The Tjitsma (Wijnaldum) die: a 7th century tool for making a cross-hatched pattern on gold foil, or a master template?

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ABSTRACT: *Excavation of the dwelling mound of Tjitsma in Friesland produced an important small bronze die with a geometric cross-hatched pattern. The pattern was recognised as being very similar to those on gold foils commonly found in gold and garnet jewellery of the 6th-7th centuries, from both Merovingian and Anglo-Saxon contexts. It is the first die to be found with a 'boxed' pattern. The die is a lost wax casting and is fully described here, with the pattern compared to gold foils in garnet jewellery. It is in a 'positive' form which makes it unusual, because patterned gold foils were generally thought to have been punched with negative dies. The method of producing the model of the complex pattern for lost wax casting is investigated. Danish dies of simpler pattern are also described.*

Introduction

Between 1991 and 1993 a dwelling mound in the coastal area of the province of Friesland in the north of the Netherlands was partly excavated. This dwelling mound, named Tjitsma (near the village of Wijnaldum; 53°12' N, 5°27' E), is part of one of the rows of dwelling mounds that are still visible in the landscape. The occupation of Tjitsma started around AD 175 and lasted until at least the tenth century.

The excavation was executed by students and staff from the universities of Groningen and Amsterdam. One of the most important reasons for excavating this mound was the large number of metal-detector finds that had emerged, which indicated that the top of the mound was eroding. During excavation the metal finds were registered by context as this would also shed some light on the process of erosion of this kind of monument. Another reason was the isolated find of a large, spectacular gold and garnet brooch from Wijnaldum in 1954 which suggested that Tjitsma represented the remains of an early-medieval trading place of some importance (Besteman et al 1992). Nijboer and van Reekum (in press) provide a technical description of the brooch.

During the three excavation seasons much evidence was found for local crafts such as glass and bead making, antler working, and weaving that were executed closely together. Much evidence was found for the working of iron (slag, hearth lining, a smithy floor, hammerscale and tuyères), copper alloys (scrap metal, crucibles, moulds, semi-manufactured objects, ingots, bars and rods), lead (scrap metal and a possible model), silver and gold (touchstones, crucible, droplets, rods and ingots and a piece of uncut garnet) (Tulp in prep).

Among these metalworking finds was one special object: it was recognized as a die, apparently for pressing a cross-hatched pattern onto gold foil (Figs 1 and 2). The die was found in a refuse layer that was dated between 650 and 750 AD (find number w93/ l1567) (Nijboer and van Reekum in press; Bos and Nijboer 1996, 109). The find is special because, although studies have been made on the different types of contemporary gold foil (Avent and Leigh 1977, Meeks and Holmes 1985), there is far less known about the dies used for making these foils, and this die had a well preserved pattern that could be studied.

Patterned gold foils were a common feature of contemporary garnet-inlaid goldwork of which there are many fine examples, *eg* the Wijnaldum brooch, Sutton Hoo regalia and Kentish gold jewellery (Karras 1985, Nijboer and van Reekum in press, Bruce-Mitford 1978, Kendrick 1938). Several geometrical patterns have been found on foils in garnet jewellery and the majority may be divided into two main groups, described by Avent and Leigh (1977, Fig 1) (see Fig 6 below). The simplest pattern is a uniform grid of tiny ridges referred to as a 'standard' pattern. A more

Figure 1: Top surface of the die under oblique illumination showing the positive pattern. The broad lines of the boxed pattern are higher and thicker than the fine lines that form the smaller squares within. Corrosion has caused loss of the pattern near the centre. The die is 17.4mm wide by 16.1mm high.

complex pattern of wider and deeper ridges that enclose a number of tiny squares is referred to as a 'boxed' pattern. Foils are very thin – those measured from Sutton Hoo are between 0.02-0.03mm thick.

Figure 2: Back surface of the die under oblique illumination, showing an impression of woven cloth which was used as part of the mould-making procedure. Corrosion has damaged part of the impression. The protruberance on the left edge is where the polished section was made.

The Tjitsma die is of the more complex 'boxed' pattern which makes it particularly interesting to study as it is more difficult to make than a 'standard' pattern and is the only 'boxed' pattern die that has been found. The die is also unusual in that it has a positive pattern by comparison with the five negative pattern dies which have been found in recent years in Denmark (Vang Petersen 1991, 53; Jørgensen 1993, 54; Vang Petersen 1993, 33-4; Høilund Nielsen and Vang Petersen 1993, 225; Watt 1990). There are many gold foils with 'boxed' patterns found in contemporary garnet jewellery and those examined in detail, such as Sutton Hoo, have been made with negative dies, so the function of the Tjitsma die is less clear, but the quality of the pattern suggests it was of some importance. Rather than a die for punching foils directly, it could have served as a template from which other negative dies could have been made by investment casting of wax impressions.

The Tjitsma die has a cross-hatched pattern of a small size which is similar to those on contemporary gold foils. Stamped gold foils were cut to shape and then set behind pieces of polished garnet mounted in cloisons in gold jewellery. Because of the angular pattern on the foils the light is reflected back through the garnets. This highlights '…their natural colour, giving them an attractive deep red colour, thereby imparting life and sparkle to the stones which would otherwise look dull and dark in their gold settings' (Meeks and Holmes 1985, 143). The sparkling can be compared with a diamond that sparkles because of the faceting (Avent 1975, 16). Dies were therefore an important and integral part of the goldsmiths' range of tools for making garnet-inlaid goldwork.

The research on this die was divided into several steps. The first was to describe and characterize the physical form of the die pattern with reference to 'boxed' patterns on gold foils. Secondly, analysis and metallography determined the material of the die and the extent of the corrosion. Thirdly, examples of some contemporary garnet jewellery were examined and comparisons made between the characteristic pattern of this die and the gold foils in the jewellery. It was hoped that it might be possible to link the die with certain objects to give information on workshops and trade routes, or at least to establish a 'design connection' between the physical characteristics of the 'boxed' pattern on the die and those of foils from the wide geographical area within the sphere of influence of the contemporary Anglo-Saxon, Frisian and regional continental goldsmiths,

which would ultimately suggest a common origin. Finally, the method of manufacture of the die was investigated. The five other dies found in Denmark have also been examined optically at low magnification as part of this investigation.

Earlier research

Prior to the discovery of dies from archaeological sites in the Netherlands and Denmark there were many ideas on how the cross-hatched pattern on gold foil was produced. Arrhenius (1985, 39) thought that textiles instead of a die were used for the finer patterns and suggested that the textile could have been stretched over a plain wooden stamp. Another possibility was that the textile was used as a backing and the foil was hammered against it. Maryon (1971, 79) suggested that with a three-cornered file some notches could be cut across the edge of a chisel. This would result in a row of small pyramids, and row after row of small pyramidal points could be hammered into the gold foil.

However, a more common view (which now seems to be correct) was that dies were used to produce the cross-hatched pattern and various materials were considered for these. Avent and Leigh (1977, 4) suggested copper alloy, lead, wood and bone as possible materials. East (1985, 141) added antler to the list and it was proposed that ivory could also have been used (Meeks and Holmes 1985, 156-7). Not all materials are suitable for making such a die because either the material was not strong enough or was not able to be accurately formed to the finest detail found on the foils. Meeks and Holmes (*stet*, 151) carried out experiments using various materials and examined foils by scanning electron microscopy. For example, with fine-grained wood it was impossible to cut to the required fine detail, and when struck it soon became damaged. Ivory was tough enough to perform equally as well as copper alloy dies, but would not last as long (*ibid* 156-7). Lead was also thought of as a possible die material (Avent and Leigh 1977, 5) as it was soft enough to cut the pattern in it easily, but in practice it would not have lasted a single punch. Copper is also unsatisfactory as it is too soft and such a die would be quickly damaged during its use as a punch. Avent and Leigh (1977, 4-5) note that copper alloy dies could have been engraved by hardened iron tools only with some difficulty; alternatively such dies could have been cast from an original model of wood or wax. Copper alloys, like tin-bronze (copper with 10-12% tin) and brass, were considered most likely for die manufacture by Meeks and Holmes (1985, 156-7). They successfully made and used dies of both 'standard' and 'boxed' patterns by cutting cross-hatched lines of the required accuracy directly onto brass to closely reproduce gold foils of the Sutton Hoo type. The dies described above are negative and could have been cut directly, unlike the positive Tjitsma die which could only have been cast. The choice of suitable material for positive dies therefore is limited to castable tough metals, *ie* bronze or brass (see Die manufacture below).

The backing material used during punching gold foils successfully was also important. Lead or a material of similar properties was necessary. When punching the gold foil Meeks and Holmes discovered the thickness of the lead and the type of material backing the lead to be of significance:

> 'If a very thick block of lead is used, the force with which the die is struck is absorbed into the block and the definition of the foil pattern is not fully sharp. If a thin lead sheet is used, but placed on a wooden block, definition is impaired once again, the hammer blow being absorbed by the wood, and shallow-punching results. The best punching technique to achieve maximum definition on gold foil was found to be with the gold foil backed by a lead sheet (about 4 - 8 mm thick) placed on an iron anvil or some other solid surface.' (*ibid*, 155)

The recognition and study of the six known dies from the Netherlands and Denmark is important in defining the workshop practice of die and foil production in the Saxon period.

Description of the Tjitsma die

Although the die is corroded, the surface still retains the physical form of the original boxed die pattern that has been revealed by careful removal of superficial corrosion products during conservation. In the middle is an area of corrosion that has broken part of the pattern away but there is sufficient uncorroded pattern to be able to characterize it by scanning electron microscopy (SEM) with the large depth of focus that this technique provides. In the Netherlands the die had been coated with a solution of Benzotriazole and Paraloid B27 to prevent further corrosion. This coating had to be carefully removed with acetone before examination in the SEM, to assist imaging.

The die is of a positive form, which means that the pattern appears as ridges standing proud of the surface (Fig 1), and is the reverse of a negative die in which a

Figure 3: SEM detail of an area of irregular elongated 'boxes', towards the top of Fig 1. Field of view 8.2mm across.

pattern of grooves would be cut into the surface. The die is almost square (17.4mm x 16.1mm) and is 2.9mm thick. The surface is divided by ridges into a regular, and in some places an irregular, geometrical pattern of small squares or rectangles, typically with sides about lmm long. Each of these 'boxes' is subdivided into either 16 or 20 smaller squares by finer ridges, depending on the region of the die. Most of these smaller squares are difficult to see without a microscope.

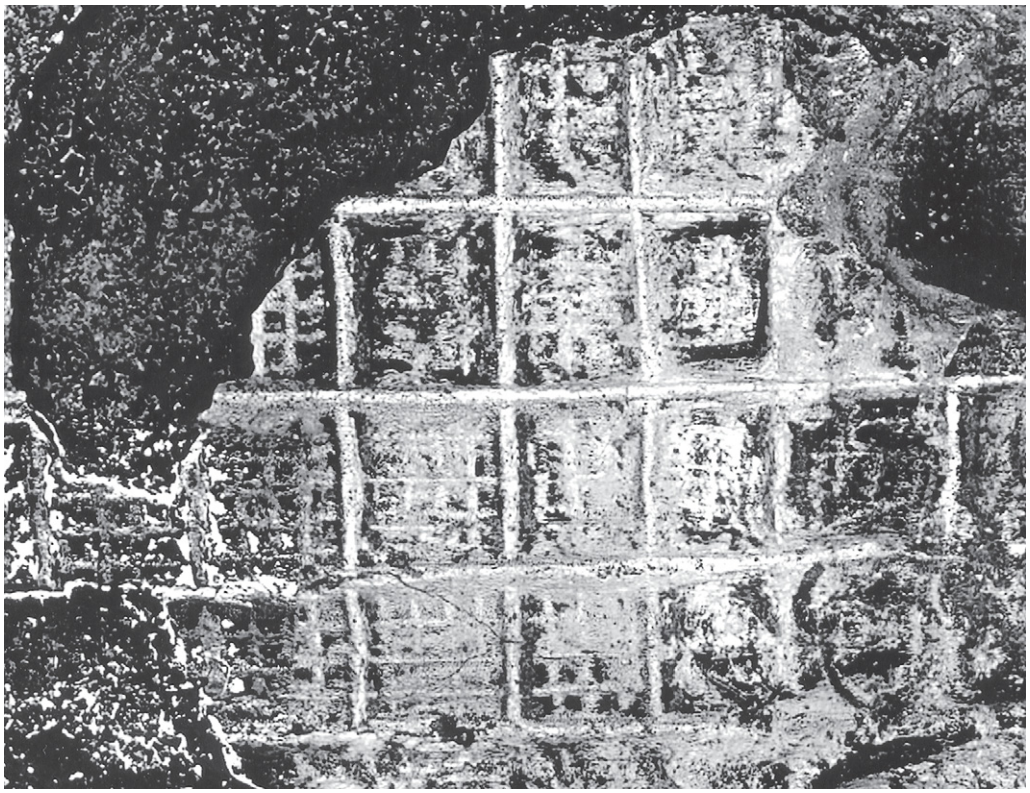

Figure 4: SEM detail of more uniformly square 'boxes' which contain the best preserved pattern of smaller squares, towards the bottom of Fig l. Field of view 6.8mm across.

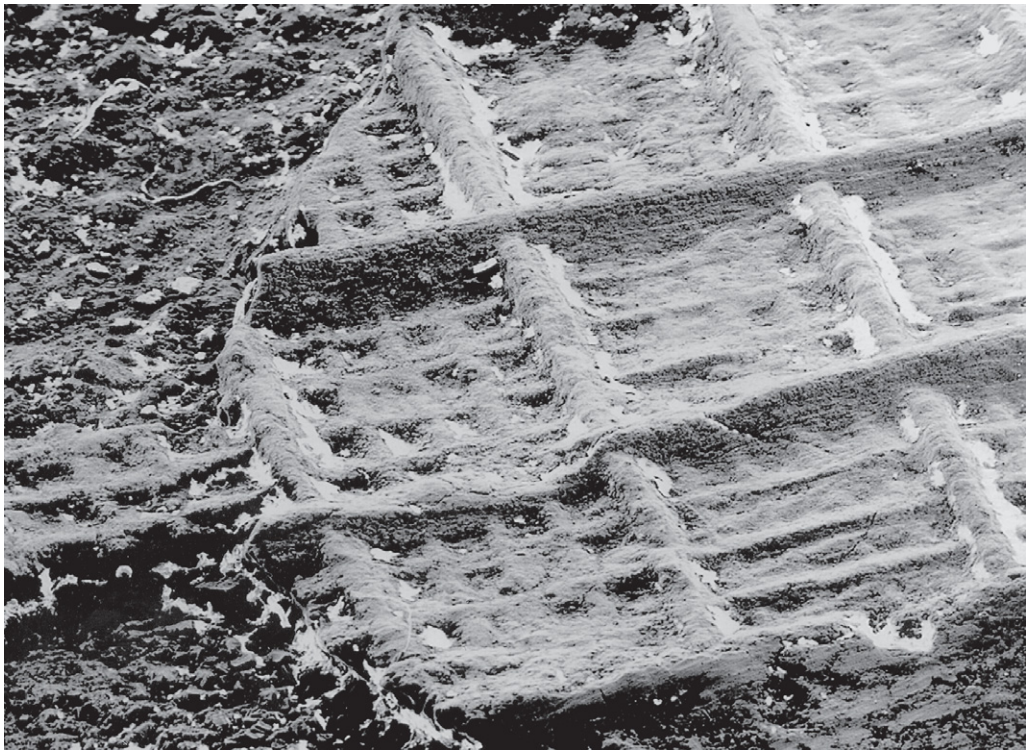

Figure 5: SEM oblique view of part of the die pattern, showing the depth of the broad 'boxed' ridges that form the positive pattern. The smaller squares of the pattern are formed by the finer ridges within the boxes. Some double lines indicate mis-cutting the model for the original die. Field of view 3.6mm across.

Overlapping SEM micrographs were taken (at the Ancient Monuments Laboratory, English Heritage in London) of the whole of the front of the die and assembled into a large mosaic picture so the 'boxed' pattern could be studied more closely. Further micrographs at higher magnification were made of interesting details and irregularities of the die pattern. Figures 3 and 4 show areas where the pattern is best preserved. An oblique view (Fig 5) clearly shows the positive form of the die pattern with the 'boxed' outlines being rounded ridges that are much higher and broader than the ridges that form the small squares within. Figure 5 also shows the intersection of the 'boxed' ridges where those in one direction (left-right) are higher than those set at right angles, indicating that on the original 'model' one set of 'boxed' lines was cut slightly deeper. Where they meet, the lines cross very neatly showing the sharpness of the tool and the depth of the cuts on the original 'model' of the die pattern. The box, centre left of Figure 5, contains 4x5 squares, which are formed by the 3x4 finer ridges within the box (Avent and Leigh (1977), call this a 'special boxed' pattern). The fine ridges that run between adjacent boxes show that the original lines on the die 'model' were linear cuts across the face at a shallower depth than the 'boxed' lines (Meeks and Holmes 1985). In some cases the finer ridges appear to be doubles or faint multiples (Fig 5 lower right) due to miscuts in the original 'model'. Not all of the boxes are square and Figure 3 shows an area where the 'boxed' lines are rectangular. Figure 1 also shows some 'boxed' lines which are diverging near the top, but by comparison the lines at the bottom are parallel and the boxes are square. These characteristics give the die a unique 'fingerprint'.

Because the pattern on this Frisian die has the same detailed physical form of raised ridges and smaller squares as the 'boxed' patterns found extensively on contemporary Anglo-Saxon gold foils, it suggests at some stage in the history of the 'boxed' pattern that there was probably a common origin for this design. Hence there appears to have been the possibility of shared traditional knowledge between workshops responsible for this die and other regional gold foil production, in order that the complex 'boxed' pattern could be accurately reproduced and the design maintained throughout the sphere of influence of the makers of garnet jewellery over both time and space.

On the back of the die (Fig 2) there appears to be another plain geometrical pattern, but in this case it is most likely to be a cloth impression which is related to its manufacture in a manner similar to that of contemporary Scandinavian oval brooches in which cloth was used as a support for wax models in making moulds for lost-wax casting (Fuglesang 1992). This is evidence that the die was cast by a method used by contemporary Scandinavian jewellers. Fuglesang notes

that the earliest known examples of textile impressions occur in the seventh century, which fits well with the date of the die. As the pattern on the back has not been deformed, this suggests the die has not been struck, compared to the Scandinavian dies, described below, which have. However, it would be possible to impress foils by the method illustrated by Watt (1990, 47) in which the die is placed face up, covered with foil which in turn is covered with a suitable backing material and then struck directly from this side with a mallet. Alternatively, foil could be placed on the die and rubbed to take the impression, but this was probably the least satisfactory method.

The fact that the die is positive and appears not to have been struck from the back raises questions of its purpose. The quality of the pattern suggests it was an important jeweller's tool. Thus, if it was made to be a working die, it would produce foils with the sharpest features on the back, compared to the common foils punched with negative dies that are sharpest on the front. Alternatively, it might have been used, for example, as a master template for making wax impressions that have been used directly as models for lost wax casting of negative dies, which could then have been used for punching the common positive foils.

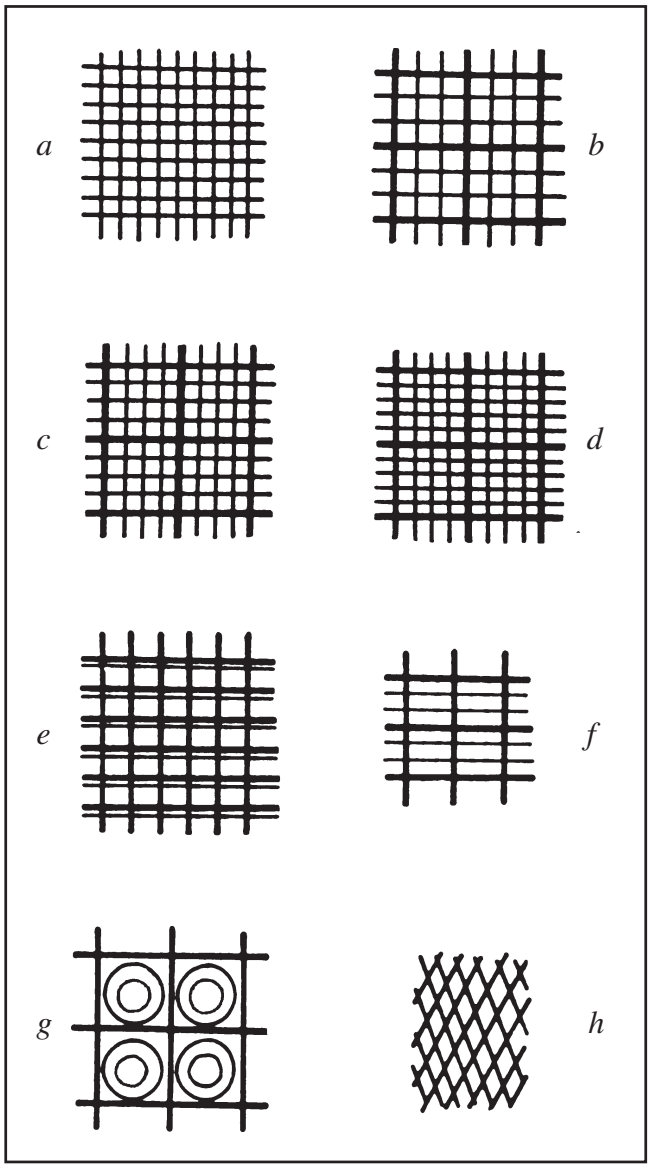

Figure 6: Foil patterns (stylized) recognized by Avent and Leigh (1977, Fig 1); a standard; b boxed; c,d special boxed; e,f irregular patterns; g ring stamped; h lozenge pattern.

Analyses and metallography

Analyses of the die were made at the Ancient Monuments Laboratory of English Heritage in London. Non-destructive surface analysis by X-ray fluorescence (XRF) was made to avoid damage by scraping or drilling as it was unclear how deep the corrosion was. The qualitative analyses gave high copper with small amounts of tin and lead, and traces of zinc and silver were also detected. This suggests that the die was made of leaded bronze, and the presence of traces of zinc is common in contemporary metalwork (Craddock, *pers com*). Metallography (at the British Museum, Dept of Scientific Research) of a taper section polished on a small protuberance on the middle of one side of the die showed an unusual metallurgical structure consisting of re-deposited copper within a corroded matrix that also contained discreet mineral grains from the burial environment. It gave no clues as to the original microstructure of the die, but confirmed extensive corrosion. It was not possible to polish deeper to find sound metal as this would have damaged the main body and pattern of the die.

Matching patterns with gold foils in jewellery

Many pieces of Anglo-Saxon and contemporary gold jewellery contain garnets backed by gold foils. The first cross-hatched foils date from the late 5th century and garnet jewellery declined after the middle of the 7th century (East 1985, 139-40). There are different types of patterns on the gold foils (Avent and Leigh 1977) and sometimes foils with different patterns are used in one brooch. This means that a workshop probably used several dies for stamping the gold foils. East (1985, 140-1) describes at least 11 different dies used on foils of the Sutton Hoo material.

Most earlier research concerning dies and foils has been focused on the different types of gold foil pattern. Avent and Leigh (1977, 2, Fig 1) divide the foils into two main

groups: those with 'standard' and those with 'boxed' patterns (Fig 6, a and b-d respectively). The 'standard' pattern consists of a uniform pattern of squares. The 'boxed' foils show wider and deeper lines around a 'standard' pattern; smaller squares are boxed inside larger squares. The Tjitsma die is of a 'boxed' pattern.

East (1985) has examined the Sutton Hoo gold jewellery. The pieces contain 4,333 cloisons and almost all of them have a gold foil backing. In the helmet, the shield, the lyre and the hanging-bowl boar-head escutcheons there are an additional 118 cloisons. The 'boxed' foils of Sutton Hoo mostly contain nine squares, which is generally the most common form of 'boxed' foils. Only the sword pommel has gold foils with 16 squares (*ibid*, 129-30). Foils with 16 or 20 squares (Fig 6, c-d) are less common and are called 'special boxed' foils by Avent and Leigh (1977, 2).

Avent and Leigh surveyed over 500 pieces of gold foil on a total of 181 objects. Special boxed foils with 16 squares, and occasionally 20 squares, were found on only seven objects (*ibid* Table 1, 24-6). When the boxes had 20 squares it was often apparent that the smith wanted to produce a 16-square box, but that the lines forming the squares sometimes diverged from their intended paths and produced 20-square boxes (*ibid* 1977, 15). In their survey they identified which way up the foils were displayed in their settings (*ibid* Table 1,16-26). In 169 of the pieces of jewellery, they recorded 138 settings with foils having their positive sides displayed, 95 with the foils having their negative sides displayed and 15 with foils both ways round.

The pattern of a die can be compared to a fingerprint, whether it was used directly or indirectly. If the pattern could be exactly matched with a certain piece of gold foil, it would give some information about the workshop and trade. Where a die is slightly irregular, it is easier to see whether the pattern on a foil matches it. The Tjitsma die has three distinctive characteristics: first the die is positive, which means that foils punched from this die would have their sharpest features as negative impressions unlike, for example, the foils from Sutton Hoo that appear to have been punched with negative dies which give sharp positive foils. The reverse (positive) side of Tjitsma die foils might have been displayed, but these would not have been as sharp. Secondly on different areas of the die the boxed pattern has either 4x4 or 5x4 smaller squares within each box (depending on the number of smaller ridge lines that form them, Figs 4 and 5), not the more usual 3x3 squares. Thirdly, while a few boxes are square (Fig 4) others are irregular and elongated, forming rectangles rather than squares (Fig 3). These characteristics give the die a unique 'fingerprint' and the task of comparing the pattern with gold foils to try and find a match should not be difficult.

Foils in various pieces of garnet jewellery were studied at the British Museum, English Heritage and the Dover Museum in order to try to match the die to the foils. The appendix lists the jewellery that was selected for examination which had foils with boxed patterns of 16/20 small squares, or foils that have patterns that were listed by Avent and Leigh (1975, 24-6) as being miscellaneous. All the 'special boxed' foils, that were accessible, were examined with a microscope but the garnets were not removed from the objects. Sometimes it was difficult to conclude whether the foils were negative or positive, but this manner of examination proved sufficient to conclude that none of the foils studied could be linked to the Tjitsma die, so this is an area for further research. This investigation at least ruled out some objects, the description of whose foils had suggested they could possibly have been made with the Tjitsma die.

During this comparative investigation evidence was found of foils deliberately mounted to display their negative sides (as did Avent and Leigh 1977, Table 1). The high quality composite disc brooch from Dover (British Museum, MLA 1879, 10-13, 1; Rigold and Webster 1971) has all of the 'boxed' and 'standard' pattern foils displayed in this manner, even though they were punched with negative dies. Apart from not being fully sharp on this side, some of the tiny squares on the foils have been pierced through from the other side by the die, indicating the direction of punching. Thus, foils are not exclusively mounted positive side up and this supports the argument that the Tjitsma die could have been used to punch foils directly.

Die manufacture

The manufacture of a positive die like the one from Tjitsma is quite different from that of a negative die. The complex 'boxed' pattern of a negative die can be produced relatively easily by cutting two sets of parallel lines of appropriate spacing and depth at right angles. This appears to be the case with the Sutton Hoo jewellery, where the evidence from the sharpness of the foil impressions indicates that these dies (both boxed and standard pattern) were probably cut directly into metal to form the die faces (Meeks and Holmes 1985). An alternative would be to cut the pattern directly into

wax as a negative model, invest the model in clay and cast the die. With both these methods the negative pattern in the metal die could be carefully finished by running very fine tools along each line to smooth off any irregularities.

By comparison, for a positive die, an engraver would have to individually cut away the background metal for each 'box' to leave the minute pattern with its finely rounded ridges and tiny squares standing proud of the surface. In practice, it would not be possible to do this with anywhere near the accuracy of the tiny three-dimensional forms of the die. Engraving also leaves characteristic tool marks and imperfections which are not present on this die. The Tjitsma die therefore appears to be made by a different process and investment (lost-wax) casting is the most appropriate method. There are three ways of making a mould for investment casting to produce a positive die:

a) Make a positive wax impression of an existing negative die, invest it in clay to make the mould and cast in the usual lost-wax manner. This would be a very simple way for a goldsmith to reproduce a valuable tool, but now in a positive form.

b) Cut a negative die pattern directly into very fine clay using simple tools to form the criss-cross lined pattern of appropriate depths. This negative clay model would be similar in appearance to the directly cut negative metal die described above, but would probably be much easier to produce. The clay model would then be turned into a mould by pouring on wax to protect the design, then adding a back. A bronze die could then be cast in the usual lost-wax manner. A clay mould of this type would produce a first generation cast positive die. If the intention of the maker of the Tjitsma die was to produce an original die directly in positive form, then this must be the way it was done.

c) The third way to make a mould is to make a clay impression of an existing positive die and to prepare a mould as described above and then cast the die, but it would represent a second generation copy. In each case the back of the wax model could be strengthened by cloth which would result in the impression found on the back of the Tjitsma die.

Because the die pattern is so fine, the casting metal must be capable of filling the mould completely and the surface must not have a pronounced dendritic structure which would add unwanted texture to the die, and thus to the foils. It would not be possible to finish this die mechanically other than by superficial cleaning, so the original casting alloy and conditions must have been very well controlled to produce directly the accurate, fine patterned casting that is found with the Tjitsma die. Leaded bronze is a good choice of alloy for this purpose, and surface analysis of the die indicates that this type of alloy was used to make this die.

Other dies from Denmark

Not many dies have been recognized as such and one question raised by this investigation is whether other dies lie unrecognized in collections with their fine patterns obscured by superficial corrosion. In addition to the Tjitsma die, five dies with cross-hatched patterns are known from Denmark. Four are in the National Museum, Copenhagen and the fifth is in the Bornholms Museum (*pers com* Fin Ole Nielsen and Peter Vang Petersen). All are corroded to varying degrees and the patterns have been revealed by careful conservation. Two dies are from Neble and Gudme, but they are not published in detail (Vang Petersen 1991, 53; Jørgensen 1993, 54; Vang Petersen 1993, 33-4; Høilund Nielsen and Vang Petersen 1993, 225). The other three dies were also found in Denmark in recent years as treasure trove: two are from the site of Kalmargården at Tissø, Zealand (KV 64 and KN 701) and the third die is from Dalshøj on Bornholm (no. 1639x10) (Watt 1990). So far these dies have only been examined optically as part of this project, the first four are shown in Figure 7. These dies have different patterns to the Tjitsma 'boxed' pattern but fall within Avent and Leigh's general pattern descriptions.

The Neble die (C30872) is six-sided, made of copper alloy, and has a negative irregular pattern somewhere between a 'standard' and 'lozenge' design of about 5 squares per mm. The Gudme die (6205x7) is square, made of copper alloy, and has a negative irregular 'standard' pattern of about 5.25 squares per mm. About one third of the surface of the pattern is still covered with original silver foil, which is an extraordinary find as the foil is not gold. It also has a small handle protruding from one edge. The back of the die is relatively smooth and appears to have been struck during use. The shape of the Gudme die is comparable to one from Kalmargården (KN 701) which is rectangular, made of copper alloy, and has a negative 'boxed lozenge' pattern with each 'box' containing 3x3 smaller squares. The pattern is surprisingly even and regular with only two very small mistakes, and is of better quality than the Tjitsma die. It is clear that the deeper lines of the

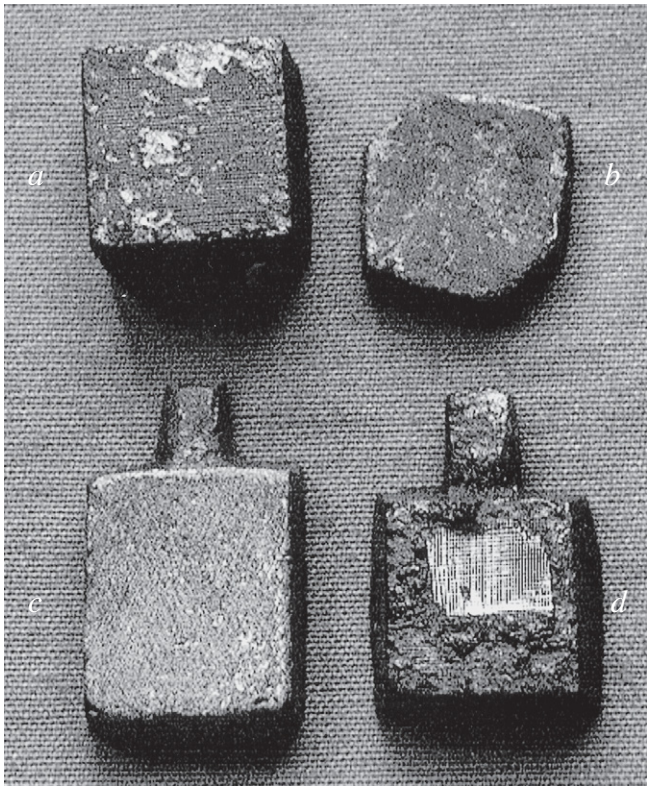

Figure 7: Four Danish dies: (a) Kalmargården KV 64, 'standard' pattern. The die is 18mm wide; (b) Neble C30872, 'standard/lozenge' pattern. The die is 22.5mm across the longest diagonal; (c) Kalmargården KN 701, 'boxed lozenge' pattern. The die is 18.8mm wide; (d) Gudme 6205x7, 'standard' pattern, with original silver foil. The die is 19.9mm wide.

pattern (the 'box') were cut first and then divided up with very regular shallower lines. The back of the die appears to have been struck in use. The sides are smooth and one has a handle. The second Kalmargården die (KV 64) is square, made of copper alloy, and has a negative, 'standard' pattern of about 4 squares per mm. The depth of some lines is greater than others and a few are double. The die is quite thick, about 12.2mm, and surprisingly the sides have also been patterned. One side has what looks like a 'standard' pattern or primitive 'boxed' pattern with a number of different smaller squares within. Another side has eight grooves of regular spacing but at an angle to the die edge and they are deeper than the grooves in the front pattern. Perhaps the edge patterns are evidence of trial cutting. The back of this die has been struck in use. The die from Dalshøj is of copper alloy, about 16mm square and 4mm thick with a handle on one side. It has a negative 'standard' pattern which is seen in the corroded surface.

All of these dies are negative and of copper alloy, and at least three appear to have been struck during use to punch foils. An unanswered question is whether the negative patterns were cut directly into the alloy or were cast via a model and mould. This can probably only be ascertained by metallographic examination, but will probably have to await the discovery of a broken negative die that could have a taper section polished through to the pattern.

Conclusions

Much high quality 7th century gold and garnet jewellery has cross-hatched pattern gold foils in cloisons behind the garnets to reflect light back to give colour to the stones. The Tjitsma die is a jeweller's tool with a 'boxed' pattern which has a similar detailed physical form of raised ridges and smaller squares as the 'boxed' patterns on gold foils from Sutton Hoo and other contemporary jewellery. The pattern of the Tjitsma die is an irregular 'special boxed' pattern (of 4x4 and 5x4 smaller squares) and the overall quality of the pattern is good. The die therefore appears to be a tool for producing patterned gold foils of this type, either directly or indirectly. It is unusual because it has a positive pattern, unlike the negative patterned Danish dies, and the evidence from 'boxed' gold foils whose impressions have the sharpest detail on the front and appear to be generally made with negative dies. If the Tjitma die was used directly as a punch it would produce foils with sharpest detail on the 'back'. However, the Dover disc brooch and many other examples examined by Avent and Leigh (1977) prove that some goldsmiths chose to display this side of the foils, so it could have been appropriate to have used the Tjitsma die directly. The similarities between the physical form of the patterns do establish a design connection between the 'boxed' pattern on the die and on foils from a wide geographical area within the sphere of influence of the contemporary Anglo-Saxon, Frisian and regional continental goldsmiths, and ultimately suggests a common origin. The back of the die has a cloth impression from a procedure during mould making and was a local characteristic of Scandinavian jewellers, which also suggests shared traditions between workshops.

The die appears to be made of cast leaded bronze, but because of severe corrosion was only analysed on the surface and on a polished section that could not be made deeper to reach core metal. The Danish dies are also of copper alloy, and all the dies are flat blocks.

There is a remote possibility of matching the die pattern with foils in garnet jewellery as the die has unique physical characteristics (a 'fingerprint') which would

be reproduced on foils made from it either directly or indirectly. The areas of the Tjitsma die that are of imperfect line spacing would produce corresponding imperfect foils that might be easier to spot than foils from the more symmetrical regions of this die. If the positive die has been used directly, this would also produce foils of different characteristics to those from negative dies. So far, no matches have been discovered, but this is an area for further research.

Considering the evidence above, the Tjitsma die is unusual as its pattern is of positive form and it has apparently not been struck; this gives rise to speculation as to its origin and purpose. The positive die could not have been made by cutting the metal directly, it must have been an investment (lost-wax) casting. There are two possible explanations for its origin; either it was made as a master die by casting from a directly-cut clay model or, more simply, it was a copy of an existing high quality negative die, cast from a wax impression - a simple way to reproduce the die pattern of a valuable goldsmiths' tool, albeit in positive form. If the die was not used for punching foils directly, its purpose could have been as a template used for producing wax impressions to be cast into second generation negative dies. The high quality 'boxed' pattern would be well preserved and could be relatively easily reproduced. Dies would have been an integral part of the goldsmiths' range of tools for making garnet-inlaid goldwork, and the high quality of the Tjitsma die pattern means that it must have had an important function within a jeweller's workshop.

Future research

The Tjitsma die is exceptional. Therefore it is appropriate that its characteristic 'fingerprint' pattern should be sought by extending the comparative survey of gold foils to the locally found (Wijnaldum) brooch and other continental garnet jewellery. If any comparable foils are found it should be possible to see whether they are sharp and positive and thus punched from a negative copy-die or have the reverse characteristics of being formed directly on the Tjitsma die. It is possible that there was a particular local tradition of using positive dies compared to the more widespread evidence that foils were generally produced from negative dies. It would be an important step if a direct match of this die could be made to a piece of jewellery. Several impressions of the die have been made at English Heritage to simplify matching the die with appropriate objects.

With this article the authors hope that very corroded objects may be looked at more closely and possibly more dies of this kind with their fine patterns may be recognized.

Appendix: description of jewellery examined

The British Museum has a number of brooches with cross-hatched foils, but none of them matched the pattern on the Tjitsma die. For example a keystone brooch from Dover (BM 1963, 11-8, 2; Avent 1975 ii, 20, corpus no. 73) has regular 4x4 squares except for one piece of gold foil that has one double line, but the line does not actually divide the box into 4x5 squares. Another keystone brooch (BM 1963, 11-8, 776; Avent 1975 ii, 9, corpus no. 24) contains several different pieces of gold foil. The number of squares within the boxes varies from 16 and/or 20 to 25. Different dies were used to make the foils of this brooch, but not one of these foils could be matched with the Tjitsma die. The 16-20 square foils were irregular, but the squares were too large.

The Sutton Hoo pommel (BM 1935, 10-10, 28 95a), containing a total of 53 boxed foils was studied. Of the foils, one had a 3x3 pattern and all the others 4x4. The pattern of the foils is very regular and is not comparable with the Tjitsma die.

The miscellaneous foils have different patterns from the boxed pattern. One brooch (Dover, grave 35, BM 1963, 1 1-8, 181; Avent 1975 ii, 20, corpus no. 74) had three ring-stamped foils (Fig 6 g) and another brooch (BM 1044 70; Avent 1975 ii, 14, corpus no. 48) had four other ring-stamped foils. A third brooch (BM 1963, 11-8, 583; Avent 1975 ii, 4-5, corpus no. 163) contained 11 foils of which six were 3x3 boxed pattern and the others of the so-called lozenge pattern (Fig 6 h). Another brooch (BM 1049 70; Avent 1975 ii, 4-5, corpus no. 6) had one standard foil and three 2x2 boxed foils.

Some brooches from Faversham held by English Heritage were studied. Only one had an irregular 4x4 boxed pattern with an extra line, but it did not have extra squares (Gilded silver brooch, Maison Dieu 444).

Two pieces of jewellery from Dover were in the Dover Museum: a small silver pendant (Dover grave 29, BM 1963, 11-8, 144; not mentioned in Avent 1975) and a Kentish brooch (BM 1963, 11-8, 141, Avent 1975 ii, 29, corpus no. 114). Foils from neither object matched the die; both had very regular 4x4 squares within the boxes.

All the 'special boxed' foils listed by Avent and Leigh (1975, 24-6) that were accessible, were studied. They were examined with a microscope but the garnets were not removed from the objects. Sometimes it was difficult to conclude whether the foils were negative or positive, but this manner of examination proved sufficient to conclude that none of the foils studied could be linked to the Tjitsma die.

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