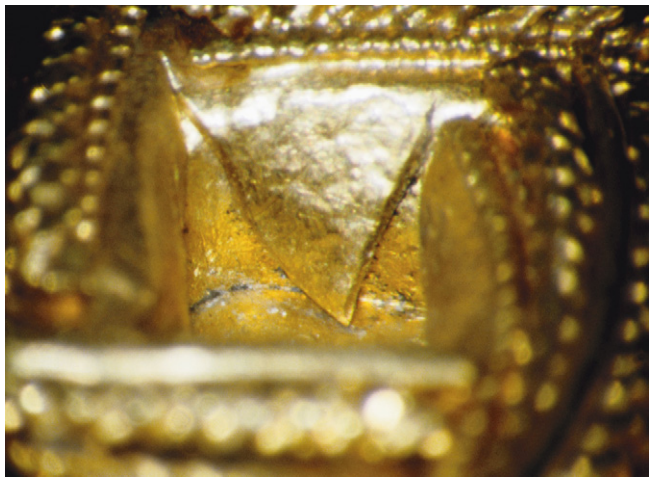

Figure 20: Details of an opening cut in the pressed sheet of pendant 13. The four triangles are bent down and, behind one, part of the inserted frame can be seen.

Each cross body is composed of four crosses, the main one has three arms each terminating in a smaller cross, and one terminating in the suspension loop. Between the lower cross arms there are circular openings in the relief sheet as well as in the back plate (Fig 18). Between the interlaced tendrils of eight pendants the relief sheet has been opened up with a chisel to give the relief decoration more depth. These openings, which do not pass through the back plate, were cut as a cross, and the points of the four cut triangles bent down (Fig 20). These bent parts round the opening help to keep the back and front plates of these hollow objects apart. Pendants 12 and 13 additionally have rectangular frames, bent from a gold strip, around these openings, acting as spacers between the relief-decorated front and the back sheet (Fig 19). These inner 'frames', whose function was to keep the front and back sheets apart, are hardly visible from the

Figure 21: Front and back of a small pendant.

outside, but the back plate, which has suffered under the weight of the beach sand, shows imprints of the inner frames. These spacing pieces have previously been mis-interpreted as settings for coloured glass or stones (Schulze-Dörrlamm 1995, 814).

Small pendants

The four small pendants (Fig 1.3-1.6) are exclusively decorated with interlaced filigree (Fig 21) and all made with the same die. No die of that form is known and no direct comparisons can be drawn with other small pendants. They are supposed to have been used as spacing pieces between the cross-shaped pendants in a complex collar.

Alloy composition of base metal and solder

Analyses of the elemental composition of the gold alloy used for the sheet, wires and granules, as well as for the solder of the gold objects from Hiddensee, were carried out at the BAM-line in the Synchrotron Centre BESSY in Berlin by synchrotron radiation-induced XRF (Armbruster *et al* 2005). First results show a high gold content, between 92% and 96%, and homogeneity of alloy composition of all the items, except for the brooch, the neck ring and one cross-shaped pendant. It can be deduced that the Hiddensee treasure was manufactured in one workshop, from one source of metal, and conceived as an ensemble. There is little comparable analytical data on Viking gold available. For instance, the large Tissø necking, which weighs 1.83kg, also has a high gold content (96%) (Verbæk 1980, no 81). In contrast to the homogeneous alloy used for the Hiddensee jewellery, the gold finds from Hedeby show a very varied picture (Armbruster 2002b, 199-200). These analyses of about 50 items of jewellery, threads, foil and gold fragments from Hedeby were made in collaboration with Ernst Pernicka at the Max-Planck-Institut für Kernphysik at

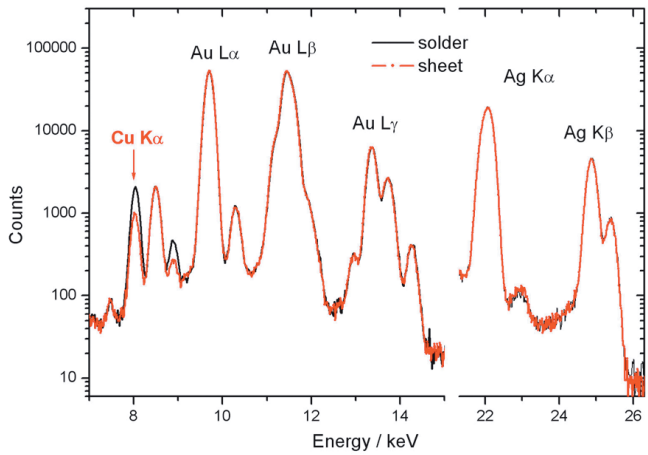

Figure 22: XRF spectrum of pendant 13 showing the raised copper content in the metallic solder compared with the sheet (after Armbruster et al 2005, 33, fig 6)

Heidelberg. The wide range of compositions of the gold items from graves and from the settlement area confirm the perpetual recycling of scrap metal and show no preference for a specific gold alloy. The objects were not conceived as an ensemble and presumably were made in different goldsmiths' workshops.

The results of the Hedeby analyses also provided the first evidence of the use of metallic solder for applying granulation and filigree in the southern part of the Viking world. These results are confirmed by the analytical data for metallic solder on the Hiddensee goldwork. The solder alloy is richer in copper than the base metal (Fig 22; Armbruster *et al* 2005, fig 6). Until these analyses were available, Viking precious metal objects were thought to have been soldered using copper salts, as is known for antique and especially for Etruscan gold granulation (Lønborg 1998, 123–5); metallic solder was only thought to have been used on copper alloys. Soldering was used for mounting and joining the constituent pieces made of sheet, wires and granules. It was carried out by using a gold alloy with a lower melting point than the rest of the metal. The various elements were assembled, and small particles of solder applied and fused in the heat of a furnace (Arminjon and Bilimoff 1998, 325–7; Lang and Hughes 1980). For granulation and filigree it appears that very small solder particles, probably obtained by filing, were scattered over the arrangement of decorative elements.

Comparable gold work

There are only seven comparable gold brooches of Hiddensee-style filigree from the Viking world:

- One small brooch from Sperrestrup, Denmark, can be directly related to the Hiddensee brooch's motif of four interlaced animals (Skovmand 1942, 114–5, fig 25; Eilbracht 1999, 211 no 238, pl 21). It still has a ring on

Figure 23: Front and back of gold brooch from Sperrestrup. Diameter c.46mm. [see also Plate 22]

Figure 24: 11th-century brooch from Hornelund. Diameter c.82mm).

the back indicating that smaller decorative elements were suspended there (Fig 23).

- The motif of interlaced loops and four animal heads meeting in the centre of the disc-shaped brooch from Randers, Denmark, is much more stylized than that on the Hiddensee and Sperrestrup brooches (Jørgensen and Petersen 1998, 300, fig 217).
- A disc-shaped brooch with a pattern of three volutes, but without animal ornament, is known from Erikstorp, Sweden, and appears to be related to one of the dies found at the settlement of Hedeby (Stenberger 1950; Knape 1994, 75).
- The brooch from Hilleshög, Sweden, has an atypical interlaced filigree motif with four animal heads in the corners of a rectangle (Selling 1947).
- One small Terslev-type brooch has a motif with three volutes (Armbruster 2002b, 101–4).
- The two disc-shaped brooches from Hornelund, Denmark, are the latest and most elaborate gold filigree objects, dating to the 11th century (Fig 24; Jørgensen and Petersen 1998, 305, fig 221). The interlaced and floral ornament of one of them appears to be related to a die in the Viborg Museum (Krongaard Kristensen 1990, 339, fig 2).

Disc-shaped Terslev-type pendants with cylindrical suspension loops are known, with two examples from the chamber grave 5 from Hedeby, Germany (Armbruster 2002b, 114–9), and one from Vester Vedsted, Denmark (Kann Rasmussen 1970, 18; Jørgensen and Petersen 1998, 298, fig 215).

There are only two gold parallels for cross shaped pendants. Both have no bird head suspension loops, but more or less cylindrical ones without any animal-style elements. They also have a fifth cross, one more than the Hiddensee pendants, positioned just beneath the suspension loop. One cross-shaped pendant comes from Hemänge, Sweden (Stenberger 1958, fig 185, 2; Eilbracht 1999, 198, no 152) and the other is part of an ensemble of four gold filigree items, with two leaf shaped pendants and a disc shaped plate for a brooch with Terslev-type motif, recorded from Lackalänga, Sweden (Knape 1994, 77; Eilbracht 1999, pls 8, 12 and 15). A fragment of a gold pendant from Trelleborg, corresponding to one of the dies from the Hedeby set, represents a stylised bird of prey with the head as the suspension loop and the wings as the body (Roesdahl 1977, figs 29–30; Armbruster 2002a, pl 9). The bird head of this fragment is a close parallel to that on the cross-shaped pendants from Hiddensee. Another animal-style gold pendant has been found in Sigtuna, Sweden, but it differs in having a barrel-shaped suspension loop and it is the pendant's body which forms an animal head (Jansson 1991, 280, fig 14).

The only cross-shaped pendants with a bird head suspension loop comparable with the Hiddensee items are from the silver hoard of Tolstrup, Denmark, which also includes a disc-shaped brooch with animal-style filigree (Fig 25; Eilbracht 1999, 125–6, pl 8; Paulsen 1936, pl 17). Other finds of cross-shaped pendants have cylindrical or barrel-shaped suspension loops. About 36 cross-shaped silver pendants of the Hiddensee-style and fragments of them are known in Scandinavia (Eilbracht 1999, pls 8–11) though all are smaller than the Hiddensee pieces. Similar finds also appear in the Ukraine where seven cross-shaped pendants from a hoard in Kiev are comparable with the pieces under consideration (Paulsen 1936, pl 27; Duczko 2004, fig 65b). Twelve cross-shaped dies made of copper alloy are known from the Hedeby tool-set, and one made of lead has been found in York, England (Duczko 1993, 187, fig 11; Armbruster 2002a).

Figure 25: Silver jewellery from the Tolstrup hoard. a, b: disc-shaped brooch with surviving pin on back [see also Plate 23]; c: cross-shaped pendants and fragments.

A remarkable 10th-century silver pendant from Skåne has a stylised animal-headed suspension loop very similar to the elaborate Hiddensee pieces, and is also worked in pressed sheet with filigree (Hårdh 1976, 77, pl 55.10; Brandt and Eggebrecht 1993, 351, VI-24). In this case, the pendant's body is fashioned as the pagan Thor's hammer, a form current in Viking amulets and jewellery, with the glaring eyes associated with Thor in Eddic tales (Graham-Campbell 2001, 180). The eyes of the Hiddensee pendants are in some cases hollow, made of a small dome, in other cases solid.

About 52 precious metal brooches of the Hiddensee style with three- or four-piece animal-style motifs are recorded, including variants (Eilbracht 1999, 209–16, nos 235–285). Except for the above-mentioned gold brooch from Sperrestrup, which is much smaller (diam 46mm), all of them are manufactured in silver (Fig 25). The silver brooch from Nonnebakken, Fyn, Denmark, has very similar animal-style ornament to the Hiddensee brooch (Roesdahl 1980, fig 88; Eilbracht 1999, 210, no 236, pl 20). The largest copper alloy die from the Hedeby tool set (Fig 5a) corresponds in many details with these brooches.

Tools of the Viking Age goldsmith

Viking metalworking tools are well known and have been found in different archaeological contexts (Müller-Wille

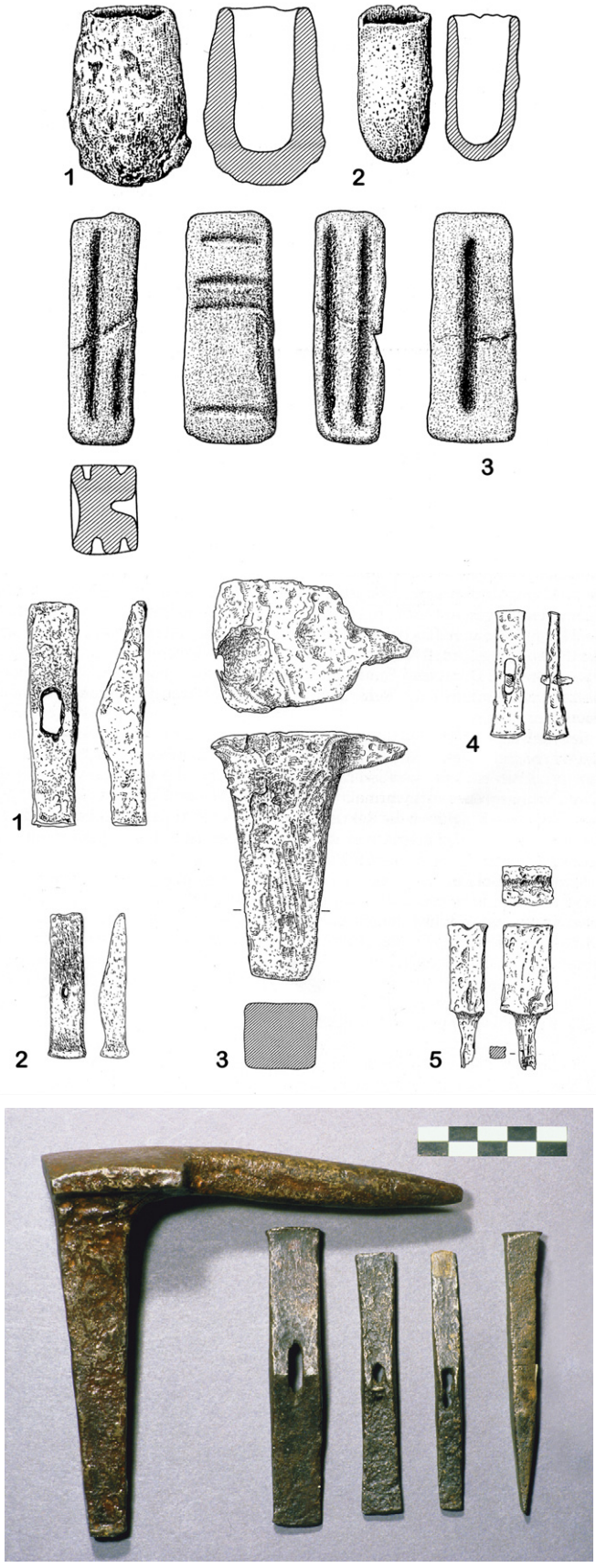

Figure 26: Metal-working tools. Top: crucibles (scale 1:2) and an ingot mould (scale 1:4) from Hedeby (after Armbruster 2002a); middle: hammers, anvil (3) and a stake (5) from Hedeby (scale 1:3, after Westphalen 2002); bottom: anvil and hammers from Staraja Ladoga.

1983). Evidence of Viking-period fine metalworking, in some cases in combination with minting, is mostly connected to central places like estate-centres or early urban sites. Metalworking tools are known from sites such as Hedeby, Ribe, Lund, Sigtuna, Birka, Borgeby and Kaupang, at the Danish fortresses of Fyrkat and Trelleborg, as well as from Viking settlements outside Scandinavia (Oldeberg 1966; Lønborg 1998).

The spectacular hoard of early medieval goldsmiths' tools, including 41 bronze dies and an iron drawplate was found during excavations at the harbour area of Hedeby, Germany, in 1979 (Schietzel and Crumlin Perdersen 1980). The dies from the hoard are of various types, representing a range of Hiddensee-style and Terlev-type jewellery (Fig 5) used in the 10th and early 11th centuries AD (Armbruster 2002b, 89–93). Other copper alloy dies, clay crucibles, stone ingot moulds, touchstones, abrasive stones with gold remains, and iron tools such as hammers, anvils, pliers, clamps and chisels came from the settlement area of Hedeby (Fig 26; Armbruster 2004).

Comparable conditions are documented from the settlement at Staraja Ladoga, Russia, where tools were recorded from the settlement and from a large tool hoard including an important set of metal working implements (Figs 11 and Fig 26c) (Davidan 1982; Vierck 1983). An excavation in 1981 at the settlement of Viborg Søndersø, Jutland, Denmark, produced a copper alloy die, an anvil and a refining crucible (Krongaard Kristensen 1990). Remains of a goldsmiths' workshop have also been found at Borgeby, Scandia (Brorsson 1998). The debris of jewellery production include fragments of clay moulds used for casting cross-shaped and disc-shaped dies in copper alloys. Their reconstructed forms are comparable with the Hedeby dies, used for Hiddensee-style jewellery (Svanberg 1998). A large tool set has been found in a grave at Bygland in Telemark, Norway (Blindheim 1963) and a hoard of metalworking tools were also discovered in the tool-chest from Mästermyr, Sweden (Oldeberg 1942–43, 9–22; Oldeberg 1966, figs 61–84; Arwidsson and Berg 1983).

Concluding remarks

The examination of the technological aspects of the jewellery of the Hiddensee treasure revealed details of the manufacturing techniques and hence the tools used. This study, based on a combination of the identification of tool marks, the study of metalworking tools, analyses of metal composition, experimental archaeology, and analogies from ethno-archaeology, ancient illustrations and literary descriptions, demonstrates how Viking goldsmiths manufactured high quality jewellery. In the Viking world, specialised artisans made jewellery which became a high status fashion among the Scandinavians.

Examination also reveals interesting information on the production of multiple items of jewellery. The processes applied in manufacture lead to results of high quality, an economic use of precious metals and, at the same time, an important reduction in the time involved in the production of an object. The method of impressed sheet metal for filigree-decorated ornaments illustrates the use of copper alloy dies and the production of jewellery in considerable quantity.

This study has outlined details of the technical know-how of the artisans of ancient Scandinavia and the technological level achieved in arts and crafts. It emphasizes the skilfulness of the goldsmiths, as well as their specialisation, technical virtuosity and sophisticated knowledge. The ideas suggested in this paper are designed to emphasize the importance of the technological approach to the classification of metal artifacts, and to encourage further interdisciplinary collaboration in the history of ancient metalwork.

References

Armbruster B R 2002a, 'Die Preßmodel von Haithabu', in K Brandt, M Müller-Wille and C Radtke (eds), *Haithabu und die frühe Stadtentwicklung im nördlichen Europa*. (Neumünster: Schriften des Archäologischen Landesmuseums 8), 219–80.

Armbruster B R 2002b, 'Goldschmiede in Haithabu – Ein Beitrag zum frühmittelalterlichen Metallhandwerk. Mit Beiträgen von E Pernicka und R Aniol', in K Schietzel (ed), *Berichte über die Ausgrabungen in Haithabu 34; Das archäologische Fundmaterial VII* (Neumünster), 85–205.

Armbruster B R 2004, 'Goldsmiths' tools at Hedeby', in J Hines, A Lane and M Redknap (eds), *Land, Sea and Home. Proceedings of a Conference on Viking-period Settlement* (Leeds: Society for Medieval Archaeology Monograph 20), 109–23.

Armbruster B R 2005, 'Notes on wire production during the Viking Age', in H Kars and E Burke (eds), *Proceedings of the 33th International Symposium on Archaeometry* (Amsterdam: Geoarcheological and Bioarchaeological Studies 3), 289–92.

Armbruster B R, Eilbracht H, Reiche I, Grüger A, Radtke M and Riesemeier H 2005, 'The Vikings in Berlin', G Andrén, H Henneken and M Sauerborn (eds), *BESSY Highlights. Berliner Elektronenspeicherring-Gesellschaft für Synchrotronstrahlung* (Berlin), 32–3.

Armbruster B R, Eilbracht H, Grüger A, Radtke M and Reiche I in preparation, *Der wikingische Goldschmuck von Hiddensee (Lübsdorf)*.

Arminjon C and Bilimoff M 1998, *L'art du métal. Vocabulaire technique* (Paris).

Arwidsson G and Berg G 1983, *The Mästermyr find. A viking age tool chest from Gotland* (Stockholm).

Baier R 1880, *Die vorgeschichtlichen Altertümer des Provinzialmuseums für Neuvorpommern und Rügen in Stralsund* (Berlin).

Blindheim C 1963, 'Smedgraven fra Bygland i Morgedal', *Viking* 26, 25–80.

Brailsford J and Stapley J E 1972, 'The Ipswich torcs', *Proceedings of the Prehistoric Society* 38, 219–34.

Brandt M and Eggebrecht A (eds) 1993, *Bernward von Hildesheim und das Zeitalter der Ottonen. Dom- und Diözesanmuseum Hildesheim - Römer- und Pelizaeus-Museum. Ausstellungskatalog 2* (Mainz).

Brorsson T 1998, 'In the workshop of the Viking Age goldsmith. Gold- and silverwork at Borgeby in Scania, southern Sweden', *Fornvännen* 93, 225–39.

Carnap-Bornheim C von and Ilkjaer J 1996, *Illerup-Ådal. Die Prachtausrüstungen. 5 Textband. 6 Katalog, Fundlisten, Literatur. 7 Tafelband* (Århus: Jutland Arch Soc Publ 25(5–7)).

Davidan O I 1982, 'Om hantverkets utveckling i Staraja Ladoga', *Fornvännen* 77, 170–9.

Dodwell C R 1961, *Theophilus, The various arts* (London).

Drescher H 1986, 'Draht', in J Hoops (ed), *Reallexikon der Germanischen Altertumskunde* 6 (Berlin), 140–52.

Duczko W 1985, *The filigree and granulation work of the Viking Period. An analysis of the material from Björkö.* (Stockholm: Birka 5).

Duczko W 1992, 'Gold- und Silberschmiedearbeiten', in Kunstausstellung des Europarates, *Wikinger - Waräger - Normannen. Die Skandinavier und Europa 80–1200* (Berlin), 200f.

Duczko W 1993, 'Scandinavian dies of the Viking Age', in C Eluère (ed), *Outils et ateliers d'orfèvre des temps anciens* (Saint-Germain-en-Laye: Antiquités Nationales mémoire 2), 185–190.

Duczko W 2004, *Viking Rus. Studies on the presence of Scandinavians in eastern Europe, the northern world. north Europe and the Baltic c.400–1700 AD* (Leiden, Boston: Peoples, economies and cultures 12).

Eilbracht H 1999, 'Filigran- und Granulationskunst im wikingischen Norden. Untersuchungen zum Transfer frühmittelalterlicher Gold- und Silberschmiedetechniken zwischen dem Kontinent und Nordeuropa', *Zeitschrift für Archäologie des Mittelalters* Beiheft 11 (Köln).

Filipowiak W 1998, 'Der Goldschatz von Hiddensee. Eine Piratenbeute der Ranen?', in A Wesse (ed), *Studien zur Archäologie des stseeraumes. Von der Eisenzeit zum Mittelalter. Festschrift für M. Müller-Wille* (Neumünster), 337–44.

Friis Johansen K 1912, 'Sølvskatten fra Terslev', *Aarbøger for Nordisk Oldkyngighed og Historie*, 189–263.

Graham-Campbell J 2001, *The Viking world* (London).

Grieg S 1929, 'Vikingertidens skattefund', *Universitetets Oldsaksamlings Skrifter* 2 (Oslo).

Hårdh B 1976, *Wikingerzeitliche Depotfunde aus Südschweden* (Bonn: Acta Archaeologica Ludensia, series in 4°, 9).

Hårdh B 1996, *Silver in the Viking Age. A regional-economic study* (Stockholm: Acta Archaeologica Ludensia, series in 8°, 25).

Herrmann J and Donat P 1979, *Corpus archäologischer Quellen zur Frühgeschichte auf dem Gebiet der DDR (7.–12. Jahrhundert) 2. Lieferung* (Berlin).

Jansson I 1991, 'År 970/971 och vikingatidens kronologi', in M Iversen an U Näsman (eds), Mammen. Grav, kunst og samfund i vikingatid. *Jysk Arkæologisk Seleskabs Skrifter* 28, 267–84.

Jørgensen L and Petersen P V 1998, *Guld, magt og tro. Gold, power and belief. Danske guldskatte fra oldtid og middelalder* (Copenhagen).

Kann Rasmussen A 1970, 'Guldskatten fra Vester Vedsted', *Mark og montre* 6, 18–20.

Kleingärtner S 2003, Der wikingerzeitliche Pressmodelfund aus dem Hafen von Haithabu, Gem. Busdorf, Kr. Schleswig-Flensburg, Schleswig-Holstein, D, unter besonderer Brücksichtigung kunst- und kulturhistorischer Aspekte. Dissertation, Christian-Albrechts-Universität, Kiel.

Knape A 1994, *Guldets magi i saga och verklighet* (Stockholm).

Koktvedgaard Zeiten M 1997, 'Amulets and amulet use in Viking Age Denmark', *Acta Archaeologica* 68, 1–74.

Krongaard Kristensen H 1990, 'Spor efter guldsmede fra vikingetiden i Viborg', *Kuml* (for 1988-89), 335–46.

Lang J and Hughes M J 1980, 'Joining techniques', in W A Oddy (ed), *Aspects of early metallurgy* (London: British Museum Occasional Paper 17), 169–78.

Links R 1997, 'Zur Herstellung von wikingerzeitlichem Hacksilber und Goldschmuckstücken mittels mechanischer Walzen', *Acta Praehistorica et Archaeologica* 29, 122–40.

Lønborg B 1998, 'Vikingetidens metalbearbejdning', *Fynske Studier* 17 (Odense).

Martens I 2002, 'Smeden og hans produkter i norsk vikingtid', in H Hofsteth (ed), *UKM - En mangfoldig Forskninginstitusjion* (Oslo: Universitetets kulturhistoriska museer skrifter 1), 173–86.

Maryon H 1949, 'Metalworking in the ancient world', *American Journal of Archaeology* 53(2), 93–125.

Müller-Wille M 1983, 'Der Schmied im Spiegel archäologischer Quellen. Zur Aussage von Schmiedegräbern der Wikingerzeit', in HJankuhn, W Janssen, R Schmidt-Wiegand and H Tiefenbach (eds), *Das Handwerk in vor- und frühgeschichtlicher Zeit. Teil 2. Archäologische und philologische Beiträge* (Göttingen: Bericht über die Kolloquien der Kommission für die Altertumskunde Mittel- und Nordeuropas in den Jahren 1977–1980. Abh der Akademie der Wissenschaften. Philologisch-Historische Klasse; Folge 3, Nr 123), 216–60.

Nestler G and Formigli E 1993, *Etruskische Granulation. Eine antike Goldschmiedetechnik* (Siena).

Oldeberg A 1942-43, *Metallteknik under förhistorisk tid* (Lund).

Oldeberg A 1966, *Metallteknik under vikingatid och medeltid* (Stockholm).

Paulsen P 1936, 'Der Goldschatz von Hiddensee', *Führer zur Urgeschichte* 13 (Leipzig).

Roesdahl E 1977, *Fyrkat. En jysk vikingeborg. II. Oldsagerne og gravspladsen* (Copenhagen: Norske Fortidsminder ser B, 4).

Roesdahl E 1980, *Danmarks Vikingetid* (Copenhagen).

Schietzel K and Crumlin Perdersen O 1980, 'Havn i Hedeby', *Skalk* 3, 4–10.

Schulze-Dörrlamm M 1995, Goldschatz von Neuendorf auf der Insel Hiddensee bei Rügen. *Jahrbuch des Römisch-Germanischen Zentralmuseums* 38 (for 1991), 810–4.

Schulze-Dörrlamm M 1999, 'Hiddensee', in H Beck, D Geuenich and H Steuer (eds), *Reallexikon der Germanischen Altertumskunde* 14, 2nd edn (Berlin/New York), 551–3.

Selling D 1947, 'Kring ett vikingatida guldspänne från Uppland', *Fornvännen* 42, 74–84.

Skovmand R 1942, 'De danske skattefund fra Vikingetiden og den aeldeste Middelalder indtil omkring 1150', *Aarbørger for nordisk Oldkyndiighed og Historie 1942* (Copenhagen).

Stenberger M 1947, *Die Schatzfunde Gotlands der Wikingerzeit. 2 Fundbeschreibung und Tafeln* (Lund).

Stenberger M 1950, 'Erikstorpspännet och Hedeby', *Fornvännen* 45, 37–40.

Stenberger M 1958, *Die Schatzfunde Gotlands der Wikingerzeit. 1 Text* (Stockholm).

Svanberg F 1998, 'Exclusive jewellery, Borgeby and western Scania c. AD 950-1050', *Fornvännen* 93, 113–24.

Treue W, Goldmann K, Kellermann R, Klem F, Schneider K, Stromer W V, Wißner A and Zirnbauer H 1965, *Das Hausbuch der Mendelschen Zwölfbrüderstiftung zu Nürnberg. Deutsche Handwerksbilder des 15. und 16. Jahrhunderts* (Munich).

Verbæk C L 1980, 'Guldhalsring fra Norvestsjælland', in P V Glob (ed), *Danefæ. Til Hendes Majestæt Dronning Margarethe II* (Copenhagen).

Vierck H 1983, 'Ein Schmiedeplatz aus Alt-Ladoga und der präurbane Handel zur Ostsee vor der Wikingerzeit', *Münstersche Beiträge zur antiken Handelgeschichte* 2(2), 3–64.

Westphalen P 2002, *Die Eisenfunde von Haithabu* (Neumünster).

Whitfield N 1990, 'Round wire in the Early Middle Ages', *Jewellery Studies* 4, 13–28.

Whitfield N 2004, 'The manufacture of beaded wire in the post-roman period', in A Perea, I Montero and O Garcia Vuelta (eds), *Tecnologia del oro antiguo: Europa y América. Ancient gold technology: America and Europe* (Madrid: Anejos de Archivo Espanol de Arqueologia 32), 127–37.

Willemsen A 2004, *Wikinger am Rhein 800–1000* (Utrecht).

Williams D and Ogden J 1994, *Greek gold. Jewellery of the classical world* (London).

Wiechmann R 1996, *Edelmetalldepots der Wikingerzeit* (Neumünster).

Wolters J 1986, *Die Granulation. Geschichte und Technik einer alten Goldschmiedekunst* (München).

Wolters J 1987, 'Filigran', in K-A Wirth (ed), *Reallexikon zur Deutschen Kunstgeschichte*, 8 (Munich), 1062–184.

The authors

Barbara Armbruster, an archaeologist and trained goldsmith, is now a research fellow at the Centre National de Recherche Scientifique at Toulouse University. She researches the history of technology of precious metals and copper alloys from the Early Bronze Age to the early medieval period in Europe and Eurasia. Her interdisciplinary approach includes archaeological, experimental, ethnological and iconographic studies as well as archaeometallurgical data. Her MA thesis was an ethno-archaeological field study, comparing the technological aspects of twisted gold and bronze rings with cruciform section with the production of comparable rings in traditional workshops in Mali, West Africa. In 1996 she completed her PhD on metal working during the Atlantic Bronze Age in Iberia.
Address: Unité Toulousaine d'Archéologie et d'Histoire (CNRS - UMR 5608), Maison de la Recherche - Université de Toulouse Le Mirail, 5 allées Antonio-Machado, F-31058 Toulouse Cedex 09, France.
e-mail: barbara.armbruster@univ-tlse2.fr

Heidemarie Eilbracht studied prehistory, early medieval archaeology, classical archaeology and history at the Westfälische Wilhelms-Universität in Münster (Westfalen). Her thesis was on Filigran- und Granulationskunst im wikingischen Norden and she has led several archaeological excavations. Since 2001 she has worked at the Humboldt-Universität Berlin on a research project concerning Viking Age metalcraft and its archaeological remains. Together with Barbara Armbruster she is responsible for a new publication on the Viking Age *Goldschmuck von Hiddensee*.
Address: Humboldt-Universität zu Berlin - Lehrstuhl für Ur- und Frühgeschichte, Hausvogteiplatz 5–7, 10117 Berlin, Germany.
e-mail: eilbrachth@geschichte.hu-berlin.de