Investigating the manufacturing technology of later Iron Age torus torcs

Tess Machling and Roland Williamson

ABSTRACT: Recent work (Machling and Williamson 2016; 2018; 2019) has identified a previously unrecognised method of sheet-working manufacture for many British gold alloy torus torcs. It was thought terminals were cast onto the neck-ring wire using a lost wax process, however, research has shown that, in addition to sheet terminals, there are two casting methods used for torus torc terminals – those that are separately cast and those that are directly cast-on. Recent X-radiography proved the Newark torc terminals to be of cast production but with elements of sheet/hammered technology and this new evidence is presented here. This paper examines the manufacturing of gold torus torcs and revises the understanding of their distribution, arguing for the origins of the sheet metal tradition beyond East Anglia. It is proposed that cast torcs are copying sheet-worked designs and this attempt at creating something designed to be made using a different technology proved unsuccessful.

Introduction

Torcs are a well-known and easily recognised form of Later Iron Age ornament. Traditionally assumed to be worn around the neck, smaller examples from, for example, Towton (Joy 2010), Leekfrith (Farley 2017; Farley *et al* 2018) and Netherurd (Feacham 1958) may suggest that some were worn as bracelets/armrings. They occur in a number of forms, including those with tubular or twisted bar/wire neck rings, and exhibit a range of terminal forms, including buffer, cage, ring (torus), loop and reel. Although found across continental Europe, they appear to have gained popularity in the British Isles where, of the 276 complete torcs identified by Hautenauve (2005) as having been found in Europe, around a third originate from the British Isles rather than the Continent. The biggest assemblage of torcs from Britain, some 60 complete examples and the remains of perhaps 158 more (Joy 2018, 3), were found between 1948-1991 within the 'Gold Fields' of Snettisham in NW Norfolk (Brailsford 1951; Joy 2016; Longworth 1992; Clarke 1954; Sealey 1979; Stead 1991). In addition to the site of Snettisham, other East Anglian torc finds include Sedgeford (Brailsford 1971; Hill 2004), North Creake (Clarke 1951), Ipswich (Brailsford and Stapley 1972; Owles 1969 and 1971), Bawsey (Maryon 1944), the SW Norfolk torc (Norwich Castle Museum and Art Gallery 2018), Middleton, Narford, Marham and East Winch (Hutcheson 2007) (Fig 1).

Beyond East Anglia torc finds are less frequent, although there are finds from as far afield as, for example, Clevedon in Somerset (Jope 2000, pl 120); Hengistbury Head (Bushe Fox 1915) and Spettisbury (Hawkes 1940) in Dorset; Glascote (Painter 1969-70), Needwood Forest (Hawkes 1936) and Leekfrith (Farley 2017; Farley *et al* 2018) in Staffordshire; Newark (Atherton 2016; Hill 2005) in the Midlands and Rawdon Billing (Whitaker 1816) and Towton (Joy 2010) in Yorkshire. In Scotland, the Netherurd (Feacham 1958) and Blair Drummond (Hunter 2010; 2018) hoards, and torc finds from Auldearn (Hunter 2014) and Deanburnhaugh (Hunter pers comm) would suggest a nationwide distribution.

The torcs under study are torus torcs, most famously represented by the Snettisham Great torc and the

Grotesque, Newark and Sedgeford torcs and Netherurd terminal (Fig 2; Table 1). A torus torc is a torc with 'doughnut', torus-shaped, hollow terminals. Traditionally assumed to have been produced in the 3rd-2nd centuries BC (Garrow *et al* 2009), recent work has suggested that the origins for torcs such as the Great torc, Netherurd and Newark torcs may lie in the earlier 4rd century BC (Machling and Williamson 2019). The Grotesque torc may be even earlier (Joy 2016, 248).

The terminals of these torcs fall into three categories:

- High craft quality gold alloy, sheet-worked torus torcs
- slightly lower craft quality gold alloy torcs with terminals cast separately and then attached, and
- poor craft quality torcs, in lower percentage gold, silver and bronze alloys with directly cast-on terminals.

The first, sheet-worked, category includes the Netherurd terminal, the Snettisham Grotesque torc, the Snettisham mini-Grotesque torc and the Snettisham (Hoard L), L20 torc. The second category is represented by the Sedgeford torc and, as has only recently been recognised, the Newark torc. The third category is represented by the Hengistbury Head and North Creake terminals, the SW Norfolk torc and any number of the Snettisham low-quality gold, silver and bronze alloy torus torc terminals which were directly cast on to the wires.

This paper will detail the methods used to produce the gold sheet-work torcs and, by comparing them with separately cast and cast-on terminal torcs and metal artefacts from other areas of the UK, will examine the possible origins of each method in the British metalworking traditions of later prehistory. It will further explore the implications of these results for our understanding of the later Iron Age in the British Isles.

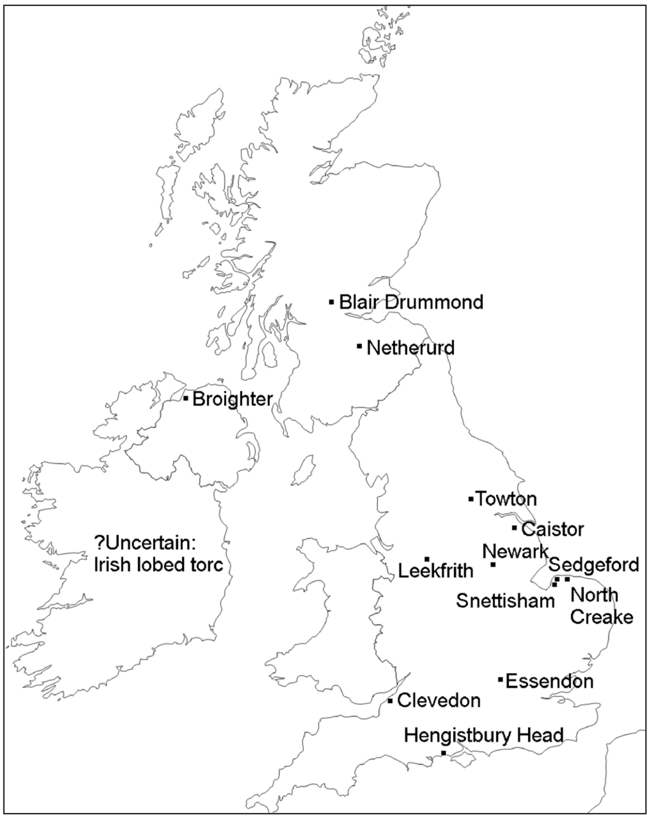

Figure 1: Sites mentioned in the text.

Sheet-work terminals: weights and components

Gold sheet-work torus torcs are composite pieces created from a number of components. In the case of the Snettisham Great torc, for example, the torc comprises

Table 1: Torcs and other items mentioned in the text.

Torc name	Museum Accession number(s)
Caistor/West Lindsey	LCNCC : 2015.36
Clevedon	BM AF.412
Hengistbury Head	BM DR.101
Leekfrith hoard	2018.LH.10.1; 2018.LH.10.2; 2018.LH.10.3; 2018.LH.10.4; 2018.LH.10.5
Netherurd terminal	NMS X.FE 46
Netherurd 'globules à la croix'	NMS X.FE 47-48
Newark	NEKMS 2006.70
North Creake	NWHCM: 1949.97
Sedgeford	BM 2005,1103.1 & BM 1968,1004.1
Snettisham Great torc (Hoard E)	BM 1951,0402.2
Snettisham buffer terminal (Hoard E)	BM 1951,0402.3
Snettisham Grotesque (Hoard L)	BM 1991,0407.37
Snettisham mini-grotesque (Hoard F)	BM 1991,0501.45
Snettisham bracelet (Hoard E)	BM 1951,0402.4
Snettisham Hoard L: L20	BM 1991,0407.38; 1991,0407.38
South West Norfolk torc	NWHCM : 2005.218
Towton	YORYM 2011.300; YORYM 2013.1017

BM: The British Museum. LCNCC: The Collection, Lincoln. LH: Potteries Museum and Art Gallery, Stoke-on-Trent. NEKMS: National Civil War Museum, Newark. NMS: National Museums Scotland. NWHCM: Norwich Castle Museum. YORYM: Yorkshire Museum.

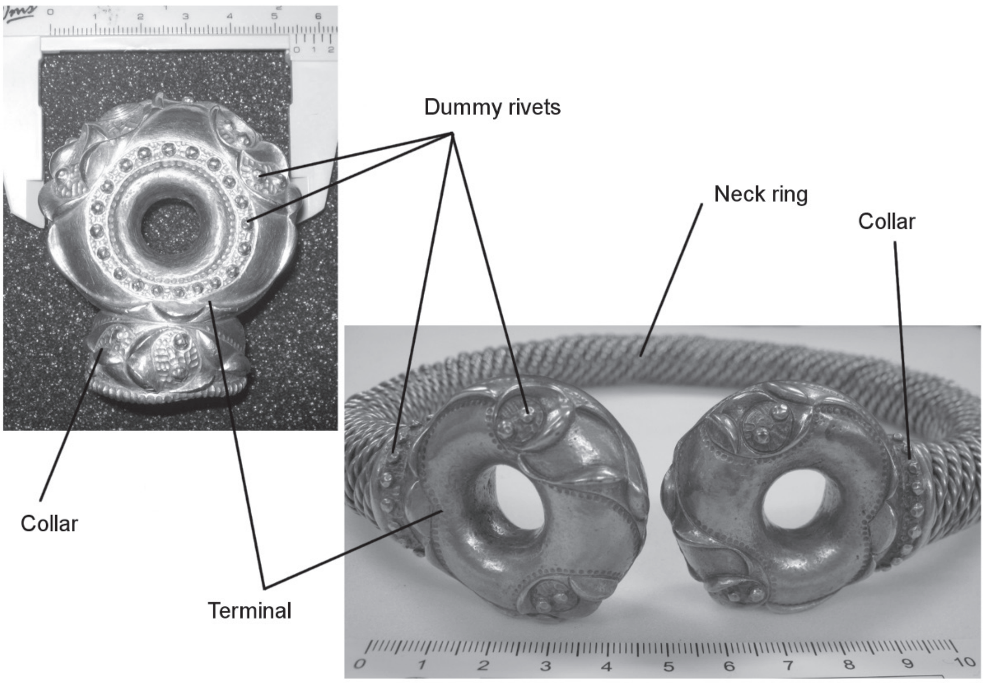

Figure 2: Left, the Netherurd terminal (NMS X.FE 46) and right, the Newark torc (NEKMS 2006.70), showing elements mentioned in the text. Minor scale divisions in mm.

64 individual wires and two terminals, created from at least three pieces of sheet gold each, making a total of at least 70 components. By comparing the weights of both the detached Netherurd terminal, and the complete Great torc, a number of insights can be gained. The Netherurd terminal, which is 61.6mm high, 52.9mm wide and 28.6mm in deep, is comparable to the Great torc terminals, which are 63.9mm high, 54.1mm wide and 29.1mm deep. The Netherurd terminal weighs 114g and the complete Great torc 1084g.

The Netherurd terminal, although previously attached to a now lost neck ring (Machling and Williamson 2018, 4) has very little remnant attachment material and, as such, is a close proxy for a terminal as it would have been when first made, prior to attachment. As such, with the Netherurd and Great torc terminal dimensions so similar, though their relative metal thicknesses are unknown, we estimate that each Great torc terminal weighed approximately the same as Netherurd, *ie* 114g. This would give a total weight of 228g for both Great torc terminals, and would leave a further 853g for the neck ring, or 13.3g per wire.

Interestingly, this approximates to a ratio of 1:8 of single terminal weight to total wire weight, and of course 1:4 for total terminal weight to total wire weight. These numbers of fours, eights and twos are echoed in wire numbers which are frequently wound in groups of two (*eg* Sedgeford), four (*eg* Newark, Ipswich No six and the Grotesque) and eight (*eg* the Great torc, Netherurd, Newark, Sedgeford, Needwood Forest and the Grotesque). In addition, all the Ipswich torcs show an eight-sided hammered profile in the neck rods (Owles 1971) and there are eight dummy rivets on the Hengistbury Head terminal (Bushe Fox 1915). Gwilt *et al* (2005, 52) have recognised similar numbers and ratios in the way the Late Bronze Age Rossett gold bracelet was cut up, which in turn relates to the division of other gold items within hoards from Wales. Many of the gold items within these hoards had been divided to conform to 1:2:4:8 ratios and Gwilt goes on to suggest a continuation of this practice into the final Iron Age/early Roman period within hoards such as the Winchester hoard (Gwilt *et al* 2005, 52).

To return to the torc components, each piece, weighing between *c*13g for wires and a three-part division (core, torus and collar) of *c*114g per terminal would be of a size to be easily melted in the small gold-melting crucibles found at several sites across Britain (Bayley 1992, 317). The mass of gold alloy used per torc is actually surprisingly small and would fit comfortably into a hand. For example, the amount of alloy used to create the entire Great torc is a cube no bigger than *c*42 x 42 x 42mm. In the case of the Newark torc, a cube of *c*33 x 33 x 33mm would be all that was needed. To make the Netherurd terminal, a cube some 19 x 19 x 19mm would be sufficient. The least amount of gold alloy went into the Mini-Grotesque torc terminal from Snettisham, a tiny cube of only 11 x 11 x 11mm, testifying to the extreme thinness of the terminal wall.

Making the torcs

Sheet-work torcs

It is likely that the torus torcs started life as ingots, or were perhaps directly worked from crucible 'puddles'. In the case of the sheet needed for the terminals, either bar, ring or flat circular ingots of the type found in the Snettisham (British Museum 1992,1202.3, 1991,0501.172 and 1991,0501.72) and Essendon (British Museum 1994,0401.2, 1994,0401.41, 1994,0401.42 and 1994,0401.3) hoards, would be possible starting material. For wires, these ingots would have been hammered to the appropriate length (Meeks *et al* 2014, 149).

In the case of terminals, a number of different possibilities exist. For sheet-work torus torcs, at least three components went into making each terminal. These comprise the torus, the central 'apple core' shaped core and the collar (Fig 3). For the torus, discussions with goldsmiths suggest that there are four ways that this could be achieved (Machling and Williamson forthcoming). For the first, the torus was made from a rectangular sheet of gold, curved into a cylinder (Fig 4). The core, made by a similar method to the torus cylinder (Fig 4) was then inserted and the torus closed, seamed and sealed as a whole. Following this, the collar – made from a tubular section which was possibly raised – could be attached and the terminal fitted to the wire neck-ring. This method appears most practical and allows an easier means of inserting the core than would be possible with the second method below, although the absence of apparent seams around the body of the terminal makes this method unlikely according to current evidence.

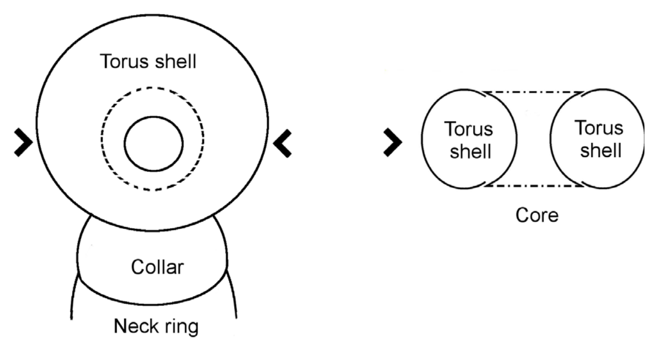

Figure 3: Left, diagram showing elements of a torus torc terminal; right, cross-section through the hollow terminal.

The second method would involve the production of a raised hollow tube (or made from a rod ingot with a longitudinal pierced central hole being increasingly widened along its length) which was then curved inwards along both edges to form a 'doughnut' torus shape. The tubular core was then inserted into this, the core ends curved and the torus sealed. Then the collar was attached and the terminal attached to the wires. This method seems most likely and fits the evidence that can be seen visually on the Snettisham Grotesque and Great torcs and on the interior of the Netherurd terminal.

The third method, suggested as a possibility by Julia Farley (pers comm), is that the entire terminal was raised from a single piece as a balloon shape with the terminal central hole punched through before the core was inserted and the terminal sealed. However, the separate addition of the collar that can be seen in the Netherurd terminal and the Snettisham Great, Grotesque and Mini-Grotesque torcs and which – in the balloon method would be part of the original shape – makes the balloon method less probable.

A fourth method, involves the seaming of two torc shell halves with minimal dotted solder to hold the two pieces together on the interior of the core (Fig 5). However, on the exterior of the torus, the join is invisible. Only after the two shell halves have been joined was the collar added. This method has only so far been identified in the Snettisham Mini-Grotesque torc.

It is likely that the core and collar were fashioned by a similar method to the torus, from tubes that were then

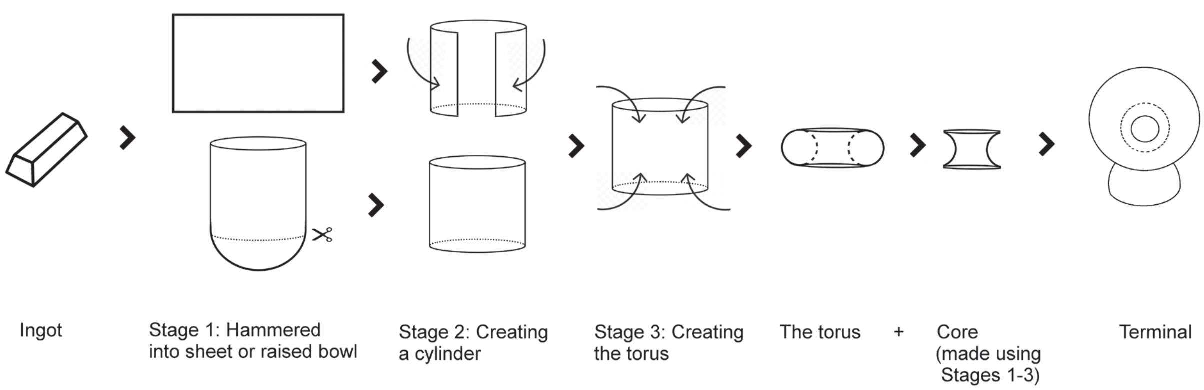

Figure 4: Two possible methods of creating a torus torc: from a sheet (above), or raised bowl (below).

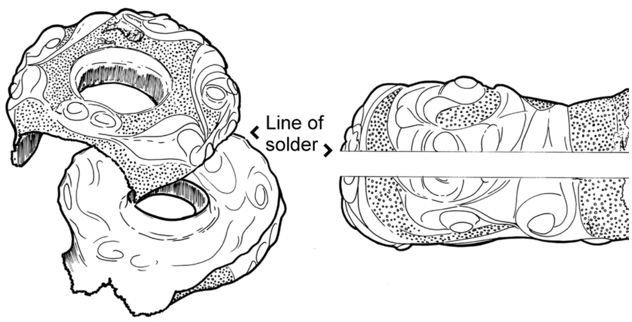

Figure 5: Illustration of the half and half method used to create the Mini Grotesque torc from Snettisham (BM 1991,0501.45). Terminal length 44mm.

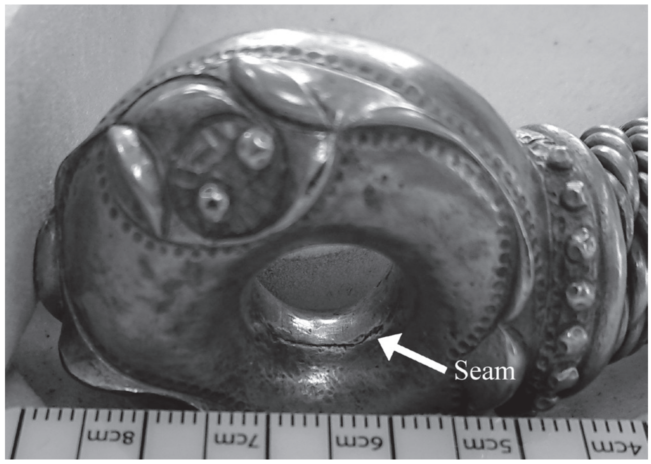

Figure 6: Seam on the interior of the Newark torc terminal core. Minor scale divisions in mm.

expanded and/or flared. Evidence suggest that the torus, collar and tube had thinned edges, seen in the cracking of the core sheet margins in the Snettisham Great torc, and which may have allowed for easier joining of the gold sheets (see below).

Cast terminal torcs

For cast terminal torcs there seem to be several methods utilised: the most common, and least successful, is the lost wax – directly cast-on terminal – method described by Meeks *et al* (2014, 151). However, this method does not seem to have been used for high craft quality gold torcs, but only for lower quality gold, silver and bronze alloys. The method used for higher quality gold cast terminals, such as Sedgeford and Newark, involves the lost wax casting method described by Meeks but achieved, not by casting-on, but rather by the separate casting of each individual terminal.

Newark and Sedgeford are the first examples of torus torcs to have been identified where a terminal was cast separately then soldered onto the wire neck-ring. In the case of the Sedgeford terminal this casting appears to have been carried out in a single process but with Newark there is an intriguing blend of cast and sheet elements which appear to demonstrate the use of a three stage method which prevented the cast from faulting.

New information regarding the Newark torc

In a recent paper (Machling and Williamson 2018) the Newark torc was identified as having sheet-worked gold terminals. However, following a 450kV X-radiograph carried out at GE Inspection technologies in September 2018, it has been recognised that this interpretation was incorrect and that the torc terminals instead show a hybrid of casting and other techniques more often seen in sheet-work/hammered torcs. Therefore, a short intermission to examine how this mis-attribution came about is necessary.

The Newark torc has been closely examined on a number of occasions and from visual examination showed a number of characteristics typical of a sheet-worked gold torc. These include the torc being of high quality gold; the terminals not having been cast on (evidenced by the 'clean' and unaltered nature of the gold in the vicinity of the collar/wire junction) and, in addition, there is definite external evidence of seams, albeit narrow, where the core apparently joined the terminal torus (Fig 6). Such evidence was seen on the sheet-work Netherurd, Great and Grotesque torcs. Although not diagnostic, the terminal was also hammered all over – a technique not seen in any other cast terminal torcs (including its nearest cousin, Sedgeford, where hammering only occurs over a small area of terminal repair).

In addition, the close similarities with Netherurd, in terms of form, decoration and identical tooling patterns – evidencing the same maker/finisher – led us to believe that it was a sheet-worked sibling (Machling and Williamson 2018). Clinching the interpretation was XCT (X-ray computed tomography) carried out at the National Physical Laboratory (NPL) in Kew in March 2017. This XCT showed what appeared to be hollow relief decoration which would be typical of repoussé sheet-working and almost impossible to cast. However, when examined under the high powered (450kV) X-radiograph and XCT it soon became apparent that the NPL XCT was producing misleading results (due to X-radiography artefacts caused by the density of the gold and limited available length of the scan).

The September 2018 X-radiograph gave a much clearer picture of the torc and showed that the relief was not hollow on the interior, but solid, and revealed an internal flat profile to the terminal walls far more typical of casting (Fig 7). However, it was also very clear that the

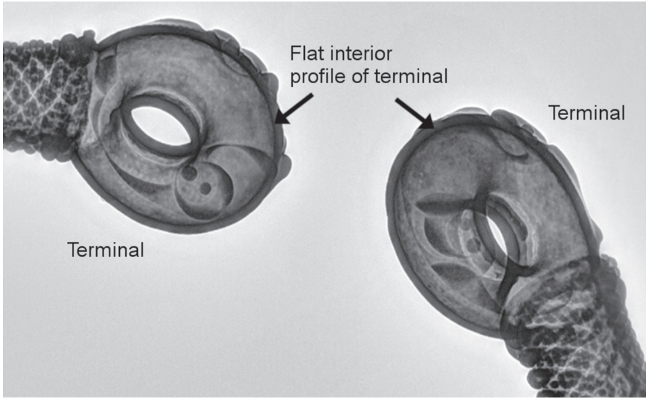

Figure 7: X-radiograph of one of the Newark torc terminals showing their smooth interior profile. Terminal length 49mm.

terminal was not cast-on, but cast separately and then carefully finished before being joined to the wires.

The Newark torc, identical in size and form to the Sedgeford torc, has two obvious differences: it has seams running around the central core hole (Fig 6) and a central aperture which is 2mm wider than that in the Sedgeford terminal. As mentioned above, the seam was initially thought to be indicative of sheet-work construction of the type seen in the Snettisham Great torc and the Netherurd terminal. However the X-radiograph (Fig 8) showed that this feature was in fact a ring of gold alloy, added to fill a deliberate gap in the vicinity of the torc core casting. This ring was probably added through the neck of the torus and then fixed before the collar was added. This feature can be seen on both of the Newark terminals and has been executed so precisely that we believe it to be a deliberate constructional feature, rather than a repaired fault. The reasons for this addition appear

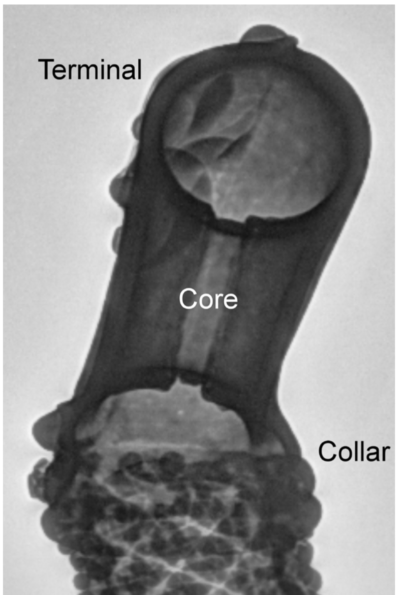

Figure 8: X-radiograph cross-section of the Newark torc terminal showing added core. Terminal length 49mm.

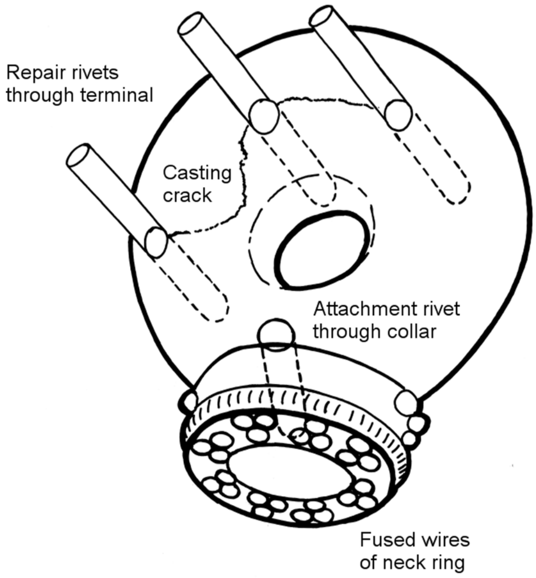

Figure 9: Composite illustration of the Sedgeford torc terminals (BM 2005,1103.1 and BM 1968,1004.1) showing the repaired casting crack, and fused neck ring wires.

twofold: firstly, this gap would have allowed access into the interior of the cast torus which might be of benefit during the decorating process and secondly, most importantly, as a means of preventing the torus from cracking during casting. This gap in the cast would have allowed room for contraction/expansion of the molten gold during cooling and so would prevent cracking of the type seen in the mis-cast Sedgeford terminals (Fig 9).

In many torcs, including the Sedgeford torc and many of the Snettisham examples, evidence of casting cracks can be seen. These cracks have sometimes, as on the Sedgeford torc (Fig 9), been intricately repaired using rivets and infilling gold. The cracking, and subsequent repair, can also be seen on other Iron Age cast items, for example horn-caps, and as Spratling (1972, 256) notes, ‘it was evidently considered preferable to repair the fabric by running in additional metal than to attempt a re-casting’. However, the Newark torc terminals are unique amongst all other known hollow cast terminals in that there are no cracks or faults in either terminal. We propose that for the Newark torc the mould was deliberately made in such a way that it created a gap in the casting of the torus to circumvent the problems seen on other torcs and that this unusual method indicates two very different levels of torc goldsmithing in the British Iron Age: with craftsmen highly skilled in a range of gold-working techniques using them to produce precision gold-work in both sheet and cast techniques (*eg* Netherurd and Newark) and those, less skilled, who could produce cast torcs, albeit faulty ones (many of the East Anglian torcs).

It would appear that casting was being used to copy sheet-work torcs. But it also seems that the casting technique could have been utilised by skilled goldsmiths, versed in both sheet and cast working, when gold quality was insufficiently good to allow for sheet-working (*eg* in the Newark torc) or, perhaps in the case of the East Anglian torcs, when the sheet-working skills needed to carry out a Netherurd/Great torc style terminal were not present in a region and so casting became the only option available (Machling and Williamson 2018, 400).

Evidence of manufacturing method

Evidence of seams where the sheets of gold were joined are visually obvious within the Netherurd (Fig10) and Grotesque torcs (Meeks *et al* forthcoming). In the case of the Grotesque torc an X-radiograph (by Janet Ambers, Department of Scientific Research, British Museum) on display in Room 50 of the British Museum, clearly shows evidence of an overlap of sheet between the torus and core. In addition, evidence of an overlapped join between each terminal and the collar is visible. In the interior of the Netherurd terminal, the joint between the core and torus shell is prominently visible and a thickened ridge of material along the interior of the terminal-collar join would suggest an overlap in the sheets at this point (Fig10).

In addition, there are a number of other tell-tale signs of sheet-work manufacture: these include dents (seen on the Snettisham Great torc) which point to a thinness of terminal wall unlikely to be possible to achieve in casting, hammering/planishing marks on the interior and exterior (as seen in the Netherurd terminal and on the exterior of the Great torc), evidence of repoussé/relief work on the interior of Netherurd (Fig 9), fine

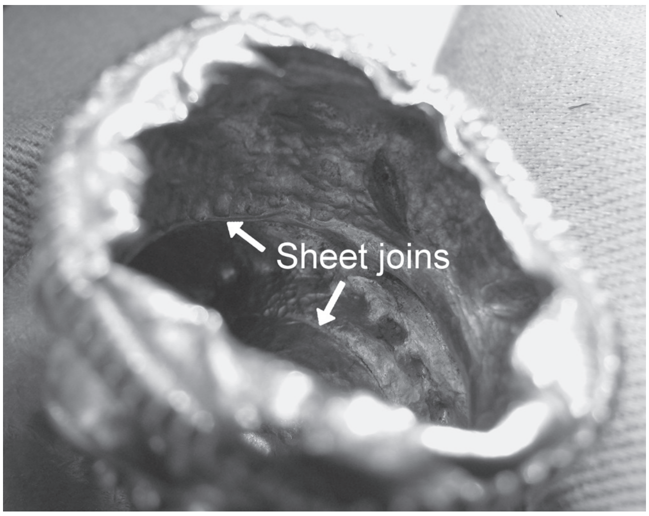

Figure 10: The interior of the Netherurd terminal showing sheet joins. Aperture width 23.5 x 21.5mm.

cracking caused by overworking of the gold (visible on the Great torc and on Netherurd) and, in addition, weight. The Netherurd terminal, which measures 61.6mm x 52.9mm x 28.6mm, weighs 114g, whereas the detached Sedgeford terminal, which is much smaller (50.8mm x 43mm x 20.3mm), weighs an equivalent 117g; Netherurd is thinner sheet and Sedgeford thicker cast. The mini-Grotesque from Snettisham is the extreme of the sheet-working technique, with measurements approximately equivalent to Sedgeford (44mm x 43mm x 15mm), and yet which weighs only 22g.

In the case of cast torcs, bubbles can be seen in the casting on Sedgeford, and hammering/planishing is almost entirely absent, except in small areas where gold has been added to cracks in the cast, and then has been overworked. In addition, many of the Snettisham gold, silver and bronze alloy torcs, show cracking, incomplete casts, cold shuts, bubbling and metal dribbles. None of these aspects are visible in the Newark torc.

Assembling the torcs

Once the separate components for each torc had been made, they needed to be joined together. The precise mechanism by which this joining occurred has yet to be explored. However, from the minimal amount of alteration to the original sheet margins and thinness of the seams seen in the sheet worked examples (and detail such as the cracking in the core sheet margins still visible), either a very light solder, or some form of diffusion or mechanical bonding (*eg* compression) may have been utilised to create the terminals. It is also likely that decorative effects (such as the dummy rivets on the face of the Netherurd terminal, or the pie crust decoration on the face of the Snettisham Great torc) may have served an additional purpose as a means of bonding, by allowing overlapping or crimping of the sheet margins.

The collar was then added to complete the torc. These collars were almost certainly made in a similar way to the core, and appear to have been attached by overlapping the sheet (in the case of the Snettisham Great torc and Grotesque torc) and perhaps using a minimal amount of additional solder as with the core join. In the Netherurd terminal, there is a slight ridge of material at the torus/collar boundary (Fig 9), suggesting that perhaps the sheet was pinched together to make the join.

The connection with the wires appears to be more mechanical in most cases, with both the Netherurd terminal and other sheet-worked terminals, for example the Clevedon torc (Jope 2000, pl 120), showing a lip of material, which appears to have been crimped

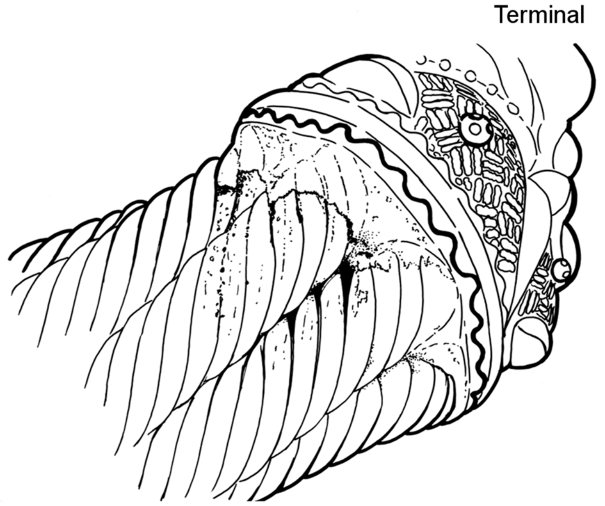

Figure 11: The Great Torc terminal showing poor neck ring attachment with widely spaced wire cables and excess solder. Width of neck ring 32.3mm.

around the wires of the neck-ring. The absence of solder on Clevedon might suggest this bond was entirely mechanical, although there does appear to be evidence of a small amount of solder on the Netherurd torc which might suggest a combination of both manual pressing and a small amount of solder to secure the bond.

The Snettisham Great torc appears to be different to many of the other torcs, and has components which were less expertly assembled than other high craft-quality gold torus torcs of the type. This torc is unusual as the joint between collar and wires is extremely messy: there are a large number of wide gaps between the wire ropes of the neck-ring which have been filled with poorly-applied quantities of gold solder, perhaps overlying and surrounding pressed-in sheet from a collar lip (Fig 11). It would seem that the eight wire ropes of the neck-ring, as made, were not wide enough to snugly fill the collar aperture. Therefore, they had to be splayed open to fit the collar, as witnessed by the widening of the neck-ring as it joins the terminals. As such, the ropes of the neck-ring had gaps in between, would have been able to move and became unstable when the torc was complete and in use. This would appear to demonstrate that the Great torc terminals were not specifically made to fit the Great torc neck-ring.

There are two possible explanations for the addition of so much solder: either the excess attachment material was necessary to secure the poorly fitting neck-ring, or the mass of solder is proof of a bodged repair to a substandard original joint. Perhaps, as Spratling (1972, 261) says, this is yet more evidence that 'soldering had not been mastered by the majority of southern British smiths'. Even today the joint looks precarious, with the solder cracking away from the wires in many places, suggesting that the solder did not bond well with the underlying wires (Bob Davies pers comm). Whatever the reason for the solder application, the underlying truth is that the Snettisham Great torc has an incorrectly sized neck-ring and/or incorrectly sized terminals. This could be explained in a number of ways:

- Was this an error in measurements which required a late fix due to the impossibility of taking the time to recreate each element of the torc again? This seems unlikely in such a highly crafted prestige item.
- Were the most complex and skilled part of the torc, the terminals, ordered in from a distant sheet-working goldsmith, with the wires, the least complex element, being made by a less skilled goldsmith, local to the commissioner – and this in turn led to discrepancies in measurements?
- More interestingly, does it suggest that torc elements were being recycled or remodelled into new designs, perhaps due to a scarcity of gold?

Recent work on the origins of the Clevedon terminal suggests that this may be likely (Machling and Williamson 2019). We may never know the answer to this question, but the possibilities are intriguing.

In the cast gold torus torcs of Sedgeford and Newark the attachment method becomes more complex, perhaps in the case of the Newark torc demonstrating greater skill than that seen in the sheet-work torcs. For Sedgeford the torc terminals have been attached using a single rivet through the neck of each torc terminal, which appears to have its wires pre-soldered (Fig 9) prior to attachment (Meeks *et al* forthcoming).

For Newark a very different attachment mechanism can be seen. It would appear in this case that the wire neck-ring was first attached to the collar (before the collar was attached to the terminal) using a twisting, screw in technique that socketed the wires within the collar, and with just a minimal amount of solder being added to secure the wires. From 3D-microscope images of the join it would appear that the boundary between wires and collar is no greater than 200µm (Fig 12).

This would suggest the possibility of a highly controlled heating environment, for example a muffle furnace, being utilised to create the fixing bond between terminals and wires. It would appear from X-radiographs (Figs 7 and 8) that the wires were then cut flush with the collar, before the collar was soldered to the rest of the terminal (perhaps again using a muffle furnace technique as the join is very clean and fine).

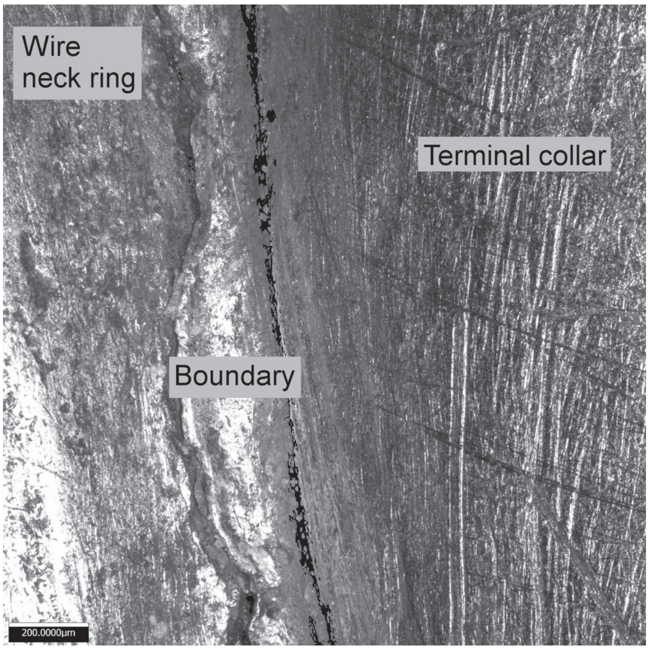

Figure 12: 3D-microscopy showing the attachment boundary between the neck ring (left) and collar (right) of the Newark torc. Scale bar (bottom left) 200 microns.

In lower quality gold, silver and bronze alloy torus torcs, it would appear that the directly cast on method described by Meeks *et al* (2014) was utilised. Numerous examples of cold shuts (British Museum 1991,0407.39, Hengistbury Head terminal), metal dribbling (British Museum 1991,0407.23; 1991,0407.32), holes (British Museum 1991,0407.28; 1991,0407.39; 1991,0407.23), visible wires (British Museum 1991,0702.15; 1991,0407.39; 1991,0407.23) and incomplete castings (*eg* the North Creake terminal) can be easily identified.

Decoration

The decoration of the torcs, and the tools needed to complete the tasks, are described in two other papers (Machling and Williamson 2018; Machling and Williamson forthcoming) and are the subject of ongoing research. Initially it seemed likely that for sheet-work torcs the decoration was carried out using the repoussé technique, prior to the components of the torc being assembled, with only slight finishing and punched tooling occurring after the completion of the torc. However, recent experimental work with a master goldsmith, Ford Hallam, has indicated that much of the decorative work may have been carried out once the torc terminal was in complete form and utilised an exterior working technique similar to the Japanese method of *uchidashi* (Katori *et al* 2006) rather than using the traditionally assumed, interior-worked, repoussé. In the case of the cast torcs, it is likely that the main areas of decoration were cast and then the terminals were tidied up prior to attachment. The Ipswich torcs (Brailsford and Stapley 1972; Owles 1969; 1971) hint at such a method, where the main detail was added during the cast, but the finer detail tooling had yet to be completed.

For the Newark torc, it is probable that most decorative elements on the collar were completed only after the collar's attachment to the wires and the terminals. It would appear that on both sheet-work torcs and the Newark torc that, prior to attachment, the surfaces of the terminals were extensively planished and possibly scraped (Machling and Williamson forthcoming). It should also not be forgotten that tooling and other evidence suggests that both the sheet Netherurd terminal and cast Newark terminals were made/finished by the same maker (Machling and Williamson 2018). In the case of the Sedgeford torc, it would appear that only areas of repair were planished and/or hammered.

Choosing the construction method

An aspect that is yet to be fully understood is the reason for choosing sheet-worked gold over cast for what are apparently very similar torcs. Regional differences in the traditions of gold-working might explain this preference, with sheet-work technology being more common in certain areas, and absent in others. The reasons for this theory are given below.

Previously it had been thought there was a hiatus in gold-working from the later Bronze Age to the late Iron Age, but recent finds, such as the middle to later Iron Age Leekfrith torc hoard (Farley 2017) and the re-dating of Scottish ribbon torcs to the earliest later Iron Age (Hunter 2007, 289), suggest the reappearance of gold-working in northern and western areas much earlier than had previously been assumed. In southern Britain, gold is all but absent from the later Bronze Age to later Iron Age.

Gold is not a common material in prehistoric SE Britain, and could not have been sourced locally, instead being imported or recycled. There is also a limited history of traditional gold sheet-working of the sort seen in northern and western Britain and Ireland. As Northover (1995, 303) states, 'to metalsmiths working in southern England, the metallurgy of gold and gold alloys would have been completely unknown'; thus gold sheet-working would be an unknown craft. It also appears that bronze sheet-working, as typified for example by the Llyn Cerrig Bach assemblage (Fox 1945; Macdonald 2007), the Witham Shield (Jope 2000, pl 62-67) and

Torrs pony cap (Jope 2000, pl 100-1), possibly again due to easier access to bronze resources, seems to have reached a peak of skill in the north and west in the Iron Age (Spratling 1972, 346).

The skills held by these sheet-bronze workers (with the caveat of the possible *uchidashi* technique, which has yet to be identified in bronze sheet-work) appear to cross into gold sheet-work. Probably the most obvious connection is the use of thicker sheet gold than might be typical in Continental Europe (Northover 1995, 303) and the repeated use in the decoration of gold of elements that had a far more practical use in sheet-worked bronze. If one looks at the functional rivets joining the sheet elements of, for example, the Waterloo helmet (Jope 2000, pl 122-3), these can be seen on many torcs: for example, on the face and collar of the Netherurd terminal, on the collar of the Sedgeford and Newark torcs and on the face of the Hengistbury Head terminal (Bushe Fox 1915). These, now dummy, rivets appear to mark out the position of a join: a non-functional indicator of something used practically in bronze sheet-work. In the case of the Ulceby bit (Jope 2000, pl 275f) the very practical method of sealing the bronze sheet over the iron core uses a 'pie crust' crimping technique which can be seen as a decorative element on the face and collar of the Snettisham Great torc, although once again marking the position of a seam, and perhaps having some functional purpose. Further examples of metal-working practice immortalised in decorative elements can be seen when the dummy rivets in the centre of the roundels on the Netherurd terminal, the Great, Sedgeford, Newark and Clevedon torcs are compared to the decoration of the inscribed bone slips from Loughcrew (Crawford 1925, 17). On the Loughcrew slips, the dots in circles mark out compass points used to construct the flowing designs. It is possible that the dummy rivets in the torc roundels memorialise such compass points, again pointing to a decorative effect which harks back to an original technical purpose.

In terms of practicality, gold sheet-working is a far more controlled and portable craft, which does not require so many tools nor produce so much waste as casting (as can be seen from the many faulty cast torcs, the method was not successful for this type of hollow torc). In addition, it will also leave far less trace in the archaeological record. Sheet-work also allows for cold working, offers less possibility for adulteration as alloys would not be constantly re-melted, and perhaps most importantly offers the possibility of creating far larger forms in lesser amounts of gold.

By comparing the Snettisham Great torc, Ipswich torc No two and one of the Snettisham tubular torcs this becomes obvious. Despite having similar neck-ring diameters, the overall size and impression of the Great torc is of a torc made from a much larger amount of gold, though their weights are comparable at 1084g to the 1044g of Ipswich No two). The tubular torcs from Snettisham take this to an extreme, with a far larger torc being made from a mere 110g of sheet gold. In short, sheet-work offered 'more bang for your buck' in a way that would never be identifiable to any onlooker. In addition, sheet-working allows for the finer decoration of an object, as can be seen in the Netherurd and Great torc examples.

In the southern British Iron Age a tradition of casting in bronze flourished. However, the majority of these items were not hollow, but were either solid or with a limited hollow mouth (for example, see the numerous copper alloy horse paraphernalia of the period). It is therefore quite likely that if asked to produce a hollow torus torc, the method used in Iron Age southern Britain would be casting – but the intricate requirements of making a hollow torc terminal, designed to be made using sheet technology, proved to be almost impossible.

Discussion

As has been shown, the individual technological and decorative characteristics of torus torc terminals show evidence of a pattern of great diversity, linked by a number of related techniques. These show a comparable working technique for sheet-worked torus torcs, and poor copying of the form to create cast torus torcs.

The find spots of sheet-worked torus torcs – and indeed other sheet-work torc examples – are concentrated away from southern England with the finest sheet-worked examples, apart from the Great torc, all coming from beyond the East Anglian area. The Netherurd, Blair Drummond, Clevedon, Broighter and Leekfrith hoards all contain torcs of exquisite sheet gold workmanship, all drawing on the sheet-workers' craft to create truly unique pieces. In addition, the Netherurd and Newark torcs might point to a highly skilled northern sheet-working workshop, capable of creating the sheet Netherurd terminal, but also capable of adapting their technique to create highly crafted cast torcs, in lower gold percentage alloys, when required. Conversely, the many faulty and poorly achieved examples from East Anglia and the south east suggest that skilled goldsmithing was not widespread in southern Britain.

The anomalous and very large assemblage from Snettisham has masked and distorted the broad picture of British Iron Age gold-working and in particular gold-working that was being practised beyond southern England. Snettisham, for whatever reason, became a depository for torcs and other items of many forms, dates and from many different locations. It should be treated as some form of anomalous 'ritual' museum: the final depositional location, rather than an indicator of the source of material. It is an anomaly that is not representative of the rest of the British Isles and, as such, the origins for sheet gold-working beyond the confines of East Anglia need to be explored.

If Snettisham is removed from the picture, a more standardised pattern of deposition and torc types can be seen. Many were placed in the ground as assemblages of three to four torcs (*eg* Leekfrith, Blair Drummond and Netherurd) with or without coins. These torcs are usually of high quality gold craftsmanship, and all have a sheet-work component within the hoard.

In terms of dating, it has long been assumed that there is a hiatus in gold-working in the period from 800-400 BC (La Niece *et al* 2018, 409) and this is almost certainly the case in southern Britain where gold could not be easily sourced and the capability to work it was probably lost (Northover 1992, 237). However, in many areas, the highly skilled and developed sheet-working capability (which is likely to have had an historic antecedent) seen in relatively early torcs such as the Leekfrith bracelet, and perhaps even in ribbon torcs, suggests this hiatus might not be as long as previously thought. Recent work on the Clevedon torc (Machling and Williamson 2019) might also suggest an earlier dating for torus torcs originating in the 4th-3rd centuries BC.

It is also possible that scarcity of gold and different depositional practices might explain the hiatus, with gold not being deposited in the ground, or being recycled into new objects that never reached burial. In addition, limited recovery may also be a factor, with the discovery of the Caistor, Towton, Newark and Blair Drummond torcs only occurring within the last 10-15 years, and the Leekfrith torcs being found only in 2016. One or two additional early torc finds could change the hiatus theory entirely.

The relationship of the different sheet-worked torc types to one another also needs to be addressed. Recent work on the Clevedon torc (Machling and Williamson 2019) has shown this torc is likely to be a reworked torus torc, and suggests there may be a relationship between torus torcs and other torc types. More work will be necessary to more fully understand this relationship and to see if it extends to other gold alloy torcs.

A further factor that needs exploring is the relationship of gold-working to bronze sheet-working. As has been noted above, there are elements of sheet-work bronze manufacturing methods seen in the decorative elements of several torcs. There do appear to be links between gold and bronze sheet-workers, as hinted at by Northover (1995) when he noted that British gold sheet-work is considerably thicker than continental gold sheet-work and corresponds well with the thicknesses of sheet-worked bronze (Northover 1995, 303). However, recent replication work by Ford Hallam using an exterior decorative working technique such as *uchidashi,* as opposed to traditional repoussé, and which matches the visual evidence seen on numerous torcs (*eg* Clevedon and Netherurd), may suggest that there were very specific gold working techniques which are yet to be been seen in Iron Age sheet bronze work.

Conclusions

Until the examination of the Netherurd torc terminal in 2015 and our further work on the Newark, Sedgeford, Clevedon and Snettisham torcs, it was accepted by most scholars that torus torcs represented an homogeneous suite of cast-on-technology torcs with a centralised production centre in East Anglia. This picture still remains current. As La Niece *et al* (2018) recently described it, the torcs were 'connected to the same "East Anglian" workshop' (La Niece *et al* 2018, 415) and all, apart from the sheet-work Grotesque and tubular torcs, were thought to be 'cast on' (La Niece *et al* 2018, 418). In addition, earlier Iron Age torcs have been automatically assumed to be imported (La Niece *et al* 2018, 410), due to their stylistic similarities. Those that exist beyond East Anglia, for example the Newark torc and Netherurd and Clevedon terminals, have been largely ignored from an academic point of view and have not been the focus of detailed research.

Close examination of the torcs has proved that there are a number of manufacturing technologies evident in British Iron Age torus torc making which include sheet-working, casting-on and separately cast terminal torcs, and that sheet and separately cast torc terminals were achieved using highly advanced goldsmith skills and techniques. However, the casting on technique appears to be the least competent and achieved less than adequate results.

From the evidence above, enough doubt has been cast on the previously assumed East Anglian production centre and production techniques to make a re-evaluation of many of the torcs necessary. Finds such as the Blair Drummond hoard (Hunter 2018) have demonstrated that British goldsmiths were quite capable of producing quality gold-work, which impeccably copied continental designs. In short, when the different construction and decorative techniques of many different torcs were identified, the long-held picture of the manufacture and distribution of Iron Age gold torcs collapsed.

It is now time to question everything we thought we knew about Iron Age gold-working and reconfigure our theories to take into account an understanding of the technological characteristics of each individual torc and the relationship of that technology to what came before. Only when this is done will we be able to achieve a more realistic picture of British gold-working and start the long journey to attempt to understand the craft of the Iron Age goldsmith.

Acknowledgements

The authors would like to thank the curators of all the museums where the torcs are held: Glyn Hughes, Fraser Hunter, Julia Farley and Jody Joy. We would also like to thank Michael Lloyd, Ford Hallam, Bob Davies, Hamish Bowie and the many goldsmiths, jewellers and metal smiths who have shared their knowledge so freely with us. Kenny Watson of GE Inspection Technologies is thanked for providing the Newark torc X-radiograph. We are grateful for permission to produce the images within this paper: Figures 5, 9 and 11 are © Roland Williamson, Figures 2 and 10 are used with permission of the National Museums Scotland, Figures 2, 6, 7 and 8 are used with the permission of the Newark National Civil War Museum, Figures 6, 7 and 8 are used with the permission of GE Inspection Technologies and Figure 12 is used with the permission of the National Physical Laboratory. Also Justine Bayley is greatly thanked for asking us to write for *Historical Metallurgy*.

References

Atherton R 2016, 'The Newark Iron Age torc', *Transactions of the Thoroton Society of Nottinghamshire* 120, 43-53.

Bayley J 1992, 'Goldworking in Britain from Iron Age to medieval times', *Interdisciplinary Science Review* 17(4), 314-21.

Brailsford J W 1951, 'The Snettisham Treasure', *British Museum Quarterly* 16(3), 79-80.

Brailsford J W 1971, 'The Sedgeford Torc', *British Museum Quarterly* 35(1), 16-19.

Brailsford J W and Stapley J E 1972, 'The Ipswich Torcs', *Proceedings of the Prehistoric Society* 38, 219-34.

Bushe Fox J P 1915, *Excavations at Hengistbury Head, Hampshire in 1911-12* (Oxford).

Clarke R R 1951, 'A Celtic torc terminal from North Creake, Norfolk', *Archaeological Journal* 106, 59–61.

Clarke R R 1954, 'The early Iron Age treasure from Snettisham, Norfolk', *Proceedings of the Prehistoric Society* 20, 27–86.

Crawford H S 1925, 'The engraved bone objects found at Lough Crew, Co. Meath, in 1865', *Journal of the Royal Society of Antiquaries of Ireland* 15(1), 15-29.

Farley J 2017, Portable Antiquities Scheme: WMID-FD08D9. https://finds.org.uk/database/artefacts/record/id/820219 [accessed 9 May 2017]

Farley J, Gilmore T, Sutherland Z and Nicolls A 2018, 'The Leekfrith torcs' *Transactions Staffordshire Archaeological and Historical Society* 50, 110–114.

Feachem R W 1958, 'The 'Cairnmuir' hoard from Netherurd, Peebleshire', *Proceedings Society of Antiquaries of Scotland* 91, 112–16.

Fox C 1945, *A find of the Early Iron Age from Llyn Cerrig Bach, Anglesey: Interim Report* (Cardiff).

Garrow D, Gosden C, Hill J D and Bronk Ramsey C 2009, 'Dating Celtic Art: a major radiocarbon dating programme of Iron Age and early Roman metalwork in Britain , *Archaeological Journal* 166, 79-123.

Gwilt A, Kucharski K, Silvester R and Davis M 2005, 'A Late Bronze Age hoard from Trevalyn Farm, Rossett, Wrexham', *Studia Celtica* 39, 27-61.

Hautenauve H 1999, 'Les torques tubulaires de Snettisham. Importation continentale ou production insulaire?', *Lunala, Archaeologia Protohistorica* 7, 89–100.

Hautenauve H 2005, *Les torcs d'or du second Âge du Fer en Europe: techniques, typologie et symbolique* (Rennes).

Hawkes C F C 1936, 'The Needwood Forest torc', *British Museum Quarterly* 11(1), 3-4.

Hawkes C F C 1940, 'An Iron Age torc from Spettisbury Rings, Dorset', *Archaeological Journal* 97, 112-14.

Hill J D 2004, Portable Antiquities Scheme: PAS-F070D5. https://finds.org.uk/database/artefacts/record/id/508203 [accessed 9 May 2017].

Hill J D 2005, Portable Antiquities Scheme: DENO-4B33B7. https://finds.org.uk/database/artefacts/record/id/751306 [accessed 9 May 2017].

Hunter F 2007, 'Artefacts, regions and identities in the northern British Iron Age', in C Haselgrove and T Moore (eds), *The later Iron Age in Britain and beyond* (Oxford), 286-96.

Hunter F 2010, 'A unique Iron Age gold hoard found near Stirling', *PAST: Newsletter of the Prehistoric Society* 65, 3–5.

Hunter F 2014, 'Auldearn', *Discovery and Excavation in Scotland* 15, 97.

Hunter F 2018, 'The Blair Drummond (UK) hoard: Regional styles and international connections in the later Iron Age', in R Schwab, P-Y Milcent, B Armbruster and E Pernicka (eds), *Early Iron Age gold in Celtic Europe: Science, technology and archaeometry. Proceedings of the International Congress held in Toulouse, France, 11-14 March 2015* (Rahden), 431-40.

Hutcheson N 2007, 'An archaeological investigation of later Iron Age Norfolk: Analysing hoarding patterns across the landscape', in C Haselgrove and T Moore (eds), *The later Iron Age in Britain and beyond* (Oxford), 358-370.

Jope M 2000, *Early Celtic Art in the British Isles* (Oxford).

Joy J 2010, Portable Antiquities Scheme: SWYOR-CFE7F7. https://finds.org.uk/database/artefacts/record/id/392736 [accessed 1 September 2019].

Joy J 2016, 'Hoards as collections: Re-examining the Snettisham Iron Age hoards from the perspective of collecting practice', *World Archaeology* 82(2), 239–53.

Joy J 2018, 'Snettisham: Shining new light on old treasure', *Jewellery History Today* 31, 3-5.
Katori M, Io T and Ibusr K 2006, *Kinko no dento giho* [A manual of traditional gold/metal work] (Tokyo).
La Niece S, Farley J, Meeks N and Joy J 2018, 'Gold in Iron Age Britain', in R Schwab, P-Y Milcent, B Armbruster and E Pernicka (eds), *Early Iron Age gold in Celtic Europe: Science, technology and archaeometry. Proceedings of the International Congress held in Toulouse, France, 11-14 March 2015* (Rahden), 407-30.
Longworth I 1992, 'Snettisham revisited', *International Journal of Cultural Property* 1(2), 333–42.
Macdonald P 2007, *Llyn Cerrig Bach: a study of the copper alloy artefacts from the insular La Tène assemblage* (Cardiff).
Machling T and Williamson R 2016, 'The Netherurd torc terminal – insights into torc technology', *PAST: Newsletter of the Prehistoric Society* 84, 3–5.
Machling T and Williamson R 2018, '"Up Close and Personal": The later Iron Age torcs from Newark, Nottinghamshire and Netherurd, Peeblesshire', *Proceedings of the Prehistoric Society* 84, 387-405.
Machling T and Williamson R 2019, '"Cut and shuts": The reworking of Iron Age gold torus torcs', *Later Prehistoric Finds Group Newsletter* 13, 4-7.
Machling T and Williamson R forthcoming, '"Damn clever metal bashers": The thoughts and insights of 21st century goldsmiths, silversmiths and jewellers regarding Iron Age gold torus torcs', in C Gosden, H Chittock, C Nimura and P Hommel (eds), *Art in the Eurasian Iron Age: Context, connections, and scale*. (Oxford).
Maryon H 1944, 'The Bawsey torc', *Antiquaries Journal* 24, 149-51.
Meeks N, Mongiatti A and Joy J 2014, 'Precious metal torcs from the Iron Age Snettisham treasure: Metallurgy and analysis', in E Pernicka and R Schwab (eds), *Under the Volcano: Proceedings of the international symposium on the metallurgy of the European Iron Age* (Rahden), 135–56.
Meeks N, Mongiatti A, O'Flynn D and Hook D, with contributions from Fenn J forthcoming, 'Technology and manufacture', in J Joy and J Farley (eds), *The Snettisham Treasure* (London: British Museum Research Publication 225).
Northover P 1992, 'Materials issues in the Celtic coinage', in M Mays (ed), *Celtic coinage: Britain and beyond* (Oxford: BAR BS 222), 235-99.
Northover P 1995, 'The technology of metalwork: bronze and gold', in M Green (ed) *The Celtic World* (London), 285-309.
Norwich Castle Museum and Art Gallery 2018. *The south-west Norfolk torc.* http://www.rnrm.org.uk/saga_bu/ncm_budica/so_/so_swnt_det.html [accessed 26 February 2018].
Owles E 1969, 'The Ipswich gold torcs', *Antiquity* 43, 208-12.
Owles E 1971, 'The sixth Ipswich torc' *Antiquity* 45, 180.
Painter K S 1969-70, 'An Iron Age gold-alloy torc from Glascote, Tamworth, Staffs', *Transactions of the South Staffordshire Archaeological and Historical Society* 11, 1-6.
Sealey P R 1979, 'The later history of Icenian electrum torcs', *Proceedings of the Prehistoric Society* 49, 165–78.
Spratling M G 1972, *Southern British decorated bronzes of the late pre-Roman Iron Age*, unpublished PhD thesis (University of London).
Stead I M 1991, 'The Snettisham treasure: Excavations in 1990', *Antiquity* 65, 447–64.
Whitaker T D 1816, *Leodis and Elmete.*

The authors

Tess Machling is an independent archaeologist and researcher, based in St Albans.
Email: t.machling@ucl.ac.uk

Roland Williamson is a museum replica maker of 35 years' experience, and owns Bodgit & Bendit replica makers. He is based in Cheltenham.
Email: bodgitandbendit1@gmail.com