Review of a metallographic investigation of Roman ferrous armour from Northern Britain

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1. Introduction

A small group from Reading and Cranfield Universities undertook a Metallographic [study of the structure of metals and their alloys] analysis on a small sample of specimens of Roman protective armour which was thought to originate from, or close to, auxiliary forts on Hadrian's Wall. The study sampled seven items of ferrous armour which originated from four sites and from armour which protected five different parts of a soldier's body.

The paper is focused on the metallurgical investigation of six samples (excluding Sample-5) and its main archaeological question is 'what are the metallurgical properties of the samples?' Importantly the paper explained that this was the first stage of a project funded by the AHRB [The Arts and Humanities Research Council] to research Roman ferrous armour from Britain and elsewhere within the Roman empire (Fulforda et al 2004:242).

2. Discussion

The samples were poorly provenanced and, with the exception of the sample from Vindolanda which was excavated from a Period IV barracks dated of the 1st Cohort of Tungrians between AD 105 - 120 (Birley 2009:91), the samples can only be dated to between the late 1st and early 3rd centuries AD (Fulforda et al 2004:242).

Ferrous artefacts have a poor chance of poor survival in an archaeological context and more than half of the samples were pitted or heavily corroded and partially mineralised. Perhaps this is why unprovenanced and unrelated types of armour were selected for the analysis. Metallographic analysis, on six samples, was conducted through examining sections, cut from each sample, through an optical microscope. The samples were tested for Mean Hardness (Hv) using a Vickers micro-hardness testing machine and also Samples 2 and 6 were examined with a Scanning Electron Microscope (SEM). Sample-5 (see Table 2.1), the well preserved Newstead shield boss, was polished and examined with an inverted microscope but it was not destructively tested for Mean Hardness. Each of the samples had its thickness, of un-corroded metal, measured. Sample-7 was subjected to a spectrographic chemical analysis on its de-rusted surface (Fulforda et al 2004:242-243, 245).

The testing determined that a range of different of techniques had been employed and some samples had been manufactured using a significantly more complex process (see Table 2.2). Sample-

1 was made from steel and Sample-2 had an inner layer of iron and outer layers of steel (Fulforda et al 2004:243). The manufacturing processes included hardening by warm-working or cold-working and construction from layers of metal less than 1 mm thick.

Fulforda et al (2004:247) stressed that there was a variety of material within the samples, specifically steel (an alloy of iron and carbon (Tylecote and Black 1980:87)), wrought iron (iron with larger slag content) and iron. Interestingly they didn't expand the discussion into how or where the material was manufactured or whether this was a deliberate or chance occurrence. For example both samples from Carlisle used steel; a useful analysis would have attempted to determine whether arm guards and scale armour from all locations was made from steel or whether Carlisle's metal-working process resulted in the higher carbon content. Birley (2008:22) says that Romans at Vindolanda mined and smelted ironstone locally, both military and civilians were engaged in this occupation, and that blacksmiths produced ironwork of exceptional quality which that was effectively steel. Tylecote and Black (1980:88) explain that making steel at a consistent hardness was a difficult and time-consuming process and McDonnell (1989:378) adds that a sample's hardness is a reliable way of quantifying the metal's quality.The two samples from Vindolanda had significantly different hardness possibly suggesting that different armour was made to different standards (such as making the helmet from harder and thicker iron) or different methods of hardening, such as quenching in water, or some other liquid such as urine or oil, or carburisation, were used.

Table 2.1 is derived from a larger set of samples which has allowed statistical interpretations such as the Mean and Standard Deviation to be calculated on Mean Hardness, as well as comparisons with later Periods. Table 2.2, including Mean Hardness from close to the surface which has a higher Hv, has a Mean of 256 Hv and a Standard deviation of 69.5 which suggests that the Fulforda et al samples had a similar Mean Hardness.

Period/Date	No. of measurements	Mean HV	Standard deviation
Romano-British	18	270	131
5th-10th Centuries	12	463	198
11-12th Centuries	14	373	189
13th Century or later	14	363	154
14th Century or later	11	343	147

Table 2.1: Mean and standard deviations of hardness results on cutting edges of knives (McDonnell 1989:378)

Fulforda et al (2004:247) only undertook chemical analysis on one sample; curiously they agree that this is something that would be of value "whenever circumstances allow" so perhaps time, resources or funding were not available for further analysis. Caple (2006:155) emphasises that without the ability to compare a single sample to other provenanced/dated samples it would mean very little. So it would have been useful if they used a consistent method to analyse all of the samples. Caple (2006:155-160) suggests that potential methods for metal analysis are X-Ray Florescence spectrometry, Optical Emission Spectroscopy (OES) or Inductively coupled plasma mass spectrometry (ICP-MS). These techniques could have provided chemical information which would have helped to determine whether the raw material was locally smelted or supplied from elsewhere.

3. Conclusion

The analysis is self-admittedly shallow in its depth of research - specifically the small number of samples, the lack of provenance and secure dating, employing different methods to analyse the samples and the failure to associate the raw material to the geographic locations or the historical and archaeological context.

Caple (2006:21) wrote that scientific investigation is performed to determine how an item was made, confirm the age or cultural affinity and add information about ancient materials or technology. The analysis certainly fulfilled two of these objectives but inconsistently and on a small and potentially unrelated set of samples. Overall the paper, although interesting, is little more than a 'pilot' for more extensive and detailed research on Roman ferrous armour. If a more extensive study is conducted, assuming that sufficient samples can be obtained, potentially for destructive testing, it would have relevance for both archaeological and historic Roman research.

Table 2.2: Summary of Specimens (Core data, Thickness and Mean Hardness)
(after Fulforda et al 2004:244)

No.	Source	Date	Provenance	Use	Metal	Layer No.	Thick (mm)	Mean Hardness (Hv)
1	Carlisle	2nd century	Excavated Hoard	Arm Guard	Steel	1	0.87	258 [238 near surfaces]
2	Carlisle			Scale Armour	Iron/ Steel	1	0.40	263 [438 at surface]
						2	0.40	231
						3	0.40	189
3	Halton Chesters	Undated		Chain Mail	Iron	1		211
4	Newstead	Flavian or Antonine		Arm Guard	Iron	1	0.92	219
5	Newstead			Shield Boss	Iron	1	0.10	Well preserved sample was not destructively tested therefore Hv is unavailable
						2	0.10	
						3	0.25	
						4	0.25	
6	Vindolanda	AD 105 - 120	Barracks	Helmet	Iron	3	1.17	313 [325 at surfaces]
7	Vindolanda			Lorica	Iron	1	0.45	200
						2	0.35	187

Notes:

1. Mean Hardness (Hv) = Vickers Pyramid Number
2. Sources are at or close to Auxiliary forts on Hadrian's Wall (Fulforda et al 2005:242)
3. The Vindolanda *lorica* does not indicate which part of cuirass it is from i.e. *lorica hamata* (mail) , *lorica squamata* (strip) or *lorica segmentata* (scale) (Fulforda et al 2004:241)

Table 2.3: Summary of Specimens (Non-Metallic inclusions, Equiaxed Ferrite Grains and Comments)
(after Fulforda et al 2004:244)

No.	Source	Use	Metal	Layer No.	Non-Metallic Inclusion			Single edge structure of equiaxed ferrite grains	Comments
					Slag	Str.	Area		
1	Carlisle	Arm Guard	Steel	1	Yes	No	0.2%	50 µm - lamellar pearlite grains 0.6-0.7%C	very clean slowly cooled from ±850°C and with decarburisation on both surfaces
2	Carlisle	Scale Armour	Iron/ Steel	1	Yes	No	0.2%	130 µm - outer same as layer 2 but with pearlite at outer surface 100 µm - small particles	outer 2 layers of harder iron (same sheet folded) carburised (to steel) on outside surface, welded to 1 softer inner layer
				2	Yes	Yes	1.3%		
				3					
3	Halton Chesters	Chain Mail	Iron	1			4.5%	50 µm - slightly elongated layer grains with small particles in grains	very clean warm worked
4	Newstead	Arm Guard	Iron	1	Yes	No	0.5%	150 µm	4 layers all different Small grain sizes at outer layers suggest warm-worked (±650°C)
5	Newstead	Shield Boss	Iron	1	Yes	Yes	2.3%	25 µm	
				2	Yes	No	1.8%	20 µm	
				3			4.6%	70 µm - small particles in grains	
				4	Yes	Yes	5.0%	50 µm - Inner	
6	Vindolanda	Helmet	Iron	3	Yes	No	2.4%	60 x 30 µm - elongated ferrite all similar grains, with small particles in grains	all 3 layers similar very high hardness heavily cold-worked
7	Vindolanda	Lorica	Iron	1	Yes	Yes	2.9%	100 µm - sometimes smaller along length - small particles in boundaries	very clean 2 layers; large hammer used or rolled
				2	Yes		<0.5%		

Notes:

4. Str. = Stringers
5. Area = Area fraction (there are three ways to calculate Area fractions but the article doesn't explain which was used)
6. µm = micrometer or 1/1000 of a millimeter
7. Equiaxed Ferrite Grains form through tempering when the cooling material re-forms crystals with edges of equal size (measures in µm)

3. Bibliography

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