Journal of Danish Archaeology vol. 8, 1989, pp 126–143

Early Bronze Age Spiral Ornament – the Technical Background

by PREBEN RØNNE

INTRODUCTION

"There is something eloquent, yet restrained and academic, in the Spiral Style of the Early Bronze Age. The turns of the spirals are close, the punching masterly in its technique, a play of light on the broad surfaces of the bronze; and yet the effect is created merely by means of the fine punch line." (J. Brøndsted 1939, pp. 63–65).

One of the features intimately linked with the Early Bronze Age in Scandinavia is spiral ornament. The spirals, and the jewelry and weapons on which they occur, have become an important element in the popular picture of the Scandinavian Bronze Age. The spirals have intrigued and captivated observers. The belt discs in particular are decorated with innumerable spirals, like the one from Langstrup, which is often depicted, as being one of our finest pieces of ancient metal craftsmanship (fig. 1). The spirals are close and executed with almost incredible precision. They are drawn as a groove, interrupted at the centre of each spiral. The ends of each groove exit at precisely the same angle, it has a uniform width and the coils are equally far apart (fig. 2). As Brøndsted says, the execution of the spiral ornament is masterly in its technique.

Spirals are the absolutely predominant motif on bronze objects in the middle of the Early Bronze Age. In Period I, they begin to appear on a few objects; in Period II they are ubiquitous, being found everywhere where a spiral can be formed, and in innumerable variations and combinations. They continue into Period III, but to play a more modest role.

The very important part played by spiral ornament in the Bronze Age has made it a prime target for study. It has had regional, chronological and technical significance for our perception of the period, and nearly all students of the Bronze Age have in one way or another worked with it and formed an opinion on its origins.

If one works with ornamental detail and style in archaeological material in the modern manner (e.g. Rønne 1987a-b and 1989), the technique behind the ornaments is in principal of no consequence. It is the final form which is important. But only in principle, for if further interpretations are to be put on the style, it is in many cases necessary to know the technique behind the production of the individual details, so as not to confuse technique with art; but there may be other reasons.

It is commonly assumed that the spiral ornament of the Bronze Age has been punched into the surface of smooth-cast bronzes. There are a number of features, however, which suggest otherwise. The great uniformity and consummate precision show that the spirals cannot have been individually punched: another technique must have been used. It must have been one which made possible a standardized production of many uniform spirals on the same object. The only technique which fulfils this criterion is casting "à cire perdue". The geometrical uniformity, seen for instance in the belt from Langstrup, could be obtained only by forming the spirals with the same stamp. A stamp in the form of a spiral must have been pressed into a wax model and the spirals have been already formed in the bronze in the casting.

In the following, some of the points invalidating punching as the only method of producing spiral ornament will be discussed and the case for believing that this ornament was in all probability stamped into the model will be stated.

THE PUNCHING THEORY AND THE RESEARCH-HISTORICAL BACKGROUND

As far as research history is concerned, the technical discussion is closely bound up with the chronological division into three periods: Stone, Bronze and Iron Ages. The acceptance of this division came to hinge on the technique employed to produce Bronze Age ornament. Opponents of the tripartite division argued that the

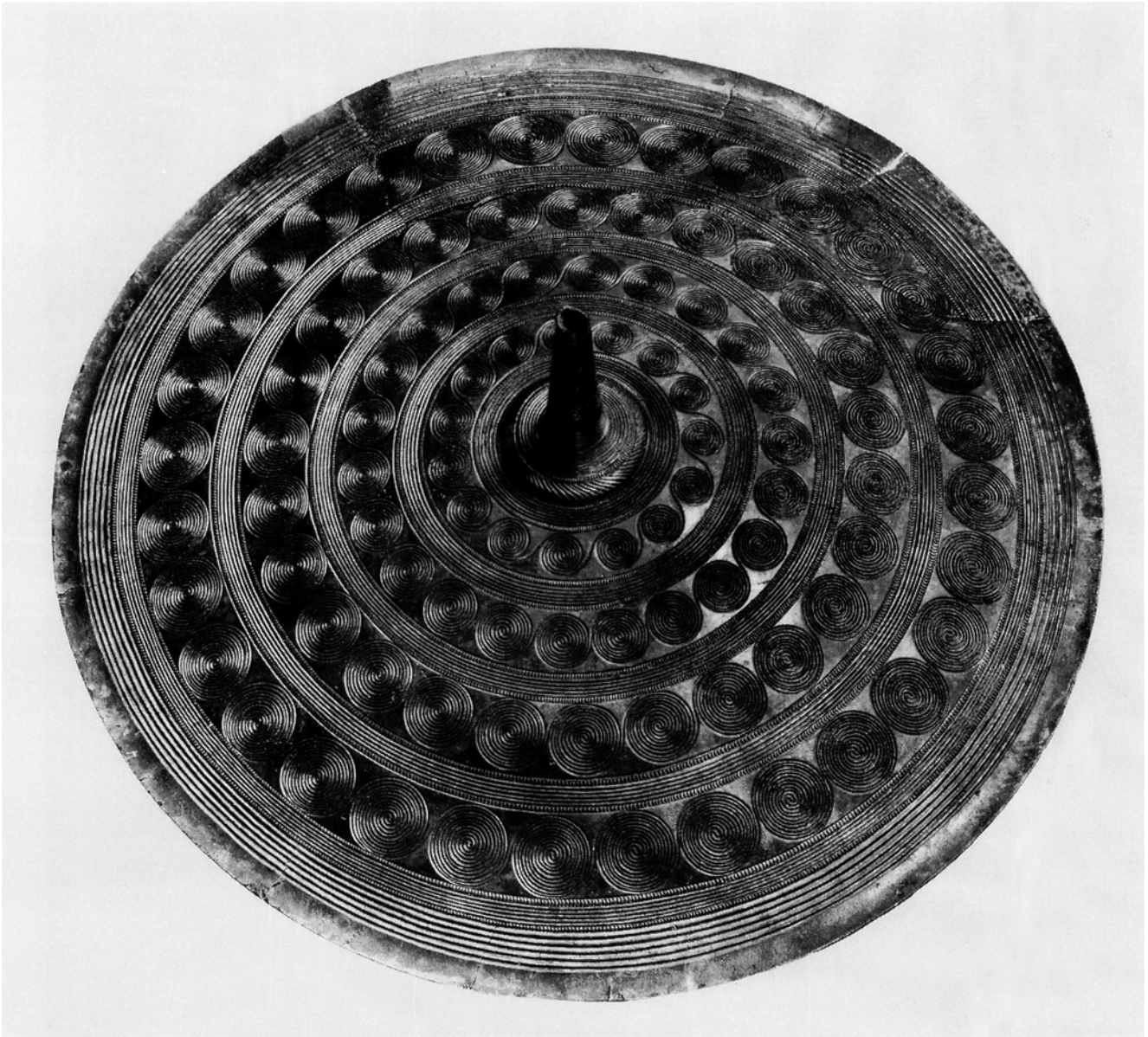


Fig. 1. The belt disc from Langstrup in Northeastern Zealand is one of the finest pieces of craftsmanship known from the Early Bronze Age. (National Museum photo).

coration could not have been made without knowledge of steel, proponents that it could.

Actually, this is not the place to discuss research history, but the research tradition does have a decisive effect on our present perception of Bronze Age technique, and some of the background should be understood. This can be done succinctly by quoting Sophus Müller, who in *Vor Oltid* from 1897 discussed the arguments behind the tripartite division. In European context, the discussion was hardly over, but in Scandinavia the division was accepted without question. The quotation reveals something of the background behind our present chronological system and its dependence on an understanding of the metal technique of the Bronze Age.

"It long remained a mystery by what technique the fine line ornaments so characteristic of the Scandinavian Bronze Age were produced. That they were not made during casting was clear enough: for that they are too sharp-

Fig. 2. Detail of the ornament bands on the Langstrup belt disc. Centres, spiral grooves and coils are absolutely uniform within each band. (National Museum photo).

ly defined. They could not be engraved, because iron was not known in the Bronze Age; and good quality steel is also required to cut hard tin bronze. Opponents of the Bronze Age maintained, on the contrary, that the ornaments could have been produced only with a steel burin. This little tool therefore long remained a dangerous weapon threatening the very heart of the tripartite division: if steel was available for making the ornament, the concept of a Bronze Age would have to be abandoned."

"It was a Copenhagen craftsman, the goldsmith Boas, who solved the problem. He often visited the National Museum, and the curators were not slow to notice that he had a good eye for ancient metal technique. He was asked about the execution of Bronze Age ornaments and urged to discover how they could be produced without using steel, only bronze tools. On the following day goldsmith Boas brought a piece of brass on which he had with a punch of the same metal executed the spiral ornament described. This answered the question posed by both proponents and opponents of the Bronze Age theory: the ornaments have been punched. Bronze can be chased with bronze." (Müller 1897 pp. 257–58).

The perception of the technique behind Bronze Age line ornament which Müller described in the light of research history at the end of the previous century has in this century been generally accepted. Popular archaeological handbooks carefully describe how the bronzes have been chased, and learned theses are based on the assumption that all spiral and circle ornaments have been hammered with great force into the smooth bronze surface. It has now to be asked, however, whether the proof of the theory on the punching of line ornament is still satisfactory, more than a hundred years after it was formulated.

With copper, tin and the alloy bronze, North Europe entered an epoch in which metal and metalwork influenced developments. To Scandinavia, all raw material was imported in a given form, but it could be melted, cast and shaped according to local wishes or tradition. Local metal techniques became important to the community and were prerequisite to the change from Stone Age self-sufficiency to Early Bronze Age dependence on import of raw materials.

The bronze objects were produced by craftsmen who had mastered the technique of melting and casting metal. Their form and decoration were a result of the technique or techniques these bronze-casters had mastered. Our knowledge of technique is crucial to the interpretation. Technique is therefore always an important aspect of Bronze Age research.

Fig. 3. Enlargement of the centre of one of the spirals on the Langstrup belt disc, photographed from a silicone rubber cast. The black stripe crossing the raised spiral groove impression is a shadow caused by a hair. Even at this strong magnification, not a single punch mark is visible. (After Savage, Lowery & Shorer).

The immediate reason for taking up this subject once more at the present juncture is a recent doctoral thesis from Lund University. This deals with the technical basis for decoration, especially spirals and concentric circles (Herner 1987). Herner bases her work and interpretations on the traditional and widely accepted view that the spiral and circle ornaments were punched. On the basis of this technical belief and a qualitative evaluation of the ornaments, far-reaching culture-historical conclusions are drawn.

The punching technique is thoroughly treated in many places – also in recent works – but as things stand I believe that punching as the predominant technique for forming line ornament in the Bronze Age is no more than a widespread and accepted postulate. As will be apparent from the following, another technical explanation is possible.

PUNCHING AS A TECHNIQUE FOR PRODUCING SPIRAL ORNAMENT

Under the influcence of archaeological tradition, I have previously worked on the assumption that the line and point ornaments were stamped into a cast and smoothly polished bronze surface. But personally, I have never accepted that the spiral lines were hammered in the smooth surface of the bronze. There are several reasons why not, and I will present them briefly here. My argumentation and documentation will concentrate entirely on the spirals.

1. Lack of punch marks. I myself have seen original spiral ornaments only at the magnification provided by an or-

dinary magnifying glass. Normally the groove is entirely without damage to the sides, and it has a very uniform deep and even bottom without visible damage. One of the spirals from the Langstrup belt disc is illustrated in fig. 3 at a very considerable magnification. There are *no* traces of marks produced by punching.

According to the punching theory, ornaments are produced with continual small blows on the head of a small chisel-like instrument which is slowly moved forward. In this way, continuous smooth lines are supposed to have been chased.

After personal attempts to punch spirals with a steel punch in copper, which is much softer than bronze, Elisabeth Herner writes that the blow has to be extremely heavy to make the deep grooves of which most good spirals are made (Herner 1987 pp. 143–45). She did not manage to make a deep groove by punching, but the slightest blow on the punch made adventitious marks which could not be erased later. It was not possible to produce an even spiral line, and the punched groove mostly consisted of small, short elements.

Herner concluded from her experiments with the punching of spirals that Bronze Age chasers must have been highly skilled, because none of the features she mentions can be observed in the original Bronze Age spirals. Her experiment is very illuminating: it is only in theory that lines can be formed from an infinite number of points. In curved lines, of which the spirals are formed, a punch will always leave marks after each blow as a regular row in the sides of the groove. These must be found all along the groove in its sides and bottom. A curved line made up of many short straight bits would *always* reveal this at a suitable magnification.

Fig. 4. Presumptive punch. (After Sophus Müller, c. 1:1).

It is clear that a broad punch must leave a broad track if the whole tool is hammered down into the bronze surface. The broader the punch, the clearer the marks and notches in the whole groove and its edge. If an attempt is made to make the punch narrow until it is almost a fine point – it has been suggested that awls were used as puncheons (Herner 1987 p. 141 and p. 146 note 23) – then the traces must be seen as unevenness over the whole bottom of the groove. A sharp object hammered with great force into a hard, smooth surface must leave traces after every blow. It would make no difference if punches with curved edges were used, for the curve changes constantly in a spiral.

I have not seen traces of punches showing precise, regular, small blows all along the ornament groove, either in circles or spirals of the Early Bronze Age. Occasional notches may be seen in the centre of some spiral grooves, which have been identified as punch marks and as evidence of punching as a working method, but they are found only in the centre. Have the Bronze Age chasers really been able to deliver so precise a blow that we are unable to ascertain a single mark throughout an ornament groove?

2. Absence of traces of punch blows in the metal matrix. It is not only macroscopically that we should expect to see traces of punch blows: They should also be visible in the structure of the actual metal. With electron microscopes we can see the crystalline structure of bronze. Andreas Oldeberg has had an ornament groove analysed (Oldeberg 1976 p. 89). The metal showed no sign of destruction. Oldeberg attributed the absence of traces to annealing of the metal after punching.

3. No proper punches have been identified, and the curve and constant width of the ornament lines do not accord with punches. A few bronze objects have been identified as punches, but it has not been demonstrated satisfactorily that they have been used to chase line ornaments like spirals and circles. Müller depicts an almost chisel-like bronze implement and suggests that it was used as a punch (Müller 1894 p. 258 fig. 148, here fig. 4). It can naturally not be ruled out that it was used to hammer lines in bronze, but the edge is about 3 mm wide. It cannot possibly have been used to produce such curved

Fig. 5. No punch marks can be seen in the grooves, and the straight lines between the spirals do not meet. This shows that another technique must have been used.

lines as we see in spirals or circles with a diameter which is often less than 10 mm; and the innermost curves are less than 3 mm in diameter. Some scholars have recognized the difficulties and suggested that the corners of the punches or awls were used, but with the strong blow necessary, such fine points or corners would inevitably have been compressed at the very first blow and the width of the groove slowly increased until the punch were resharpened or replaced by another.

4. Flaws in particular parts of the running spirals. Flaws and inaccuracies are not unusual in the ornaments. For example, some spirals do not link in the joining lines, or two spirals overlap. These faults are known even in spiral ornaments with a very precise execution and no traces of punching. Many of these very faults render it extremely unlikely that the grooves were punched so precisely in the hard bronze surface that the blows cannot be seen, and that there are no faulty blows. It can hardly have been possible for the chaser to have concealed every trace of the punch blows, if he could not get two lines over a millimetre wide to meet (fig. 5). It is equally remarkable that it is usually the straight stretches between the spirals which fail to join. A straight line must be easier to punch continuously and without marks than a curved one!

5. Punching of objects which are difficult to support. The very hard and precise blows that punching would have required would also have required a support which could absorb the blow, but at the same time have been firm enough to leave a distinct impression of the punch in the bronze surface. This would have caused serious problems when particular types of artefacts were chased, for example double buttons, tutuli with centre boss and spearhead sockets. They would have been almost impossible to support properly, when the precise and hard punch blows were to be made.

6. Uniform centres. In the centres of spirals there are sometimes one or more small notches in the first millimetres of one or both grooves. It is remarkable that the small marks are often exactly alike in practically all the spirals of the same band. This might have occurred in individual production of the grooves, but it seems unlikely. The marks are not punch marks, and I will return to their origin below.

7. Geometrically uniform spirals. The spirals are commonly geometrically the same in the same running spiral band or spiral group. This applies especially to the innermost coils. There are many exceptions, but these can all be explained. The usual thing is that the spirals, if drawn separately, could nevertheless be superimposed. It is not merely the regular curved lines which are geometrically alike; the same applies to many irregularities in the spirals. This is practically unthinkable in individually punched spirals.

CIRE PERDUE CASTING

Archaeologists have known for a long time that ornaments were cast in the Bronze Age. This applies primarily to the deep ornaments on swords. The few pieces of jewelry with openwork ornament are also generally believed to have been cast with the ornaments. The cast ornaments are – in well-preserved pieces – very sharply defined.

Nor is there any doubt that some of the decoration in many women's accessories must have been cast, for instance the ribbed centre found in many gorgets. Many belt discs and tutuli have a moulded bead or ribbed ornament around the centre spike. Such decoration cannot be produced by blows of any kind.

B. Brorson-Christensen has in the course of conservation worked with the sounding plates of the lures. The backs are not polished and the surface therefore appears as it was when it was removed from the mould. On these and other pieces, fine lines have been observed: "in many places we see... how incredibly sharply fine incised lines in a wax model are reproduced in casting" (Brorson-Christensen 1966 pp. 343–44). It is generally recognized that the lures were cast à cire perdue.

There can be no doubt that the plastic ornaments could be cast in a way to stand perfectly sharp on the finished bronze, also point and line ornaments. The question remains: why should spirals and the other detail not be cast at the same time?

One would already expect to find scratches or other unevenness in the mould on the first pieces cast by the smiths. But people of the Bronze Age were just as inventive and practical as we are: It did not need many scratches for the Bronze Age smiths to realize what they could be used for. Once they had realized how much was to be saved by making the decoration in the wax, they made it there. It would have been easiest to make the spirals in soft wax, and we usually seek the easiest and best solution.

Müller, and others with him, have maintained that casting could not reproduce the detail found on the spirally ornamented objects, but this is not so. There are not only the fine cast lines on the sounding plates, but many more recent cast bronze statues and other small cire perdue cast objects contradict this claim. Even much finer detail than spirals can be reproduced sharply in casting. Photographs from modern casting processes show that very fine details can be faithfully reproduced (e.g. Jackson 1972 p. 81).

We know for certain that cire perdue casting was used in the Early Bronze Age. The horse drawing the sun chariot from Trundholm is a well-known example (Drescher 1962 p. 42), but it is not only that which has been cast using the "lost wax" method. Many other Bronze Age forms cannot possibly have been cast in any other way. Ci-

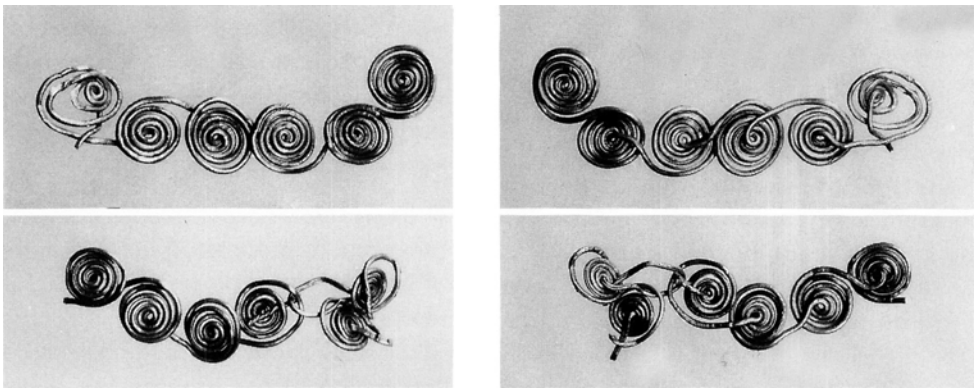


Fig. 6. Coiled gold thread found in a so-called "wizard's bag" in a grave in Hornherred, Zealand. The wire has a mean thickness of about 0.8 mm. (National Museum photo, c. 1:1).

re perdue casting has been a well-known and widely used technique in the Early Bronze Age.

A recent and important technical study has demonstrated that ornament lines – in two cases from the Late Bronze Age at least – were really cast (Knudsen 1978): Two bronze neckrings from Trørød in northeastern Zealand. Svend Aage Knudsen has with metallurgists from the Danish Technological Institute at Tåstrup studied their ornament grooves. It could be clearly demonstrated that the grooves were cut, and microtraces showed that parallel groves were cut with the same tool. The grooves were cut into a wax model on which the mould was made.

There can therefore be no doubt that it was possible to cast line ornaments, as we know them from the Bronze Age, and the technique was known and exploited in the Late Bronze Age and most likely also in the Early Bronze Age.

It must be concluded that it was possible to form the spiral ornaments in the wax model and thus to transfer them to the bronze already during the casting process à cire perdue. This is a far more likely procedure than punching after casting.

HOW WERE THE SPIRALS FORMED IN THE WAX? – BALLERMOSEN AND AN EXPERIMENT

In a soft material like wax, the spirals could have been made freehand, for example be cut or scratched; but there is not much in their form to show that this was the case. Among other things, the uniformity and precision speak against individual shaping. The literature contains several attempts to explain the precision of the spirals, for example string compasses or concentric circles with moving centres (Ringbom 1933 and Savage, Lowery & Shorer 1982). There is perhaps an even simpler explanation: the spirals have been impressed with a stamp, explaining both the accuracy and the uniformity.

In a grave from Ballermosen in Hornsherred, Zealand, a round, spirally wound gold wire 0.8 mm thick with 12 spirals in a row has been found (fig. 6, Ke I 112 A), broken into three pieces. The spirals are about 1 cm in diameter. If one or more of the spirals is pressed down into a plate of wax, an impression of a spiral or several in a row will be obtained.

It will not be claimed here that this piece has been employed to produce spiral ornament, since its spirals are not quite like those we see decorating bronzes; but it inspired a little experiment with a round copper wire and a small disc of beeswax. The wire was wound up in various ways and then pressed into the wax. The impressions were then compared with the original spiral ornaments.

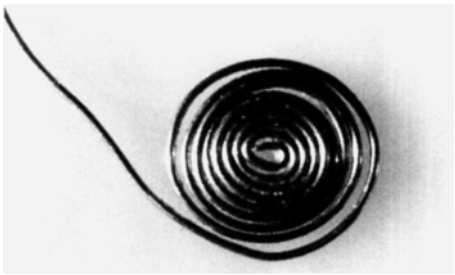


Fig. 7. Spiral 1, coiled copper wire.

Fig. 8. Drawing of a running finished spiral. (After Sophus Müller).

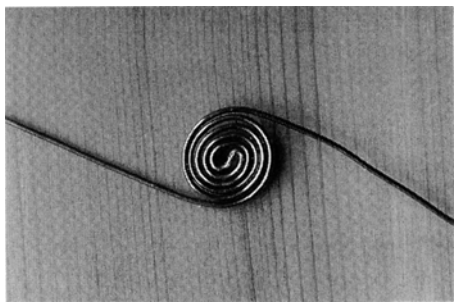


Fig. 9. Spiral 2, coiled copper wire.

Spiral 1. In the first attempt to roll wire into a spiral, a start was made from one cut end (fig. 7). The wax impression yielded a clear spiral, but several placed together did not give a running spiral as known from the Bronze Age. Both the centre and the way the spirals could be joined were wrong in a composite row, whereas the impression corresponded to the outermost spiral in a completed spiral row (fig. 8).

Spiral 2. The next wire was wound up in an attempt to produce a running spiral, i.e. a spiral in which the wire reaches out to two sides. It was bent in the middle and wound about the bend. In this way a regular running spiral (fig. 9) was produced. The individual impressions

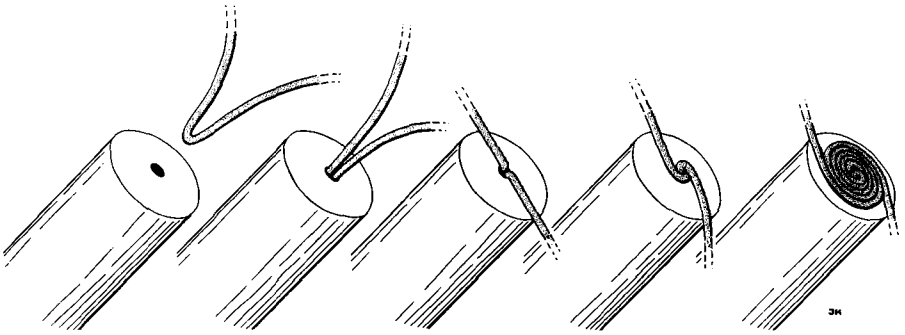


Fig. 10. Spiral 3. The copper wire is coiled as illustrated in the drawing. (J. Kraglund del., after SKALK 1988:6).

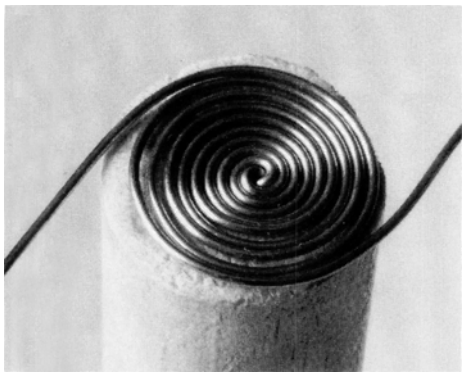


Fig. 11. Spiral 3 as a finished stamp.

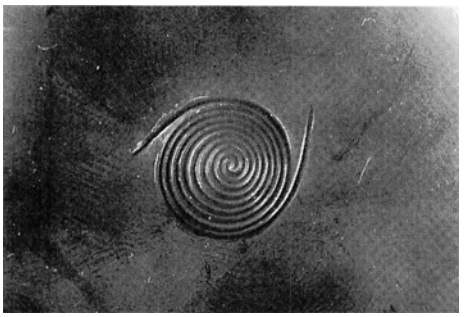


Fig. 12. Impression of Spiral 3 in wax.

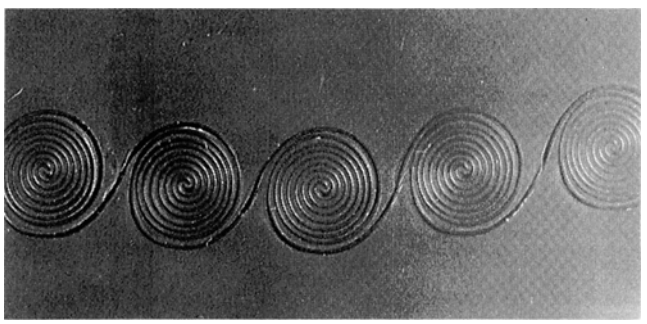


Fig. 13. The individual impressions of Spiral 3 can be assembled to form a running spiral.

could be placed together to form a long row, which could run back into itself. The centres of the spirals, however, differed from practically everything we know from the Bronze Age. The groove continued unbroken through the centre of the spiral. In the original spiral ornaments it continues unbroken only in connection with two interrupted grooves in the centre.

Spiral 3. With Spiral 2, a running spiral could be impressed in one long continuous groove, but nearly all Bronze Age spirals consist of two grooves both of which break in the centre. In order to obtain this picture, the wire had to be broken in the middle and not just bent back. Two single spirals like Spiral 1 could be placed together with the free wire turned in opposite ways. This did yield a running spiral consisting of two grooves which were not joined at the centre, but the two wires were impossible to manage, and the impression in the centre was not like the original one. Distance and angle between the grooves changed, for instance. It was therefore evident that the stamp could only have been formed from one continuous wire, although the wire had nonetheless to be broken in the middle. The only way this picture could be obtained was by not merely twisting the wire at the bend, but also making the wire disappear backwards in the centre of the spiral. Fig. 10 shows how the desired picture was obtained. First, a hole was made in a small piece of wood. Then the wire was bent double and pushed into the hole. In this way one wire becomes two and both wires disappear out of the centre of the ornament. Then both wires are laid on the wood block and wound up to form a spiral. When the spiral has attained the desired size, the ends of the wires are turned in opposite directions, and the stamp can be used (fig. 11).

The impression of Spiral 3 (fig. 12), which gradually turned into a proper stamp during the experiment, is at

the centre and in all its features exactly like the original spiral ornaments seen in fig. 2, for example.

The individual impressions of Spiral 3 can be combined in various ways. The joining grooves can be laid as a single groove midway between the two spirals (fig. 13). This gives the impression of an extremely common type of spiral. In nearly all cases in which an attempt was made to combine several impressions, one could see where the wires met. The attempts also gave a few examples of the junction occurring in such a way that it could not be distinguished with the naked eye.

If the impressions of Spiral 3 are staggered a little, as shown in fig. 14, the spirals can fit together anyway, but now with a double joining line. This spiral motif is extremely common as a running spiral in the motif repertoire of the Early Bronze Age.

In the following, both the wire spirals and the impressions formed by them will be called stamps.

THE ORIGINAL SPIRALS, TRACES OF SPIRAL STAMPS

Observations have shown that even the finest lines could have been formed in wax and reproduced by casting in the Bronze Age (Brorson-Christensen 1966). Line ornaments could be formed in wax and cast using the "lost

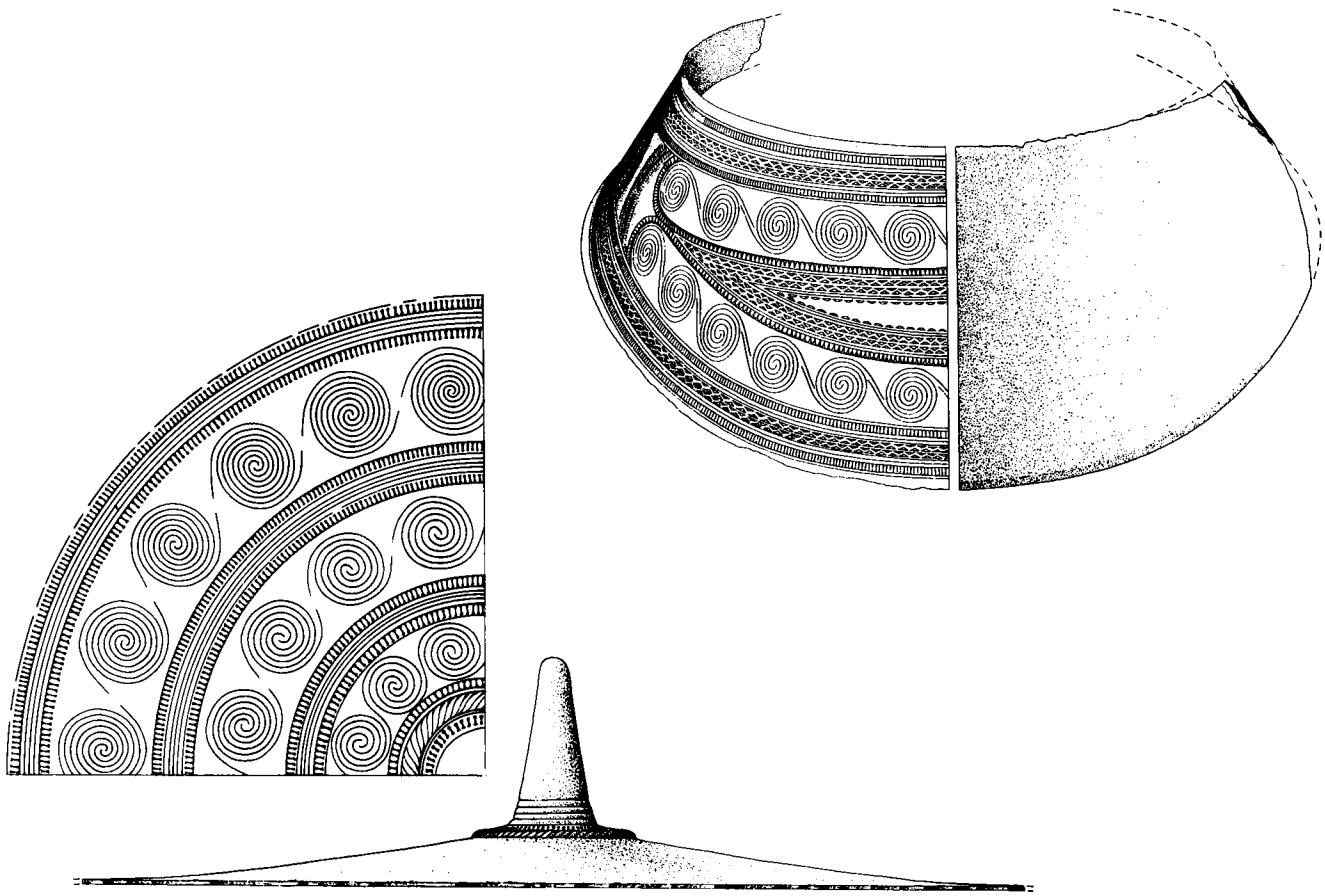


Fig. 14a-b. Impressions of Spiral 3 can be combined in various ways. The drawing shows two common types of running spiral, both of which can be made up of impressions from Spiral 3. (Both after Aner & Kersten).
a: If a row of running spirals with single joining lines is desired, the wire from the second stamp is pressed down so as to meet the groove from the foregoing stamp. The joining very often makes small marks at the junction of the two grooves.
b: If a row of running spirals with double joining grooves is desired, the wire is not pressed down into the foregoing spiral groove. It is displaced so that the wire comes to lie parallel to the groove from the foregoing stamp, and the joining grooves can run tangentially into the outermost curved groove of each spiral.

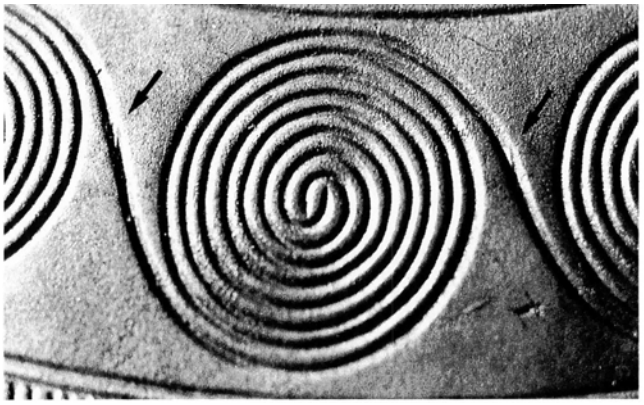


Fig. 15. Spirals from the central band of three on the large belt disc from Vognserup Enge. The junctions between the three spirals are seen in the joining grooves as very small notches. The joins are marked by arrows. The belt disc is dated to Period II. (NM B 17072).

Fig. 17. Spirals from the central band of the large belt disc from Vognserup Enge. The join can in the photograph be seen only in the joining groove to the right. (NM B 17072).

Fig. 16. Spirals from the central band on the large belt disc from Vognserup Enge. The joins are marked by arrows. (NM B 17072).

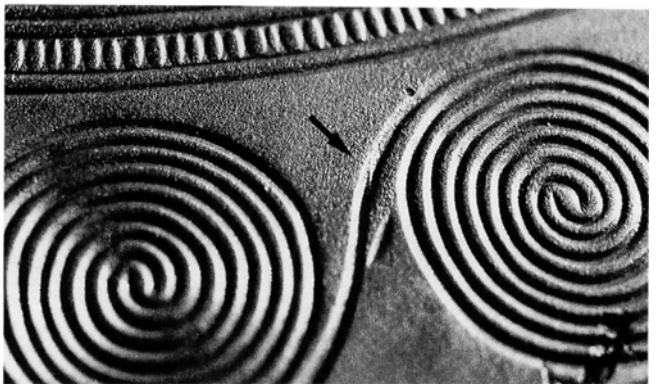


Fig. 18. Spirals from the central band on the large belt disc from Vognserup Enge. The join is distinct. (NM B 17072).

wax" method. With coiled copper wire it is possible to press or stamp the individual units of the spiral ornaments. Running spirals can be imitated in wax by placing the stamps together in rows.

It has been possible to form the spiral ornament in a wax model, and it has been possible to cast it in bronze.

That it is possible to form spirals in wax which resemble the original ones exactly is in fact itself not sufficient evidence to establish that this is how it was done in the Bronze Age. The wax plates with trial stampings showed, however, unmistakable features in the running spiral ornaments which revealed that they were composed of several individual stamps.

It is therefore natural to study the features which were characteristic of stamping in wax and compare them with the original bronzes.

Fitting together of two spirals with single joining grooves

The most difficult part of stamping spirals with single joining grooves was the fitting of the connecting groove between them. The wire from the last stamp had to be pressed down into the groove formed by the wire of the previous one. Optimally, the grooves fitted so it was hardly possible to perceive the join, but in nearly all cases the join was, in fact, distinct. It could vary somewhat, but a common feature was that if the grooves were congruent there was a more or less distinct notch in the wax of the otherwise unbroken groove. This feature was therefore looked for specially in the original bronzes, and corresponding marks found in many of the well-preserved bronzes which I investigated.

Obviously, the fitting of the stamps varied somewhat in

Fig. 19. Spirals in the outermost spiral band of the three on the large belt disc from Vognserup Enge. The joins are more difficult to see in the outermost band than in the central one. They are marked with arrows. The spirals in the two outermost bands of this belt disc are geometrically uniform. (NM B 17072).

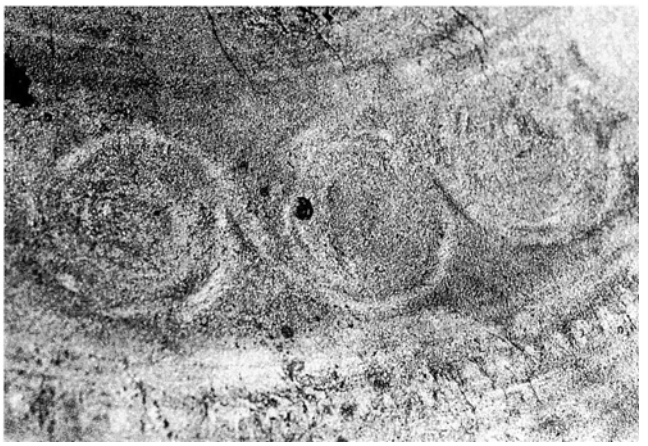


Fig. 20. The back of the large belt disc from Vognserup Enge. The pressure from the stamps has passed through the thin layer of wax and left distinct marks on the back of the model, which have been reproduced on the back of the finished bronze. The picture shows the central spiral band. (NM B 17072).

Fig. 21. On the socket of this spearhead from Valsømagle, there are four completed spiral rows with single joining grooves. In the row shown here the joins are very clearly seen. The stamps have not been fitted so carefully as in the belt disc from Vognserup. (NM B 7523).

appearance in the experiments, and this again is duplicated in the original bronzes.

The marks from joining spirals on the large belt disc from Vognserup Enge (NM B 17072, figs. 15–19) are very small, and very uniform. The joining of grooves is revealed by small "notches" or "angles". In the picture they are marked with black arrows. The fitting of stamps is distinct in nearly all the joining grooves between the spirals, but they are so fine and slender that they have to be looked for specially in order to be seen. The belt disc is from Period II of the Early Bronze Age.

On the socket of the spearhead from Valsømagle (NM B 7523), there are four rows of running spirals. One row is depicted in fig. 21. The junctions between spirals are clear in nearly all the joining lines (see also fig. 30). There can be a long or a short overlap between the grooves, or they may not even meet.

In the archaeological literature, a few spiral ornaments are illustrated in which the join between the stamps is seen, for example Oldeberg 1976 no. 3258, where the joins can be distinguished at a few places in both bands. The frontispiece in Herner 1987 is a composition in which the grooves have a long overlap.

With careful examination of joins it is in many cases

Fig. 22. The joins of the spiral stamps reveal how spirals with two lines were produced. The individual grooves have not been linked. (NM B 9530).

Fig. 23. The two grooves leaving the central spiral do not quite reach the spirals on either side. (NM B 9530).

Fig. 24. Problems in fitting the grooves. (NM B 11308).

possible to see which groove lies above the other and in this way discover in which order the stamps were made.

Only a few pieces are emphasized here, but an examination of the individual pieces has shown that traces of joining stamps are found in very many of the running spirals. Marks of the kind described here are inconceivable in punched ornaments.

Joining of spirals with double joining line

Spirals with a double join were very difficult to stamp in wax. The difficulty was that two grooves both had to run in as tangents at the same time, which means that four grooves have to be correctly placed in the same impression. It was characteristic of the stamping that one of the grooves in many cases did not quite reach the spiral it was intended to meet. In other cases the groove could overshoot the outer spiral groove and run on into the spiral.

If these features are looked for in the original bronzes, it appears that the Bronze Age bronzesmith did not always manage to get all his spirals to fit.

The smith who made the belt disc from Glæsborg, Randers county (NM B 9530), has in nearly all cases managed to get the grooves to fit on each other exactly. In a few places one of the grooves does not meet the outer groove of the next spiral (figs. 22 and 23).

In the little belt disc from Tømmerby, Hjørring county (NM B 11308), there have also been problems with the placing of the grooves (fig. 24).

The fact that grooves do not quite reach each other in the examples shown here is easy to explain, if the spirals are formed by stamping with coiled metal wires, but the lack of a join is almost inconceivable if the spirals were punched with such care that traces of the blows are invisible.

Deep joining-grooves between the spirals

When the stamp is pressed down into the wax, the spiral itself presents a large surface, while the wire making the joining groove between spirals has a small surface. The single wire is therefore more easily pressed into the wax than the spiral itself. In this way the joining line becomes deeper than the spiral in the finished bronze object. This happened in several of the experiments, and it can be observed in several originals. It can be seen, for instance, in one belt disc from Sværdborg, Præstø county (NM I B 1091, fig. 25). The conjunction of impressions is seen in the joining groove.

Had the spirals been punched, this phenomenon would be difficult to explain.

Deeper grooves in the centre of the spirals

Sometimes the grooves are deepest right in the centre. This must be due to the fact that the wires in the stamp were not bent down as soon as they emerged from the back of the spirals.

In other cases the wires can be pressed down so hard that the grooves are shallow in the centre.

Differing ornament depth

In some cases the ornaments are impressed at a varying depth. This can be seen, for example, in a gorget from Bornholm (NM 2884, fig. 26).

Weakly impressed ornaments may naturally be due to ordinary carelessness with the stamps, but there may possibly also be technical reasons. It could be that the wax was too cold and therefore too hard. There are doubtless other reasons. The composition of the wax, and the thickness and closeness of the spiral coils, are other reasons why a stamp leaves too shallow an impression.

Marks from wire coiling

The experiments revealed that when one starts to coil the wire after it has been inserted in the wooden block, it tends to rotate. It is then necessary to fix it. In a soft copper or gold wire one can imagine that the device used to hold the wire in position has left marks in it in the form of very small notches. Experiments showed that it is normally necessary to hold only one wire, rarely both of them, and only at the beginning of twisting. As soon as the coiling begins it can be finished without using anything but the fingers.

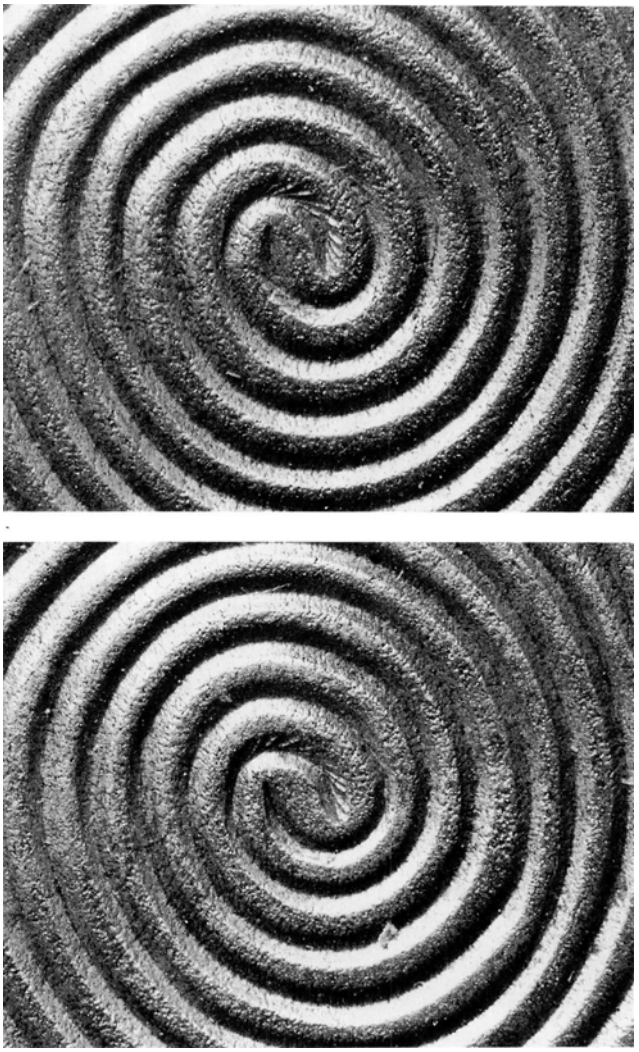
The marks to be looked for would then be in the inner millimetre at the bottom of the coils.

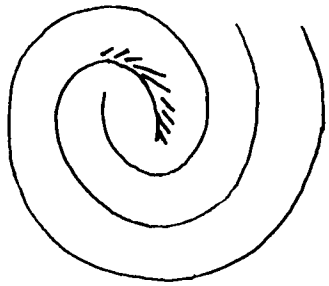
Small notches in the centre of the groove were a common observation in the centre of the spirals, often only one small one, but three or four, close in a row, is normal. There can also be several very small and very close notches. They vary in appearance, but it is characteristic that they are not found in the smoothly curved lines. They are often found on a straight part of the spiral. A straight piece like this can sometimes be seen in the innermost millimetre of the spiral centre, just before the

Fig. 25. Sometimes the groove joining two adjacent spirals is deeper than the groove in the spirals themselves. The join is also visible. (NM B 1091).

Fig. 26. The grooves may have different depths. One spiral stamp may have been pressed harder into the wax than the preceding one. (NM 2884).

Fig. 27. A feature often confused with punch marks is the small marks, "notches", sometimes seen at the centre of the spirals.





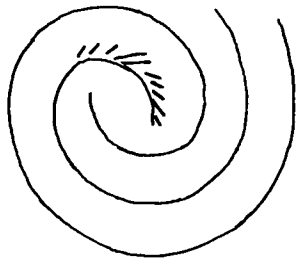


Fig. 28. The marks from the fixed wire are repeated in spirals made with the same stamp. (NM 6633).

groove embarks on a smoothly curved course.

On the spirals from the large belt disc from Vognserup, the notches are very small, hardly visible with the naked eye. They cannot be seen on all of the spirals, but this is of no consequence, because such minimal traces can be erased or slurred in innumerable ways. What is important is that when they are there, they are uniform. On the end which turns down at the centre of the spiral in figs. 16 and 17, there are some very fine notches. On the right spiral in fig. 18 there are also small notches. The marks are the same.

Stronger marks are seen in fig. 27. That the picture seems to show a small difference is due to the slightly different angle and distance of the spiral centres to the camera.

In fig. 28, several small marks are seen close in a row, but as with the others, only in the centre of the spirals (NM 6633).

Such small notches in this position have previously been interpreted as traces of punching. When they occur, they are very uniform in the same spiral band or group, and they are found practically only in the centre of the spirals. It is extremely rare to see similar marks elsewhere in the spiral grooves. The explanation must be that they are impressions of marks in a stamp. The marks must have been produced when the stamp was made.

Overlap in spiral stamps

In some spots the space left in the spiral field was too small to accommodate the number of spirals of the size selected. There are examples of the stamp's final coil being turned up, so that it filled less. The central spiral in fig. 23 contains one coil less than the others in the band. One might also choose to retain the stamp unchanged and increase the distance between two or more spirals, or press them closer together.

On the largest of the belt discs from Sværdborg, Præstø county, the bronzesmith has chosen to press the spirals closer together. In a couple of places they have come so close, however, that the stamps overlap (fig. 29, NM B 1090). It is difficult to believe that a chaser would allow several carefully punched curves to overlap in this manner. On the contrary, this "overstamping" in fact suggests stamping. The manner in which the last stamp erases the grooves in the first could be replicated in the wax experiments.

The overlaps can be interesting in that they may show in which order the smith has worked. On the spirals of the belt disc shown here the smith has stamped the spirals from right to left.

Fig. 29. Sometimes spirals overlap. (NM B 1090).

Interruptions in the running spiral wire

In rare cases, breaks are seen in the spiral groove. A very good example is seen in the spearhead from Valsømagle (fig. 30, cf. fig. 24). In the smooth, continuous spiral grooves there are short breaks, which in a couple of places contain lentiform impressions. This phenomenon can occur when there is a kink or twist in the wire, just as when one presses a piece of twisted wet rope slightly down into a soft material: if the rope is not pressed too deeply, a row of lense-shaped impressions will be formed. The impressions in the Valsømagle spearhead have been made by a wire with local twists which interrupt the otherwise smooth course of the spiral groove. They are not punch marks.

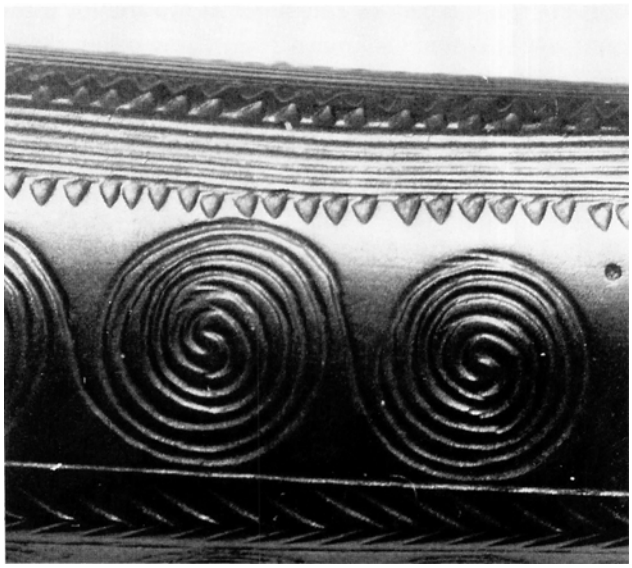


Fig. 30. Two spirals in one of the four spiral bands on the large decorated spearhead from Valsømagle. At a few spots in the groove there are interruptions. These can occur if the wire was not absolutely straight. If it has had any kinks, lentiform impressions can be formed, as seen in this groove. The smith apparently preferred to unwind the wire in order to straighten it out, since the two spirals are not geometrically alike. The centre remains unaltered, however, so that there is every likelihood that the same wire was utilized. (NM 7523).

The spiral on the Valsømagle spearhead is also interesting, because the smith has apparently attempted to fill in the breaks by unwinding the wire, straightening it out, and again winding it into a spiral. The make-up of the stamps is clearly seen in fig. 24. In the enlargement fig. 30, the wires in the joining grooves have passed each other, and the groove from the left spiral sticks down somewhat under the groove from the right spiral. The end of the right spiral groove is seen on top and adhering to the outer groove of the left spiral. This means that the left spiral was the first of the two to be stamped. It could be that the artist was dissatisfied with the many interruptions found in two of the innermost coils. He has rolled the stamp up as far as the first two millimetres of the spiral. The centres are the same and therefore unchanged. It is logical that he stopped here. It was not

necessary to continue, because there is no mistake in the centre, and the centre actually presents the greatest difficulty when the spiral is wound up. The faults have been partially repaired, but minor interruptions can still be discerned, or irregularities in the groove at the same places where the major interruptions were seen before the stamp was repaired.

Unrolling a stamp and then winding it up again can alter its geometry, but it can often be decided from the centre whether it is the same wire which has been used. It is a moot point whether it is still the same stamp.

It is interesting that the artist who decorated the Valsømagle spearhead has used the same stamp for the final spiral as for those running in the spiral row. This gives a problem with one groove which does not get a natural ending. He lets this groove end between two spirals. If the spiral row is closed, as known from many other closed spiral rows, the last spiral must have been stamped with a wire rolled up as in Spiral 1.

Stamp marks on the backs of the bronzes

On the thin bronzes it is quite common to see the spirals and their joining lines on the back (fig. 20). The impression is naturally slurred, but it does show what ornaments have been pressed into the face. The wax plates used for the experiments showed exactly similar traces, when they were of the same thickness as the original bronzes. If they were thicker, however, there were no marks from the impression. This was a phenomenon which was not manifested until late in the trials. To start with, thicker plates were used in the belief that it was easier. Just after the thin wax plate set, it was almost leather-like and could to some extent be bent and pressed. At this stage it proved to be easiest to work with. These marks on the backs of the thin bronzes have previously been identified as traces of punch marks.

OTHER WAYS OF MAKING SPIRAL ORNAMENT

There were probably other ways of producing spiral ornaments. It cannot be completely ruled out that spirals or other ornaments were punched in the Early Bronze Age. There is one spiral in Denmark, however, with possible punch marks. This is a brooch of Bornholm type from Olsker, Bornholm county (NM B 80, Ke III 1454 B). The spiral grooves are discontinuous, and here and there are marks which might derive from a chisel-like instrument. It cannot be decided, however, whether the marks were made directly in the metal or in a wax model. The latter possibility seems the most likely, because the rest of the ornament must have been formed there.

It has been demonstrated that ornament grooves were drawn or cut into the wax model in the Late Bronze Age (Knudsen 1978). I know of no proper drawn spirals; but false spirals drawn into the wax model are known, e.g. Oldeberg 1976 no. 3305.

The ornament of the Early Bronze Age is naturally more than just spiral stamps. There is very great variation in the composition of details and perhaps methods. The aim in the present paper has been restricted to those techniques which may be linked to spiral ornament.

CONCLUSION

Based on the above, it can be established that the spiral ornament of the Scandinavian Bronze Age has not been produced by punching. On the contrary, the running spirals must have been produced by repeated stamping with coiled metal wire. The spiral ornaments must have been impressed in a wax model and cast "à cire perdue". Spirals which could have been produced by another means must be regarded as the exception.

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Photographs
Where nothing else is stated, the photoes have been taken by the author.

NOTE
A grant from Carlsbergfondet has made it possible for me to study the Bronze Age decoration in detail. The material I have studied belongs to the rich collections of the National Museum of Denmark. I am grateful for the help from Carlsbergfondet and of my collegues at the Department of Prehistory.

REFERENCES

Acta. Arch.	Acta Archaeologica.
Ke	See ANER, E. & K. KERSTEN.
Medd. LUHM	Meddelanden från Lunds Universitets Historiska Museum.
Offa	Berichte und Mitteilung aus dem Schleswig-Holsteinischen Landesmuseum für Vor- und Frühgeschichte in Schleswig und dem Institut für Vor- und Frühgeschichte an der Universität Kiel.
PACT	Journal of the European Study Group on Physical, Chemical and Mathematical Techniques Applied to Archaeology.
PPS	Proceedings of the Prehistoric Society.

ANER, E. & KERSTEN, K. 1973: *Die Funde der älteren Bronzezeit des nordischen Kreises in Dänemark, Schleswig-Holstein und Niedersachsen. Bd. I. Frederiksborg und Københavns Amt.* København, Neumünster.

BROHOLM, H. C. 1944: *Danmarks Bronzealder* II. København.

BRORSON-CHRISTENSEN, B. 1966: Oldtidens tilvirkning af våben og redskaber. Bronze. In: *Jeg ser på oldsager* p. 334. Politiken, København.

BRØNDSTED, J. 1939: *Danmarks Oldtid* II, *Bronzealderen.* København.

DRESCHER, H. 1954: Ein Beitrag zur Verwendung von Messtäben und anderen Zeichenhilfsmitteln während der Bronzezeit. *Offa* Bd. 13. Neumünster.

– 1962: Neue Untersuchungen am Sonnenwagen von Trundholm und über die Gusstechnik bronzezeitlicher Tierfiguren. *Acta Arch.* Vol. 33. København.

HERNER, I. 1987: *Profession med Tradition. Teknisk-kvalitativ analys av den äldre bronsålderns spiralornamentik, dess central- och lokalproduktion.* Acta Archaeologica Lundensia. Series in 8° . Nr. 15. Lund.

JACKSON, H. 1972: *Lost Wax Bronze Casting. A photographic essay on this antique and venerable art.* New York.

JENSEN, J. 1979: *Danmarkshistorien.* Bd. 3. *Bronzealderen* 1, *Skovlandets folk.* Sesam, København.

– 1988: *Danmarks historie,* bd. 1. *I begyndelsen. Fra de ældste tider til ca. år 2000 f.Kr.* Gyldendal & Politiken, København.

JOHANSEN, Ø. 1979: Verkzeug für das Metallhandwerk der Bronzezeit? *Acta Arch.* Vol. 50. København.

KNUDSEN, S. Aa. 1978: Bronzehalsringe fra Trørød. Et offerfund fra slutningen af yngre bronzealder. *Søllerødbogen.* Historisk-topografisk selskab for Søllerød kommune. København.

LOMBORG, E. 1965: Valsømagle und die frühe Spiralornamentik. *Acta Arch.* Vol. XXXVI. København.

– 1969: Den tidlige bronzealders kronologi. Et forsøg på at fastlægge grænsen mellem perioderne I og II. *Aarbøger for nordisk Oldkyndighed og Historie* 1968. København.

LOWERY, P. R., SAVAGE, R. D. A. & WILKINS, R. L. 1971: Scriber, graver, scorer, tracer: notes on experiments in bronze-working technique. *PPS,* Cambridge.

MÜLLER, S. 1897: *Vor Oldtid.* Kjøbenhavn.

OLDEBERG, A. 1942, 1943: *Metallteknik under förhistorisk tid,* bd. I–II. Lund.

– 1974, 1976: *Die ältere Metallzeit in Schweden,* bd. I–II. Stockholm.

RINGBOM, L.-I. 1933: Entstehung und Entwicklung der Spiralornamentik. *Acta Arch.* Vol 4. København.

RØNNE, P. 1987 a: Stilvariationer i ældre bronzealder. Undersøgelser over lokalforskelle i ældre bronzealders anden periode. *Aarbøger for nordisk Oldkyndighed og Historie* 1986. København.

– 1987 b: Kronologiske problemer ved overgangen fra bronzealderens periode II til III. *Aarbøger for nordisk Oldkyndighed og Historie* 1986. København.

– 1988: Spiralens gåde. *Skalk* 6. Højbjerg.

– 1989: Nogle lokaltypiske oldsager fra Sjællands ældre bronzealder periode II. In *Regionale forhold i Nordisk Bronzealder* (J. POULSEN, ed.), 5. nordiske bronzealdersymposium, Aarhus.

SAVAGE, R. D. A., LOWERY, P. R. & SHORER, P. H. T. 1982: The technique of the decoration on a belt-plate from Vognserup Enge, Kundby sogn, Tuse herred, Zeeland. *PACT* 7 part II. Second nordic conference on the application of scientific methods in archaeology. Helsingør.

THRANE, H. 1977: Bagsiden – Et kig bag den fine facade af bronzealderens metalhåndværk. *Fynske Minder.* Odense.