THE BRITISH MUSEUM
LONDON WC1B 3DG

Mr Scott M Lankton
8065 Jackson Road
Ann Arbor
Michigan 48103
USA

19 May 1989

Dear Mr Lankton,

On my return to England I must say how much we appreciate all the skillful work you put in in making the replica of the Sutton Hoo sword. It is by any standards a remarkable piece of work and we shall of course display it in our Gallery along side the original.

It was very pleasant to meet you in Kalamazoo and I trust that we will have the opportunity of welcoming you in London so that you may see the results of your labour displayed.

With every best wish.

Yours sincerely,

David Wilson

Sir David Wilson
Director

Scott Lankton holding the nearly finished forging.

A Replica of the Sutton Hoo Sword

BY SCOTT MICHAEL LANKTON

The Ship Burial known as Sutton Hoo[1] was found near present day Woodbridge, in Suffolk, in 1939. It is considered to be one of the richest and most important archeological finds in Great Britain. Coins from the burial mound date the site at no later than 625 A.D.

The exact origin of the people who raised this mound to their leader is still in some dispute. The Anglo-Saxons believe it to be the burial of an East Anglian king, perhaps Redwald. Many parallels to the famous Saga of Beowulf[2] have been drawn. The garnet inlay gold sword fittings bear striking resemblances to work found in Scandinavia. Regardless of the exact origin of this collection of treasures, they lay for 1300 years on a hill overlooking the river Deben. Who was responsible for the Sutton Hoo Ship Burial? This is a question for historians and archeologists to debate. What did the Sutton Hoo sword blade look like when new? This is a question which shall be addressed in the remainder of this paper.

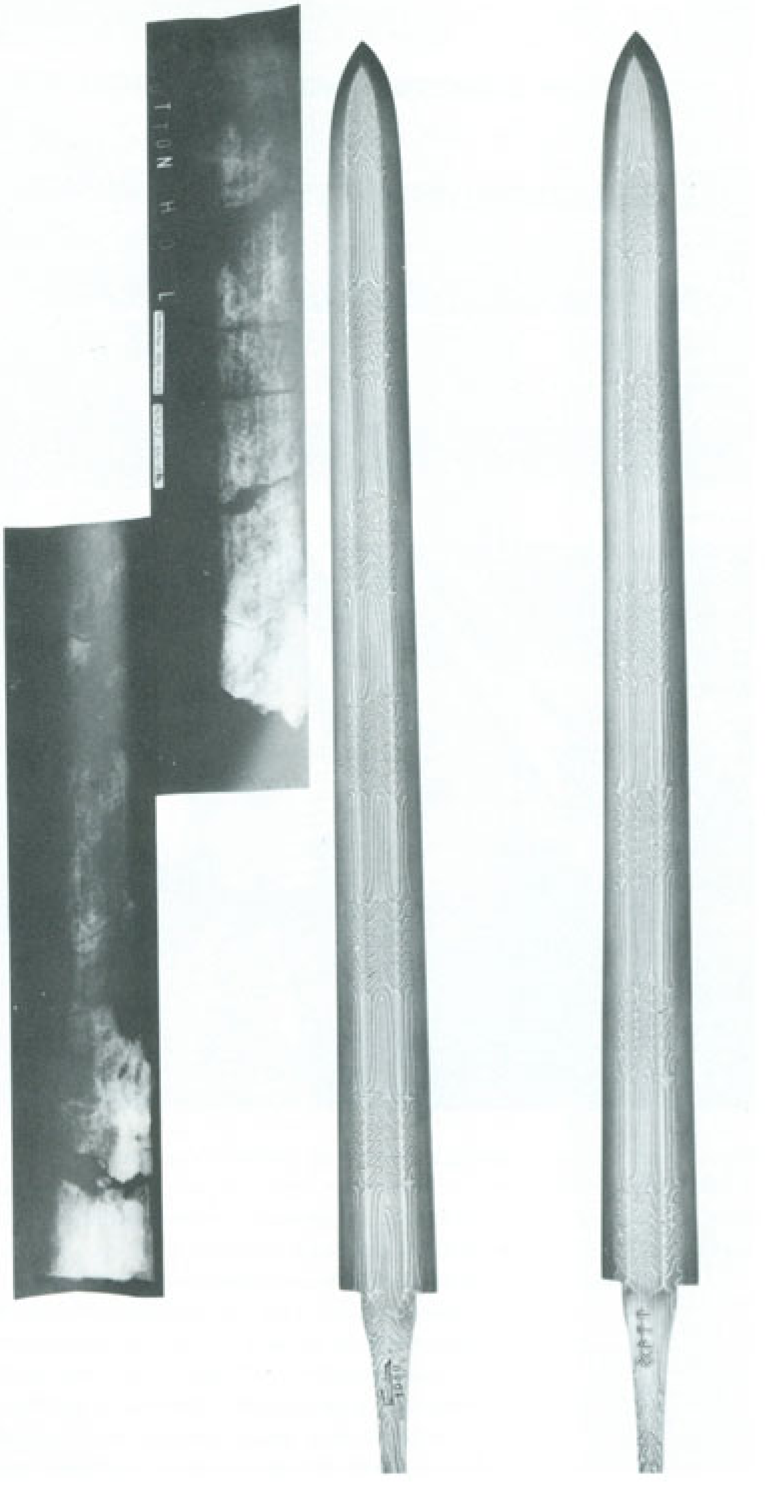
In 1939 the owner of the property on which the mounds are situated, Mrs. E. Pretty, decided to conduct a dig. As work progressed, the significance of the site became apparent, and the British Museum was called in. Mrs. Pretty donated the rich array of objects found to the museum. And they are still digging today!

This is how I came to make a modern replica of the sword blade. In 1981 I had made a Viking-style sword for Professor Robert Engstrom, my former jewelry instructor at Western Michigan University. It was given the name "Guldtand" which is Swedish for Goldtooth. In 1985 this sword was displayed at the International Congress on Medieval Studies. This Congress is hosted by Western Michigan University in Kalamazoo. A scholar from the British Museum, Leslie Webster, mentioned that the museum was interested in having the Sutton Hoo sword blade reproduced, but had been unable to find anyone [crazy enough] to do the job. Other projects from the tomb had been replicated, including the helmet, the harp, the purse and the shield. The University Museum of National Antiquities in Oslo said this of a tenth century sword from Lodingen, Norway: "Our most competent modern goldsmiths and blacksmiths have studied the pattern welding and goldsmith's work on this and numerous other swords. The result at which they arrived accord the highest honours to the masters of the past. The goldsmith's work on the sword could be copied today, but only with infinite care and a great deal of time; as for the blacksmith's work, it has been impossible to find anyone willing to attempt to copy it, to pit his ability against that of the Viking craftman."[3]

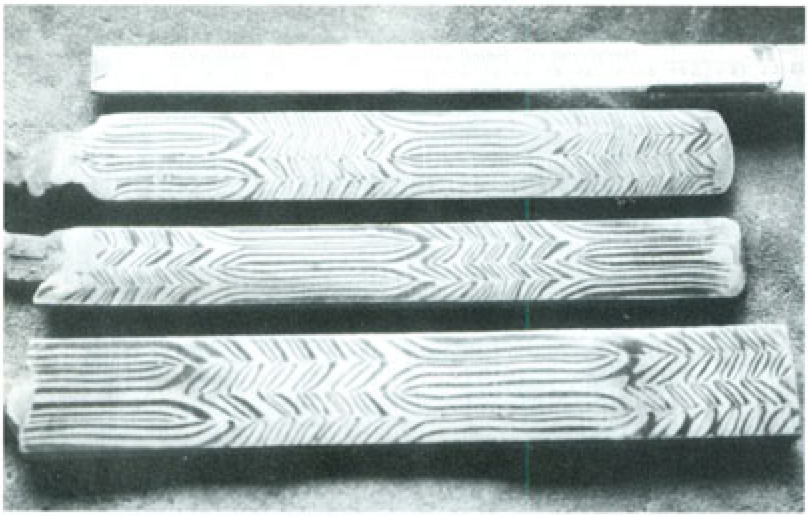
The Engstroms contacted me in Aachen, West Germany while I was studying at the International Teaching Center for Metal Design with Manfred Bredohl. After I returned to the states, and nearly four years of correspondence across the Atlantic, the project was ready to begin.

For several months I had been living with the radiographs of the original sword, supplied by the British Museum Research Laboratory. Slides, enlargements, and tracing paper were used to work out the possibilities of pattern. In the end I found myself mostly in agreement with Angela Care-Evans' interpretation.[4]

"The condition of the iron sword-blade in the Sutton Hoo burial was indifferent when found.....The blade and its scabbard had corroded into one inseparable mass, but radiography has revealed that beneath the corrosion products the iron of the blade has survived sufficiently well in restricted areas for an interpretation of its structure to be possible.....The radiographs suggest that it was built up of four bundles of seven rods twist-forged in an alternating pattern and lying back to back with four more bundles of seven rods. The bundles of rods twist alternately to right and left, forming a double band of the characteristic herringbone pattern that is one of the most distinctive features of such blades. The twisted bands alternate with straight bands along the length of the blade.....In broad terms, and remembering that any interpretation of radiographic evidence may be misleading in one way or another, the proportions of the pattern-welded blade appear to be as follows: the average length of both the twisted and straight areas is 5.3 cm, and the pattern repeats at least eleven times.....The sword-blade has been sliced in the British Museum Research Labo-



Both sides of the sword (shown with radiograph), showing juxtaposition of the interrupted twist pattern.
Photo by Weyer



Sample billets.

Eight billets before welding which will form the twisted core bars.

ratory, but the cut section contributed no additional information about the physical composition of the blade, although it confirmed the existence of a skin- or fur-lined scabbard."

Once the general pattern was determined, it was time to start making samples so that the specifics could be worked out. The seven layers of each "interrupted twist" bar could be clearly counted in the radiograph. The exact number of revolutions of each twisted section was not quite as clear but the average was four complete turns. This number ended up being the maximum amount that the bars could take without shearing. When forged to the final form each twisted and each straight section needed to be 5.3 cm long.

So, what thickness of starting layers would yield the correct thicknesses in the end? What lengths of twist and straight would eventually elongate to the proper size? And which materials should be used?

A sample cross-section taken at the British Museum Research Laboratory revealed that no metal remained that could be analyzed. The presence of phosphorus was detected which indicates the use of phosphoric ores. The only iron material available with a significant phosphorus content is wrought iron, and this was chosen as one of the metals.[5] Although many old weapons have been analyzed[6] to determine the materials used and the relative hardnesses achieved, there was no way to know the specifics of the Sutton Hoo sword because of its condition. The severe oxidation did, however, have one positive effect, namely the fact that iron and steel oxidize at different rates thus producing the clear pattern of the radiographs.

It would be foolish to suggest that the materials available in 550 A.D. could be had in 1989, or that this modern sword could look precisely like the original. Instead, the original has provided the inspiration for this modern piece. I am sure that the original smith used the best steels available to him at the time, in any case.

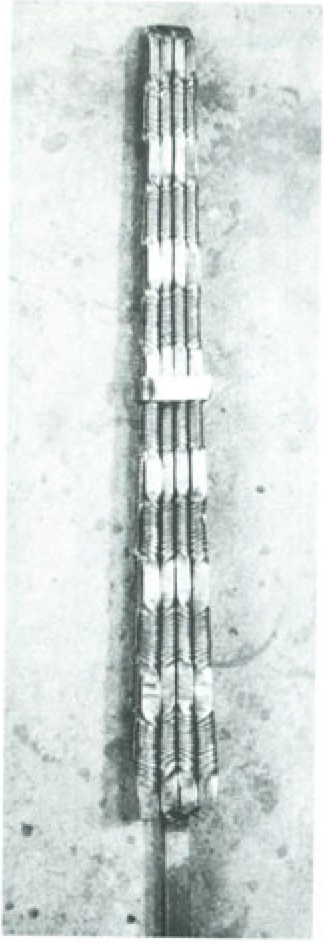
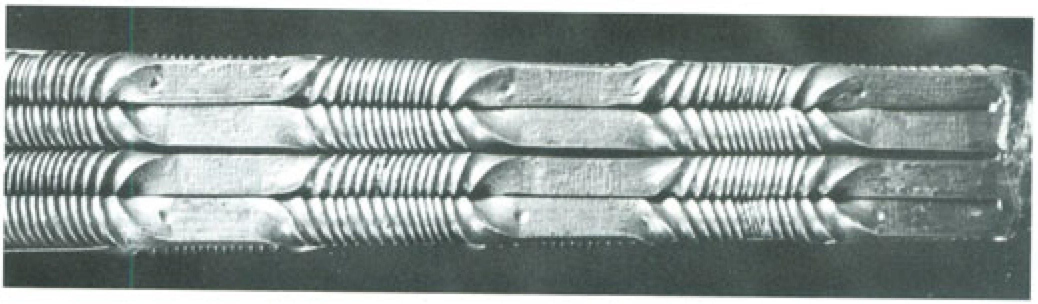
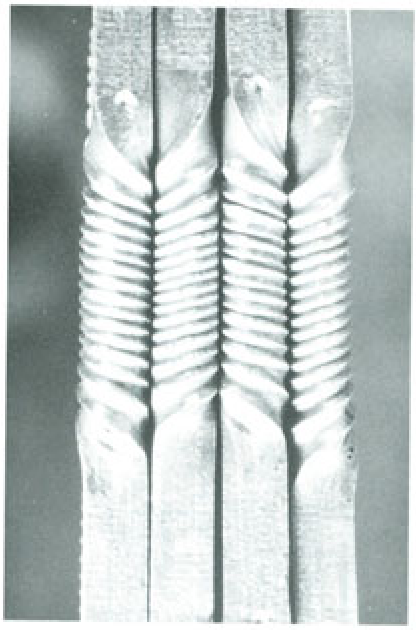
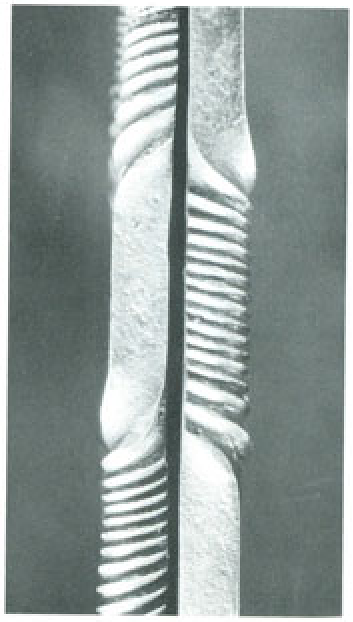
The radiographs showed that the edge consisted of a continuous laminate wrapped around the central core. These laminations could not be counted accurately. The steels chosen to make the edge were 1045 (80%) and 1018 (20%). The final edge billet had 180 layers.

For the eight billets used to construct the core two other steels were selected to be combined with the wrought iron. They were 1018 and Type L6. These were chosen for their physical characteristics and for the contrast which they provided when the finished blade was etched. (See Analysis Table).

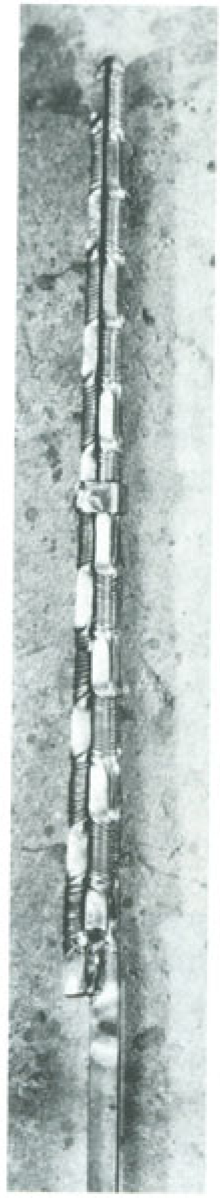
The first sample billet was prepared. The seven layers were forge-welded, drawn out, twisted, cut into eight pieces, and rewelded into a bundle. This bundle was then drawn out, polished, etched, and studied. Several of the samples were X-rayed for comparison with the original. I repeated the process seven times, adjusting the variables as I went along, and keeping close records. Finally, I had a sample that very closely matched the radiographs of the original.

The radiographs primarily show the central plane of the blade where the inner faces of the two sides of the core bundle meet. The original surface pattern of the blade was oxidized completely away, thus revealing that portion of the pattern which was protected within the center of the relic.

To make this type of "interrupted twist" pattern, one must take several things into account. One is that a twisted section of laminate will resist elongation at a substantially different rate than a straight section of the same laminate. Visually, when a person looks at an interrupted twist pattern, the eye tends to count the transition area as a

The core bundle ready for welding, note collar and details.



Side view

part of the straight section. So to make the two appear to be the same length, trial and error (lots of the latter) led me to make the twisted sections nearly twice as long as the straight sections. In the finished piece, both were very close to the same length. This was critical if the two-sided, juxtapositioned pattern was to line up like the original.

To begin the sword, ten billets of the same proportion as the last sample were made. (See Fig. 1). These were forge-welded and drawn out into slightly tapered square rods 500 mm long, 10 mm at the big end, and 6 mm at the small end. It was critical to avoid forging a parallelogram which would skew the layers and ruin the pattern. The rods were then center-punched at the intervals shown in Fig. 2. They were then divided into two groups, one group was twisted clockwise and the other counter-clockwise. The eight best rods were selected and put together as illustrated in Fig. 3. The tapered rods produced a tapered core bundle. This was important since if the sword's taper was forged later, the pattern would become uneven and distorted, especially near the tip. This bundle was arc-welded together at the ends and a handle was added. It was now slowly heated in a large coal fire, fluxed with borax and returned to the fire. When an even welding heat was drawn, the rods were hammered together. Success!

The core billet was set aside and the billets to form the edge were made as shown in Fig. 4. This 1070 mm bar was wrapped around the core billet which had its tip rounded off. It was held in place temporarily by arc welds near the hilt which would be removed later. The piece was heated, fluxed, brought up to welding heat and fused in the usual manner. After welding, and a cold drink, a spring fuller was made for the hammer to forge the depression down the center of each side simultaneously. This worked out quite well. As the edges were forged, it became obvious that this sword wasn't going to measure up. It was getting too long to match the proportion of the original and the welding flaws were unacceptable. Even though it was now scrap, the blade was forged out and ground for practice and study. Later it would prove to be valuable as a test piece for heat treating and etching.

Figure 1: Twisted billets construction.

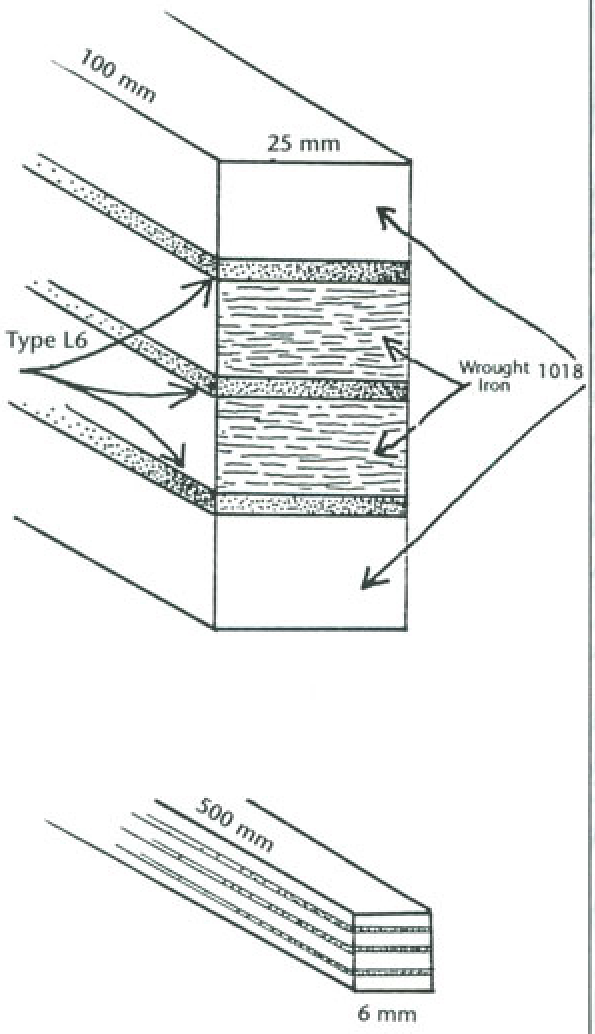


Figure 2: Core bars showing center-punched intervals.

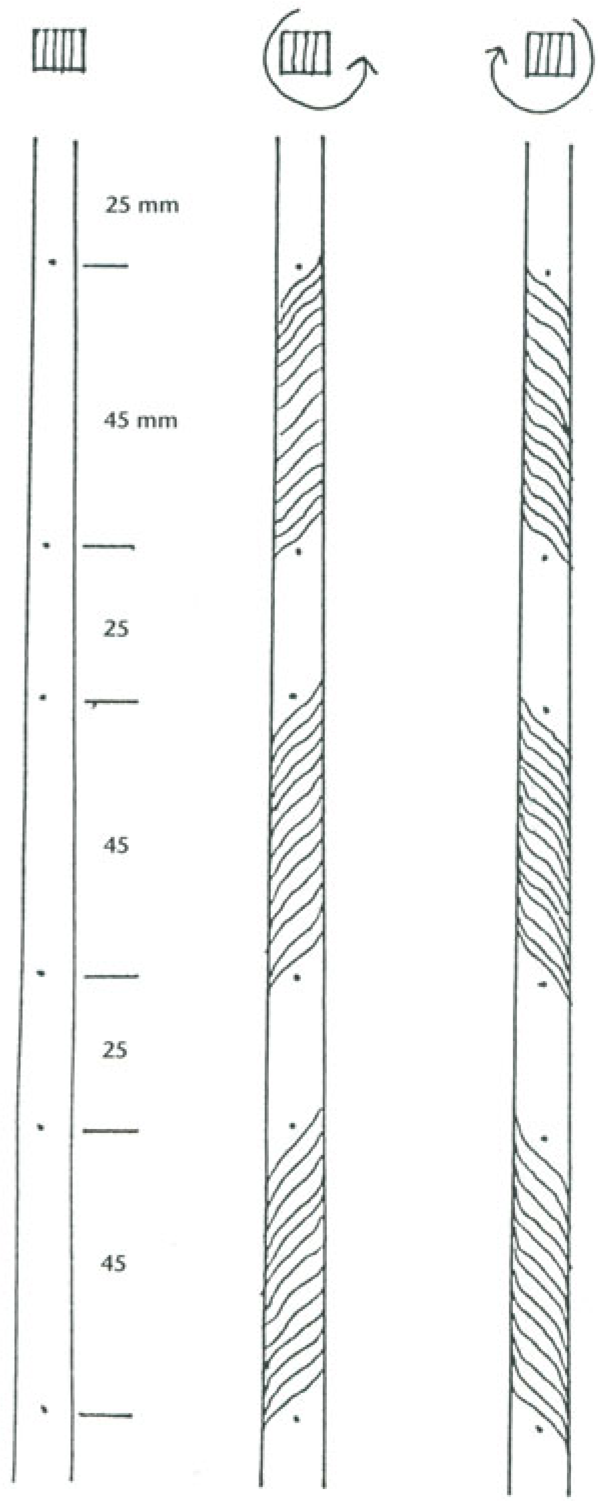


Figure 3: Eight bars combined.

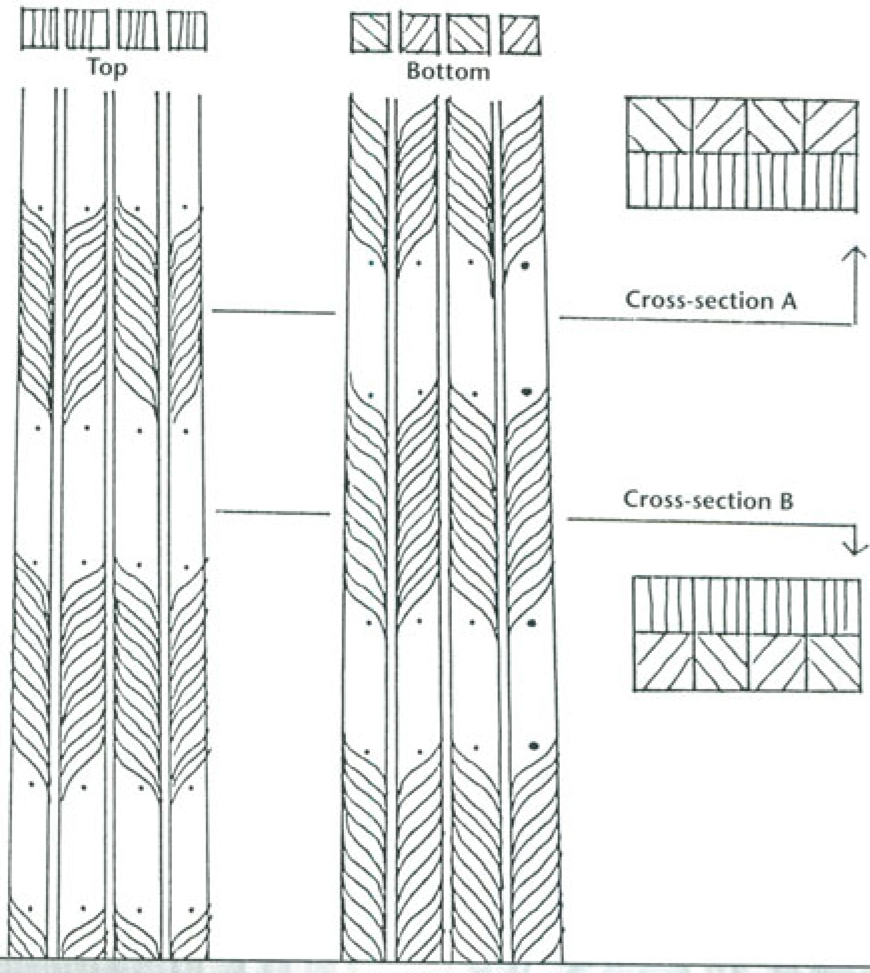
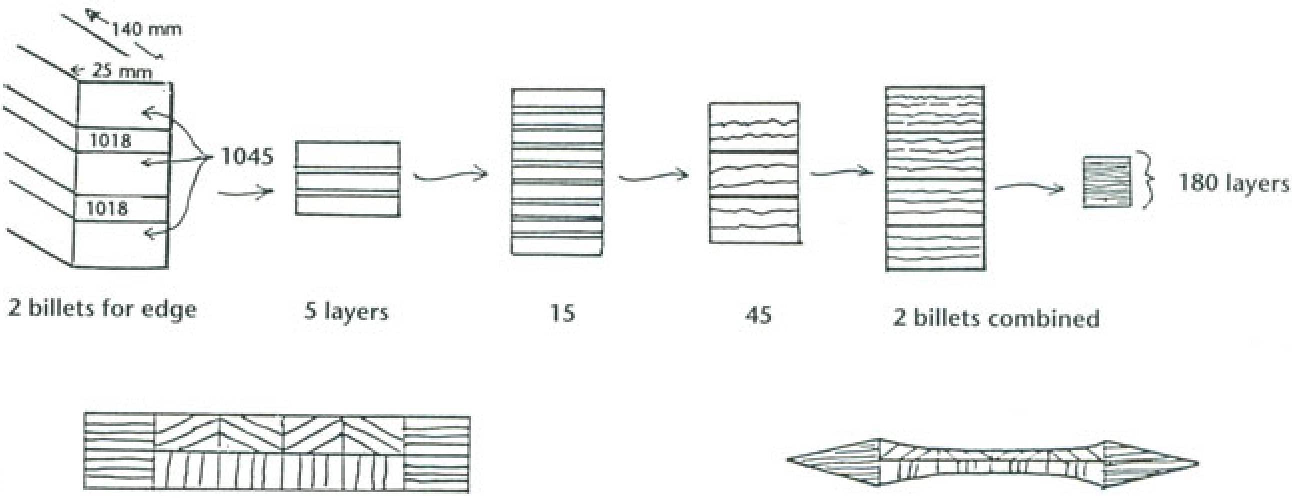
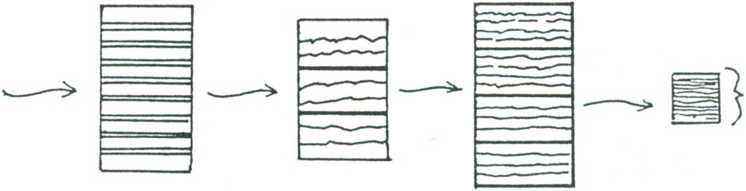


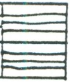
Figure 4



Cross-section of final billet.

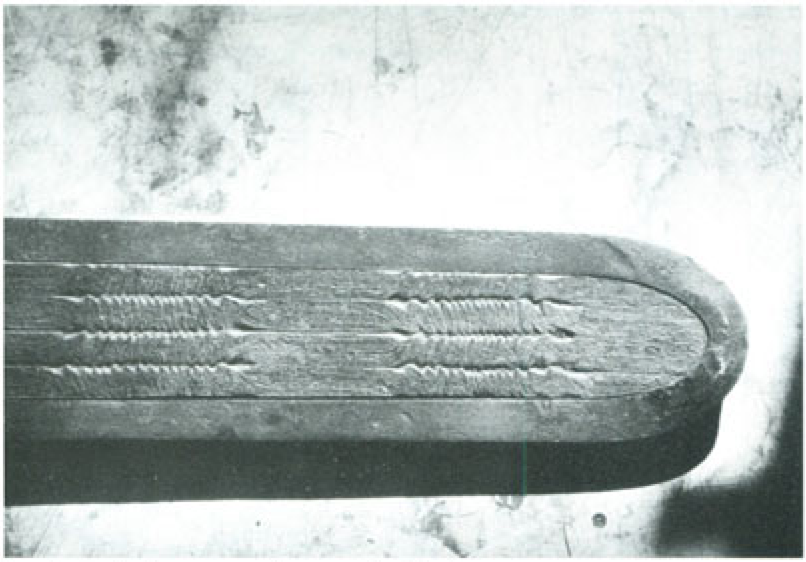
Cross-section of final sword.



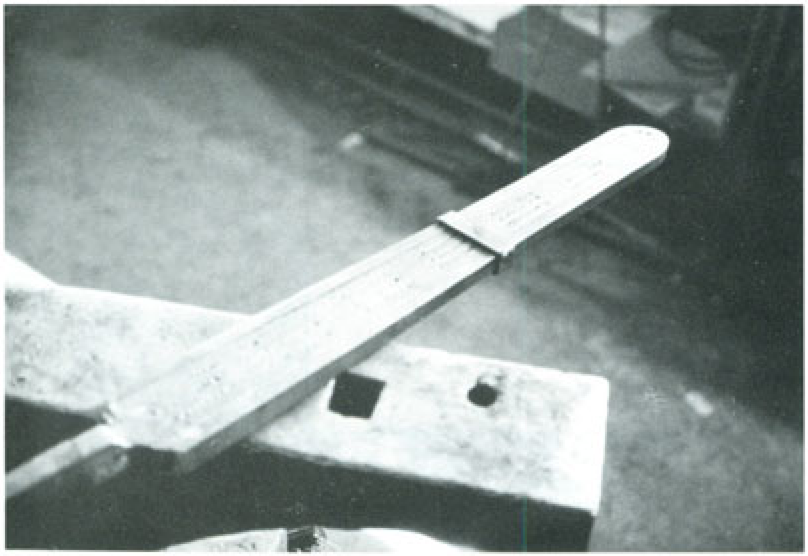


llet.

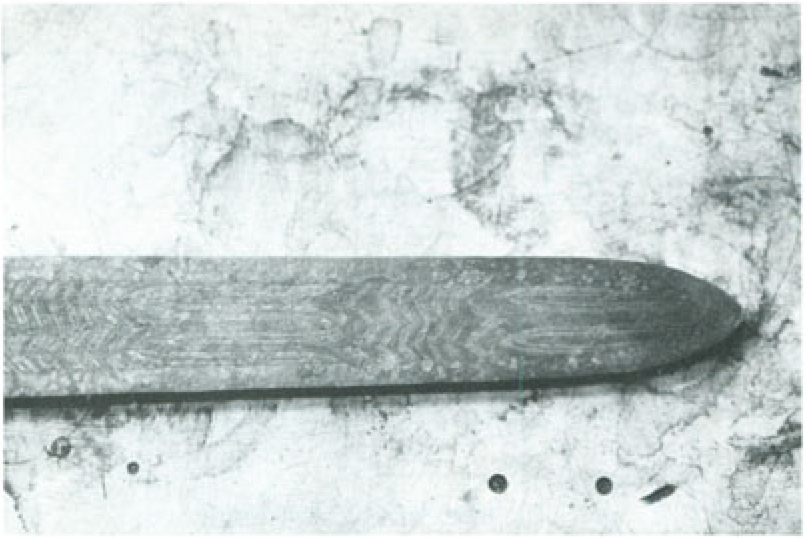
Cross-section of final sword.



Laminated edge wrapped around welded core.



Laminated edge wrapped around welded core.



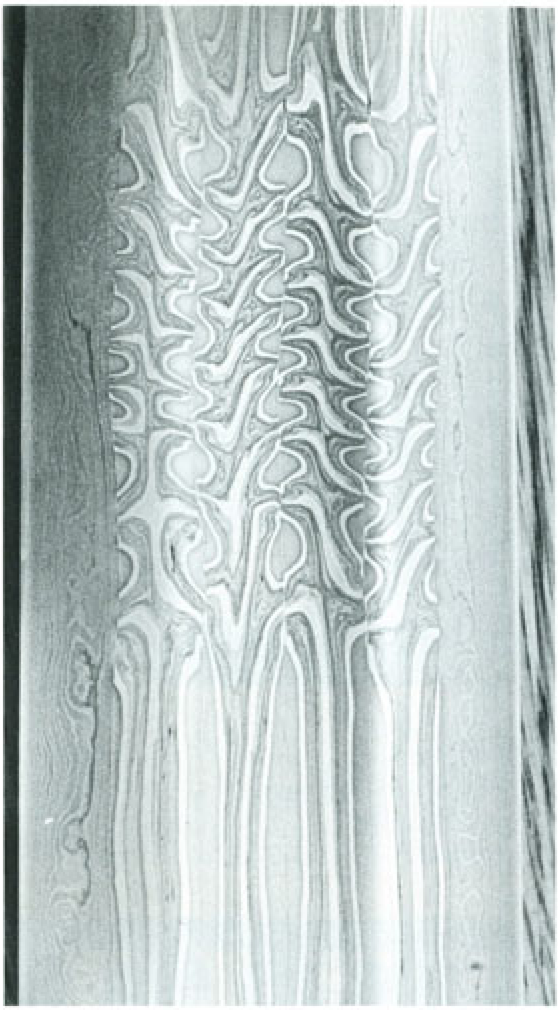
Edge welded to core.

The second time I proceeded essentially as before, only with a bit more care. I was determined not to fail again. Ten more billets were made as in Fig. 1 and given the same treatment as before. Superstition and respect for unseen powers played a part throughout the process. Interestingly enough, the day that this second core was welded into one was March 20, the Vernal Equinox, a day of balance. A collar was used this time to help hold the twisted rods together in the heat. Covered in water, I bowed to the fire, stood on this earth and drew in the air. What a life!

The forge-welding took beautifully this time. A new pair of edge billets were made as before (See Fig. 4). This time another collar was used to hold the edge to the core billet. No collars were used on the first sword attempt. This second try proved to be successful. The piece was worked into a gradually tapered blank. It began to look like a sword at last! The blade was fullered and the edges were forged out. This step alone took seven hours. It was hammered as closely to its final shape as possible, of course. Steel was a valuable commodity in the sixth century and we can be sure that the original smith wasted very little of it. My blade ended up having the same measurements as the original, except at the hilt where it was 8 mm narrower.

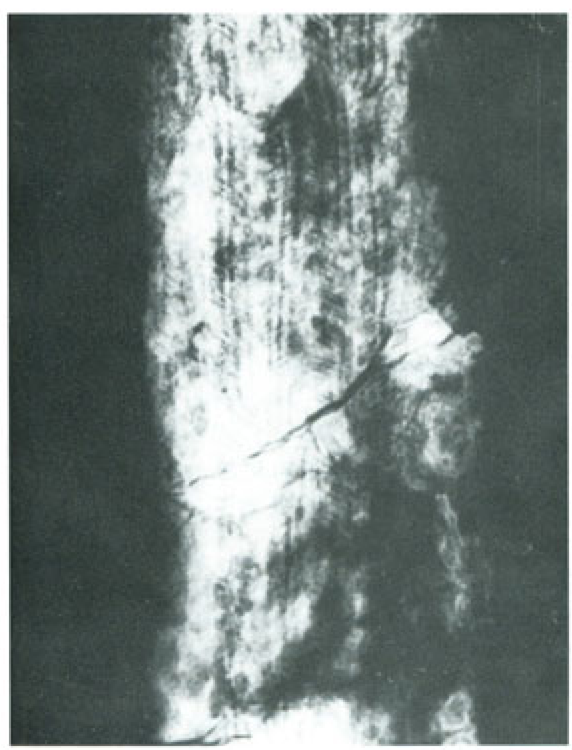
After several days of grinding, filing, stoning, and finally sanding up to 120 grit, the sword was ready for the final, critical step, hardening. A test was made on the first sword. It hardened nicely in oil. A large charcoal fire was laid. Slowly and gently the thin blade was stroked back and forth. When the color was just right, it was pulled from the fire and plunged into the oil. After the blade was tested for proper hardness with a file, it was tempered in the heated oil for an hour. It took about seven days to polish the sword up to 600 grit for etching. This was with sandpaper, and by hand. The first two etches in ferric chloride proved unsatisfactory. A test was made on the first blade using nitric acid. The result much improved. The second blade was polished one last time and immersed in a 30:1 solution of nitric for five minutes. This was what I was looking for. I was ecstatic, but what would the people at the British Museum think?

Sir David Wilson, Director of the British Museum, came to Kalamazoo in May, 1989 to give a talk on the Sutton Hoo Ship Burial. The sword was presented to him there and below is the letter that he sent to me from London the following month.



LEFT: Tip of finished sword. *Photo by Weyer*

FAR LEFT; Detail, finished blade.



Radiograph of original sword, British Museum.

19 May 1989

Dear Mr. Lankton,

On my return to England I must say how much we appreciate all the skillful work you put in in making the replica of the Sutton Hoo sword. It is by any standards a remarkable piece of work and we shall of course display it in our Gallery along side the original.

It was very pleasant to meet you in Kalamazoo and I trust that we will have the opportunity of welcoming you in London so that you may see the results of your labour displayed.

With every best wish.

Yours sincerely,

Sir David Wilson
Director
The British Museum, London

Scott Lankton presenting the sword to Sir David Wilson, Director, British Museum.

Acknowledgments:

I would like to thank Bob and Audrey Engstrom for their help throughout the project, as well as the staff of the British Museum, Dr. Michael Tite, Janet Lang, Leslie Webster, and Angela Care-Evans. Many others also provided help, support and advice which proved invaluable. A special thank you is also in order to all of those who were close to me during this project and helped me see it through to completion.

Bibliography:

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b. *The Sutton Hoo Ship Burial*: Vol. II, Arms, Armour and Regalia, 1978.

2. Robert T. Farrell, "Beowulf and the Northern Heroic Age", in *The Vikings*, London and Chichester: Phillimore, 1982.

3. Anders Hagen and Aslak Liestol, Eds., "Ancient Norwegian Design", translated by Elizabeth Seegerg, J.W. Cappeien: Oslo, 1961.

4. Rupert Bruce-Mitford, *The Sutton Hoo Ship Burial*, Vol. II, pg 307, Londong British Museum Publications, 1978.

Jaap Ypey, Rekonstruktionsversuch der Schwerklinge von Sutton Hoo, in *Archäologisches Korrespondenzblatt*, pgs 495-98, 1983.

5. **Wrought Iron**
Iron Silicate, 1.0-3.0% (by volume)
Carbon, 0.02-0.08%
Sulphur, 0.025%
Phosphorus, 0.25% or more
Manganese, 0.05%
Iron, balance

1018
Carbon, 0.15-0.20%
Manganese, 0.60-0.90%
Phosphorus, 0.04% maximum
Sulphur, 0.05% maximum
Iron, balance

1045
Carbon, 0.43-0.50%
Manganese, 0.60-0.90%
Phosphorus, 0.04% maximum
Sulphur, 0.05% maximum
Iron, balance

L6
Carbon, 0.70%
Manganese, 0.35%
Silicon, 0.25%
Chromium, 1.00%
Nikel, 1.75%
Iron, balance

from AISI typical steel analyses

6. Bernhard Salin, La civilisation Merovingienne d'après les sèpultures: *Les textes et le laboratoire, III*: Les techniques (1957), p. 311, and R. Tylecote and B. Gilmour, *Ferrous Metallography of Tools and Weapons*, BAR, 155, p. 251, 1986.

of this process, the edges were slowly and carefully forged down to keenness–a task that alone took seven hours. Controlled hammering coaxed out the life that was beginning to reveal its character. The balance of the weapon, trueness of line, and inherent beauty of proportion were brought to maturity under the patient eye of the smith (fig. 10).

So the sword had grown and reached its final shape. Now the fuller groove was finely ground, the entire sword filed and honed with stones, and then it was sanded with 100-grit paper.

Heat treating was done in the soft, reducing atmosphere of a 1550 degree F. (845 degree C.) charcoal fire, a gentle, even warming that would not harm the thin, sharp edge or tip. When the entire blade glowed red, it was drawn from its warm bed and plunged into a tube filled with oil, which had a color much like the legendary blood. The blade came out; it looked fine.

Finishing was accomplished by sanding the surface through the use of five grits from 100 to 600 of carborundum sandpaper. Etching was tried with ferric chloride ($FeCl_3$), but two attempts did not give satisfactory results. The blade was polished again. With a degree of trepidation, the craftsman subjected the surface to a solution of one part nitric acid added to thirty parts of water at 50 degrees F. (10 degrees C.). Now the vitality emerged which a Sutton Hoo sword would possess. The nitric solution attacked the various alloys in different ways and provided suitable color contrast and topography. Baking soda and water cleaned and neutralized the faces. A few polishing strokes would keep it glowing.

✣

Afterword: Why We Did It

By Robert Engstrom,
Professor Emeritus of Art, Western Michigan University

In 1961, the University Museum of National Antiquities in Oslo wrote of the tenth-century sword from Lødingen, Norway:

> Our most competent modern goldsmiths and blacksmiths have studied the patternwelding and the goldsmith's work on this and numerous other swords. The results at which they arrived accord the highest honours to the masters of the past. The goldsmith's work on the sword could be copied to-day, but only with infinite care and a great deal of time; as for the blacksmith's work, it has been impossible to find anyone willing to attempt to copy it, to pit his ability against that of the Viking craftsman.[1]

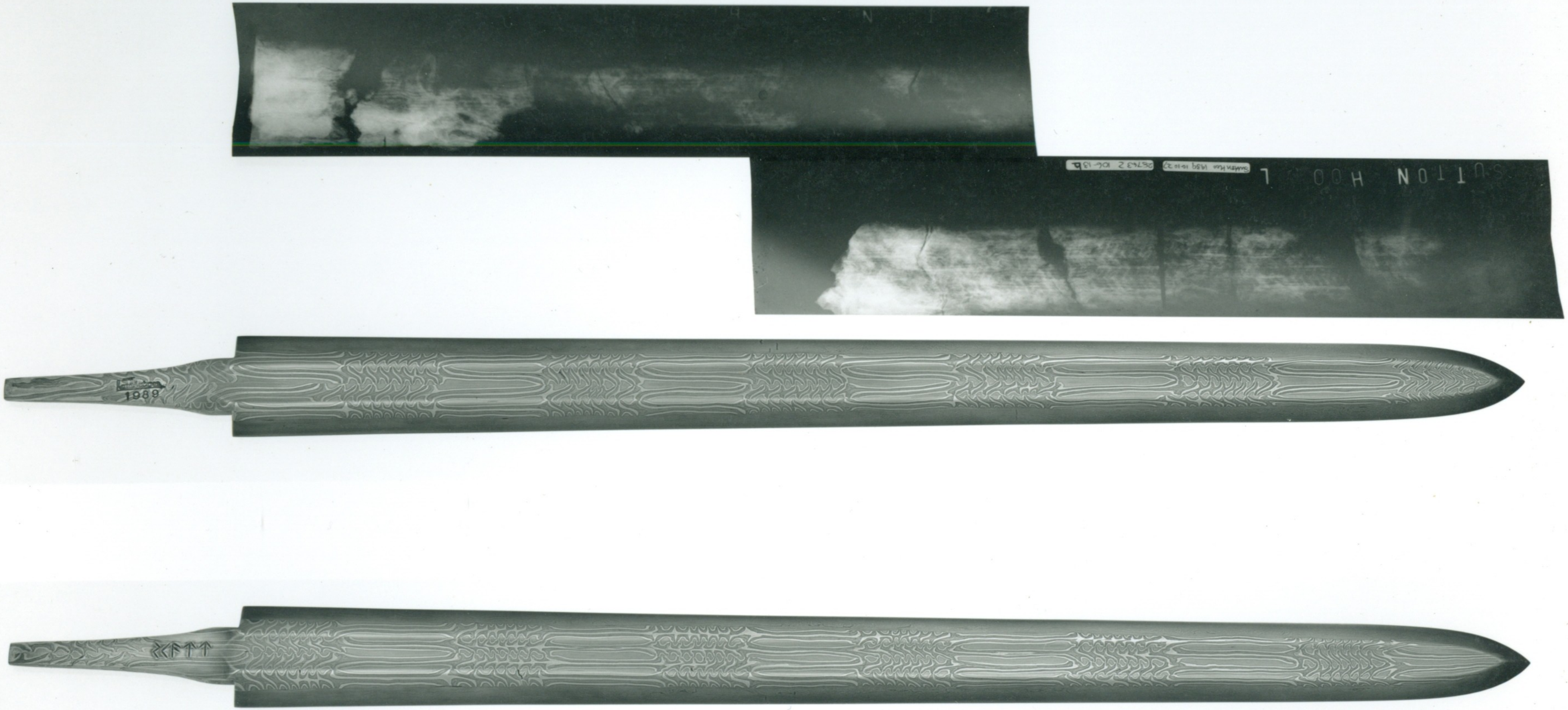
Since that time, a few modern smiths have accepted the challenge.

Our story begins with my wife Audrey's obsession, which began on our first trip to Scandinavia in 1967 and grew during the year we spent with our family in Oslo while I was on leave as jewelry professor at Western Michigan University in 1968-69. Her obsession led her to learn the necessary languages to continue her research. In 1975 the two of us combined camping with gleaning every museum and historical site to which she could lead me, and we also met many notable Scandinavian metal artists. Accumulation of data has been constant since that time. When she had difficulty finding information in nearby libraries, she started acquiring her own books, some of which were discovered through the book displays, both new and used, at the annual International Congress on Medieval Studies at Western Michigan University. It was impossible not to fall victim to her obsession. She very soon had me attending sessions at the Congress.

I was also teaching an art history class that included the vigorous work of Northern European craftsmen. Here the obsession found another willing mind, and it belonged to Scott Lankton, one of my metal students. He wanted to learn about smithing iron and joined with several others to build a small experimental forge. After earning his bachelor's degree at Western Michigan University, he purchased a rundown smithy, and, in everyday work, he learned about iron. The open challenge of the Viking sword needed an answer. Mr. Lankton and I resolved to make that blade.

It was a two-man job. I was the striker during a hot summer week in 1982 at what seemed the Armageddon while Mr. Lankton mastered the forging of a pattern-welded Viking-style blade, which we dubbed *Guldtand*. I used chisels, made and tempered long ago by a Finnish jeweler, to carve its runic name into the blade. Pure gold, hammered in, flexed itself snugly into the undercut cavities. The grip was walnut, and I fashioned fittings and pommel of cast silver with alloyed gold.

This completed sword was shown during a session of the International Congress on Medieval Studies in 1987. British scholars passed on the news of its existence to the British Museum, where it was hoped to have a replication made of the pattern-welded sword that had been excavated from the major mound at Sutton Hoo. 1989 would be the fiftieth year from its discovery in 1939.



Sutton Hoo Sword Replication
Collection of The British Museum, London


SUTTON HOO
L

CYRIL STANLEY SMITH
31 MADISON STREET
CAMBRIDGE, MASSACHUSETTS 02138

16 January 1990

Mr. Scott Lankton
c/o The Anvil's Ring

Dear Mr. Lankton

During a extremely hurried visit to London last August I had the exciting experience of seeing the rearranged Sutton Hoo material in the British Museum and was enormously impressed by your reproduction of the famous sword. It is by far the best pattern-welding I have ever seen. It was the late Herbert Maryon of the Museum laboratory who first introduced me to the term "pattern welding". The making of composite textured metals was an important bit of the pre-history of metallurgical structural science and I devoted the whole first chapter in my 1960 book, A History of Metallography -- recently reprinted as paperback by MIT Press -- to pattern welding. The book was intended as a contribution to the history of science, but it has been noticed far more by practical smiths than by learned scholars: the Artist Blacksmith Association of North America even made me an honorary member on the strength of it!

I file my copies of the Ring and if perchance you have any reprints of your article I would very much like to have one for separate use. Also, could I have a photograph or two, for example the sample billets on page 8 of your article and the two details of the finished sword, page 13, and permission to reproduce them in the next article I write on the history of metallurgy?

With congratulations on your superb work,

Sincerely,

Cyril Stanley Smith

PS: I still have a spare copy of my History of Metallography and if you are interested in the scientific side of the story I'd be glad to send it to you.