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Drawing Wire

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Very few experiments have been conducted on drawing wires of iron made from bog ore. One of them, however, was carried out at the forge at Lejre Land of Legends in Denmark. The iron used for the experiments was obtained from three different sites in Denmark where well-documented experiments in the extraction of bog iron ore took place. Hardwood charcoal, a one kg blacksmith's hammer, two pliers (one with serrated jaws) and two modern hardened steel drawplates were used. The experiments demonstrated how the blacksmiths quickly developed a routine for extracting the soft, slag-containing iron. The experiments

demonstrated that it was neither difficult to wind the wire nor to cut and assemble rings, such as those used in, for example, chain mail. Viewed in an archaeological context, the most important result was the characteristic waste left behind by the process which should be identifiable in the source material.

> Using a hammer on an anvil, the purpose of the experiments was to forge thin rods of bog iron ore, pull the rods into wire though gradually smaller holes in a drawplate, bend the wire and forge rings with the same dimensions as those found in chain mail from the Iron Age of Southern Scandinavia.

Chain mail

It is well known that in the Iron Age wire was made from gold, silver, and copper – but it is a relatively new realization in Northern Europe that wire was also extracted from bog iron ore. Metallurgical insight into how rings in chain mail are made, opened up the possibility of experimental archaeological experiments to learn how the process of making wire, as well as bending and welding it, was carried out in the Iron Age.

In Scandinavia, the oldest and almost completely preserved chain mail dates to the beginning of the Late Roman Iron Age (shortly before CE 200). It is part of the weapon deposit found in Vimose on the Danish Island of Fyn[1] , and it is estimated that when new it weighed 8.031 kg and was made of 19,123 iron rings (Engelhardt, 1869; Müller, 1895, XXII, 341; Wijnhoven and Moskvin, 2020, p.9) (See Figure 1). Indeed, chain mail may have already been in use in Scandinavia half a millennium before the Vimose chain mail was crafted. During the excavation of the weapon offering find in the Hjortspring bog on the Danish Island of Als, Gustav Rosenberg from the National Museum in Copenhagen observed a 10-12 m2 area with “a light, ochre-colored layer of iron rust, in which lay numerous extremely thin and fragile rust shells of small iron rings, which undoubtedly were originally joined together as chain mail”(Rosenberg, 1937, p.47). Most rings had a diameter of 6 to 8 mm (Hansen, 2003, pp.64-65). However, the find cannot be confirmed as it was not preserved, photographed or drawn.

The rings

Iron Age chain mail is characteristic in that the rows of rings lie horizontally. This is also the case in the sleeves when the arms are outstretched. The ´pattern´ is one-dimensional, without decreases or increases and is more reminiscent of a tunic than it is of the three-dimensional chain mail of medieval times (Pind, 2012, pp.175-176; Wijnhoven, 2015, Fig. 13). Sophus Müller, director of the National Museum in Denmark from 1895 to 1921, described the chain mail from Vimose as being made of “small rings of iron, each circa one cm wide and two mm thick, chained together in such a way that each ring is linked to four others. Regarding the manufacture of the rings, he wrote the rings are either all riveted together, or rows of riveted and forged rings alternate with each other" (Müller, 1895, p.41). Müller did not mention the manufacturing processes, but rather only the size of the rings, how they were joined and how they were distributed. Only through metallurgical analysis was it revealed that the iron in the rings could have been produced from Northern European bog iron ore and that they were produced in different ways (Jouttijärvi, 1995, p.54; See Figure 2).

The rings are either solid (without signs of joining), welded (bent, overlapped and welded), riveted (bent, overlapped and joined with rivets) or bended (bent but not overlapped). Most often, a combination of solid and riveted rings occurs, frequently supplemented with individual bended rings (Burgess 1953a; 1953b; Smith, 1959; Drescher, 1981). This is quite similar to the chain mail from Brokær in Southern Jutland[2] , which dates to the older Roman Iron Age (shortly before CE 100) (Jouttijärvi, 1995, Fig. 1-3; Rasmussen, 1995, p.42). Other chain mail, such as that from Hedegård in Central Jutland[3] , consists exclusively of riveted rings (Madsen, 1999, p.85). Its rings are quite small and uniform, 5 mm in diameter, and made of wire with a diameter of only 0.9 to 1.0 mm. Currently, this chain mail weights 10.36 kg. Its rings are some of the thinnest and smallest found in chain mail from Scandinavia.

Drawing the wire

Using a hammer on an anvil, the purpose of the experiments was to forge thin rods of bog iron ore, pull the rods into wire though gradually smaller holes in a drawplate, bend the wire and forge rings with the same dimensions as those found in chain mail from the Iron Age of Southern Scandinavia[4] . With the experiment, we wanted to assess the use of charcoal and iron, how much time the process took and we also wanted to uncover some of the choices the blacksmiths were faced with in the process. And we were interested in specifying what traces their choices may have left in the archaeological record.

The work was inspired by both David Sim (1997) and Tråd av myrmalmsjärn (Wire of Bog Iron Ore) (Johansson, Benavente and Mathieu, 2007), an experiment carried out at Bäckedals Folkhögskola in Sweden under the guidance of K.G. Lindblad. In the Bäckedal experiments, a pneumatic hammer was used to forge the bloom to a dimension that could be pulled through the largest hole in the drawplate (Johansson, Benavente and Mathieu, 2007, p.1). Sim, however, used a machine power to pull the wire through the drawplate (Sim, 1997, p.367). For the Lejre experiments, the intention was to get even closer to the conditions of the Iron Age by working without pneumatic hammers and machine tools and exclusively using charcoal in the forge.

The experiments were carried out in a closed, covered forge with a stationary setup of a forge and anvil (See Figure 3). Hardwood charcoal and iron extracted from bog ore from three different sites in Denmark were used: Store Dyrehave in North Zealand and Guldforhoved and Ikast in Central Jutland[5] . It was important to use bog ore with roughly the same values of carbon and phosphorus as those in the wire in the rings of the chain mail, as bog iron ore behaves in very different ways in the forge and on the anvil than modern iron does. For instance, bog ore iron always contains slag, as the reduction process of the Iron Age did not separate iron and slag completely (Lyngstrøm, 2008, p.14) (See Figure 4).

First, a Store Dyrehave billet (48 g) was heated in the forge and divided in two on the anvil. The billet was forged from a slag-rich bloom with 0.1% carbon and 0.0% phosphorus[6] . A piece of the billet (26 g) was forged in six heats into a 13.6 cm long rod with tapered ends and a slightly rounded circumference. Several slag inclusions already worked their way to the surface of the iron during the forging, and despite the points being annealed and subsequently filed to remove the iron scale, the iron was very hard and the rod broke into several pieces during the first draw (See Figure 5). Similar issues arose in the Bäckedal experiments, as the thin dimension of the iron hardened quickly here too (Johansson, Benavente and Mathieu, 2007, p.1). Sim, who, unlike the Lejre and Bäckedal experiments, did not use a modern drawplate, but rather one he had forged himself, did not anneal the iron, and after the fifth draw the hardness in the iron wire was greater than it was in the drawplate (Sim, 1997, p.369).

With these experiences, another Store Dyrehave billet (57 g) originating from the same bloom was forged into two thin rods (12.4 and 16.1 cm in length) in five and six heats, respectively (See Figure 6.). As the smiths expected difficulty from the slag-laden iron and anticipated that hardening would occur during the draws, they decided to reduce the friction by rubbing the wire with beeswax after each annealing and filing (See Figure 7). The rods could then be drawn through three holes. The short piece broke, but both fragments were subsequently drawn through the 2.5 mm hole. The longer of the two rods was drawn to almost double its length (25.7 cm). Next, the smiths used two billets from a bloom with 0.05 carbon and 0.2% phosphorus. These had a lower slag content than that found in the Store Dyrehave iron. The billets came from bog iron ore sourced in Guldforhoved. The first billet (65 g) was forged into two thin rods of 9.1 and 10.4 cm in five heats, which were drawn through three (up to 2.5 mm) and six (up to 2.2 mm) holes in the drawplate, respectively.

The tip of the wire broke several times, but the cent piece remained intact on both pieces. It was annealed, filed, and greased between each draw. Sheep tallow was used here, as it was a more available resource than beeswax and worked satisfactorily. The smiths also switched to a pair of pliers with serrated jaws that provided a significantly better grip during drawing (See Figure 8).

The second Guldforhoved billet (approx. 300 g) was then heated in the forge, and 63 g was cut for use in the experiments. The iron appeared stable and without major slag inclusions, but the smith was nevertheless careful to cut off parts with slag (See Figure 9). In five heats, it was forged into a 25.3 cm long, thin rod that could be pulled through three holes (up to 2.0 mm) before breaking into three pieces. One of the pieces was then drawn through nine more holes (up to 1.1 mm) and reached a length of 22.9 cm. The wire seemed stable, but based on the core issue, we opted to stop drawing, even though we might have been able to continue towards the dimensions (0.2 mm) that were reached in the Bäckedal experiments.

Finally, a billet from a bloom extracted from bog ore iron from the Ikast area was placed in the forge. The bloom had a content of less than 0.1% carbon and 0.3% phosphorus. Its slag content was equivalent to the iron from Guldforhoved. The Ikast billet (737 g) was homogeneous and without visible slag inclusions (See Figure 10). A 52 g piece was cut off and divided in half, one part of which was forged into a round rod with slightly tapered ends (30 cm in length) in six heats. The rod broke and a piece 18.7 cm in length was drawn through four holes (up to 2.0 mm) to a length of 29.9 cm. The other part of the billet was forged into a rod 20.5 cm in length with a slightly rounded circumference and pointed ends. It was drawn through five holes to a diameter of 1.5 mm and a length of 31.6 cm, with the smith carefully assessing the quality before each draw (See Figure 11).

Identifying the waste and making the rings

The drawing resulted in seven long iron wires that were 15-31 cm in length with diameters between 1.1 and 3 mm and several shorter wires. A modest amount of slag (under 50 g) lay in the forge and on the floor was anvil slag of quite a few hammer scale flakes and spheroids (10 g in total), as well as several pointed ends of forged rods and short pieces of drawn wire. This is such a characteristic waste, it should be possible to identify it in the archaeological material (See Figure 12).

Without any complication, two iron wires (each nearly 30 cm in length with a diameter of 2 mm) made of iron from bog iron from Central Jutland could be wound into a spiral around a mandrel 1.7 in diameter. Likewise, the Ikast iron wire (31.6 cm in length with a diameter of 1.5 mm) and a Guldforhoved iron wire (22.9 cm in length with a diameter of 1.1 mm) were wrapped around a mandrel (See Figure 13). The spirals were cut so they overlapped slightly and were then struck together with a hammer (See Figure 14). The soft iron adhered easily without heating (See Figure 15).

Conclusion

Forging, and especially drawing, the soft, slag-bearing iron was a new process for the smiths, but once the wires were drawn, it was not difficult to wind, cut and assemble the rings. The blacksmiths also quickly developed a routine during the first part of the process, for despite the number of heats being fairly stable throughout the experiments, the individual heats – and thus the time on the anvil – became progressively shorter. Similarly, the attention to slag, greasing the wire and replacing the pliers made the drawing considerably easier and faster.

The progressively better iron used for the experiment helped to emphasize the increased skills of the blacksmiths. The experiment would probably have achieved different results had it been started with the iron with a lower slag content and ended with the iron with higher slag content. Importantly, the characteristic debris of tapered ends of forged rods and short pieces of drawn wire should be identifiable in archaeological material.

1 The chain mail from Vimose is Museum Catalogue No. NM 24219 (National Museum in Copenhagen, Denmark)

2 The chain mail from Brokær is Museum Catalogue No. ASR C 3281 (Ribe Viking Museum)

3 The chain mail from Hedegård is Museum Catalogue No. HOM 151x1954 (Horsens Museum)

4 The experiment was supported and conducted at Sagnlandet Lejre (Lands of Legends) in August 2009. It is Journal No. HAFF 04/09. Technical report and account are stored in Sagnlandet Lejre's research archive (Lyngstrøm 2009) and was previously published in summary (Lyngstrøm 2015). The experiment was carried out in constructive collaboration with blacksmiths Jokum Lind Jensen and Roar Helweg Cloud.

5 The bog ore iron was the result of experiment HAF 07/01 in 2001, in which iron was extracted from bog ore from Store Dyrehave, and experiments HAF 12/00 and HAFF 04/09 in 2000 and 2009, respectively, in which iron was extracted from bog ore from Guldforhoved. The quantity was supplemented with iron extracted by Arne Jouttijärvi before 1991 on basis of bog ore from Ikast, as we wanted to extract iron with phosphorus content similar to that in the original rings.

6 Several samples were taken from all blooms. The values for the carbon and phosphorus content are given here as a rounded average.

Keywords iron

Country Denmark

Bibliography

Burgess, E. M., 1953a. The Mail-Maker's Technique. *The Antiquaries Journal* vol. XXXIII, pp. 48-55.

Burgess, E. M., 1953b. Further Research into the Construction of Mail Garments. *The Antiquaries Journal* vol. XXXIII. pp. 193-202.

Drescher, H., 1981. *Untersuchung des Ringgeflechtes aus Sörup I, Grab K 10*. I: K. Raddatz, Sörup I. Ein Gräberfeld der Eisenzeit in Angelen (= Offa-Bücher Band 41). pp. 185-190.

Engelhardt, C., 1869. *Viemose Fundet. Sønderjyske mosefund* 2. København.

Hansen, L., 2003. *Die Panzerung der Kelten. Eine diachrone und interkulturelle Untersuchung eisenzeitliche Rüstungen.* Kiel.

Johansson, M., Benavente, R. and Mathieu, F., 2007. *Tråd av myrmalmsjärn* - på projektarbete fra Bäckedals Folkhögskola, Människa Natur Teknik, med K.G. Lindblad som vejleder. Intern rapport. Unpublished.

Jouttijärvi, A., 1995. Technische Untersuchung der kaiserzeitlichen Ringbrünne von Brokær. I: B. M. Rasmussen, Brokær – ein Reichtumszentrum der römischen Kaiserzeit in Südwestjütland. *Acta Archaeologica* 66. pp. 102-109.

Jouttijärvi, A. 1996. Fremstilling af ringbrynjer. *Early Iron*. Netværk for tidlig jernteknologi. København. 53-60.

Lyngstrøm, H., 2008. *Dansk jern - en kulturhistorisk analyse af fremstilling, fordeling og forbrug/Датское железо – исторический анализ его производства, распространения и использования*. Nordiske Fortidsminder C, nr. 5. Det Kongelige Nordiske Oldskriftselskab. København.

Lyngstrøm, H., 2009. *Ringbrynjer fra danske jernalderkulturer*. Teknisk rapport og beretning. HAFF 04/09. Sagnlandet Lejre. Intern rapport. Unpublished.

Lyngstrøm, H., 2015. Træk! *Skalk* 08/2015. pp. 12-15.

Madsen, O., 1999. Hedegård – a rich village and cemetery complex of the Early Iron Age on the Skjern River. *Journal of Danish Archaeology* 13. pp. 57-94.

Müller, S., 1895. *Ordning af Danmarks Oldsager*. II Jernalderen. København.

Pind, L. H., 2012. Ringbrynje fra Århus. *Kuml.* pp. 171-184.

Rasmussen, B. M., 1995. Brokær – ein Reichtumszentrum der römischen Kaiserzeit in Südwestjütland. *Acta Archaeologica* 66. pp. 39-109.

Rosenberg, G., 1937. *Hjortespringfundet*. Nordiske Fortidsminder 3. København.

Sim, D., 1997. Roman Chain-Mail: Experiments to Reproduce the Techniques of Manufacture. *Britannia* 28. pp. 359-371.

Smith, C. S., 1959. Methods of Making Chain Mail (14th to 18th Centuries). A Metallographic Note. *Technology and Culture* 1/1. pp. 60-67.

Wijnhoven, M. A., 2015. The Iron Tunic from Vimose (Fuen, Denmark): Further Research into the Construction of Mail Garments. *Gladius* 35. pp.77-104.

Wijnhoven, M. A. and Moskvin, A., 2020. Digital replication and reconstruction of mail armour. *Journal of Cultural Heritage* 2020.

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FIG 1. THE ALMOST COMPLETELY PRESERVED CHAIN MAIL FROM THE WEAPON DEPOSIT FOUND IN VIMOSE, FYN, DENMARK (AFTER MÜLLER 1895, XXII 341).

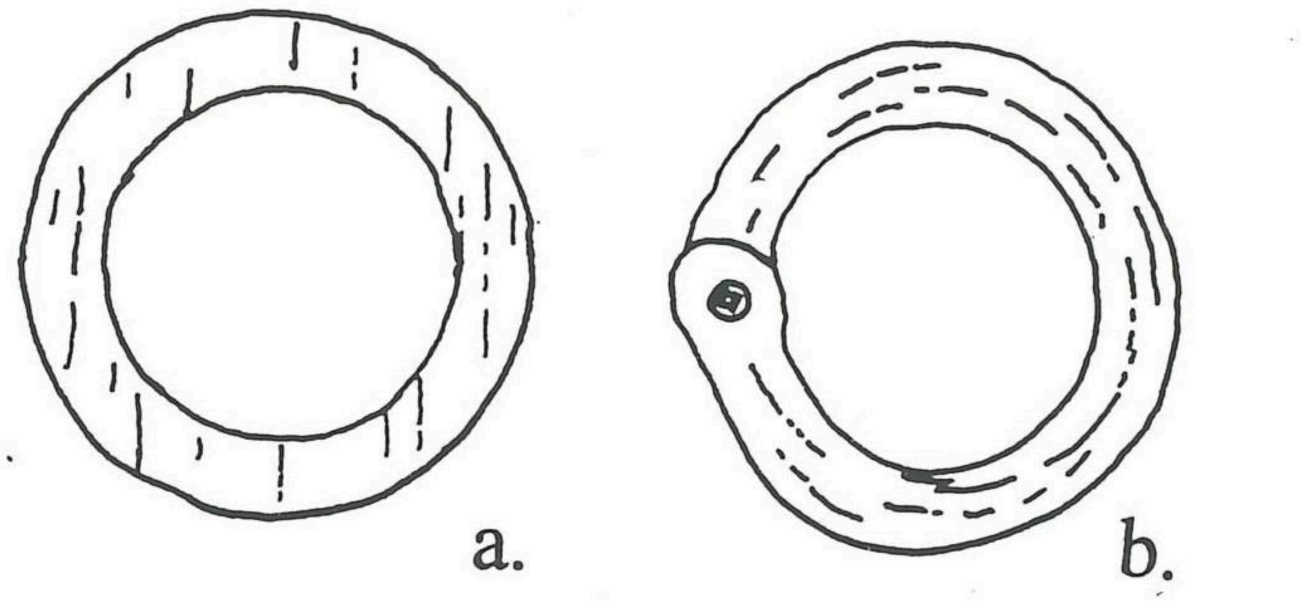

FIG 2. METALLURGICAL ANALYSIS OF A SOLID RING (A) AND A RIVETED RING (B). THE LINES INDICATE SLAG INCLUSIONS FOUND (AFTER JOUTTIJÄRVI 1996, FIG. 3).

FIG 3. THE EXPERIMENTS ON DRAWING WIRE FROM BOG ORE IRON WERE CARRIED OUT IN LEJRE, LAND OF LEGENDS, DENMARK. PHOTO BY M. NIELSEN

FIG 4. BOG ORE IRON ALWAYS CONTAINS SOME SLAG - AS VISIBLE IN THIS 11 CM LONG ROD MADE OF STORE DYREHAVE BOG ORE. PHOTO BY H. LYNGSTRØM

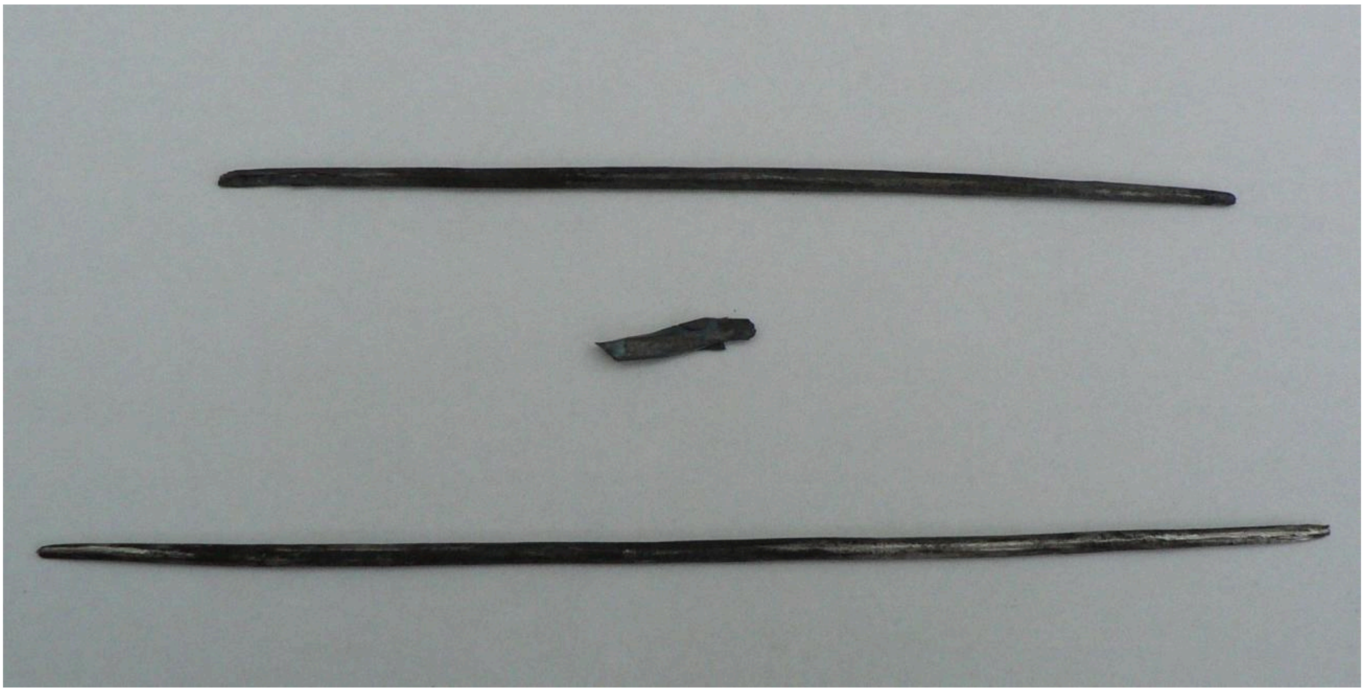

FIG 5. DESPITE THE POINTS BEING ANNEALED AND SUBSEQUENTLY FILED MANY RODS BROKE INTO SEVERAL PIECES DURING THE FIRST DRAW. PHOTO BY H. LYNGSTRØM

FIG 6. ONE OF THE RODS FROM A STORE DYREHAVE BILLET. 12.4 CM IN LENGTH. PHOTO BY H. LYNGSTRØM

FIG 7. THE SMITHS DECIDED TO REDUCE THE FRICTION BY RUBBING THE WIRE WITH BEESWAX AFTER EACH ANNEALING AND FILING. PHOTO BY H. LYNGSTRØM

FIG 8. A PAIR OF PLIERS WITH SERRATED JAWS PROVIDED A SIGNIFICANTLY BETTER GRIP DURING DRAWING. PHOTO BY H. LYNGSTRØM

FIG 9. THE IRON FROM THE GULDFORHOVED BLOOM WAS STABLE WITHOUT MAJOR SLAG INCLUSIONS, BUT THE SMITH WAS NEVERTHELESS CAREFUL TO CUT OFF PARTS WITH MINOR SLAG INCLUSIONS. PHOTO BY H. LYNGSTRØM

FIG 10. THE BILLET FROM THE IKAST BLOOM HAD A CONTENT OF LESS THAN 0.1% CARBON AND 0.3% PHOSPHORUS. PHOTO BY H. LYNGSTRØM

FIG 11. THE SMITH CAREFULLY ASSESSED THE QUALITY OF THE IRON WIRE BEFORE EACH DRAW. PHOTO BY H. LYNGSTRØM

FIG 12. SEVERAL UNFINISHED RINGS, POINTED ENDS OF FORGED RODS AND SHORT PIECES OF DRAWN WIRE WAS FOUND ON THE FLOOR. PHOTO BY H. LYNGSTRØM

FIG 13. THE WIRE WAS EASILY WRAPPED TO A SPIRAL AROUND A MANDREL. THE SMALLEST MANDREL WE WRAPPED AROUND WAS 4 MM IN DIAMETER. PHOTO BY H. LYNGSTRØM

FIG 14. THE SPIRALS WERE CUT SO THEY OVERLAPPED SLIGHTLY. PHOTO BY H. LYNGSTRØM

FIG 15. AFTER CUTTING THE RINGS WERE STRUCK TOGETHER WITH A HAMMER. THE SOFT IRON ADHERED EASILY WITHOUT HEATING. PHOTO BY H. LYNGSTRØM