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The Excavations at Wijnaldum

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Scientific analysis of the gold disc-on-bow brooch

A.J. NIJBOER & J.E. VAN REEKUM

1 INTRODUCTION

The gold cloisonné disc-on-bow brooch from Wijnaldum-Tjitsma has been recently analysed and inspected for a material-scientific description. Previously the brooch was described in terms of its art history and archaeology,[1] but a technical examination was wanting. By means of various scientific methods, a description of the materials was obtained as well as a closer observation on the manufacturing- and decoration techniques of the brooch. One of the motives to analyse the composition of the metal alloys of the diverse small components, was to ascertain whether all the fragments belonged to the same brooch. Additionally, information on the history of the brooch and it's destruction is provided. After a preliminary microscopic examination of all components of the brooch, the following scientific techniques were applied:

- X-ray photography for an examination of the construction, primarily of the foot-plate,
- Scanning Electron Microscopy (SEM) for detailed images of several segments of the brooch in order to obtain more information about the manufacturing- and decoration techniques,
- X-ray Fluorescence (XRF) for an analysis of the various metal components of the brooch,
- X-ray Diffraction (XRD) for a determination of the cloisonné inlay and the white filling in the roundels of the foot-plate,
- High Pressure Liquid Chromatography (HPLC), Gas Chromatography (GCMS), Fourier Transform Infra Red (FTIR) in combination with XRD was employed for the paste underneath the gold backing foils beneath the cloisonné inlay.

A reconstruction of the main segments of the brooch is on display in the Fries Museum in Leeuwarden.[2] Figure 1 illustrates the assembled brooch, in combination with the associated fragments.[3] The numbers and letters in Figure 1 are used in this paper to indicate the different components of the brooch.

The various components of the brooch have been recovered at several stages and the archaeological history of the brooch is intricate. The footplate was found in the early 1950s, during drainage works on the Tjitsma terp near Wijnaldum. It was recovered almost intact. The majority of the gold sheet on the back, two roundels and some cloisonné inlays were missing. From the 1980s onwards, several other pieces have been found like two heavily damaged pieces of the head-plate with similar cloisonné decoration as the above mentioned foot-plate. Additionally the following fragments were recovered:

- 2 pieces of the connecting bow were recovered as one gold filigree and one silver 'filling' fragment (Fig. 1),
- 7 fragments of gold sheet (Fig. 1, no. 6 up to 12),
- 2 pieces of silver 'filling' (Fig.1, no. 2 and 3),
- 1 fragment of the gold rim with twisted beaded wire (Fig. 1, no. 13),
- 1 piece of the hinge with gold sheet and silver filling (Fig. 1, no. 5),
- 1 piece of gold filigree of a stylized animal head with a garnet eye (Fig. 1, no. 4).

The above mentioned fragments were found by amateur-archaeologists and were collected by Mr J. Zijlstra. The Fries Museum at Leeuwarden acquired most of the components of the brooch. During the excavation on the Tjitsma terp in 1991, 6 more fragments of gold sheet (Fig. 1, no. 15 up to 19) and in 1992 a piece of the head-plate were recovered.

From onwards the 1950s, all the major components of the disc-on-bow brooch from Wijnaldum have been recovered except for the disc itself. As yet no fragments of the disc have been found which could be significant for the final interpretation of the presence of the brooch on Tjitsma terp.

The paper will first describe the analyses of the singular materials which were employed during the manufacture of the brooch. The determination of the non-metals, silver alloys and the gold alloys are

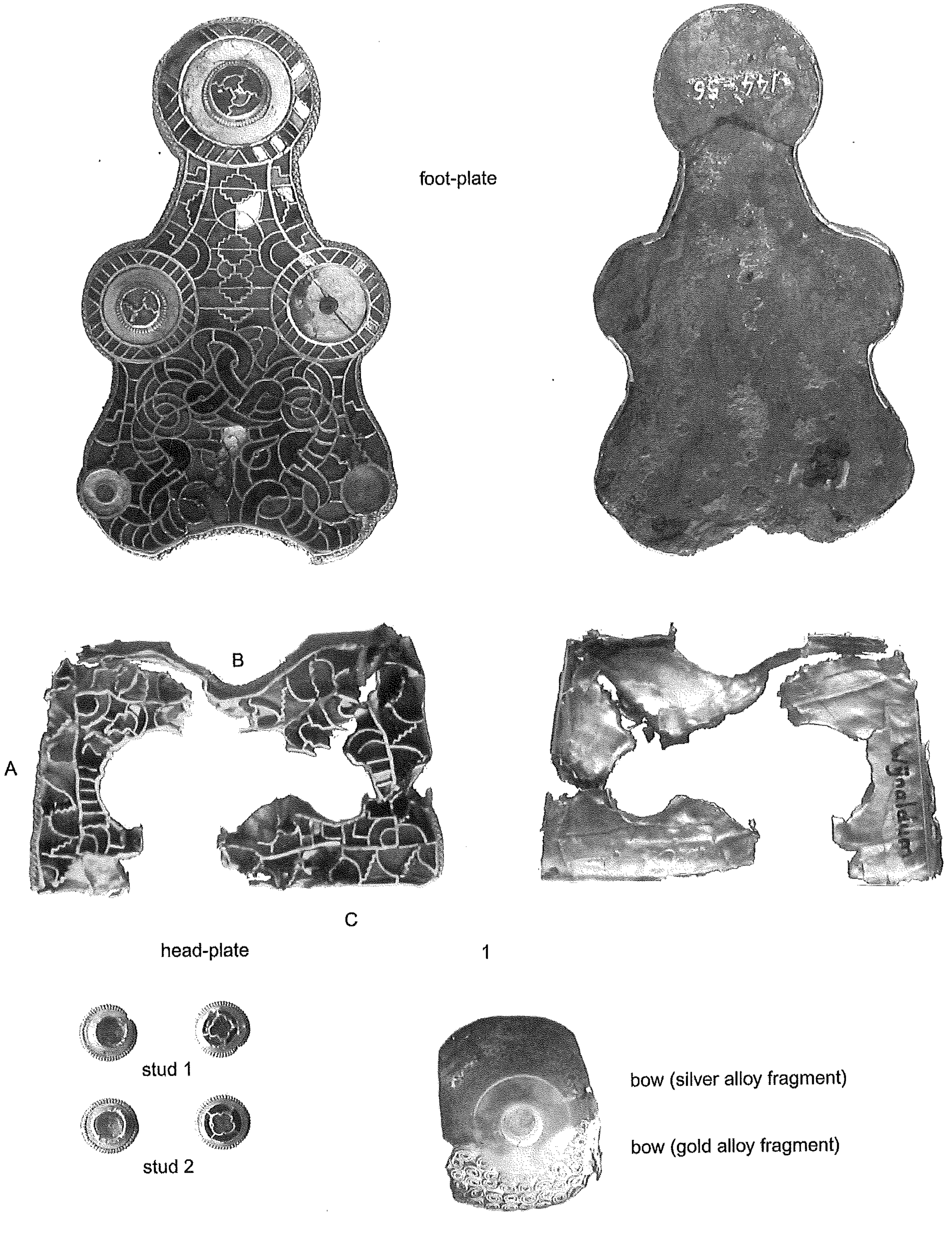

Figure 1. Photograph of the various components associated with the Wijnaldum brooch (computer graphics by H.J. Waterbolk, GIA).

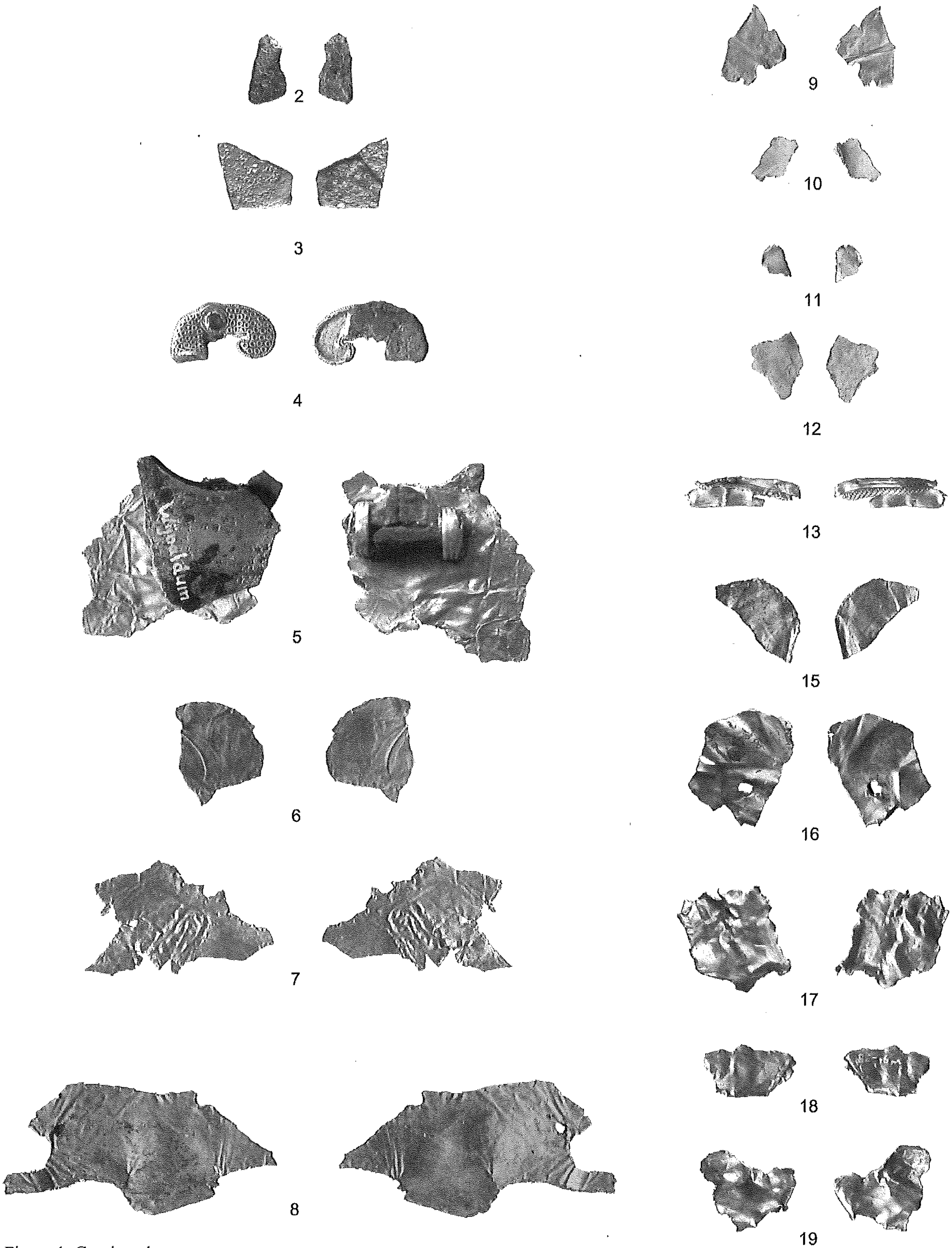

Figure 1. Continued.

presented before a discussion of the manufacturing and decoration techniques is given.

2 ANALYSES OF THE MATERIALS

2.1 *Non-metals*

The non-metals of the Wijnaldum brooch consist of garnets, white fillings in the roundels of the foot-plate and white paste underneath the cloisonné inlay.

The cloisonné surface of the foot-plate has been characterized by Bruce-Mitford as a 'a continuous carpet-like spread of garnets'.[4] The assumption that garnets were employed during the manufacture of the brooch is rational since the colour of the transparent stones is wine-red and they do not resemble glass. In order to characterize the garnet more precisely, a particle was temporarily lifted from a heavily damaged fragment of the head-plate (B) and analysed with a Debeye-Scherrer camera. The analyses demonstrated that an 'iron-aluminium garnet' or almandine, with the chemical formula $Fe_3Al_2(SiO_4)_3$ had been employed. Almandine belongs to the group of garnets. Other varieties of garnet are pyrope, spessartite and grossular. The almandine variety can be found in Sweden, Austria and Italy[5] but garnet or almandine which was used in early dark-age jewellery in Northern Europe, is thought to come from Bohemia.[6]

The white filling in the roundels of the foot-plate was analysed by XRD. It appeared to be aragonite or orthorhombic calciumcarbonate. Aragonite is valued for its colour, lustre and surface pattern and therefore frequently used as an inlay material. It is quite soft (3.5-4 on Mohs'scale) and therefore easy to cut. The appearance of the aragonite in the Wijnaldum brooch is opaque white with a greenish streak and tiny black veins. The surface displays a silky lustre and because of preservation occasionally a fibrous structure (Fig. 7). Due to post-depositional changes, the original appearance of the aragonite inlay has altered. The process of post-depositional changes of aragonite has been hardly documented which makes it difficult to identify archaeological samples of aragonite. Modern specimens can be distinguished in diverse varieties. The original aragonite of the Wijnaldum brooch could therefore have been mother of pearl or other varieties such as:[7]

– An 'alabaster variety', which have been reported in Mexico and Pakistan or,

– A snow-white coralloid or 'flos ferri' variety of aragonite which is typical for the mines of Styria in Austria.

The more fibrous variety shows a silky shine and a cat's-eye effect and is often cut into cabochon-shaped stones and beads. Besides the above mentioned provenances, aragonite is also found in Czechoslovakia, Sicily, France, England and Spain.[8] It has been rarely attested as inlay material for garnet cloisonné jewellery. An identification of the aragonite as mother of pearl is ambivalent. Of all the samples analysed by Arrhenius, only one contained aragonite as an inlay, probably as mother of pearl[9] though inlay of mother of pearl has been fairly often registered by Nerman.[10]

A small sample from the white paste underneath the gold foil, was taken from head-plate, fragment C. The sample derived from a cell without the almandine inlay. The paste was analysed by HPLC, GCMS and FTIR. Other samples of the paste came from head-plate, fragment B of which from one of its cells, the almandine inlay was temporarily lifted. These samples were analysed by XRD, HPLC, GCMS and FTIR. Analysis by XRD demonstrated the presence of a silicate combination: $H_2Si_2O_5$. The analyses by FTIR, HPLC and GCMS indicated a mixture of a silicate, a binder (all samples contained both a resin and a protein, similar to animal glue), sulphur and a sulphur compound. The samples were uniform in composition. Paste mixtures were set in the cells after which the gold foil and the almandine was positioned. This was heated slightly in order to soften the paste. After cooling, it would keep the backing foil and the almandine in it's cell at its proper height.

Diverse paste materials which came from garnet cloisonné jewellery have been analysed by Arrhenius. She made different clusters, based on the main components of the paste, like a carbonate-, silicate- gypsum- sulphur- and an organic group.[11] Within these clusters, wax was frequently a constituent of the paste mixture, though, unlike the paste of the Wijnaldum brooch, a combination of a resin and animal glue has not been reported. It appears that the paste mixture of the Wijnaldum brooch belongs to the silicate group but is dissimilar from the mixtures which were analysed by Arrhenius with regard to the binder. The presence of sulphur improves the adhesion quality of the paste and has been attested by Arrhenius as a component of some of the paste mixtures.[12] It has been reported that sulphur only occurs in volcanic regions and is hard to obtain in northern Europe.[13]

2.2 *Silver alloys*

Silver alloys were predominantly employed during the manufacture of the brooch as framework for the gold sheet on the back and the gold sheet with cloisonné on the front. Four fragments silver were analysed by XRF. The composition of the silver alloys is shown in Table 1. The high copper content of the filling of the foot-plate is probably due to corrosion of the metal since a thick copper-corrosion layer covers the back. The other three samples had been cleaned by a conservator to a silver-shiny surface.

2.3 *Gold alloys of different parts of the brooch*

The composition of the gold alloys have been analysed by XRF and are presented in Table 2. Clusters can be made such as indicated by the composition of the foot- and head-plate. Probably a slightly different gold alloy has been used for the foot-plate. Its gold and copper content is higher and its silver content is lower than the metal components of the gold alloy which was used for the manufacture of the head-plate and associated rim fragment. The gold content of the foot-plate varies around 95%. 23 Carat gold contains 95.83% of pure gold, and is supposed to be the best grade of gold alloy for decorative purposes. Because of its purity it stays bright indefinitely, but is quite soft and easily worn.[14] The gold alloy of the Wijnaldum brooch is essentially a binary alloy made by melting gold with some silver since many of the samples do contain less than 2% copper.

The rim fragment and the head-plate are correlated on account of the similar construction. The gold sheet on the back had been connected by small gold rivets and was decorated with a twisted, beaded wire. The rim of the foot-plate is not associated with a construction using small rivets. The rivets of the head plate are probably used in order to strengthen the construction. This was necessary because the hinge is likely to have been attached to the back of the head-plate. The component of the brooch with the hinge had to be sturdy because of the substantial weight of the complete brooch. The backing foil of head-plate B has the highest gold content of all samples. The manufacture of the thin foil from gold sheet requires an extremely soft and malleable alloy with a high gold content. The relatively high silver content of the front and back of the bow fragment can be correlated with the silver-content of the head plate. The difference in copper content can not be explained. It could be that the X-ray beam had been located on one of the copper corrosion spots on the front of the bow.

2.4 *Composition of the gold sheet fragments*

Table 3 presents the composition of gold sheet fragments which were analysed by XRF. The most obvious cluster consists of sheet number 10, 11 and 12 because of the copper content which is present as a trace element. The three fragments differ in appearance from the other fragments and it is likely that these sheet fragments do not belong to the Wijnaldum brooch. Two other fragments, number 7 and 19 have a relatively high copper content.

The gold content of all the gold sheet fragments is very high, which makes the alloy soft and malleable, and therefore easy to roll or stamp into such thin sheet.

Comprehensively, the gold content of the Wijnaldum brooch is high when compared with the gold jewellery from Sutton Hoo and other sites. The results from the Sutton Hoo jewellery demonstrate a range of gold content from 97 to 70% which compares with the range found in the coins, blanks and ingots in the purse (96.9 to 69.2%). Only the gold content of the sword pommel (97%) and the two shoulder clasps (93.5 and 94%) from Sutton Hoo correlates with the analyses of the gold alloys from the Wijnaldum brooch. The gold content of the Wijnaldum brooch does not reflect the general ‘flight from the gold standard’ which can be deduced from Kent’s time-fineness graphs based on the gold content of the Merovingian tremisses during the 7th century BC. This ‘flight’ is also reflected in the gold content of jewellery and on account of the gold content, the manufacture of the brooch is possibly dated to the early 7th century.[15]

Table 1. Composition (in percentage) by XRF of silver alloys.

Specification	Au	Ag	Cu	Pb	Ni	Co	Cd
Backside foot-plate	1.33	69.82	26.30	1.62	0.25	–	0.04
Bow	1.41	95.07	2.54	0.80	0.13	0.01	0.04
Fragment 2	2.77	93.41	2.50	0.91	0.19	0.01	0.03
Fragment 3	2.47	93.27	2.68	1.42	0.13	0.02	0.01

Table 2. Composition (in percentage) by XRF of gold alloys used for the brooch.

Specification	Au	Ag	Cu	Pb	Ni	Co	Cd
Foot-plate rim	95.25	3.02	1.53	0.01	0.12	0.03	0.02
Foot-plate roundel	95.06	3.21	1.11	0.09	0.16	0.16	–
Foot-plate stud	95.52	3.32	0.84	0.06	0.08	0.09	–
Head-plate A (back)	94.59	4.99	0.25	–	0.09	0.03	–
Head-plate B (back)	93.45	5.99	0.34	–	0.17	0.03	0.03
Head-plate C (back)	94.03	5.56	0.26	–	0.10	0.02	0.01
Fragment rim, 13	93.80	5.20	0.84	–	0.11	0.03	–
Backing foil h-pl.B	96.85	2.69	0.28	–	0.14	0.04	–
Bow (front)	91.59	5.85	2.13	0.25	0.15	0.02	0.00
Bow (back)	92.59	6.72	0.47	–	0.19	0.02	–
Stud 1	93.69	4.22	1.94	–	0.08	0.02	–
Stud 2	93.10	4.45	2.25	–	0.09	0.04	–
Animal head, 4	96.59	2.08	1.12	0.08	0.08	0.04	0.00

Table 3. Composition (in percentage) by XRF of gold sheet fragments.

Specification	Au	Ag	Cu	Pb	Ni	Co	Cd
Sheet with hinge, 5	96.66	2.91	0.30	–	0.07	0.04	0.01
Sheet, 6	96.67	2.90	0.25	–	0.11	0.03	–
Sheet, 7	95.64	2.98	1.24	–	0.11	0.02	–
Sheet, 8	96.43	3.14	0.27	0.04	0.10	0.01	–
Sheet, 9	96.65	2.87	0.32	–	0.13	0.02	–
Sheet, 10	96.80	3.02	0.03	–	0.11	0.04	–
Sheet, 11	96.18	2.63	0.02	–	0.11	0.02	0.04
Sheet, 12	96.16	2.67	0.01	–	0.12	0.03	–
Sheet, 15	96.90	2.66	0.29	–	0.12	0.03	–
Sheet, 16	96.35	3.09	0.41	–	0.08	0.03	0.03
Sheet, 17	96.72	2.84	0.30	–	0.10	0.03	–
Sheet, 18	96.16	3.15	0.55	–	0.10	0.04	–
Sheet, 19	95.56	2.82	1.51	–	0.07	0.02	–

3 MANUFACTURING- AND DECORATION TECHNIQUES

3.1 *Head-plate*

Examination with a microscope and a scanning electron microscope revealed aspects of the production and decoration technique of the brooch. The bulk of the head- and foot-plate is obtained by a silver 'filling'. This gives the brooch its strength after which the gold sheet could be applied for the visible parts. Many Saxon silver brooches are made by casting the silver framework.[16] A soap-stone mould has been found on the farm Hinna, Hetland Parish, Rogaland. The mould shows the exact outlines of a square-headed brooch without ornamentation.[17] After casting the silver could be decorated with techniques like hammering, embossing and carving.

The silver fragments of the Wijnaldum brooch displays casting characteristics and thus the silver framework is considered to have been cast.

The cloisons are made by soldering pre-shaped gold strips on an underlayer of gold sheet. Figure 2 illustrates a soldering seam between a gold sheet surface and a cell wall. The cell wall has rounded edges where the angles of the cloison are made. This is the result from bending. Another method for shaping cell walls consists of filing and soldering but this would result in a straighter angle. Thus it is probable that the cloisons from the Wijnaldum brooch are made by bending gold strips.

Additionally Figure 2 illustrates that the cell walls have a small protruding edge to mount the almandine. This protruding edge on top of the cell walls could be made by gently hammering or rubbing the soft gold cell walls, after having placed the almandine.

All head-plate fragments have a rim with small gold rivets. These rivets connect the two-ribbed rim of the gold sheet which is folded around the silver filling, with the gold sheet on the backside of the head-plate. Some torn pieces of gold sheet from the backside are still present on the head-plate frag-

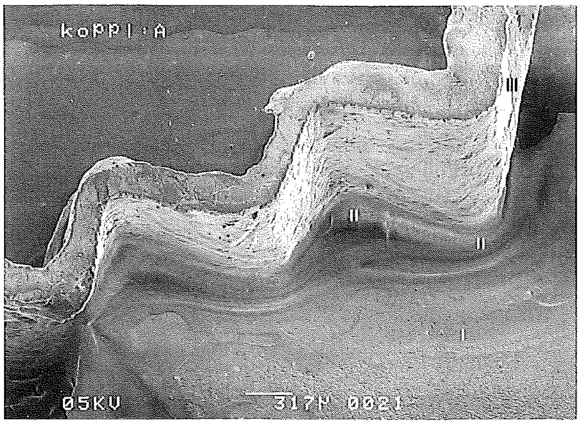

Figure 2. SEM photograph of head-plate A. Magnification 31.5 ×. I = gold sheet, II = soldering seam, and III = cell wall (photo GIA).

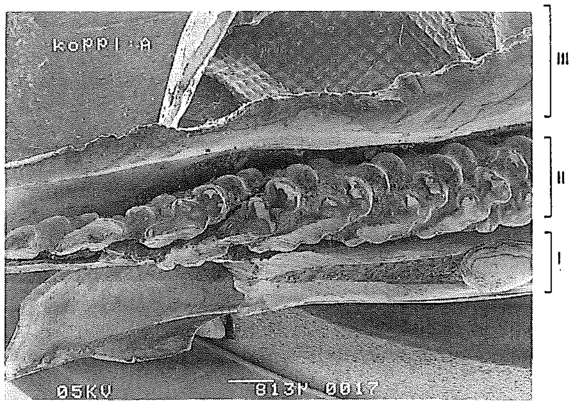

Figure 3. SEM photograph of head-plate fragment A. Magnification 12.3 ×. I = ribbed edging with one rivet at the right, II = decorative cord consisting of three beaded wires, and III = front of the headplate with cell walls and backing foil (photo GIA).

ments. Above the two-ribbed rim of the upper gold sheet, a decorative rope is soldered. This rope consists of three twisted beaded wires. Figure 3 shows the rim of head-plate fragment A, with the twisted beaded wires, one rivet and a piece of backing foil in a cloisonné cell.

Fragment A of the head-plate is heavily damaged, probably caused by ploughing. It is one of the pieces, found by amateur-archaeologists during the 1980s. The beaded wire of the head plate shows signs of wear and must originally have been in use for a considerable time. Beaded wire can be made with several devices. Duczko describes an experiment with a beading-file, made according to a description by Theophilus. The beading-file is a small iron bar with a lengthwise groove with sharp edges. The implement leaves a groove round the maximum diameter of every bead as result of the pressure exerted by the groove of the tool.[18]

Another method to make beaded wire is by using an *organarium* which has also been described by Theophilus. The *organarium* is an iron implement with an upper and a lower part with holes and grooves on both sides. When the upper iron part is lowered, beads are formed while turning the wire or rod. The holes have different diameters and one is supposed to start beading the wire in the largest hole.[19] Untracht illustrates a two-piece die which is similar to the above mentioned *organarium*.[20] The beaded wires of the Wijnaldum brooch do not have a groove around the maximum diameter of every bead, which would have been indicative for a beading file. This indicates that the beaded wire is made with an *organarium* or a die as described by Untracht.

Backing foil is present in all cloisonné cells and also underneath the garnet-eye of the stylized animal head. The backing foil (Fig. 3) is folded into shape and covers the base and partially the sides of the cell walls. The almandine is placed inside the folded foil. All visible foils in the cells without the almandine, demonstrate that the foil has folded edges. The Wijnaldum foil is similar to the 'standard foils', discussed by East and Meeks & Holmes.[21] Standard foils display a pattern with a simple uniform grid. An example of another type of foil is the 'boxed' foil where more robust, wider lines enclose small squares. The most common standard foil of the Sutton Hoo jewellery has a line spacing of 4 lines/mm. The foil of the Wijnaldum brooch exhibits 4 to 5 lines/mm. Less fine spacing of 3.5 lines/mm is more prevalent in Anglo-Saxon garnet jewellery.[22] Meeks and Holmes suggest that foils with the fine spacing of the Sutton Hoo jewellery could have been manufactured with a brass or ivory die. The pattern is stamped into the gold foil with a die which has very fine cutting grooves. Such fine and regularly spaced grooves are hard to produce without the use of an implement and thus the use of a 'mechanical die-cutting jig' has been suggested. This instrument cuts grooves of the required spacing into the flat die faces, like a pantograph. The movement of a lever on a scale is imparted to the die face in a corresponding but much smaller pattern. By experiment, Meeks and Holmes were able to produce very similar foils with the aid of a grooving jig.[23] A mechanical die-cutting jig produces negative dies. In 1996, a positive die for making boxed pattern foils was discovered in the conservation laboratory of the University of Groningen during mechanical removal of the corrosion layers on the artefact. This die was excavated at Wijnaldum and dates to the 7th century. Figure 4 presents photographs of the die and a detail of the pattern while Figure 5 illustrates the lines of the boxed pattern which could be identified after examination with a scanner and a microscope (the grey lines in Figure 5 are reconstructed). From Figure 5 it is deduced that the line pattern is regular though not as uniform as suggested by the experiments of Meeks and Holmes with a die-cutting jig. The die from Wijnaldum is slightly less mechanical than the dies produced by Meeks and Holmes. Some of the lines in Figure 5 are askew though most are aligned and straight. The subdivision of the individual boxes into squares in neither regular. The die from Wijnaldum has preserved 16-, 20- and 25-square boxes while the size of some of the boxes suggest a smaller or higher number of squares.[24]

3.2 *Bow fragment of gold*

The bow fragment of gold is decorated with several pieces of beaded wire which are bent into a S-shape with spirals. The beaded wire resembles the beaded wires discussed above. It is intermittently soldered on the gold sheet which is visible on the SEM photograph (Fig. 6) as dots where the solder is melted.

Untracht explains how filigree is soldered nowadays.[25] A mixture of (gold) solder scraping with water, flux and gum is made. This mixture is painted on the wire. At the wire ends, particles of solder can be placed in order to obtain a solid joint. The amount of solder used must be just enough to make a solid junction, too much solder will flood the beaded wires. The heating of the filigree piece, to melt the solder, requires skill of the craftsmen, because the thin wires are very easily melted themselves. Interval soldering of wire to sheet, like the s-shaped spirals of the bow, is sufficient. It is not necessary to solder the whole wire to the ground sheet.

3.3 *Hinge and pin*

The hinge fragment which comprises the remains of the pin, exists of a segment of gold sheet (no. 5, Table 3) with silver filling and a copper alloy pin-fragment. The copper alloy pin is riveted in between two upright sections of silver- or copper alloy which are covered with gold sheet. The gold sheet is decorated with a two-ribbed rim similar to the rim of the head- and foot-plate. Figure 7 illustrates a fragment of the gold sheet which covers the hinge and which is part of the gold sheet that covers the back of the brooch. This construction makes it probable that a section of the sheet is cut out and bent upwards to cover the hinge. The covering sheet of the hinge could be partially soldered.

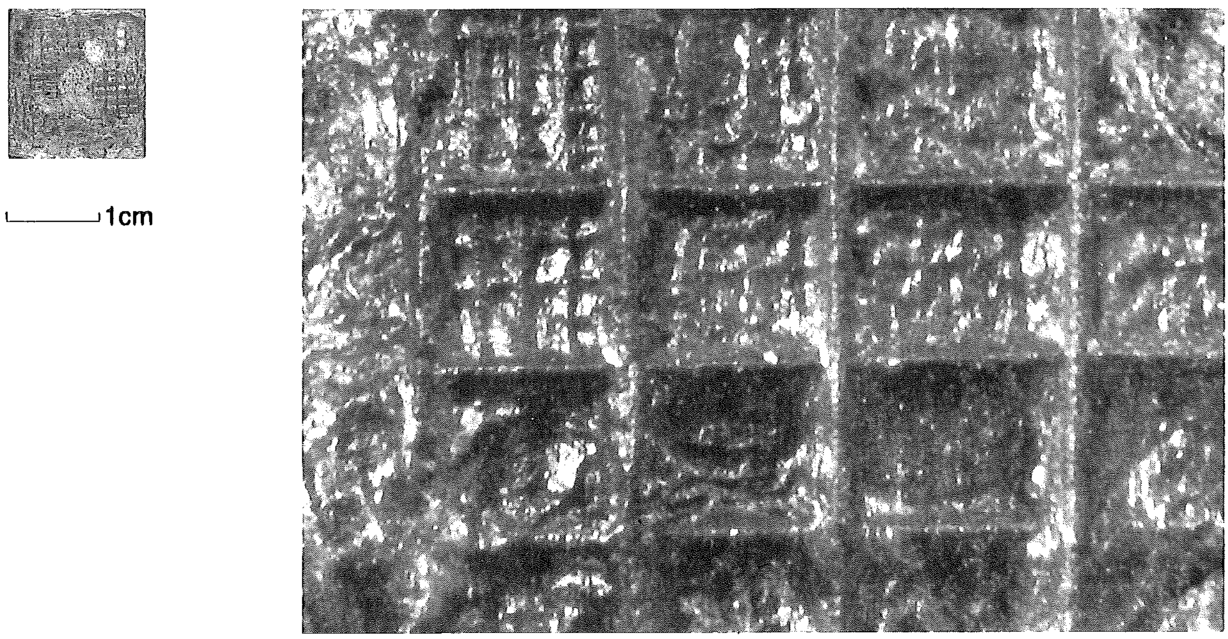

Figure 4. Positive die for making boxed pattern foils including a detail photograph of some of the boxes (300 × enlarged) (photo GIA).

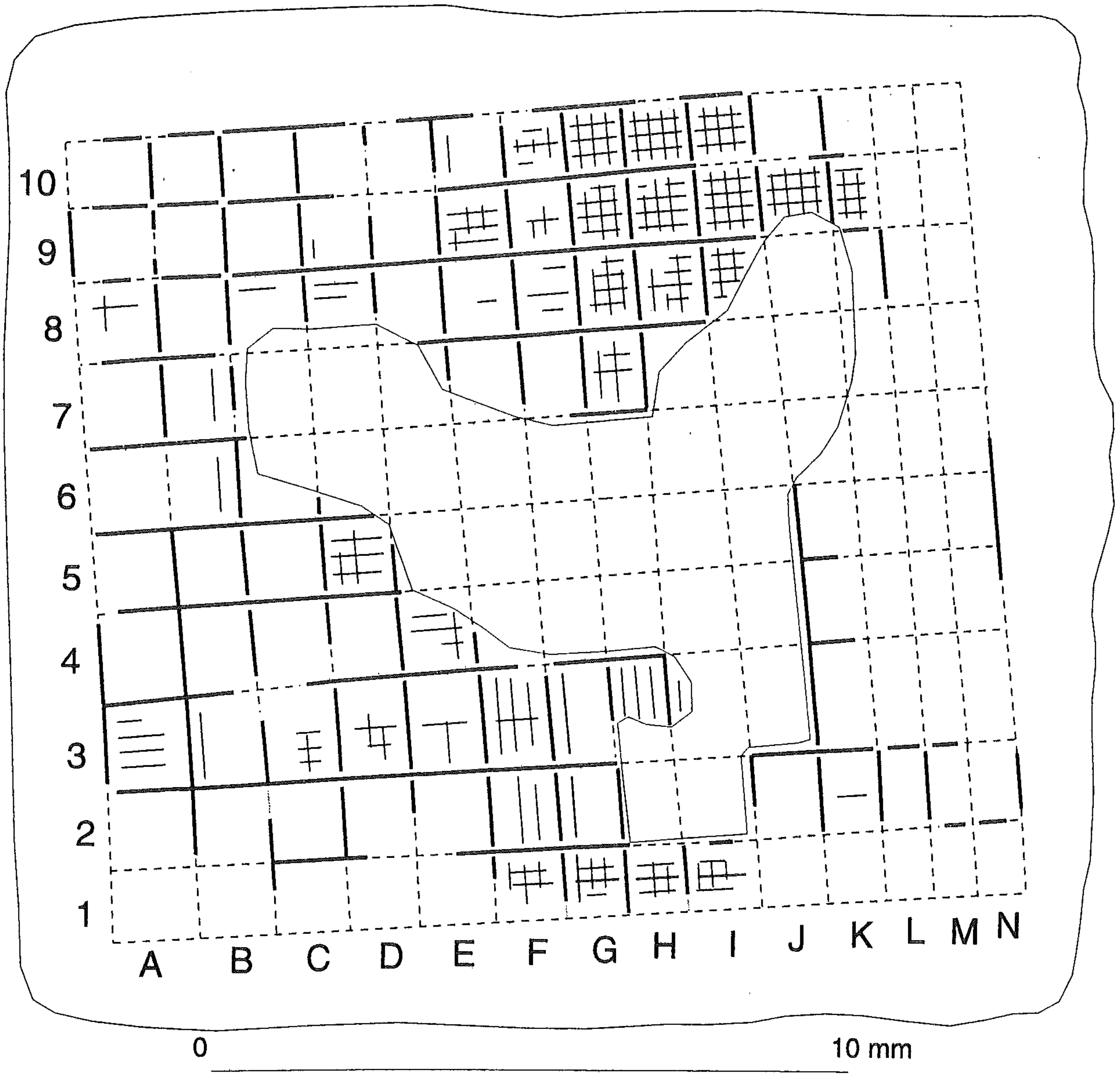

Figure 5. A line drawing of the die. The dark lines were identified by a scanner and under a microscope while the grey lines are reconstructed (drawing by H.J. Waterbolk, GIA).

3.4 *Foot-plate*

The construction of the foot-plate which consists of gold sheet with cloisons on a silver framework is similar to the fragments already discussed as is the rim which is decorated with two ribs and a rope of three beaded wires. The gold sheet at the back is attached to the brooch by folding the gold sheet from the front over the backing sheet. An X-ray photograph (Fig. 8) reveals several holes in a symmetrical pattern. These holes in the foot-plate are probably associated with the construction for fastening both the pin catch as well as the backing sheet to its framework. The hinge and catch construction for the pin can be illustrated by the gold and silver disc-on-bow brooch from Hoogebeintum of which the hinge and catch construction for the pin has been preserved. The reverse of this brooch displays a decoration of two animals which originate from the catch and continue to the top and side of the foot-plate. Mazzo Karras suggests that an animal head decorated the end of the catch.[26] The Wijnaldum brooch is comparable in size and con-

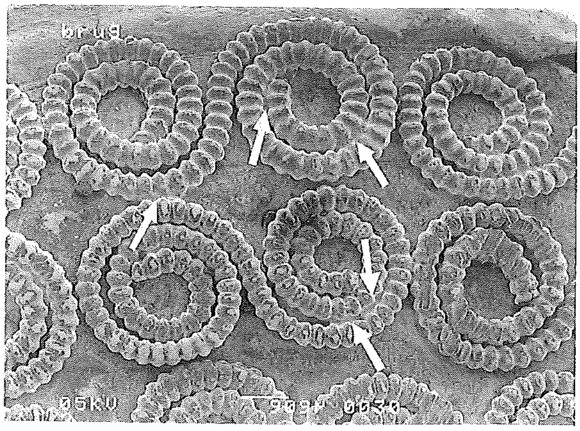

Figure 6. SEM photograph of the bow fragment of gold. The arrows indicate the soldering joints. Magnification 11 × (photo GIA).

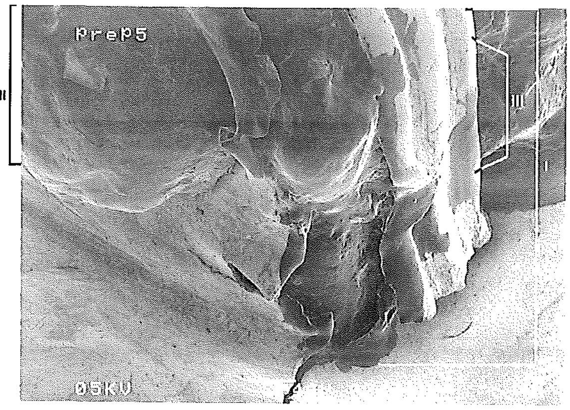

Figure 7. SEM photograph of the hinge. Magnification 13.4 ×. I = vertical section of silver- and copper alloy, II = detail of copper alloy pin, and III = ribbed gold edging covering the silver and copper alloy (photo GIA).

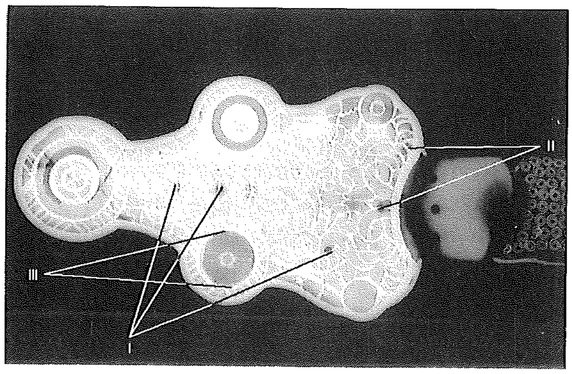

Figure 8. X-ray photograph of foot-plate and bow. I = holes in the silver framework, II = two larger holes for connecting the bow, and III = tube with several cuts in the edge (photo R. Gerritsen).

struction with the Hoogebeintum brooch which is almost complete. Both are disc-on-bow brooches with similar construction characteristics. Taking its size and weight into consideration, the Wijnaldum brooch must at least have had a similar complicated and strong catch. This could account for the number of holes which are revealed by the X-ray photograph. Especially the many small holes in between the two roundels in the centre and the roundel at the top could have been used for joining the animal decorations of the catch. Nearby the side of the foot-plate which is closest to the bow, at least two larger holes are visible on the X-ray photograph. The silver framework of the bow has three holes and therefore the bow might have been connected to the foot-plate by a row of three rivets. The attachment of the studs to the roundel and the foot-plate is revealed by the roundel without a stud. A small tube is present in the middle of the aragonite inlay. This tube has an edge with several small cuts which are revealed by the X-ray photograph. This implies that the studs are connected by folding outwards the edges of the tube. The small cuts facilitate the folding. The tube is pierced through the gold sheet but is not visible at the back of the foot-plate. The tube therefore, does not perforate the silver framework. The gold tubes which are soldered to the back of stud 1 and 2 are bigger than the small tube left in the foot-plate. This means that stud 1 or 2 are not an integral part of the foot-plate, although the same folded and cut edges are present at the end of both tubes. The circular shapes formed by the cell walls of the different head-plate fragments indicate the initial presence of two roundels in the middle of the head-plate. Both studs were probably placed in the centre of these roundels.

The top of the foot-plate is decorated with two small roundels. One of these roundels is filled with the aragonite inlay and a round, flat piece of almandine while the decoration of the other roundel has not been preserved. The gold cylinder of the roundel is soldered to the gold sheet which covers the silver framework. Figure 9 is a SEM photograph of the roundel with preserved inlay. The gold cylinder of the roundel is an element of the cloisonné structure. This cylinder encloses another gold cylinder which contains the aragonite and almandine setting. The gold cylinder with the aragonite and almandine setting is attached to the roundel by a small projecting edge which has been rubbed or hammered. This method of fastening the cylinder is similar to the setting of the almandine.

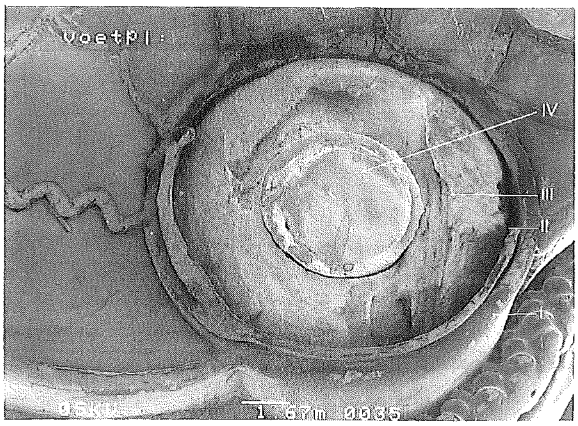

Figure 9. SEM photograph of the roundel with preserved setting at the top of the foot-plate. Magnification 6 ×. I = gold cylinder of roundel, part of the cloisonné structure, II = gold cylinder for aragonite inlay, III = aragonite, and IV = aragonite in its setting (photo GIA).

4 RECONSTRUCTION OF THE GOLD SHEET AT THE BACK OF THE FOOT-PLATE

Due to the holes in the foot-plate which were revealed by the X-ray photograph, it was possible to reassemble some fragments of the backing gold sheet. The gold sheet numbers 5, 6, 7, 8, 15 and 16 and 17 belong to the back of the brooch. The reconstruction of the gold sheets on top of a X-ray photograph is presented in Figure 10. Most of the gold sheet fragments which belonged to the back of the foot-plate, could be reassembled since they match. Several gold sheet fragments show traces of cutting. A small pair of scissors was used to shear the gold sheet at the back of the foot-plate. Especially gold sheet 8 demonstrates the shearing traces on the side to the middle of the foot-plate.

Table 3 displays the difference in copper content of gold sheet 10, 11 and 12. Since these sheet fragments also have a different appearance, it is assessed that these fragments do not belong to the brooch.

5 CONCLUSIONS

The XRF analysis of the gold alloys indicates that for the various decoration- and construction techniques, slightly different gold alloys were used. All alloys which were analysed, have a very high content of precious metal. It seems that silver and to a lesser extent also copper were melted together with very high percentages of pure gold. This is probably done to make the alloy harder, because pure gold is too soft for most purposes. Especially the gold alloy of the foot-plate, the gold sheet from the back and the backing foil reveal very high gold contents. As such the gold content of the Wijnaldum brooch mirrors the 'gold standard' as revealed by the late 6th and early 7th century Merovingian tremisses.

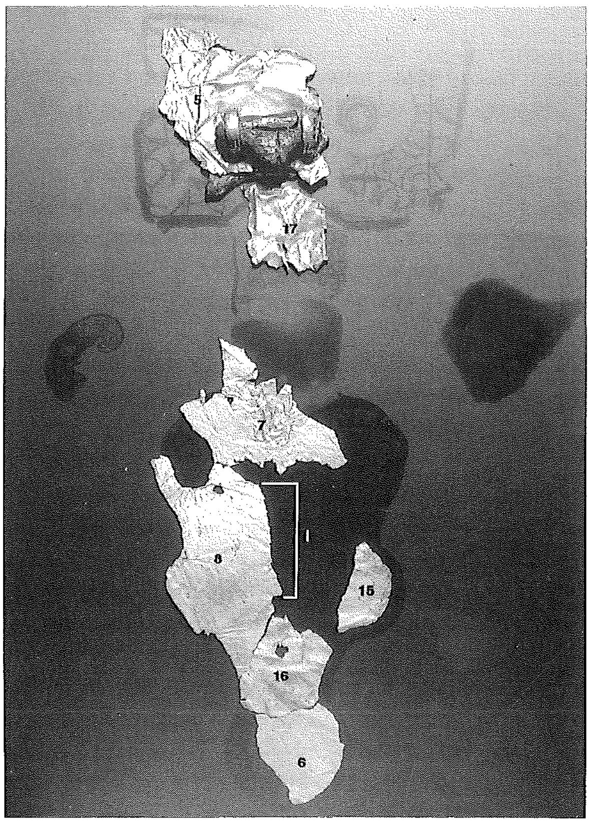

Figure 10. The reconstruction of fragments of gold sheet on a X-ray photograph. I = shearing traces, 5 to 8 and 15 to 17 are the numbers of the gold sheets as used in Figure 1 and Table 3 (photo R. Gerritsen).

The examination by SEM illustrates that the manufacture of the brooch involved a highly qualified craftsman as is indicated by the fine spacing of the grid on the foil. The brooch is made by combining several metalworking- and decoration techniques, which all exhibit the subtle eminence of its composer. On account of the craftsmanship, it seems unlikely that the segment of gold filigree with a stylized animal head, belongs to the brooch mainly because of the inferior quality which is displayed in the filigree itself and the plain setting of the garnet.

From an archaeological point of view it has not been established why this brooch was present on the Wijnaldum site. Taking into consideration that many traces of metalworking have been recovered during the excavations, it is suggested that the Wijnaldum brooch is associated with the metalworking activities on the site. The context and nature of the deposition of the various fragments of the brooch remains ambivalent as well as the reason why the fragments were actually preserved at the site. Nevertheless, the positive die for making boxed pattern foils which has been recovered at Wijnaldum confirms the stature of the goldsmith who worked at the site. The evidence for shearing on the backing gold sheet and the fact that the different components which belong to the brooch, are not really torn but only disconnected like the two studs and the bow, implies that the brooch was reused or mended. Both possible interpretations of reuse or repair are associated with the many data on goldsmithing on the site such as the touchstones, a crucible for melting gold and the die. Reuse is implied by the cutting marks on the gold sheet from the back of the foot-plate as well as by the absence of two roundels of the head-plate and the disc itself. Several pieces from the brooch were found at various stages during a period covering more than 40 years. It is notable that during this period no fragments of the disc were recovered while it seems as if both roundels from the head plate were intentionally separated from the head-plate (Fig. 1). It is suggested that these roundels were taken from the head-plate and might have been used to compose a new ornament. The disk itself could have been transformed into a pendant as has been frequently attested for Anglo-Saxon disc brooches.[27] The Monkton disc brooch might even derive from a larger and grander brooch.[28] In this context it is furthermore relevant to recall the 7th century demolition segment of an almandine buckle from Dronrijp and the disconnected foot-plate of a substantial gold brooch from the Wieuwerd hoard.[29] A late example of reuse of 7th century garnet jewellery is found on the Egbert shrine at Trier. During the late 10th century, the outer roundel of a possible Frisian disc was reused in the Egbert workshop during the manufacture of the shrine.[30] On the other hand, it could be that the evidence for shearing on the gold sheet of the back of the foot-plate points to mending. The flattened beaded wire demonstrates that the brooch was extensively worn. The gold sheet of the back of the foot-plate could have been sheared in order to replace the catch of the pin. Because of the weight and dimensions of the brooch, especially the pin and catch are under a lot of strain when worn regularly. Altogether, the idea rises that the Wijnaldum brooch was in possession of a goldsmith for reuse or repair.

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NOTES

1. Bruce-Mitford (1955, pp 16-17), Mazzo Karras (1985, pp 168-170), Schoneveld (1993, pp 7-24), and Zijlstra (1991, pp 51-55).
2. The weight of this reconstruction on perspex is 253 g.
3. The numbering of the fragments of the disc-on-bow brooch from Wijnaldum in Figure 1 agrees with the numbering of the fragments in the loan-conditions of the Fries Museum in Leeuwarden.
4. Bruce-Mitford (1955, p. 16).
5. Macdonald (1983, p. 161).
6. Schoneveld (1993, pp 13-14).
7. Macdonald (1983, p. 95).
8. Dragsted & Krijger (1978, p. 299).
9. Arrhenius (1971, p. 223).
10. The identification by Nerman of inlay as mother of pearl are presented in Arrhenius (1971, pp 231-233).
11. Arrhenius (1971, pp 216-222).
12. Arrhenius (1971, pp 90-94). Sulphur was most likely a separate component for the paste mixture of the Wijnaldum brooch since during the pre-treatment of the samples for the analyses, the smell of sulphur was noticed in the laboratory.
13. Arrhenius (1971, pp 93-94).
14. Untracht (1975, pp 8-9).
15. Bruce Mitford (1978, pp 611-613, Appendix C). The majority of the Sutton Hoo gold jewellery was analysed by atomic absorption spectrometry with an analytical precision for gold of ±2%. The analytical precision worsens as the sample weight decreases. The metal composition of the disc-on-bow brooch from Wijnaldum was analysed by XRF with an analytical precision for gold of ±0.5%.
16. Jessup (1974, p. 22).
17. Hougen (1967, p. 10).
18. Duczko (1985, pp 17-22).
19. Hawthorne & Smith (1979, pp 88-90).
20. Untracht (1985, pp 168-169).
21. East (1985, pp 129-142) and Meeks & Holmes (1985, pp 143-157).
22. East (1985, p. 137).
23. Meeks & Holmes (1985, pp 148-157).
24. We would like to thank Dr N. Meeks of the British Museum and Benner Larsen, Dianalund, Denmark for their valuable comments on the the die from Wijnaldum. Dies for making foils from excavations are extremely rare. Two positive dies for standard foils were recovered in Denmark as detector finds from Gudme and Neble (Høilund Nielsen & Vang Petersen 1993, p. 225). The die from Gudme has been associated with local goldsmithing activities by Thrane who also mentioned a die from the settlement Dalshøj on Ostbornholm (Thrane 1994, p. 110). The die from Dalshøj is correlated to the central settlement of Sorte Muld from where gold cloisons, raw and worked almandine fragments for the production of cloisonne jewellery are reported.
25. Untracht (1985, pp 178-179).
26. Mazzo Karras (1985, pp 166-168).
27. Avent (1975, p. 3 and Table 5).
28. Hawkes (1974, pp 250-252).
29. Besteman et al. (1993, pp 20-22) and Mazzo Karras (1985, pp 165-166).
30. Vierck (1974, pp 359-360). The provenance of the various spolia on the Egbert shrine is debated in e.g. Vierck (1974), Ronig, (1993, pp 36-37), and Westermann-Angerhausen (1973, 1987). Especially the reuse of the 7th century garnet jewellery has attracted much attention. The discs have been linked to workshops in England (Sutton Hoo), Frisia and Trier as well as to various Merowingian workshops.