Science

Radiographie Study of Pattern Welded Swords

What follows is first an excerpt from the paper of **Janet Lang** *and Barry Ager* from 1989 [1)] that was instrumental in utilizing **X-ray techniques** for the study of pattern welded blades. Second; I mention the rather new (2016) work of *Ulrich Lehmann* who used X-ray tomography to charcterize some spatha from Westphailai, Germany

Meanwhile X-raying has become routine but the interpretation of the resulting pictures is often far from clear. So why should one do all this X-raying? Because a lot of ancient pattern welded blades do not show any signs of pattern welding on their more or less corroded surfaces; here is an example. They tend to show their inner structure in X-ray images, however,

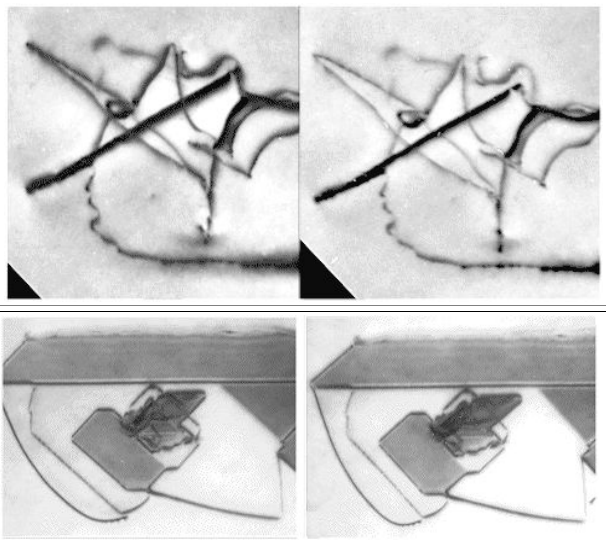
- I have said it before and I say it again: you can X-ray a twisted or straight *perfect* striped rod all you like and you will see nothing whatsoever (beside the thickness variation). The X-ray transparency of *pure* iron, carbon or phosphorous steel is simply very much the same; differences are too small to give a clear contrast. What you can see are inclusions / regions with a considerably higher or lower density than iron. Since higher densities are rather unlikely (there are only a few common elements like lead or gold that are denser than iron), you see lower density regions like enrichments of slag, flux or oxide particles and, of course, empty space like voids, corrosion pits or "missing" weld seams. You would *not* see just *one* small slag particle in an otherwise perfect iron matrix. You will see a weld seam lined with many particles, however.

  Janet Lang and Barry Ager do not explain why they see anything at all. But they do see a lot since those old swords are not made from pure homogeneous steel. I guess the question *why* they see what they see just never came up.

  So much to the first problem. The second problem concerns the reconstruction of a three-dimensional structure from a two-dimensional "shadow image". If you ever looked at an X-ray of parts of your body where you essentially see the bones (much higher density than the rest of the slime bag that's you), you know that from the picture you cannot tell if some bone is in front or behind some other one. Same thing here. A sword with a uniform steel core and two panels of twisted rods on each side looks much the same as a sword with just one twisted rod throughout.

  Janet Lang and Barry Ager solved this the problem to some extent by taking stereo X-rays, allowing to see the revealed structure three-dimensionally with the proper hardware. Some experienced microscopists (like *me*) can do it without hardware but unfortunately the stereo pictures were not published so I can't tell you how well it worked.

  Go right ahead and try if *you* can do it. It's easy. Just look with your left eye only on the picture on the left, with the right eye only on the picture on the right:



Stereo TEM picture of a dislocation tangle (top) and of stacking faults / dislocations in silicon
More stereo couples of more reasonable objects

Source: My PhD work

Here is what some of the many X-ray pictures look like. If you can make sense of that, you're a better man than I. (If you're a woman you are better already)

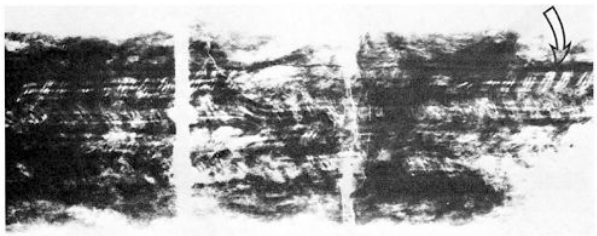


Fig. 7.4b Registration number 1939 10–10 95, 19–29. Seventh century sword from Sutton Hoo, Suffolk. This shows the two layered pattern. The area where the twist layers overlap slightly is arrowed.

Fig. 7.6a Registration number 1894 8–3 87, Later fifth–sixth century Anglo-Saxon sword from Strood, Kent, showing four coincident bands of straight and twist. Xeroradiograph by courtesy of the Royal Marsden Hospital.

It doesn't actually matter if you and I understand this kind of pictures because the authors do. So what are their results and conclusions?

- **First** of all, a lot of swords got sorted. Pattern welded or not? If pattern welded, what kind exactly. That is very valuable information but doesn't tell us anything about the metallography.
  We do get interesting statistics, however. The percentage of pattern welded swords as a function of time, for example:

Century AD	5 - 6	5 - 7	6	6 - 7	7	9-10
Percentage	44	55	77	88	100	45

  Pattern welding in England obviously peaked in the 7th century. Not so obvious is that the 8th century is missing in the table above. Why? No swords that could be dated to this century have been found so far, for reasons not entirely clear.
  We do get a bit more information about the time line, though. The table shows that in England true pattern welded blades continued to be forged by Anglo-Saxon swordsmiths into the late ninth and early tenth centuries - while on the Continent a new type of *plain steel blade* had already come into production as early as ca. 800 AD. This new form of blade appeared in England around 900 AD.
- **Second**: The new type of blades often carried simple inscriptions by embedded pattern welded "wires". We have encountered that before. The simple inscriptions appear after 800 AD and seem to lead up to the more famous "+VLFBERH+T" and "INGELRII" inscriptions found later All of that is discussed at length in the paper. Here is an example of an "S" shaped symbol:

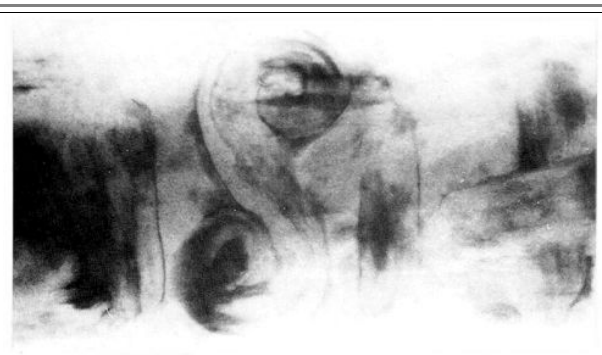


Fig. 7.7b Registration number 1848 10–21 1. Late ninth or early tenth century Anglo-Saxon sword from the R. Witham at Lincoln. This shows part of the inscription, with the S-scroll on the reverse clearly visible.

- **Third**, we get a few specific data. Swords with a uniform core and a pattern welded layer on each side are mostly from the 6th and 7th century. Of all the pattern welded blades at most about 58 % were double-sided. Some areas in England yielded higher percentages of pattern welded swords than others - in particular Kent -. and that might be due to the proximity to the continent (where the pattern welding experts lived) and to the relative prosperity of that region.
- **Fourth** we learn something about saxes or seaxes. They first appeared in the sixth century as an undecorated blade, but apparently did not come into common use until the ninth-tenth centuries. Then about half had pattern welded or otherwise decorated parts.
- **Fifth**, the authors discuss the purpose of pattern welding. Their conclusion is that: "On balance it seems most likely that pattern-welding was largely decorational. It is quite possible that pattern-welding was thought to improve the properties of the swords, and it might be remembered that a smith with the skill to produce fine pattern-welding might be likely to produce a good quality sword anyway."
- **Sixth** and finally, the origin of pattern welded swords is discussed. The authors conclude that there is strong evidence that there was some kind of sword-making industry in England but that the techniques used were not as sophisticated as on the continent. Some swords were likely imported.

There is much more in this paper (read it yourself) but since we learn not much about the metallography, I will stop here.

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1) **Janet Lang** and **Barry Ager**: "Swords of the Anglo-Saxon and Viking Periods In the British Museum: A Radiographie Study"; in: "Weapons and Warfare in Anglo-Saxon England", edited by Sonia Chadwick Hawke, Oxford University Committee for Archaeology, Monograph No. 21 (1989), chapter 7, p. 85 - 122