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REPORT

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TITLE Examination of Roman and Medieval Iron from Fundbury, Dorset.

Examination of Roman and Medieval Iron from Poundbury, Dorset.

by R.F. Tylecote.

Introduction; Methods of construction.

The main problems with early edge tools and cutlery were to combine carbon steel and wrought iron to give economy in the use of steel, and to overcome the brittleness of early carbon steel. The reason for the high cost of steel was the slow rate at which diffusion of carbon into iron occurs in order to convert it into steel. The conditions must be reducing and require a temperature of at least 900°C; a time of 6 hours would give a depth of carburization of the order of 0.1 in. (2.5 mm). By the early medieval period steel cost about five times that of iron and could only be made from iron made from low phosphorus ore which is relatively scarce.

Thus a number of techniques for combining iron and steel were devised. By the early medieval period four well-differentiated techniques of welding can be seen (Fig. 1). But in the Roman and pre-Roman Iron Age simple carburization of iron was still being practised. Even so, as we see from the Llyn Cerrig Bach chariot tyre, good quality homogeneous steel could be produced. (The carbon content was about 0.8% and the hardness 250 HV).

The specimens examined were cut from the tools, particularly the knives, which showed evidence of residual metal. In cutting, the bulk of the scale flaked off so that the metal examined is comparatively free of scale.

After sectioning across the width of a blade, or part of a blade to give a "V" shaped specimen, several specimens were mounted in such a way that their cross-sections was examined. The mounts were polished, and etched in a 2% solution of nitric acid in alcohol (Nital).

Results.

1. Roman - mostly 3rd - 4th century AD.

Fe 574. Nail rod or wire from fill of later 4th century graves.

Mainly fine-grained ferrite with a little slag and some granular carbides. Hardness, 134 - 148 HVI.

Fe 400. Iron wire or nail bar from 3th - 4th cent. settlement.

Coarse-grained ferrite with some slag. A hardness of 197 HVI suggests appreciable phosphorus content.

Fe 262. Iron wire fragment from the 3rd - 4th cent. settlement. Fine-grained ferrite with some spheroidised carbides. The hardness is 138 HVI which in view of the carbide content suggests a low phosphorus content.

Fe 176. A round "billet" measuring 10.5 by 2.7 cm diam.

Possibly intended for nail-making, this came from the fill of later 4th cent. graves. Fine-grained ferrite with some slag stringers and grain boundary carbides; hardness 150-185 HVl.

Fe 567. Object, possibly a knife blade from Roman cemetery 3.

Almost all steel with a carbon content in the range 0.1-0.2%. The structure is of the widmanstätten type with rather spheroidal pearlite. It is fairly homogenous with very little slag. The hardness is 135 HVl which suggests low phosphorus.

Fe 497. A knife from the same cemetery. Made of very coarse-grained ferrite with little slag. A hardness of 201 HV suggests appreciable phosphorus.

Fe 264 a and b. Two possible ring-handled knives from 3rd-4th cent. Late Roman levels. (a) contains a good deal of carbon but it is distributed in a very uneven way not suggestive of an edge tool. There are areas of sorbite or tempered martensite with a hardness of 229 HV, and lower carbon areas of coarse-grained pearlite with ferritic grain-boundaries having a hardness of 131 HV. The pearlite is spheroidised rather than lamellar showing that it had been held for some time between 600° and 700°C.

(b) is all ferrite with very little slag. The hardness is 134 HV.

<u>Fe 583.</u> A pointed object from the Late Roman settlement. This is almost entirely ferrite but of very variable grain size. The slag stringers and the grain structure show evidence of piling. The hardness is 140 HV suggesting low to moderate phosphorus. There is a little pearlite in places but ~~this~~ the carbon content does not amount to more than 0.1% ~~carbon~~ anywhere.

<u>Fe 364.</u> A knife from the Roman cemetery No. 3. Very heterogeneous but clearly steeled. The join is diffuse. The back is mainly ferrite with a hardness of 150 HV. The cutting edge is ferrite + pearlite with a widmanstätten structure indicating that it has been at a high temperature, cooled rapidly and held at 600 - 700°C which spheroidised the pearlite. The hardness obtained by such treatment is 205 HV. Why did the smith fail to quench it?

<u>2. Post - Roman.</u>

<u>A. Pre - Saxon.</u>

<u>Fe 309.</u> Dark Age, knife. A fairly homogenous but piled structure consisting of ferrite with partially spheroidised cementite. The carbon content varies from about 0.2 - 0.5% at the cutting edge to 0 - 0.2% at the back. The maximum hardness is 214 HV1. Unless supported by some hammer hardening at the cutting edge, this would not be a very efficient knife.

<u>B. Post Roman - Saxon or later.</u>

<u>Fe 736.</u> Knife. Ferrite with very fine and evenly distributed carbide

with a carbon content varying from about 0.1% at the back to about 0.6% at the cutting edge. The corresponding hardnesses are 105 and 210 HV1. It would seem that the carbon content had been achieved by long-term carburizing at about 750°C or, possibly, high temperature carburizing at over 900°C followed by spheroidising during working at 700 - 750°C.

Fe 605. Knife. This is a very sophisticated piece of work. The back of the knife is predominately coarse-grained ferrite with a hardness of 186 HV1. (Fig. 2 (a)). The cutting edge is a carbon steel, folded and welded to the back near the cutting end; the weld is indicated by white decarburized bands which do not seem to have resulted from arsenic enrichment. The mid-section is ferrite-and-pearlite with about 0.4% C; the pearlite is not resolvable at x 600. The hardness of the cutting edge of tempered martensite with some excess grain boundary carbide is 553 HV1. It seems that the heat treatment has been done by gradient heating with the edge of the knife heated to 800°C or so and then quenched into water while the rest of the knife was protected and therefore allowed to cool more slowly. This knife would make a very efficient tool. The tempering was probably done by the heat-flow back from the main body of the knife after the edge had been cooled to below 100°C.

Fe 62. This is described as a punch or chisel. As it is mostly tubular or semi-tubular (see sketch Fig. 2(b), it is much more likely to be a wood cutting chisel or gouge. A piece was cut from mid-section and the fact that its construction shows that it consists of an outer piece of steel welded to an inner semi-tube of iron would seem to confirm the chisel hypothesis. But the inner iron part is ferritic with a hardness of 177 HV. In the absence of carbon this hardness shows that it is high in phosphorus. This layer has been welded to a layer of 0.5% C steel with a widmanstätten structure with a hardness of only 146 HV showing that it is low in phosphorus. This would be logical if the cutting edge of the chisel was intended to be carburized. Unfortunately it is badly rusted and it was not possible to confirm this.

Fe 125. A knife. This consists predominantly of tempered martensite with a small piece of low carbon slaggy ferrite welded to the back; this has a hardness of 160 HV. The tempered martensite is very homogeneous and has a hardness of 520 HV1 but contains one large lense of slag. A good knife.

Fe 126. A knife from the post Roman settlement. An interesting example of pattern welding; after etching in Nital it was found to consist of alternate streaks of a thick dark phase with thin streaks of a light phase. The thin streaks are chevron-shaped (Fig. 2 (c)), showing that after being put in as laminations they received forging pressure in such a way that they were bent at the centre line of the blade. The light phase is a pure ferrite and it has a hardness of between 276 and 330 HV. It could be a ferrite with high levels of As and P. No martensitic structure was developed. The dark phase which had a hardness of 135-245 HV is probably tempered martensite or pearlite. A good knife.

Fe 503. A well-made, steeled, knife from the post Roman settlement. The back consists of ferrite and pearlite with a carbon content of between 0.2 and 0.4% and a hardness of 172 HV1. The edge is tempered martensite (sorbite) with a hardness of 330 HV1. The join is diffuse with no sign of arsenic enrichment.

Unstratified.

Fe 339. So-called "molten iron scrap". This is well-corroded forged sheet metal. It is mostly coarse-grained ferrite with a small amount of slag. The hardness is 93-107 which suggests a low phosphorus content.

The slag content suggests that it is wrought iron of Victorian or much earlier date and not modern mild steel.

Fe 522. All rust.

Fe 21. Unstratified but in a Roman or post-Roman context. This is a sharp homogeneous knife which seems to be entirely tempered martensite with a hardness of 401 HV.

Fe 550. Large knife, unstratified but in a Roman or post-Roman context. An interesting and unusual structure. A ~~piece~~ strip of iron has been carburized at one ~~end~~ edge to give ferrite-and-pearlite with about 0.3% carbon and a hardness of 156 HV1. This has been welded along most of the width of the blade to piled wrought iron in which the very coarse ferrite has a hardness of 125 HV. While the pearlite is spheroidised, no heat-treatment has been given.

Fe 603. A knife of post-Roman type. This is a much better blade than the one above. It is much the same in construction but a piece of comparatively homogeneous steel has been welded along part of the width of the blade and this has been effectively heat-treated to give a tempered martensite with a hardness of 615 HV1 (Fig. 2(d)). The weld shows the white lines of arsenic enrichment. The rest of the blade is very slaggy ferrite with a hardness of 138 HV.

Conclusions.

This is not a very inspiring collection of knives taken as a whole. They are poor in quality compared with the collection from medieval Winchester, and probably represent a developing situation from a rather provincial (?) settlement of the Roman period to an improving smithing situation in the post-Roman period.

If we look at the summary in Table, in particular the fourth column we do see a fairly steady improvement in the hardness of the cutting edge. The three undoubtedly Roman knives are poor with no heat-treatment at all. Amongst the Saxon or later knives we find three out of seven up to modern standards. The effort put into the pattern welded blade was largely wasted if we look upon it as a cutting implement.

The improvement in the level of heat-treatment after the Roman period has been noticed elsewhere and clearly shows that the Migration peoples had reached a very good level of smithing by the time they reached this country.

The other objects, i.e. mostly nails, are no more than one would expect, i.e. wrought iron. The round "billet" was possibly for nail-making. The chisel is a poor example of the smith's craft if we can assume that he intended that the carbon steel be harder than the phosphoric iron.

Finally it is clear that the source of the metal was variable. Some of the iron, e.g. that in Fe 497, was high in phosphorus, while that in Fe 736 must be very low in this element. Naturally most of the steel is low in phosphorus, but the steel in Fe 126 is probably quite high in As and P. This blade was probably quenched between the upper and lower critical temperatures of iron, i.e. 700 and 900°C.

As far as the construction goes, steeling (Type B of Fig. 1) predominates but the two-layered sandwich which we see in Fe 603 and 550 might be considered as a sub-division of Type A.

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Table.

Summary of results on Knives.

Fe No.	Type	Hardness (HV1) Back	Hardness (HV1) Edge	Remarks.
Roman — 3 - 4th century AD.				
567	homog.	135	135	Low carbon (0.1 - 0.2% C)
497	—	201	201	All ferrite (+ P)
364	steeled	150	205	Not quenched
Post Roman.				
Dark Age.				
309	carburized	---	214	Not quenched
Saxon and later.				
786	carburized	105	210	High-carbon cutting edge. Not quenched.
605	steeled	136	553	Martensitic edge.
125	steeled	160	520	Mostly martensite edge.
594	homog.	162	162	ferrite and little cementite throughout.
126	P.-welded	135	245	Pattern-welded but not well heat treated.
503	steeled	172	330	Tempered martensite edge.
Unstratified.				
21	Homog.	401	401	Tempered martensite
550	carburized	125	156	Not heat-treated.
603	steeled	138	615	A two-layered sandwich quenched to give tempered martensite.

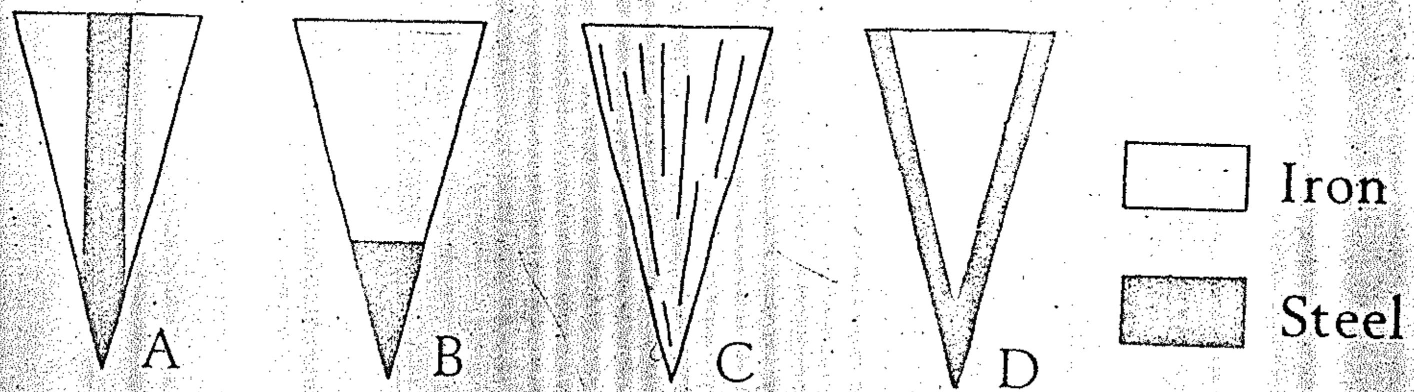
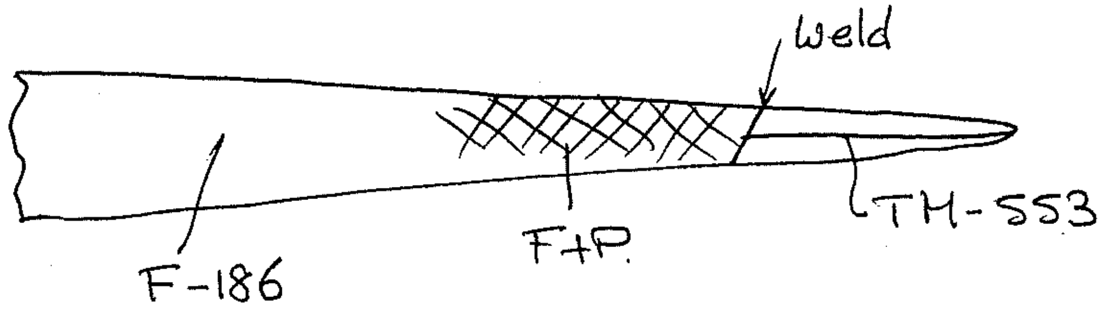
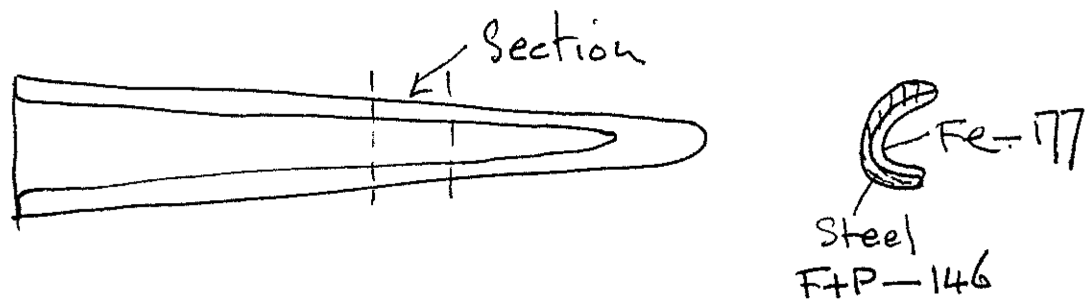


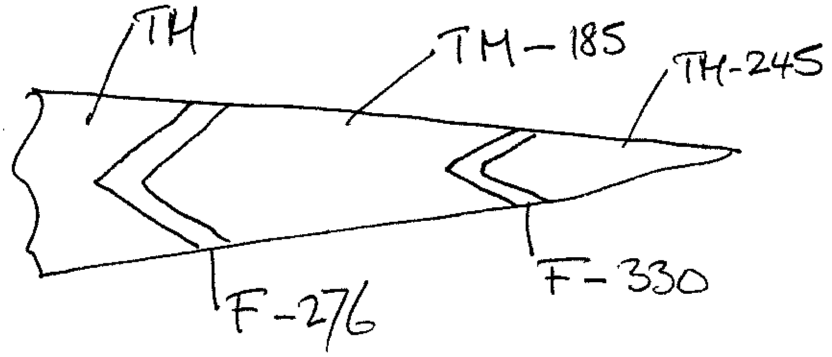
Fig. 1



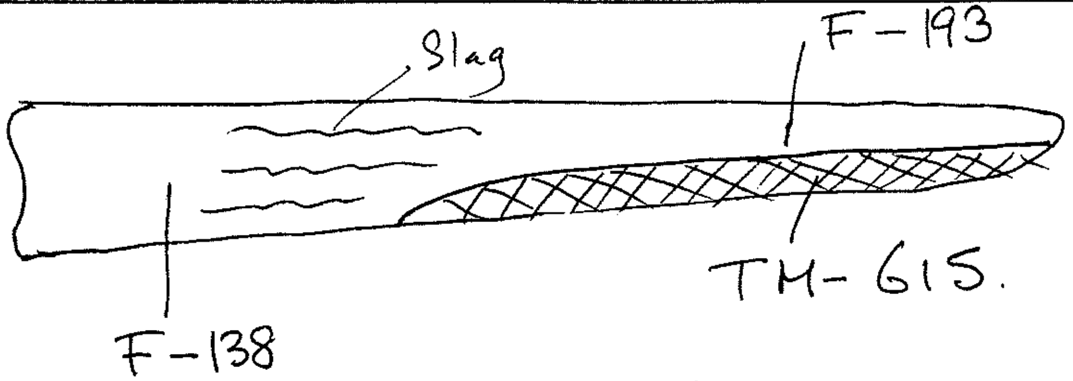
A - Fe 605.



B - Fe 62.



C - Fe 126.



D - 603.

Fig. 2. Not to scale.