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CEREMONIAL OR DEADLY SERIOUS?
NEW INSIGHT INTO THE FUNCTION OF IRISH EARLY BRONZE AGE HALBERDS

Ronan O'Flaherty, Michael D. Gilchrist and Trevor Cowie

ABSTRACT

This paper describes a series of highly focused experiments, carried out under laboratory conditions, as part of a wider Irish-Scottish project which is investigating the function of the Early Bronze Age halberd. Earlier trials showed that these artefacts, when hafted properly, were capable of piercing sheep-skulls without suffering significant damage and that by extension they were therefore capable of being used as weapons. Having observed that up to 50 % of museum specimens bore evidence of edge damage, a new set of laboratory trials were undertaken to replicate this damage and to determine how it occurred and under what circumstances. These trials indicate that most of the edge damage on Irish halberds results from impact with other halberds, in a yielding environment (suggesting that both halberds could move) and at tightly-controlled energy-levels which remained capable of lethal effect. It is argued that this is consistent with skilled combat-use and that many of the Irish halberds must have been employed to such end.

KEYWORDS

*Halberds – Bronze Age – function – edge damage
– replica – experimental testing*

INTRODUCTION

The halberds of the Early Bronze Age period in Europe have tended to be regarded as largely ceremonial objects. In Ireland, archaeologists have pointed to a perceived weakness in the hafting technique in support of a view of these objects as non-utilitarian, as well as a presumed clumsiness in the hand.¹ Similar views have also been expressed in relation to the British and European material up to quite recently (Osgood 2000, 86; Toms 2000, 99). However, that view is beginning to change (Brandherm 2003, 2004; this volume) and practical experiment by one of the authors has shown that the Irish halberds, at least, are

very well-designed from a functional perspective, easily penetrating skull-bone and proving remarkably resilient to damage (O'Flaherty 2007a; 2007b). The supposed 'weakness' of hafting of the Irish halberds is simply not borne out by the results of practical trials. The question now is not if they could have been used as a weapon, but rather whether they were so used.

The key to answering this lies in the halberds themselves. A careful study of the museum specimens reveals that a great many Irish halberds display clear evidence of impact damage, which includes edge damage, damage to the rivet-holes, and buckling or actual breaks to the blade. In terms of edge damage, which is the focus of the current paper, what one finds is very similar to what occurs on the swords of later periods, i.e. notching, nicks and dents, and these are often taken as indicators of combat-use on the swords (Bridgford 1997; Kristiansen 2002; Molloy 2007). While it might be tempting to simply transfer this interpretation to the halberds, the authors consider that one must first identify the degree of force involved in the creation of these notches and dents, as well as identifying the most likely impacters, before drawing any firm conclusions. The legal maxim that 'force goes to intent' is a good touchstone and will form a key element in our considerations.

In a short paper published elsewhere (O'Flaherty *et al.* 2008) two of the authors described and characterised for the first time the types of edge damage which occur on Irish halberds. They also set out an agenda for a focused programme of impact replication to be undertaken under laboratory conditions at the School of Electrical, Electronic and Mechanical Engineering, University College Dublin (hereafter, simply 'UCD'). The purpose of this programme was to attempt to replicate the conditions under which the types of edge damage observed on the museum specimens were created, what other artefacts were involved and at what levels of force. In this paper, we set out the results of that study and consider its implications for the function of Irish and other halberds. This work is being carried out as part of a joint halberd-research project involving experts in

¹ Ó Ríordáin 1937, 241; Macalister 1949, 132–134; Herity and Eogan 1977, 137; O'Kelly 1989, 164 f.; Mallory

and McNeill 1991, 102; Waddell 1991, 70; 1998, 129–131.

Impacts	Corrosion	Breaghwy or similar type	Carn	Clonard or similar type	Cotton	Misc	Grand Total
Denting/Bowing		0	4	1	6	0	11
Notching		1	3	3	15	1	23
Both		0	4	2	12	0	18
Total Impacts		1	11	6	33	1	52
None	<i>high</i>	3	5	2	6	0	16
	<i>medium</i>	2	4	2	4	0	12
	<i>low</i>	6	15	4	25	1	51
	<i>(burnt)</i>	1	0	0	0	0	1
Total None		12	24	8	35	1	80
Possible Notching		0	2	0	1	0	3
Grand Total		13	37	14	69	2	135

Figure 1: Overall summary of impact damage on Irish halberds

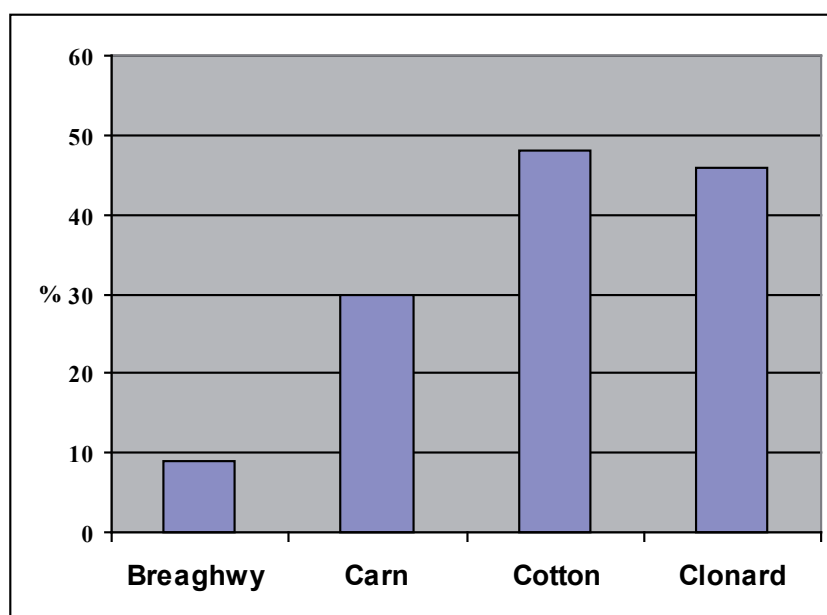


Figure 2: Percentage of each halberd type with impact

Ireland and Scotland which hopes to throw some light on just how these fascinating artefacts may have been used. Across in Scotland, the aim of the project has also been to combine conventional archaeological research, metal analysis and experimental archaeology, in order to throw light on the Scottish data. The halberds in the Scottish dataset differ in a number of ways from their Irish counterparts and one particular aim of the Scottish arm of the project is to investigate the functionality of a series of halberds mainly found in the North-East of Scotland and recently termed the 'Auchingoul' type after an important find in

Banffshire (Needham 2004, 231–234). The nature of these distinctively Scottish halberds, with their weaker-looking rivet arrangements, thin hafting plates and slender, triangular blades, makes them ideal for further testing of the 'ceremonial versus functional' argument; moreover, the experimental results will provide a good contrast with the considerably more robust Irish halberd of the type replicated by one of the authors and his Irish colleagues (O'Flaherty 2007a). If shown to be as fully functional, there is a strong possibility that such blades would have been employed in a markedly different fighting style.

In Scotland, our main strands of work to date have involved re-assessment of all the recorded halberds. As in Ireland, the survey of S. Ó Ríordáin (1937) provides a baseline until superseded by J. Cole's wider-ranging review of Early Bronze Age metalwork in Scotland (1969), which included a revised list of all the known Scottish halberds, line drawings of many of them and a catalogue of the hoards. More recently, as noted above, halberds have figured in S. Needham's excellent re-assessment of the Early Bronze Age in the North-East of Scotland (2004). The inventory of material from Scotland is much smaller than that from Ireland, making reappraisal a practical proposition: taking recent unpublished finds into account, the number of halberds from Scotland amounts to nearly 60 specimens, nearly all in collections readily accessible for research purposes (compared to nearly 190 examples from Ireland: O'Flaherty 2002).

New discoveries and antiquarian research are also offering opportunities to assess the circumstances of discovery and context of deposition. The value of this source criticism as an essential first stage in the project has become apparent with the recent re-provenancing of a fine halberd in the collections of the National Museums of Scotland, for long believed to be from the Kilmartin area of Argyll in the West of Scotland. As one of our finest and most complete halberds, this blade was initially earmarked for replication as part of the experimental element of project! Recently however, we have been able to show the true provenance of the 'Poltalloch' halberd was actually the Channel Island of Alderney! (O'Connor *et al.* 2009; O'Connor *et al.* 2010). A fresh look at archival sources has also shed light on the circumstances of discovery of another Scottish halberd: manuscript collections of the Society of Antiquaries of Scotland appear to show that a halberd found in 1826 at Portmoak Moss in Kinross was discovered with the remains of its wooden haft – the first indication that any of the Scottish halberds was actually deposited while hafted. The project is also providing an opportunity to augment the available metal analyses for Scottish halberds by sampling recent finds and by filling in the gaps in the SAM dataset.

As in Ireland, experimental techniques will be employed to investigate whether Scottish halberds were used, whether and how they could have been used in actual combat, and to investigate whether any observed blade damage presenting on museum specimens is best explained in this manner. After some initial problems, replicas of a generic 'Auchingoul' type halberd have

been commissioned using as authentic a metal composition and production technique as possible. Analysis of use-wear and impact damage observed on actual halberds will be undertaken and compared with the condition of the replicas (although it may be noted that on the whole soil conditions appear to have been less conducive to the survival of Scottish blades, which are frequently considerably more corroded than the Irish series).

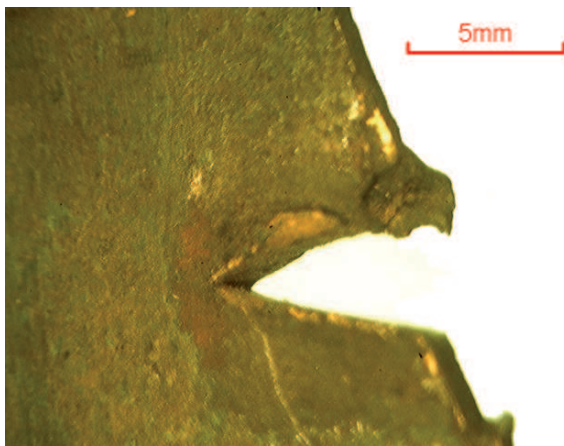
As well as investigating whether Scottish halberds were used, a major goal of the project is to explore whether and how they could have been used in actual combat. The key element of the final stage of the project will therefore be to bring the practical experience and skill of re-enactors familiar with traditional weaponry to bear on the question of the combat functionality of the different types of Irish and Scottish halberds. This will involve the design and commissioning of accurate replicas, the briefing and observation of re-enactors (suitably protected!) hopefully with the aid digital video-tagging to help identify fighting techniques. In addition to the academic research, the project will therefore lend itself to outreach and the popular presentation of archaeology.

After some unforeseen setbacks, the experimental component of the Scottish project work is now back on track – and as this paper will make clear, the remaining stages of the project can now draw on the sterling experimental results data gleaned by the Irish contingent. It is to that aspect of the project that we now return.

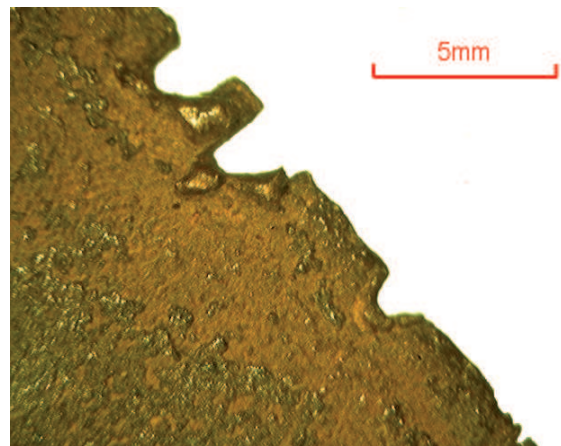
EDGE DAMAGE ON IRISH HALBERDS

Examination of 135 museum specimens in the hand showed that 52 or nearly 40 % displayed evidence for edge damage in the form of notching and/or denting. The table below (fig. 1) summarises the overall situation by halberd type and in addition records the relative level of corrosion present on specimens where no edge damage was recorded.

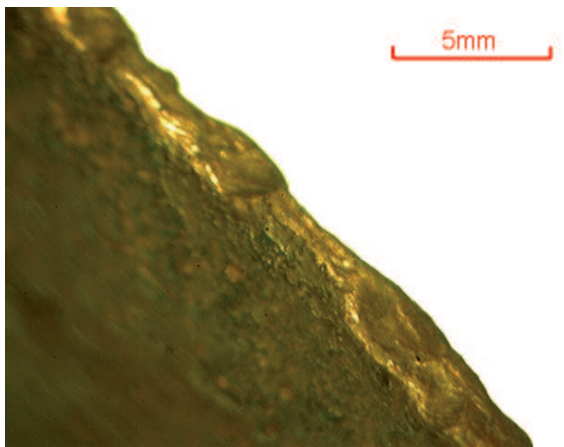
The first thing to be said is that these are minimum figures since many halberds do not survive in good enough condition to allow assessment for this type of damage. As the table at figure 1 shows, 28 of the 80 halberds for which no evidence of edge damage was noted also display medium-to-high levels of corrosion. If we are to allow in some measure for this and express the proportion of edge-damaged halberds as a percentage of those which can be accurately assessed (i.e. excluding those with medium-to-high



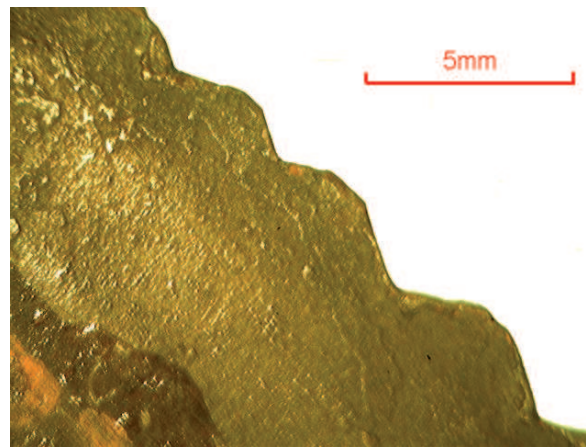
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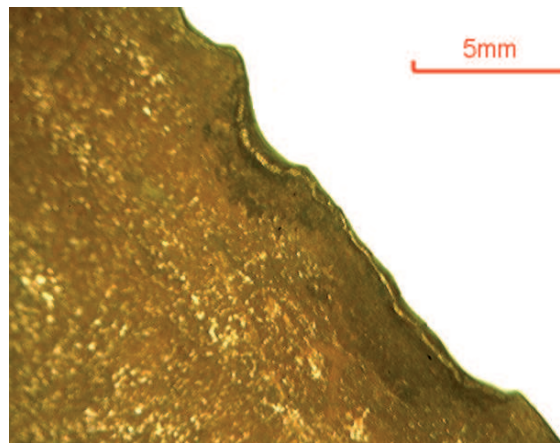
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Figure 3: Damage through impact, v-shaped notching

Figure 4: Damage through impact, u-shaped notching

Figure 5: Damage through impact, denting with a slightly 'hammered' effect

Figure 6: Damage through impact, denting with a serrated effect (halberd, National Museum of Ireland, Ref. W234)

Figure 7: Damage through impact, bowing

levels of corrosion), we might think in terms of just under 50 % of Irish halberds as showing evidence for edge damage. On the other hand, and once again excluding those with medium-to high levels of corrosion, it is equally clear that a very similar percentage displays no evidence of edge damage at all. Whether this means that these were never actually ‘used’ is another matter – it depends very much on the type of use to which the artefact may have been put. For example, the replica halberd employed to test the effectiveness of the artefact on sheep-heads (O’Flaherty 2007a) shows virtually no damage whatsoever, despite having pierced some 20 sheep-heads.

That said, the possibility that some Irish halberds were never put to any utilitarian purpose is strongly suggested by an examination of the way in which impact-damage is represented across the various halberd types, as the chart at figure 2 illustrates. It is immediately apparent that Type Breaghwy halberds are not seeing the same sort of use as other halberds: in fact halberds of this type are three times less likely to present such damage as the next lowest of the halberd types, Type Carn. In this respect, it is worth noting that Type Breaghwy halberds are quite different from the other halberd types – in the first place they are made of bronze, not copper, and appear to be quite late in the sequence (O’Flaherty 2002). Secondly, they tend to be flatter, wider and more weakly hafted than other types and, overall, give the impression of an artefact more concerned with display than utility. The fact that such halberds show so little evidence of the impact damage found on other types might even be regarded as negative evidence in support of the view that its occurrence on other halberd-types does in fact result from their being put to more utilitarian purpose.

The types of edge damage on Irish Halberds

The types of edge damage found on Irish halberds have been described elsewhere (O’Flaherty *et al.* 2008) but for ease of reference are summarised here.

There appear to be three broad categories of impact damage, i.e. notching, denting and bowing. A number of sub-categories can also be identified, but these are easily accommodated within the three broad categories mentioned. Each of these is discussed below in terms of form, breadth, depth, angle, location and association.

Each type is illustrated by an example from one of the museum specimens (all images reproduced courtesy of the National Museum of Ireland).

Notching (fig. 3. 4)

This is one of the classic impact types on Irish halberds and is also observed on later prehistoric sword-blades.² There appear to be two main types on the halberds, i.e. ‘V’ notching, so-called because the profile of the impact is v-shaped, and ‘U’ notching where the profile is u-shaped. Both types of notching can appear anywhere along the blade edges, either at right angles to the edge or at sub-90 degrees, and are often associated together or with denting on the same blade. The first type, V-notching, is strongly suggestive of impact with another blade and this is normally how it would be interpreted on swords. It is almost always deeper than it is wide, with typical depths between 1–6 mm. U-notching, on the other hand, tends to be quite regular in its proportions, e.g. 1x1 mm or 2x2 mm and generally not exceeding 2.5 mm. The regularity of its profile is particularly interesting. Initial examination uncovered no clues as to what might have created this type of impact: where it occurs on swords, experiments carried out by Barry Molloy (2006; 2007) suggested impact on a metal shield rim, but this is not a realistic explanation for such damage on the much earlier halberds. However, the experimental work to be described later in this paper quite unexpectedly provided the explanation which eluded us at this early stage.

Denting (fig. 5. 6)

This category includes quite a wide range of impacts, all of which would generally be described as ‘denting’ of some sort or other. This type of impact tends to be shallow, but generally greater than 1.5 mm in depth, and capable of extending over significant lengths of the blade edge. It can occur anywhere along the blade and is associated on some halberds with V and U-notching. In a small number of cases, the denting can be continuous, extending for up to 125 mm and presenting a slightly ‘hammered’ effect to the eye (fig. 5). In one case (National Museum of Ireland Ref: W234), a series of regular clustered impacts about 1.5 mm deep and 4.5 mm wide on the underside of the halberd presents an almost

² Bridgford 1997; Mollo 2007; Kristiansen 2002; Quilliec 2008.

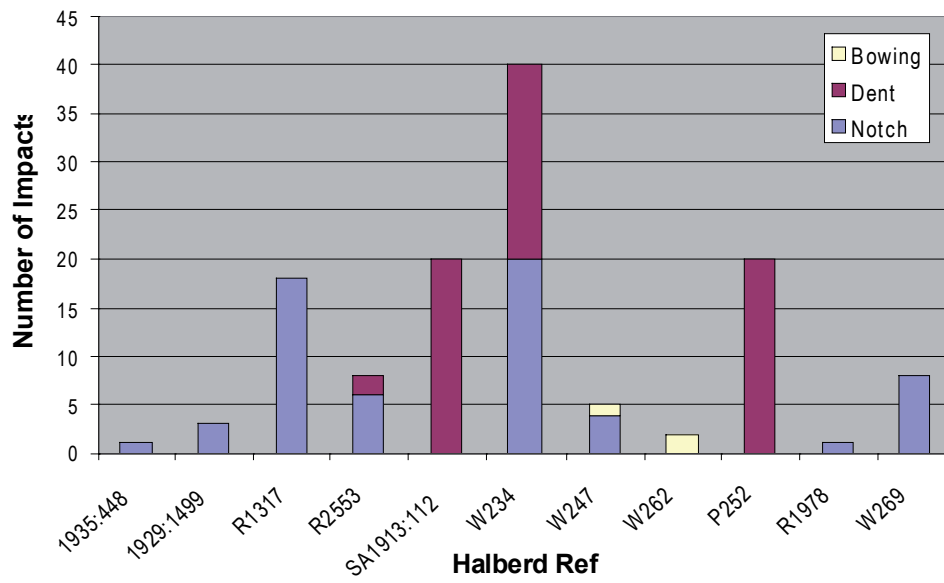


Figure 8: Combination and incidence of impacts on halberds (condensed study-group)



Figure 9: Selection of real and replica artefacts used in the testing. Metal artefacts are shown prior to post-casting treatment



Figure 10: The test facility

serrated effect (fig. 6), extending some 35 mm from just below the hafting-point. The regularity of the damage in this case, and in others, is suggestive of some form of deliberate destruction.

Bowing (fig. 7)

This occurs on a number of Irish halberds and has also been identified on later sword-types. Rather than being notched or dented, the thin blade edge is bent or bowed away suggesting a different type of impact. It is often interpreted as combat damage on swords, and some experimental work has shown that impact on bone can produce this effect (Molloy 2007). Depth is typically 1–1.5 mm, but the area of bowing can extend for as much as 8 mm. To date, on the halberds examined, it appears on the distal half of the blade, on both upper and lower edges.

Combination and Incidence

The chart below (fig. 8) shows the incidence and combinations of the various impact types on the reduced study-group of eleven halberds selected for the characterisation study. It is the authors' intention to extend this analysis of incidence and combination to the wider population of Irish halberds but for the present this chart gives some indication of the likely patterns.

The table at figure 1 showed very clearly that notching was by far the most common form of edge damage, occurring on some 45 % of halberds displaying edge damage. The incidence is higher in the condensed study group as this is made up of halberds selected for the purpose of characterising different types of damage but the combination with denting/bowing at 36 % is strikingly similar to the figure of 35 % obtained for the population as a whole in earlier studies (O'Flaherty 2002).

THE REPLICATION PROCESS

Having characterised the main types of edge damage found on the prehistoric halberds, the next stage in the process was to try to find out just how this damage occurred in antiquity. It was decided to assemble a set of real and replica artefacts from the period, any of which might conceivably have been used in a combat-situation and which were capable of inflicting some form of edge damage to a halberd (fig. 9). A set of experiments was

then designed to see what type of edge damage resulted when each was impacted against the target halberd at differing levels of force.

The only known contemporary metal artefacts from the period that could possibly be considered as a source of impact damage are (a) other halberds, (b) flat axes, or much less likely (c) simple daggers. Accordingly the replica metal artefacts created consisted of five Type Cotton halberd blades, one 'Lough Ravel' type axe, and a simple triangular dagger of Type Corkey. All were cast in copper with additional arsenic added at the rate of 2 % to recreate the quality of arsenical copper used for the vast majority of Irish halberds. The casting work was carried out by B. Rankin of Irish Arms (www.irisharms.ie). Post-casting treatment and edge-hardening was carried out by N. Burrige of Bronze Age Craft in Cornwall (www.bronze-age-craft.com).

A number of real and replica stone axes were very kindly provided by the School of Archaeology, UCD, as it was our intention to test the impact signatures created by contemporary stone artefacts as well. The real axes had already been damaged by sampling under a previous programme, but maintained good cutting edges and were more than sufficient for our experiments.

The final piece of the assemblage was a timber shaft, replicating the deduced proportions of a real halberd shaft (see O'Flaherty *et al.* 2002 for more on this). Our purpose here was to see whether any of the damage which had been observed on the museum specimens might have resulted from impact with a timber shaft, perhaps when a blow was being parried. It was felt that some of the denting which had been observed might conceivably have occurred in this way. Testing the potential of timber to create edge damage on a metal blade would also give some indication as to whether impact with a wooden shield rim should also be considered and if necessary, a replica created for testing.

Post-casting treatment

The edge-hardening of the replica metal artefacts posed a particular challenge as the standard of hardness displayed by the original copper halberds is remarkably high, rivalling some of the best Late Bronze Age work. In order to ensure that these standards would be achieved, experiments were undertaken with one halberd first to identify the process that seemed best able to deliver the required level of hardness. The hardened halberd was delivered to UCD for testing.

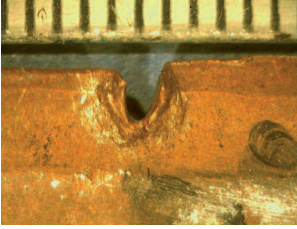
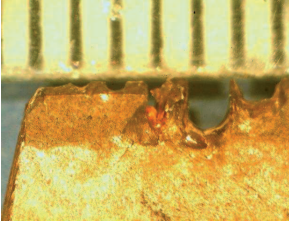
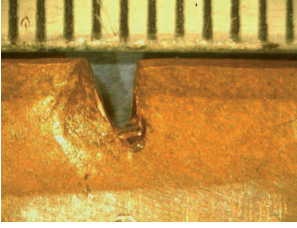
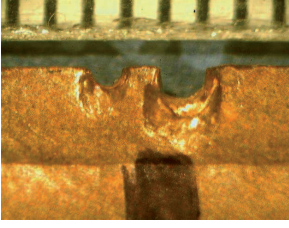
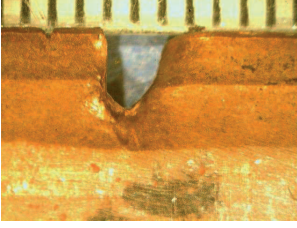
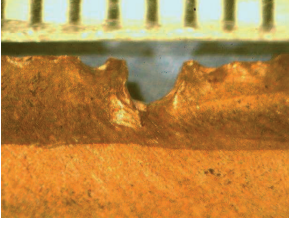
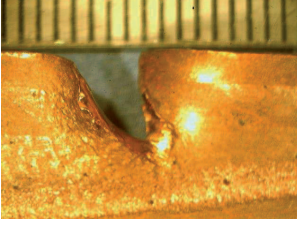
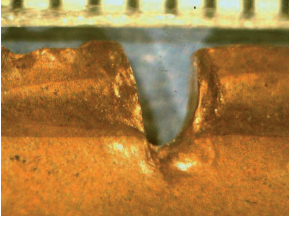
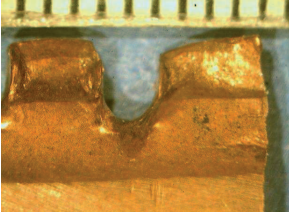
Test Data	Solid Base	Yielding Base
Energy 2 Joule Mass 6.5 kg Velocity 0.79 m/s Swing speed 2.96 m/s		
Energy 5 Joule Mass 6.5 kg Velocity 1.24 m/s Swing speed 4.67 m/s		
Energy 10 Joule Mass 6.5 kg Velocity 1.76 m/s Swing speed 6.61 m/s		
Energy 20 Joule Mass 6.5 kg Velocity 2.48 m/s Swing speed 9.3 5m/s		
Energy 30 Joule Mass 6.5 kg Velocity 3.04 m/s Swing speed 11.45 m/s	No test	

Figure 11: Impacts by Halberd on Halberd

A cross-section was excised by cutting with a water-cooled cut-off wheel. This cross-section was then mounted in resin and prepared for metallurgical examination. Hardness tests were carried out on this cross-section, both in the middle section and near the edge, to determine the effect of work hardening at the cutting edge of the halberd.

In the past, the Brinell hardness test method has often been employed to determine the hardness of Bronze Age artefacts. This method uses a 10 mm hardened steel ball indenter and loads of up to 3000 kg. This method results in very large indentations in the tested material. Furthermore, the results obtained are not independent of load. For the purpose of testing the replica halberds, the

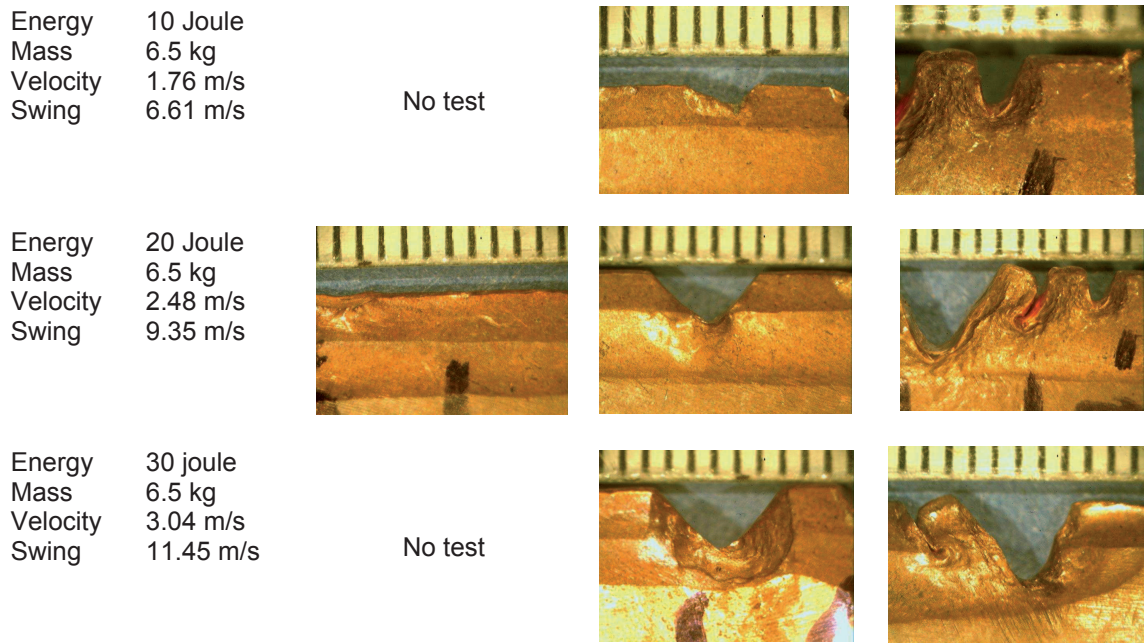
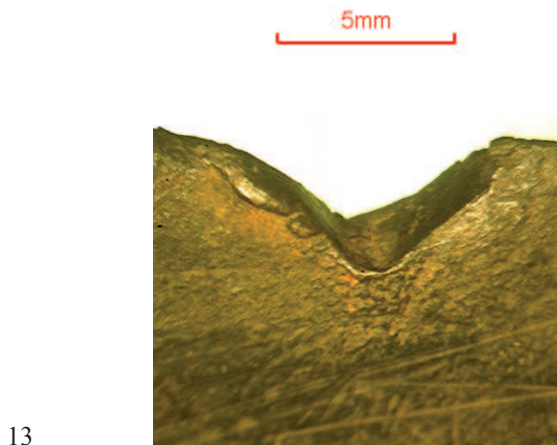
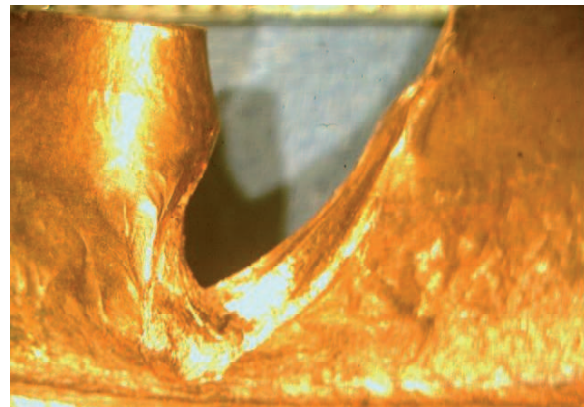


Figure 12: Impacts against other artefacts



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Figure 13: Wide V-notch on museum specimen (Halberd NMI 1935:448 - Impact A)

Figure 14: Massive damage inflicted by full-force halberd-on-halberd impact (102.8J) against a rigid base

Vickers hardness test method was selected, using a pyramidal diamond indenter and a load of 1 kg, as a combination of low loads and very small indentation size enables valid measurements to be carried out very close to the edge of the section. The value of the hardness obtained by the Vickers method is independent of the load employed.

The hardness measurement obtained at the centre of the section in the unhardened

(as-cast) region was 49.0 HV1.0, and near the blade edge, 142 HV1.0. This represents a considerable increase in hardness following post-casting treatment and is equivalent to the hardness levels recorded for Early Bronze Age pieces.³ Having established that this process would deliver the required level of hardness, the remaining metal artefacts were finished to this standard.

³ Penniman and Allen 1960 who recorded that the edge hardness of museum specimens had been increased from

62 HB to 150 HB by cold hammering.

Impact Replication

Having characterised the various types of edge damage and assembled a set of real and replica artefacts for testing, the next step was to design the test-environment. The impact replication was carried out using a Rosand high strain rate test facility, i.e. an instrumented drop-tower impact machine. The basic procedure employed was very simple: the target piece (halberd) was fixed in a vice and then the impacting piece (halberd, copper axe, stone axe, etc.) was allowed drop at various impact velocities (fig. 10). Previous experimental and computational work by one of the authors had analysed similar impact scenarios but involving biological tissue (McCarthy *et al.* 2007 and forthcoming). The resulting edge damage was recorded against each of the relevant velocities, with force calculated as a function of impact energy, and the velocity and mass of the impactor. The impacts were designed to correlate levels of energy against observed damage on the halberds which, in turn, was compared directly against that found on the museum specimens.

Due to the large carriage mass of 6.5 kg, the Rosand-rig operates at lower than actual impact velocities, but the results achieved were validated using a separate and independent wire-guided drop test rig, which operated on actual impact velocities and which confirmed the Rosand-rig results as accurate.

The integrated instrumentation on the Rosand test machine provided more complete data than could be obtained solely from this wire guided rig and it is for this reason that the following results are based on this more accurate data. In order to allow the maximum number of tests, the halberds used were chopped into a series of segments and mounted separately, as required.

Initial tests were carried out with the target piece fixed upon a solid, unyielding base which resulted in very serious levels of edge damage at quite low levels of force. Such an environment is highly unlikely to occur in a combat situation, where the target would be expected to yield with the blow of impact, but would not be inconsistent with what might be expected of deliberate destruction. The results obtained are accordingly of interest in terms of considering deliberate destruction as a source of edge damage. However, in order to better represent a combat environment, the test environment was redesigned to incorporate a foam-cushioned base to allow the target piece to 'yield' somewhat with each blow.

The results obtained are shown in the two tables below at figures 11 and 12. The first table

shows the results for halberd-on-halberd action, while the second table shows the edge damage resulting from impact with other artifacts.

The effect of allowing some degree of 'give' in response to the blow is immediately apparent in the halberd-on-halberd results. Although different zoom-imagery has been employed in order to record the damage to best effect, the scale bar – which represents millimeters in every case – clearly shows the much deeper and broader impact damage occurring when the target piece was not allowed to yield at all. It should be noted that the images reproduced here represent just a sample of those taken: each test was carried out a number of times, and the resulting damage recorded in each case. The samples reproduced here are representative of the type and scale of damage occurring.

An equivalent 'swing-speed' for an actual halberd in use is also given for each test: thus, for example, a force of 2 joules is equivalent to a halberd swing of just under 3 m/s, which is quite slow and certainly too slow to indicate combat use. However at 20–30 Joules of force, the equivalent swing-speed is between 9–11 m/s: a reasonably fast but measured blow.

As regards the effect of impact by other artifacts, tests at the lower levels of force produced little evidence for damage, so only the results of tests taken at higher levels of force are reproduced here. No tests have as yet been undertaken using the small dagger, as it proved difficult to imagine (and therefore reproduce) the circumstances where such an artifact might have been brought into play with a level of force which might actually damage a hardened halberd blade. A dagger is used at close-quarters, in a stabbing or cutting action. Without the leverage, reach and added weight of a shaft of some length, it is difficult to see how a dagger could be employed against a halberd in circumstances which would result in the type of damage observed on the museum blades. However, we continue to reflect upon this point.

DISCUSSION

The results of the various tests proved most informative. There is no doubt that the most common form of edge damage observed on the museum specimens, i.e. notching, was regularly reproduced by a halberd-on-halberd action. What was even more interesting, and completely unanticipated, was the fact that both V-notching and U-notching were created in this way. All that was different was the environment. In a yielding environment, the blade-edges moved slightly on impact, creating



Figure 15: Penetration by halberd of sheepskull during on-site trials

that characteristic u-shaped profile found on so many of the museum specimens. There was no need to seek an artifact with a u-shaped profile as the source of this type of damage (such as a hypothetical shield-rim): it results from impact with a sharp-bladed halberd in circumstances where both are in motion. On the other hand, the deeper V-notching seems to occur when both blades are held more rigidly and where there is therefore less scope for lateral movement. Overall, the edge damage observed on the museum specimens seemed best reproduced by impacts at energy levels of between 20–30 joules.

A second, and once more completely unanticipated result, was the realization that the ‘double-impact’ signature observed frequently on museum specimens and consisting of two (or sometimes more) closely grouped notches (generally u-shaped), was also reproduced when two halberds were struck in a yielding environment. Examples of these can be seen in the halberd-on-halberd table (fig. 11), at force levels of 5 and 10 joules. Each of the tests represents a single ‘drop’ through the apparatus, and this double-impact signature is created when the impactor rebounds to strike again rapidly, but at less force, close to its original impact.

Turning to look at some of the other artifacts, it is clear that the copper axe can also deliver

a deep V-notch, but this is of a wide-mouthed type that was not created by the halberd-impactors. The polished stone axe also delivers a wide-mouthed notch, which is less angular than the copper axe, but again quite unlike anything created by the replica halberd-impactors. This type of wide-mouthed V-notch is found on some of the museum specimens (see fig. 13 for an example) and as our tests seem to rule out impact with another halberd as the likely source, the real possibility exists that we are looking at impact with an axe, whether that be stone or copper. The actual specimens displaying this type of damage would have to be re-examined to see whether this represents some form of deliberate destruction rather than combat, but the instance reproduced at figure 13 would not seem to fall into that particular category.

The timber-shaft was quickly ruled out as a possible source of edge damage. Bowing or denting had been considered as possible results, but in fact the blade edge showed practically no damage whatsoever from impact with the timber shaft, even at a force of 20 joules. Damage to the shaft, on the other hand, was considerable, comprising of deep cuts into the timber.

In fact, none of the tests reproduced the type of denting or bowing found on the museum specimens, apart from some impacts against

Test No.	Drop height (cm)	Penetration (mm)	Velocity (m/s)	Force (N)	Impact Energy (J)
1	253	35	5.41	1388	32.28
2	215	17	4.54	1454	22.73
3	155	13	3.95	2363	17.21
4	126	0	3.76	883	15.59

Figure 16: Test results for halberd impacts on sheep heads

the sides of the stone and copper axes. Impact against bone is another possibility for bowing in particular, and the project-team are examining its options in this regard. Practical experiments with replica swords of the Late Bronze Age indicate this as the source of bowing observed on sword-edges (see Molloy 2007) so there is every possibility that this may prove to be the case also for the halberds. Certainly none of the other options examined to date seem to answer.

In terms of considering deliberate destruction as a possible source for edge damage on Irish halberds, the hypothesis seems unlikely. Our experiments indicate that a forceful, swinging blow – such as might be imagined should one attempt destruction of the artifact by striking it off something else – would produce much higher levels of edge damage than are observed on the museum specimens. Similarly, should the halberd be placed on a rigid base and then struck forcefully with another object, again our experiments show that the resulting edge damage would exceed anything observed on the Irish halberds to date. By way of illustration, figure 14 below shows the effect of hitting one halberd against another on a rigid base at a force of 102.8 joules – a swing speed of 17.8 meter per second, which would represent a full force blow by a six-foot man. The resulting edge damage is substantially deeper and wider than anything observed on surviving museum specimens.

This is not to say that no Irish halberd was the subject of deliberate destruction. On the contrary, it is possible to identify a small number whose condition is strongly suggestive of deliberate destruction of some sort prior to deposition. However, these are unusual: the vast majority of Irish halberds either display the sort of small-scale edge damage discussed already, or display no edge damage at all

A lethal level of force

Having established that the most likely source for the most of the impacts observed on the museum specimens was impact with another halberd, the

last remaining question to be answered was whether the level of force associated with those impacts constituted a ‘lethal’ level of force. If it did, then all the evidence would point towards the use of halberds in some form of combat situation; if it did not, and while not ignoring the anthropological evidence for sub-lethal forms of combat, it simply could not be said with any degree of certainty that the impacts observed on the museum specimens had resulted from combat use.

In order to establish the lethal capacity of the force-levels in question, one further test was conducted. On 17th June 2010, a team led by the second-named author returned to ICM Camolin, the sheep-killing plant in Co. Wexford, Ireland where the original trials which gave birth to this project had been carried out back in 2002. Once more, freshly killed sheep-heads were selected for the tests, these providing reasonably good parallels for human skulls in terms of bone thickness (if anything, being slightly thicker). The halberd blade was fixed in a movable rig designed by UCD which allowed similar data-capture to what had been achieved in the laboratory. The halberd was then allowed drop on the sheep skulls at differing levels of energy equivalent to those which had been identified as responsible for the impact damage on the museum specimens (fig. 15). The results are shown in the table below (fig. 16)

It will be recalled that that the laboratory tests had shown that the impact damage present on the museum specimens had most likely been caused by impact with other halberds and energy levels of between roughly 20–30 Joules. The results clearly show that this level of energy routinely results in penetration of the skull: in other words, it is a potentially lethal level of force.

CONCLUSIONS

What conclusions can we draw from all this about the way Irish halberds were used in the past?

It has been shown already by one of the authors (O'Flaherty 2007) that the Irish halberds

were certainly capable of being used with lethal force. In tests using the heads of freshly-killed sheep, a replica Type Cotton halberd repeatedly pierced the skulls of twenty separate animals, and gave no indication that it could not continue doing so indefinitely. The halberd itself suffered no damage and was easy and effective to handle. The comments traditionally made about the unwieldy nature of the halberd as a weapon and the weak hafting technique are simply not supported by the evidence. There is no doubt that the halberd could have been used very effectively as a weapon and need not be considered as ceremonial in nature.

The next question to be asked was whether these halberds had in fact been so used. The evidence would seem to suggest that some were and some were not, in roughly equal proportions, but probably with some differentiation in terms of halberd type. Certainly, the later Breaghwy types seem much more likely to have served a ceremonial or display purpose, having very light rivets and displaying practically none of the edge wear found on other halberd types.

As regards the edge wear itself, our experiments show that the type of impact observed on the museum specimens is best reproduced by halberd on halberd action. Halberd on halberd action is capable of reproducing both V and U notching, which are by far the most common types of impact damage occurring on the museum specimens. The experiments also strongly suggest that this took place in a 'yielding' environment, best imagined by both weapons being held in the hand. In terms of force, the morphology of the impacts observed on the museum specimens was best reproduced at energy levels of not more than 30 joules. This equates to an average swing speed of not more than 11 meter a second. This is a 'reasonable' speed, indicating a high degree of control, but the question remained as to whether this amounted to a 'lethal' level of force, consistent with use in a combat situation. A specific test was designed to answer this question and this showed, unequivocally, that the levels of force involved are indeed sufficient to penetrate the skull. If we return to that legal precept referred to at the start of this paper, that 'force goes to intent', then it would seem that some at least of these Irish Early Bronze Age halberds were indeed intended to hurt, maim and kill. It is a sobering thought that amongst the very first artifacts that humans in Western Europe chose to make from metal was an object which apparently could be used for one purpose only, and that was the killing of other humans.

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