

Wars of the Roses: battlefield arrowheads under the microscope

David Starley and Rachel S Cubitt

ABSTRACT: Whilst typological studies provide a useful framework for classifying medieval arrowheads and can give some indication of dates and function, our understanding of these artefacts, produced in hundreds of thousands, relies on too few stratified and provenanced finds. Within the typologies, the value of certain types in defeating armour is far from universally accepted. Archaeometallurgical research provides an alternative insight into the quality and likely effectiveness of these weapons. Examination of arrowheads from one certain (Towton, 1461) and one putative (Holm Hill, 1471) Wars of the Roses battlefield assemblage provided a unique and unexpected insight into the manufacture of these projectiles. It shows a demand for quantity over quality, which led to new construction methods involving brazing, and suggests that the majority of troops were only poorly protected by armour. In addition the study permitted the re-evaluation of the relationship between the Holm Hill site and the battle of Tewkesbury.

Background to current research

Considering the very large scale manufacture and use of arrowheads in the medieval and early post-medieval periods, metallurgical examination of these objects has been relatively limited (Starley 2000a). Although fairly common as archaeological finds, a high proportion of arrowheads are unstratified, and therefore undated, and often of uncertain purpose; the distinction between military, hunting and target shooting is not always clear. Typological classifications, notably those of the London Museum (Ward Perkins 1940) and Jessop (1996) have aimed to provide guidance on date and function. These typologies themselves rely on small numbers of soundly provenanced artefacts, although Jessop's more recent study (Jessop 1996) clearly benefited from larger numbers of later archaeological finds.

Typologies do of course have limitations. Some arrowheads appear to conform closely to suggested types. This may be due to specific purpose: slender 'bodkin points' were designed for the penetration of defensive mail, and broadheads were intended to cause incapacitating

damage to large animals, whether during the hunt or against horses on the battlefield. As discussed below, warheads appear to have been made to a standardised pattern. Accounts survive detailing the large scale of production of these, such as the 25,000 'quarrels' produced in the year 1256 at St Briavel's Castle, Gloucestershire (Pounds 1990, 109).

It might be expected that a disposable projectile weapon shot in large quantities by massed archers each releasing up to 14 arrows a minute, would be made of the cheapest iron available. Tudor steel was an expensive commodity, costing about three to four times the price of iron (Tylecote 1981, 46). Evidence for the use of steel comes from three sources: documentary, experimental and metallographic. For example, the Arrowhead Act of 1405 (7 Hen. IV c.7), required the jailing and confiscation of stock of any arrowsmith whose arrows were found to be soft. Towards the end of the period of military arrow use, Ascham (1545, 20) comments:

'I woulde wyshe that the head makers of Englande shoulde make their sheaf arrowe heades more harder poynted then they be: for I my selfe haue sene of late

suche heades set upo sheafe Arrowes, as ye officers yf they had sene them woulde not haue bene content wyth all’.

Perhaps the best known of the experimental studies is the work of Peter Jones (1983), which has been widely cited. Jones reports the effective penetration of bodkin points through armour plate. However, as the archer involved in the tests remembers (John Waller pers. comm.), this success was not achieved until the original arrows, which ‘curled up like a pig’s tail’ on impact, were replaced by new ones wrought from modern file steel. It would appear that the use of steel is very closely connected to the need for arrowheads to withstand impact and penetrate armour, and is therefore potentially an indicator of military use.

An earlier study (Starley 2005), sought to examine the relationship between the stylistic types of the London Museum and Jessop (1996) and the use of steel in construction, using the Starley and Cubitt technological

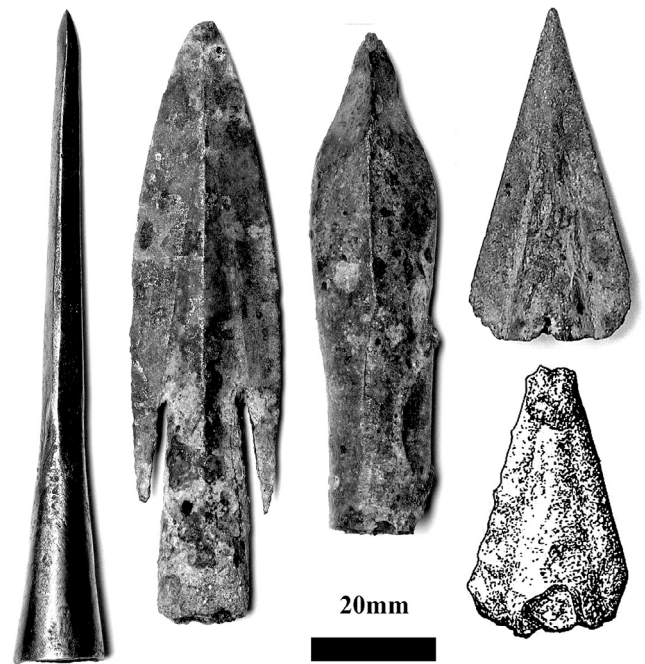


Fig 2: Medieval arrowheads. Left to right: bodkin point, Type 16, quarrel, Jessop Type M1 (Royal Armouries XI.441 above, Towton 21 below).

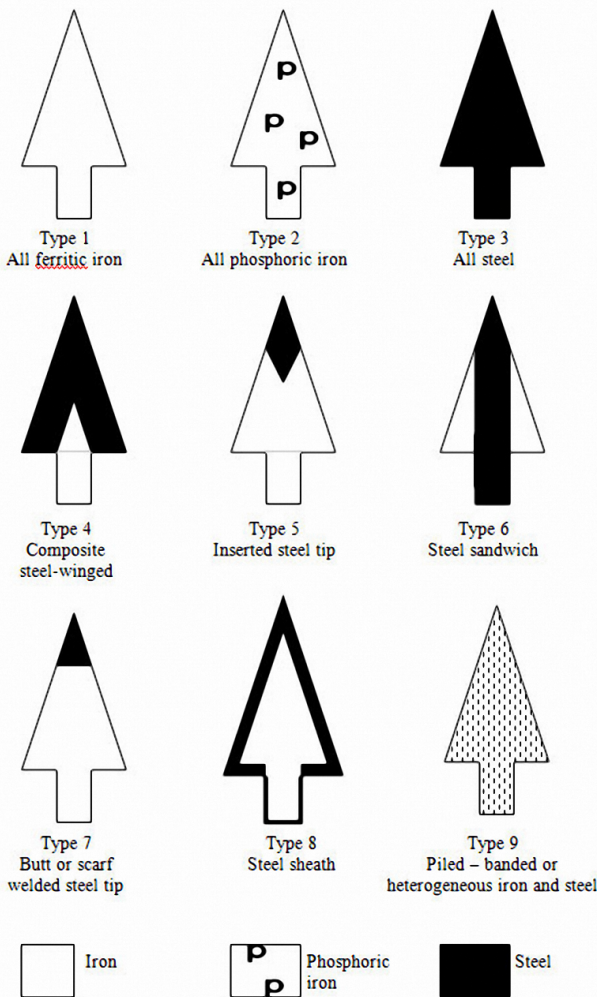


Fig 1: Starley and Cubitt technological typology of arrowhead construction.

typology illustrated schematically in Figure 1. That study brought together all known previous metallographic studies of arrowheads, which with the examination of further heads, totalled 30 artefacts. In particular it was intended to compare metallographically three supposedly military types: square-sectioned quarrels (despite modern terminology, not historically restricted to crossbows), bodkin points and the London Museum’s ‘compact winged and socketed’ Type 16s (Fig 2). Small numbers and differing sample positions limit comparability, and the certainty of the findings of this study, but it appeared that the bodkin points – even when steel was present – were not hardened, reinforcing their intended role in piercing mail rather than plate armour. Quarrel heads also generally seem to rely on their relatively high mass rather than metallurgical qualities. However, amongst all of the arrowheads examined, the Type 16 stands out as a quality product of composite construction with iron socket and steel wings/point with carefully quenched tips. Apparently making an appearance around the 14th century, this type is suggested to provide the high-tech answer to the increasing use of armour on the battlefield. Its effectiveness against plate armour might still be limited, but against more common forms such as the brigandine, composed of small platelets riveted onto leather straps, its use may have been telling.

The limitations of the previous studies lie largely in the examination of very limited numbers of artefacts from undated contexts. Non-destructive XRF analysis of

arrowheads from the Royal Armouries collection and an arrow shaft from the Mary Rose Museum (Starley 2006, 4–5) only added to confusion by frequently and unexpectedly detecting traces of copper alloys on many of the heads and on the shaft end at the point where the head had been attached. The opportunity to move the research forward came with two Wars of the Roses battlefield assemblages. The first came from an ongoing metal detector survey at Towton, Yorkshire (1461), and the second from a previously-excavated site at Holm Hill in close vicinity to Tewkesbury (1471). The results not only revealed details of the manufacture of the artefacts but provided insights to the nature and scope of the battles themselves.

Towton

The examination of the Towton arrowheads was carried out by David Starley whilst working at the Royal Armouries, in close co-operation with the archaeologist Tim Sutherland and metal detectorist Simon Richardson, whose innovative, long-term and meticulously-recorded work at Towton had produced an assemblage which included over 150 arrowheads. These topsoil finds were believed to have been brought up from greater depth by recent deep ploughing. Metallographic examination

of a selection of arrowheads was seen as a means of preserving by record artefacts which were likely to continue to degrade in storage, or indeed in the ground had they not been collected.

Methodology

All arrowheads were examined and recorded by X-radiography at the earliest opportunity. Six of the better preserved examples from the first batch were selected for metallographic examination. Due to the advanced state of corrosion, with limited metal survival, no attempt was made to cut wedge samples. Instead three heads were sectioned longitudinally in their entirety and the remaining three sectioned horizontally at several points along their lengths. The sections were mounted, ground and polished in the standard manner, then examined before and after etching in nital. Microhardness testing was undertaken on all phases of interest.

Results

A surprising initial discovery from the radiography was the arrowheads' apparently consistent form, a small conical head with attached wings. Typologically, these seem to be closest to Jessop's M1 type and are unlike anything in the London Museum's catalogue. In all cases a high proportion of the thin attached wings

Table 1: Results of the metallographic examination undertaken on the Towton arrowheads.

Arrow-head No	Socket microstructure	Wings/tip microstructure	Microhardness (mean values)	Construction and heat treatment
2	Ferritic possibly with some phosphoric iron (ASTM 3), higher carbon towards surface, quenched to form low-carbon martensite	Wings: Ferrite with phosphorus ghosting (ASTM 3), some low-carbon martensite Tip: Heterogeneous, ferrite with phosphorus ghosting and low-carbon martensite	Socket: Hv189 Wings (low C): Hv209 Wings (high C): Hv314	Socket brazed, wings possibly welded. Hardening due to phosphorus and quenching of steel
4	Ferritic (ASTM 4)	Wings: Ferrite (ASTM 4). Tip: no metal survives	Socket: Hv130 Wings: Hv101	Socket overlapped and brazed, wings brazed. No evidence of quench hardening
10	Ferritic/phosphoric iron (ASTM 5) some distortion and strain lines	Wings: Entirely corroded; possible relict martensitic structure visible Tip: Heavily distorted ferrite	Socket: Hv163 Tip: Hv208	Socket and wings brazed. Some hardening due to phosphorus, work hardening and possibly quenching
12	Ferritic with 10% fine pearlite (ASTM 6)	Tip and Wings: Heterogeneous ferrite/phosphoric iron with 10% fine pearlite (ASTM 6)	Socket: Hv141 Wings: Hv182	Socket and wings brazed. Insufficient carbon to be classed as steel, not quenched
17	Largely ferritic/phosphoric iron of very variable grain size with heavy ghosting	Wings/Tip: No metal survives	Socket: Hv170	Forged construction. Closest type: Jessop M3. No evidence of hardening
21	Ferritic/phosphoric iron (ASTM 6)	Wings: Ferrite (ASTM 6) with some areas up to 5% pearlite Tip: Heterogeneous; martensite and martensite with ferrite	Socket: Hv208 Wings: Hv209 Tip: Hv469	Socket and wings brazed. Composite construction with tip only quenched

have been lost, but the original appearance is likely to be similar to a well-preserved example (XI.441) in the Royal Armouries collection (Fig 2). A further unexpected result was the very frequent evidence on the X-radiograph for non-ferrous metal attached to the heads, which the metallographic sections showed to be the result of the brazed construction of these arrowheads. Detailed results of the metallographic examination are shown in Table 1. Whilst it might be expected that such an assembly technique would easily allow composite construction with cheaper/softer iron sockets and tougher, hardenable steel wings/points, this is by no means standard; although the best-preserved arrowhead, No 21, does conform to this. The socket is carbon free, but with some phosphorus content, whilst the applied wings contain some of the carbon-rich phase, pearlite. The tip however has received localised heating and quenching to increase its mean hardness to Hv 469, compared to 208 for the socket. Other arrowheads with this conical form sometimes give higher hardness readings for the wings or tip, where these survive, due to their slightly higher phosphorus content or to work hardening. Number 17 appears to be a head of a more conventional quarrel, possibly Jessop Type M3, manufactured from phosphoric iron.

Discussion

The results of the Towton study raise the question as to why the high quality Type 16 military arrowhead, probably developed during the time of the Hundred Years War (1337–1453), appears to drop out of use during the Wars of the Roses (1455–87). The answer probably lies in the nature of the armour worn at the time. What most people today think of as medieval armour; where closely fitting plates of iron or steel cover the whole body, was more common among the knightly class. Professional troops, such as those which campaigned in France during the Hundred Years War were apparently relatively well equipped, perhaps with armour such as brigandines. Against such armour a hardened steel tip and edge would have a distinct advantage. Compared to such professionals, the armies of the Wars of the Roses, swelled by local levies, were clearly much less well equipped defensively, as shown by the contemporary Bridport muster (Richardson 1997). Against poorly armoured troops a cheap, mass-produced arrowhead may have been as incapacitating as a better made one.

Holm Hill, Tewkesbury

The Holm Hill assemblage comprises 70 arrowheads excavated from a site interpreted as the location of medieval Tewkesbury Manor (Hannan 1997, 211). The

relatively large quantities of arrowheads recovered led the excavator to conclude that they were related to the battle of 1471 (Hannan 1997, 221). Furthermore, they were presumed to support an interpretation of the battle layout in which the Lancastrian army positioned itself on Holm Hill (Blyth 1961). Analysis of the assemblage (Cubitt 2006) was undertaken so that, in addition to making a contribution to the field of arrowhead research, it might be possible to address the wider archaeological question regarding the position of the battlefield.

Form classification using Jessop's 1996 typology showed the assemblage to be predominantly military. It comprises 46 military, 11 hunting and 13 multi-purpose types. Almost half of the military arrowheads had the small conical head with attached wing form found extensively at Towton, and reminiscent of Jessop's Type M1. At Holm Hill there was some variation within this group, and the category was subdivided in order to take account of the subtle variations seen in the angle of the wings. Jessop examined only three Wars of the Roses arrowheads in creating his typology and himself stated that some future extension of his categories might be necessary (1996, 193).

Methodology and results

The methodology employed was that of the Towton study, but in this case the high proportion of metal remaining permitted the cutting of wedge samples.

The results of the metallographic analysis of 15 arrowheads are shown in Table 2. The construction of the hunting broadheads and bodkin arrowheads generally followed the predicted pattern. All were soft piled or phosphoric structures with low microhardness values (Hv 157–181). In the case of these categories, shape seems to have been more critical than materials used and construction method. The characteristic long barbs, and the large wounds they create, are key to the function of broadheads (Jessop 1996, 199). Similarly, it is the broadening sides of military bodkins that break mail links once the slender points have found the holes (Strickland and Hardy 2005, 26). The new data from Holm Hill serve to strengthen the conclusions drawn in the Towton analysis.

Eight compact warheads were analysed. Such shapes are thought to fit contemporary descriptions of military arrowheads with little barbs (Pratt 1992, 229), probably designed in response to more plate armour appearing on the battlefield (Starley 2005, 214). Higher quality heat-treated steel was expected at the tip of these projectiles, the point of initial impact. Contrary to this pre-

Table 2: Summary results of the metallographic analysis undertaken on the Holm Hill arrowheads.

Jessop type	Starley type	Heat treatment	Brazed	Coated	Average micro-hardness	ID no	
Military compact warheads	1a	Piled including phosphorus		yes	Hv170	940599	
	1b	Iron socket/steel wings	fast cooled	yes	Hv231	940619	
	1b	Iron socket/steel wings	tempered martensite tip	yes	yes	Hv336	940506
	1c	All ferritic		yes	Hv159	940690	
	2/5	All ferritic		yes	yes	Hv167	940572
	3	Piled			Hv193	940511	
	6	Piled	slow cooled		Hv142	940693	
	6?	All steel		yes	Hv267	940536	
Military bodkins	7	Piled			Hv157	940607	
	7/8	Piled			Hv181	940659	
Hunting broadheads	4	Piled	quick cooled		Hv161	940672	
	4	All phosphoric			Hv171	940545	
Multi-purpose	9	All ferritic		yes	Hv136	940645	
	9	Piled	slow cooled	yes	Hv175	940656	

diction, however, the analyses painted a mixed picture. Only three arrowheads had steel in their construction: one wholly steel and two composite types with iron sockets and steel wings. The latter both showed evidence of heat treatment but in only one case had this produced a transformation to tempered martensite, with an average hardness at the tip of Hv 601. This compares well with the figure of Hv 609 obtained from an unprovenanced Type 16 (Starley 2000b). Four of the compact warheads sampled were closest to form Type M1. This group included one ferritic, one piled and the two composite construction arrowheads (Table 2). Crucially the same lack of steel was observed amongst the Towton microstructures. The similar results suggest that neither of the datasets is anomalous.

Discussion

The lack of steel in the Towton and Holm Hill arrowheads, compared to other warheads such as the earlier Type 16s, can perhaps be explained if they are seen as a product of their time. It is suggested that a 'quantity over quality' strategy was adopted. The Wars of the Roses were essentially civil wars. This series of fifteen battles would have put a massive strain on the resources available to each side. The high cost of steel at this time must also have been prohibitive, especially when arrowheads were required in their thousands. The other key factor in this period is the nature of the armour being worn on the battlefield, which has been discussed above.

Arrowheads constructed of softer materials are not necessarily as ineffective as might be supposed. Investigations into blunt force trauma suggest that the impact of a

projectile even without penetration can cause injury (Bourke and Whetham 2007, 22). These arrowheads were deployed in enormous quantities; a contemporary source for Tewkesbury describes Yorkist arrows raining down on their opponents (Bruce 1838). It is considered that when multiplied on this scale, what might otherwise have been trifling injuries can become incapacitating.

Turning to the wider archaeological question, it is highly likely that some of the Holm Hill arrowheads do derive from the battle of Tewkesbury – in particular the 20 M1 examples, a type which was also recovered in large numbers at Towton. The remaining 26 military arrowheads could perhaps also have been used in the conflict, as any arrowheads may have been considered suitable in time of war, but it is perhaps significant that these and the hunting types are not currently paralleled at Towton. The numbers of military arrowheads are paltry in comparison to the enormous quantities of arrows that must have been deployed in the course of the battle, weakening the argument that Holm Hill was the position of the Lancastrian army. Despite other commentators finding faults with this theory (eg Hammond 1990), it persists in the literature (Strickland and Hardy 2005, 377). Alternative interpretations in which the battle took place further south of the town (Bazeley 1903; Goodchild 2005; Hammond 1990) are thought to be more likely, although there is currently little archaeological evidence to support this conclusion (Cubitt 2006).

It is proposed that the Holm Hill arrowheads are a component of equipment shed by Lancastrian soldiers known to have fled towards the town when battle was lost. Perhaps this was an attempt to both quicken escape

and demilitarise themselves, discarding any connection to the battle in the hope of disappearing into the town and avoiding the ensuing rout. To lightly armoured soldiers, the hedges that probably surrounded Holm Hill at this time need not have been impenetrable obstacles as has been supposed (Goodchild 2005, 57). As an escape route, Holm Hill may have been an attractive alternative to the neighbouring bottleneck that is still known today as Bloody Meadow.

Coppering of arrowheads

Analysis of the Holm Hill assemblage produced additional information on the copper alloy observed at Towton. Nine of the fifteen metallurgical samples had a copper alloy component, acting variously as a brazing and/or coating material (Figs 3 and 4). The composition of the alloy was assessed using a scanning electron microscope. The average normalised results (in wt %) were 88% copper, 3% zinc and 3% tin; the remainder was iron, which is presumed to have come from the arrowhead itself rather than being a deliberate compound of the alloy. Previous X-ray fluorescence analysis of the Holm Hill arrowheads undertaken at English Heritage's Ancient Monuments Laboratory detected copper alloy in 57 of 70 arrowheads. In 18 of these the copper was apparently pure. In the remaining 39 cases, the copper was alloyed with detectable amounts of one or two of the elements tin, zinc, lead and nickel (Morris 1997, 168). It must be noted that both at Holm Hill and in the Royal Armouries collections analysed by Starley, a small number of non-military types were also found to be coppered.

The brazed military arrowheads from Holm Hill add to the growing body of evidence that some warheads manufactured in two pieces were brazed together rather than welded, as is commonly assumed. It is not known for certain how the brazing material was applied. X-radiographs of the Holm Hill assemblage appear to show that a molten alloy had welled in the sockets of several of the arrowheads, leading to the presumption that this component was dipped prior to the wings being attached. Given that thousands of arrowheads were required for each battle, such a brazing method might have been a mass production strategy employed in this period. It would have simplified composite construction by allowing the joint in the conical socket to be fused at the same time that the tip/edges were attached. Such work could probably have been accomplished by an individual with little metalworking experience. Welding, in contrast, requires a trained blacksmith.

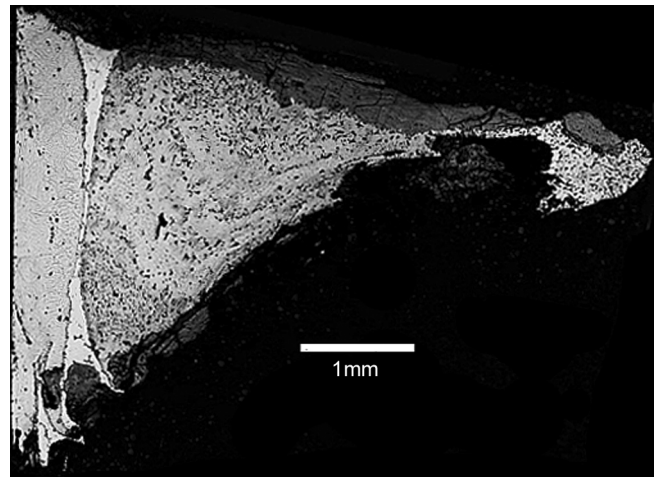


Fig 3: Section through arrowhead 940619 showing copper alloy brazing material between the socket, left, and wing, right.

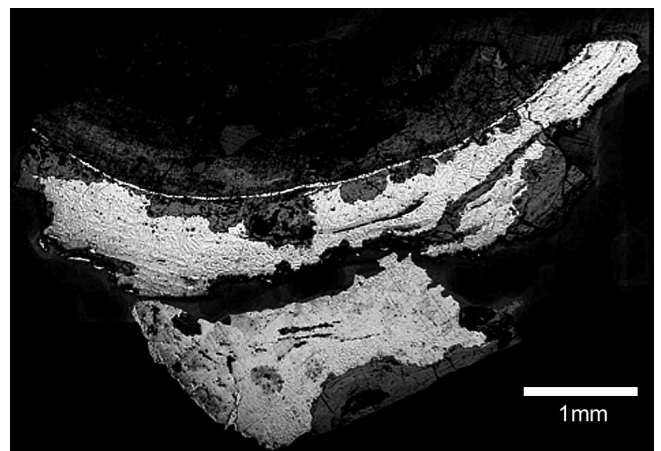


Fig 4: Section through arrowhead 940599 showing a thin copper alloy coat round the inside of the socket and outside of the wing, to bottom left of image.

An additional outcome of brazing by dipping would have been the production of a copper alloy coating. However, four of the six metallurgical samples with evidence for coating did not also have evidence for brazing. There are numerous potential explanations to support coating as a deliberate treatment in its own right. These include preventing corrosion and improving aerodynamics. It has also been suggested that copper minerals form a component of the head/shaft glue (Soar 2006, 82), and even that its function was to poison the enemy (Strickland and Hardy 2005, 286).

The effect of the coppering process on the iron microstructures must be considered, particularly in relation to the observed lack of heat treatment. The temperature increase resulting from more than momentary dipping in a molten copper alloy at above 1000°C would return the iron to the austenite region of the iron phase diagram and lead to annealing of the microstructure, evidence of which was seen in several of the metallographic samples. This would have negated any heat treatment that had

been previously applied. Further work is required before the copper alloy phenomenon can be fully detailed and explained. Experimental brazing using historically accurate materials is suggested, with the aim of recreating the observed archaeological microstructures. Perhaps then the full effect of the brazing process on the iron can be understood. Dipping of modern iron nails in molten copper alloy has been attempted but produced mixed results (Greenwood 2007).

There is currently little evidence to inform any debate on the performance of brazed and coated arrowheads, particularly their advantages or disadvantages compared with welded examples. In contradiction to the growing evidence for their widespread use it has been asserted that brazed projectiles were ineffective weapons that simply would have disintegrated on impact (Stanley 2006). Ballistic testing of brazed and coated arrowheads, taking into account the effects of blunt force trauma, would therefore be a worthwhile avenue for future research.

Conclusions

This paper primarily examines the metallurgical structures of arrowheads. Building on the little previous work done on these relatively common finds, it brings together two studies of arrowhead assemblages from battlefield sites of the Wars of the Roses: Towton (1461) and Tewkesbury (1471). In this period of extended large scale and bloody conflict, firearms were only beginning to be used on the battlefield and archery remained a dominant tactical force. The studies described here complement each other in demonstrating a previously unrecognised method of arrowhead construction: the brazing together of separate conical sockets and wings. This evidence for brazing comes after many years of recording the presence of traces of copper alloy on medieval arrowheads. Numerous explanations had previously been proposed though not, to the authors' knowledge, simple joining together of parts. Whilst clearly a fitting explanation for the arrowheads examined in the studies reported here, it is not known whether this also applies to arrowheads of other periods. It would be informative to analyse similar assemblages from other conflicts, in addition to the further experimental work suggested above.

The most common type of arrowhead present in the two assemblages examined consisted of a small conical socket with thin-sectioned wings attached. These heads were remarkably standardised in size, shape and construction, being closest to M1 in Jessop's (1996) typology. This

uniformity applies not only throughout each assemblage, but between two battles 160 miles and ten years apart, suggesting manufacture to a fixed specification. The metallurgical quality of these arrowheads, although variable, is generally far poorer than the composite iron/quenched steel structure of Type 16; another apparently standardised form of warhead, developed most probably in the previous century to counter well-armoured troops. The Towton and Holm Hill arrowheads may be interpreted as a response to a need to provide large quantities of projectiles at lowest possible cost in a short time. However, the metallurgy also allows us to suggest that the arrows were intended for use against poorly armoured troops, such as the local levies raised at short notice to swell the ranks of the opposing forces. Thus a metallurgical study throws a little light on the nature of the conflict.

The results from Holm Hill not only support the metallurgical findings from Towton, but also provide valuable interpretative information on the site itself. With a more secure knowledge of the military arrowhead assemblage to be expected at this period, it was possible to distinguish arrowheads related to the battle from those used for hunting, probably associated with the medieval Manor which previously occupied the site. This was a task that could not be accomplished archaeologically due to the unstratified nature of the finds; the majority of the arrowheads were excavated from the plough soil. It is therefore now possible to be sure that archers from the Battle of Tewkesbury were present on this site, but this may have been during the rout as Holm Hill seems unlikely to have been the Lancastrian position.

Destructive analysis of artefacts should only be undertaken where the potential gain in information can justify the loss of material. For Towton, particularly, but also Holm Hill, the condition of the objects, with ongoing deterioration in the top-soil and post-excavation archive, made metallurgical examination a high priority. When combined with X-radiography of the broader assemblage, this has not only provided a long term record of the artefacts recovered, but also an insight into the manufacture, supply and use of arrowheads which could not have been gained by visual study alone.

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The authors

David Starley is a qualified metallurgist and archaeological scientist whose PhD examined medieval and renaissance armour to determine the technology of its production. He was previously employed at English Heritage's Ancient Monuments Laboratory then as Science Officer by the Royal Armouries, Leeds, but now works as a freelance archaeometallurgical specialist. Address: 75 Albert Road, Saltaire, Shipley, W Yorks, BD18 4NS, United Kingdom. Email: davidstarley@yahoo.co.uk

Rachel Cubitt currently works as a Collections Project Officer for the York Archaeological Trust undertaking a range of curatorial tasks and assessing metalworking debris from excavations. Her other research interests include York's post-medieval iron industry and synthesising our understanding of medieval metalworking in the city. Address: York Archaeological Trust, 47 Aldwark, York, YO1 7BX, United Kingdom. Email: rcubitt@yorkat.co.uk