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Summary

A pattern-welded sword, dating to the 5th - early 7th centuries AD, was examined by radiography. Both cutting edges and core were made from multiple pieces of metal of different compositions welded together. The wiggly snake pattern has not previously been recognised on Anglo-Saxon pattern-welded swords. Two continental parallels are both later in date, and their patterns are coarser.

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WEST HESLERTON

A SNAKE PATTERNED SWORD BLADE

This sword was found complete with the mineralised remains of its scabbard and a simple copper alloy pommel still in place. The blade was very heavily corroded and although clearly in poor condition preliminary examination indicated that under the encrusted remains of the scabbard there was at least some iron surviving along most of its length. Allowing for the scabbard remains the length of the sword was approximately 90cm by 5cm wide and the blade appeard to be parallel sided along most of its length. In sectional profile the blade would appear to be flattened or very slightly convex in form. It is difficult to date closely on stylistic grounds but its burial context and overall form would suggest a date somewhere between the fifth and early seventh century.

Radiography showed the blade to be pattern-welded along its central part although the detail was not clear enough for reproduction in this report. The type of pattern was very unusual and took the form of a snake running down the centre of the blade. The pattern seems to have been the same on either side of the blade although from radiography it would seem that on one side much of the pattern has been lost to corrosion.

This wiggly snake pattern, reconstructed here in diagrammatic form (fig.1), has not been seen among the many pattern-welded swords of the Anglo-Saxon period so far identified in this country and appears to be the earliest yet identified anywhere. Two examples of snake patterns on swords from mainland Europe have been illustrated, one from Vehmaa on the west coast of Finland (Leppäaho 1964, 69, Taf 32) and another from Nijmegen in Holland (Ypey 1982, 386, Abb 15) although these are both later and date to between the ninth and eleventh centuries. In both these later examples the snake pattern is much coarser and appears on one side of the sword only, in each case with a variant of the much more common herringbone type of pattern on the other side of the blade.

Two wedge-shaped transverse sections extending approximately half way across the width were cut from the upper part of the blade. One section (fig.3) was cut aprox 10cm down from the hilt on one side whereas the second (fig.4) came from near the centre of the other side. These were taken from either side of the blade to allow an overall composite transverse view to be achieved. Metallographic examination showed the blade to be constructed from five main parts hammer-welded together. The two cutting edges had been welded on to either side of a three-part central piece. This central piece consisted of two surface pieces which would have given rise to the snake pattern on the surface after suitable polishing and etching, and a plain core piece on either side of which the snake pattern pieces had been welded. Both the cutting edges and the snake pattern pieces were also found to be made of several parts (fig.2).

Unetched a scattering of mostly small slag inclusions could be seen across both sections. These showed up as both two-phase, medium and darker grey, inclusions probably of fayalite (iron silicate) in a glassy matrix and three-phase inclusions in which a pale grey phase, probably wüstite (iron oxide) was also visible. Some large, mainly three-phase, slag inclusions were congregated along the positions of welds where they had become entrapped during the hammer-welding together of the different parts of the blade.

The structure of the blade became clearer after etching the mounted sections with nital, 2% nitric acid in alcohol (figs.3i and 4i). Each of the cutting edges had originally consisted of a sandwich of three parts, a piece of medium to high carbon steel welded between two pieces of low carbon iron. In one section each of these three parts (a, b, and c in fig.3ii) had partly survived whereas in the other section only the central steel part (d in fig.4ii) and a small fragment of one outer low carbon iron part (e) remained of the cutting edge.

In both cases the steel central parts of the welded-on cutting edges showed a quenched structure although one which was bainitic rather than martensitic. The steel cutting edge of one section (fig.3i) appeared to show a less completely quenched structure with some free ferrite (alpha iron) showing in a very variable grain structure (ASTM 1-7) largest towards the weld boundaries with the outer pieces (b) and (c) where the carbide gave a rather feathery bainitic or pearlitic appearance, which was difficult to resolve optically. Vickers micro-hardness values of 281 HV 0.1 near the fine grained centre, and 294 HV 0.1 towards the weld boundary were obtained for this piece. The structure would suggest a carbon content of about 0.5% for this piece.

The steel central cutting edge part (d) of the other section, which came from near the centre of the sword, showed a more completely quenched structure. Virtually no free ferrite was visible in a fairly uniform feathery bainitic structure which gave micro-harndess values between 424 and 488 HV 0.1.

It seems probable that the steel in both edges is more or less the same (a medium carbon steel wtih apprximately 0.5% carbon) an that the different appearance is the result of ineffective quenching near the hilt of the sword. The bainitic structure would suggest that this sword blade has been slow or slack quenched in a liquid, such as oil, with a lower thermal capacity than water which would tend to produce a faster quenched, and harder, martensitic structure in a medium carbon steel such as this.

The cutting edge pieces between which the steel was welded consisted of a low carbon iron with (originally) no more than about 0.1% carbon although there was a fairly diffuse zone near the weld marking the diffusion across the weld of some of the carbon from the steel centre of the cutting edge sandwich. A fairly typical micro-hardness value of 158 HV 0.1 was obtained from one (b) of these low carbon iron edge pieces.

The main welds between the cutting edges, pattern-welded surface pieces and the plain central core in between were also marked by narrow white lines which were highlighted in places by thin grey pearlitic lines (figs.3 and 4). Examination by electron probe micro-analysis (EPMA) showed these white lines to be locally enriched in arsenic and cobalt, an enrichment effect caused by oxidation of the surface of the iron during welding. The pearlitic lines along the welds bear no relation to the pearlitic content of the metal and appear to indicate the use of a carbon based flux to counter the deleterious effects of oxidation during welding.

On both sections the plain central core piece (f) of the blade was clearly visible (figs.3 and 4). This piece consisted of iron, in this case a very variable medium to large grain (ASTM 2-6) ferrite with some streaks of pearlite visible in places (fig.4i) and gave micro-hardness values of 176 and 180 HV 0.1. These values are rather high for what appear to be a plain iron piece but the increased hardness (plain iron usually gives a micro-hardness value of about 100-120 HV) and the occasional pearlitic streaks are indicative of a slight enrichment by phosphorus (possibly up to about 0.2%) for this plain central core piece (f). EPMA analysis showed the phosphorus content to be rather variable rising to approximately 0.5% where the ferrite grain size was at its largest.

The folded appearance of the snake pattern surface strips is clearer on one section (fig.4) than the other and shows that the snake pattern has been achieved by using a twisting process. The alternating darker and paler banding also shows that each of these surface pieces was itself made of three main parts (g-j in fig.3ii and k-m in fig.4ii). The pale bands consisted of very large grain ferrite (ASTM1) with Neumann banding (dislocation lines) visible showing that some forging work on the blade was carried out when the temperature of the blade had fallen below the normal forging temperature range of about 950-1050°C.

Micro-hardness values ranging between 245 and 309 HV 0.1 were obtained for these pieces. These greatly increased hardness values over those expected of a plain iron together with the very large grain size of these bands is suggestive of a fairly high phosphorus content, probably within the range 0.5-0.8%, for these parts.

By contrast the grey bands in these snake pattern pieces consisted of a low carbon iron which appeared as a fine grain (ASTM8) ferrite and pearlite with a carbon content of little more than approximately 0.1%. Micro-hardness values in the range of 220 to 236 HV 0.1 were obtained for these bands, rather higher than expected (approximately 120-180 HV) although the reason for this is not clear and may indicate the presence of a small amount of another alloying element apart from phosphorus.

These rather complex-seeming surface pieces appear to have been made by first of all welding a bar of low carbon iron along its length to a similar sized bar of high phosphorus iron. Next, this new bar was either forged out longer then folded in the middle and forged together so that the low carbon iron was in the middle of the resulting sandwich; or the new bar was cut in the middle and the two pieces forged together to give the same effect.

A separate bar was probably prepared by welding together a much smaller bar of high phosphorus iron to a bar of low carbon iron. A similar piling process to that described above would appear to have been followed although in this case it seems to have been repeated to give a laminated bar (B) predominantly consisting of low carbon iron but with several alternating thin bands of high phosphorus iron within it.

A new laminated bar (C) would then appear to have been prepared by taking a sandwich bar of type (A) and along its length welding it between two rather thinner bars of type (B). These bars would have been welded together in such a way that the laminations all lay along the same two sides of the resulting bar (C).

The central part of this new bar (formerly bar A) is the part that resulted in the snake pattern. This snake pattern was achieved by twisting then counter twisting the laminated bar (C) alternately by approximately 45°, each twist and counter twist resulting in one curve in the pattern. Final polishing and etching of the blade would have revealed the snake pattern. The even character of the snake pattern also suggests that an intermediate flattening hammer was used in the final forging out of the blade.

The later snake pattern sword blade from Nijmegen may have been made by much the same twisting and counter twisting process although this is not certain from the illustration whereas the snake on the pattern-welded blade from Vehmaa seems certain to have been given its distinctive profile by a corrugating process, the snake then forming an inlay, with the 'valleys' of the corrugations of the snake pattern being filled with short lengths of the more familiar twisted pattern welded pieces. This is a quite diffrent process to that used for the West Heslerton sword and possibly the Nijmegen blade as well. However the coarser snake patterns on both these later swords are perhaps more likely to have been made using an inlay technique.

There are several references to snake patterns on sword blades from early Norse literature (discussed in Davidson 1962) the clearest of which comes from Thidricks Saga in which the sword Ekkisax is described as follows:

> 'The blade is well polished and marked with gold and if you set the point down on the earth, it seems as if a snake runs from the point and up to the hilt, gleaming like gold. But if instead you hold it upwards, then it seems as if the same snake runs from the hilt and up the point, and it moves as if alive' (Davidson 1962, 166).

Davidson equates this and other more obscure allusions to snake patterns to the more familiar herringbone form of weld pattern (Davidson 1962, 166) although the snake pattern on the West Heslerton sword shows that the description of the sword Ekkisax is actually quite a good description of one rare type of pattern-welded sword.

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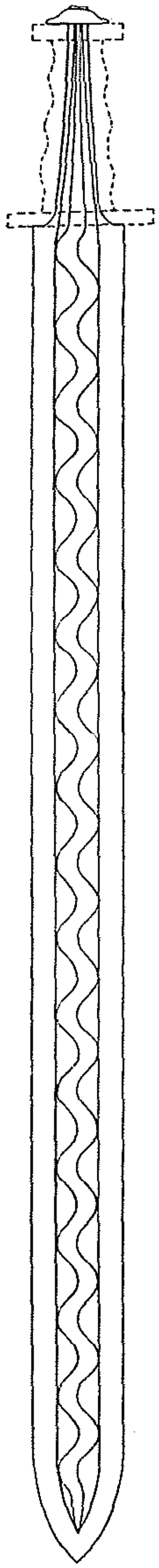

Fig 1 Simplified reconstruction of the complete blade with the snake pattern

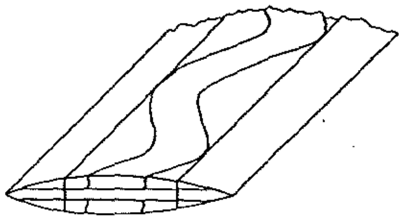

Fig 2i Three-dimensional view to show the main parts of the blade.

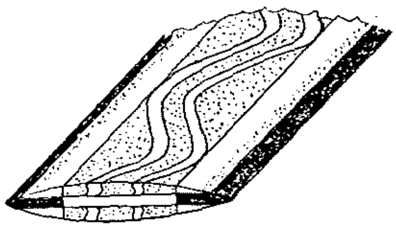

Fig 2ii Three-dimensional view to give an impression of the effect of final polishing and etching .

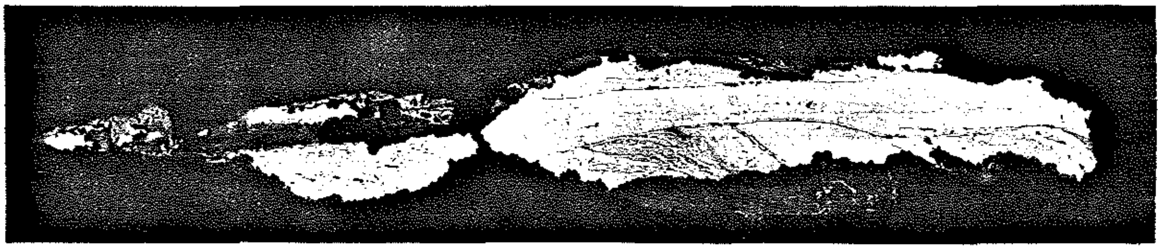

Fig 3i Photomacrograph of section from near hilt.

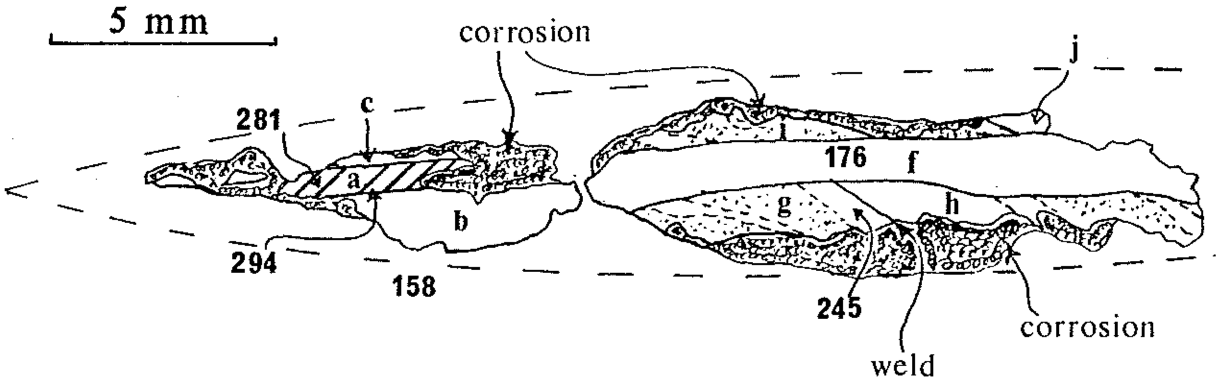

Fig 3ii Sketch of same section showing main components and vickers micro-hardness values.

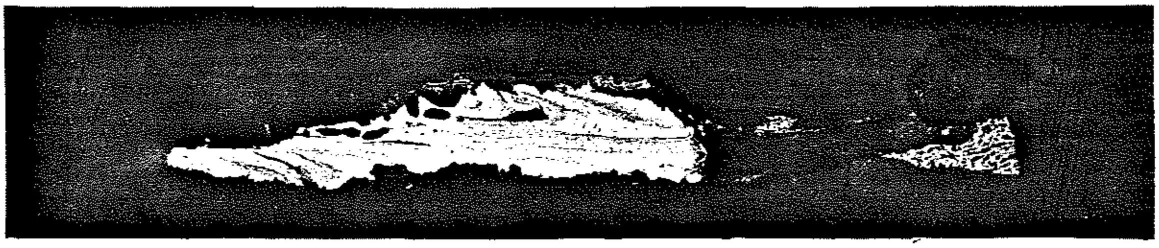

Fig 4i Photomacrograph of section from near centre of blade.

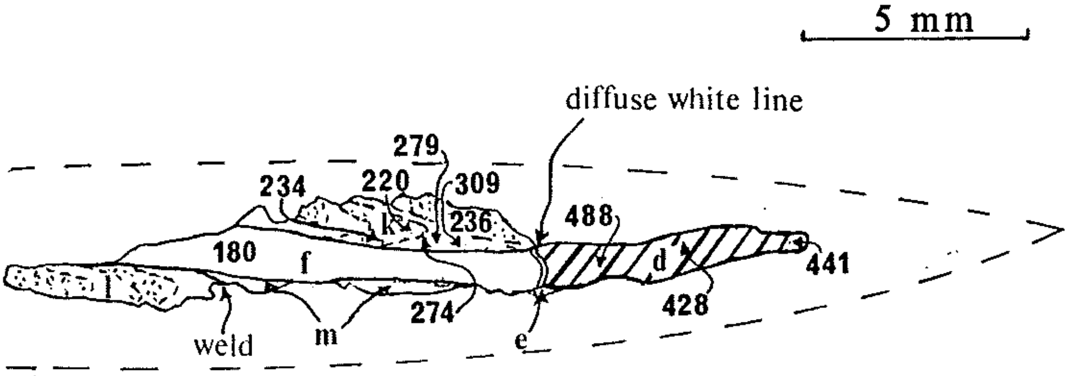

Fig 4ii Sketch of same section showing main parts and hardness values.