1 Examining the British and Irish Early Bronze Age Flat Axes of the Greenwell Collection at the British
2 Museum
3

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8

9 **Abstract**

10 This paper presents the results of metalwork wear-analysis carried out on British and Irish Early
11 Bronze Age copper and copper-alloy flat axes from the collection of Rev. Greenwell (1820-1918) held
12 at the British Museum. Greenwell was a prolific and well-known British antiquarian; part of his
13 collection was sold to John Pierpont Morgan who donated the axes to the museum in 1908. This
14 paper focuses on the copper and copper-alloy flat axes from within this collection, which date to c.
15 2500-1700 cal BC and are the earliest form of metal axe in Britain and Ireland. The 38 axes are drawn
16 from across Britain and Ireland, and whilst the contextual information associated with them is not
17 complete this paper shows that there is still much we can learn from these objects using metalwork
18 wear-analysis. In addition, some methodological insights are drawn from this analysis: in particular
19 the paper advocates for more detailed recording of corrosion and specific recording of wear marks
20 to the butts of axes.

21 **Highlights**

- 22 • This paper presents the results of metalwork wear-analysis carried out on copper and
23 copper-alloy flat axes from Britain and Ireland held by the British Museum as part of the
24 Greenwell Collection
- 25 • It argues for the recording of additional data during metalwork wear-analysis regarding
26 corrosion which can allow practitioners to interpret information regarding hafting.
- 27 • At present, it is standard to observe wear on the blades of axes, however, this paper argues
28 that analysis of the butt can also be informative
- 29 • The paper demonstrates that the majority of axes deposited at this time were used but that
30 the nature of that use was varied. Many axes were deposited whilst still suitable for use and
31 some were even sharpened prior to deposition.
- 32 • The paper also reveals some specific histories of different axes that were combined in
33 hoards and indicates the potential for further research focused on hoarding in the Early
34 Bronze Age.

35 **Key words**

36 metalwork wear-analysis; Early Bronze Age; flat axes; bronze; copper alloy; metalwork; museum
37 collections

39 **1.1 Introduction**

Early Bronze Age (c. 2500-1500 cal BC) copper and copper-alloy flat axes are found in large numbers across Britain and Ireland (see for example Harbison, 1969; Schmidt and Burgess, 1981). They are the earliest type of metal object which spread widely and relatively quickly across this geographical area. It is widely assumed that flat axes were the objects through which most communities first came into contact with and used metal for the first time. Copper-alloy axes in this region, have clear links to the earlier stone axes of the Neolithic, particularly in terms of depositional practice. Axes are rarely found on settlement sites or in burials (Harbison 1969:1-2; Moyler, 2008: 81; Schmidt and Burgess 1981: 14-15) but instead were commonly deposited in the ground either alone or as part of hoards. Schmidt and Burgess (1981: 14) note that about 90% of the 1759 axes¹ in their catalogue for Northern Britain and Scotland were associated with no other material and Harbison (1969:1-2) notes that 95% of the 2035 axes in his study of Irish early axes are isolated finds. As a result of these depositional practices, and related antiquarian collecting practices, it is common to have very little contextual information about these objects (see also, Mount, 2001 and O'Flaherty, 2003).

Bronze axes have received archaeological attention for many years: the majority of research has focused on understanding their typologies, using chemical analyses to investigate the provenance of the ores used to make them, and considering how, why, and, where they were deposited in the ground (Dolfini and Crellin, 2016: 80-1; Moyler, 2008: 79). Understanding how Early Bronze Age flat axes were used by communities across this region will help shed new light on the adoption (and adaptation) of metallurgy in the area and begin to make steps towards understanding why metallurgy spread and how metal objects and metallurgy came to be used and understood by prehistoric communities.

The Greenwell Collection is one of the key prehistoric collections held by the British Museum. The Rev. Greenwell (1820-1918) (see Graves, 2005; Murray, 2005) was a British Antiquarian who excavated a large number of barrows and collected a variety of prehistoric artefacts. Part of his collection was sold to John Pierpont Morgan who later donated the collection to the British Museum in 1908. The collection contains 579 copper-alloy axes from across Europe, of which 38 are flat axes from Britain and Ireland.

In this paper, I present the results of metalwork wear-analysis carried out on these axes in the British Museum stores. Metalwork wear-analysis is a developing field of archaeological science that allows practitioners to consider how objects were made and used by examining microscopic traces left on the surface of the objects (see Dolfini and Crellin, 2016). The technique has its foundations in the work of Semenov (1964) and was later developed first for the study of axes (Kienlin and Ottaway,

¹ This includes all types of axes from flat axes through to palstaves and later socketed axes.

1998; Roberts and Ottaway, 2003) though in recent years it has been more frequently used to study bronze weapons (see for example, Anderson, 2011; Bridgford, 1997; 2000; Gutiérrez-Sáez et al., 2010; 2014; Horn, 2013; 2014; Kristiansen, 2002; Mödinger, 2011; Molloy, 2007; 2008; 2009; 2010; 2011; O’Flaherty, 2007a; 2007b; O’Flaherty et al., 2011; Uckelmann, 2011; Wall, 1987; York, 2002). Without wear analysis archaeologists assume function based on analogy and form (van Gijn, 1999), microwear offers empirical evidence regarding function that often over-turns long-held assumptions built on analogy alone. Bradley (2017: 138) has recently commented that new data from wear-analysis of metals in particular has the power to create new understandings of the significance of metal objects. Metalwork wear-analysis allows us to gain data regarding use which can be used more broadly to consider issue of practice – how objects were and were not used, how different objects were treated and understood.

There have been a range of metalwork wear-analysis studies focusing on axes. Kienlin and Ottaway (1998) studied flanged axes from the Alpine Region and conducted the first experiments with axes used to inform wear-analysis. Roberts and Ottaway (2003) went on to develop the experimental and methodological work behind Kienlin and Ottaway’s research and applied their findings to the study of socketed axes from east-Yorkshire and south-east Scotland, UK. Moyler (2008) used a different methodology than previous scholars to examine 143 Early Bronze Age axes from Scotland, UK. Soriano Llopis and Gutiérrez Sáez (2009) have published the most comprehensive set of experiments with copper-alloy axes to date. Their experiments looked specifically at the influence of raw material on the formation of wear marks concluding that the composition of an axe’s alloy significantly affects the development of wear traces primarily in a quantitative way (Soriano Llopis and Gutiérrez Sáez, 2009). Dolfini (2011) brought together the methodological work and insights behind these studies to analyse thirty-three Chalcolithic (c.3600-2200 cal BC) metalwork objects from the Italian peninsula including 19 axes, eight daggers, five halberds and one S-shaped knife.

Moyler’s (2008) study represents the nearest parallel for the material discussed in this paper as he also focused on Early Bronze Age flat axes, though his collection was drawn only from Scotland. This paper does not use Moyler’s (2008) methodology for assessing wear, instead drawing on the protocols outlined by Dolfini (2011) for the study of axes and informed by new experiments and analyses quantifying surface texture change (Crellin and Purnell, in prep a). It also makes some suggestions for new data types to be recorded during analysis and their possible interpretation.

2.1 Materials

The term flat axe covers the earliest form of metal axes found in Britain and Ireland. Flat axes are those which do not have a socket nor the fully raised flanges and/or bevel stop that have come to define flanged axes and palstaves. Within the category of flat axe there is a great deal of variation in shape and form.

Copper flat axes are the earliest form of axe. They are usually thicker and broader than true flat axes often with a broad, square butt, they are not decorated (Schmidt and Burgess, 1981:21). Several types exist within this group: type Castletown Roche, type Lough Ravel, type Growtown/Milton Moss and type Ballybeg/Roseisle. Schmidt and Burgess (1981) argue that Castletown Roche type axes were the earliest form from which the other types developed in a multilinear manner. Copper flat axes belong in Needham's Metalwork Assemblages I and II (hereafter MA) which he places within his Period 1 dated to c. 2500-2300 cal BC (Needham 1996: 124). True bronze flat axes developed from this form, their butts became rounder, narrower and thinner and they exhibit broader blades. Within this category there are types Dunnotar, Killaha, and Migdale. Axes in type Killaha and Migdale may be decorated. Killaha axes are very common in Ireland but rarer in the rest of the British Isles (indeed Schmidt and Burgess (1981: 34) suggest Killaha axes in Scotland and Northern Britain were imports); whereas Migdale axes were more common in Scotland. Bronze flat axes of these types are part of Needham's MA III and Period 2 dating to 2300-2050 cal BC (Needham, 1996: 127-30). Developed Flat Axes show changes in form that are intermediate between flat axes and true flanged axes: slight flanges developed and some median bevels are evident. These changes make hafting within a 'knee' or 'elbow' jointed haft easier. Developed flat axes include those of type Aylesford, Glenalla, Falkland, Scrabo Hill, Bandon, Ballyvalley, and Derryniggin. Developed Flat Axes are believed to date to c.2050-1700 cal BC (Period 3) (Needham, 1996: 130-2).

Table 1 summarises the axes examined. It was possible to trace published bibliographic information for all the axes in this study; primarily this information was drawn from Evans (1881), Harbison (1969), Needham (1983), and Schmidt and Burgess (1981). Contextual information is often sparse for the axes from the Greenwell collection, as one would expect for a collection of the period. This paucity of contextual information is sadly common for much of the known metalwork in Britain and Ireland; for example, Harbison (1969: 1) suggests 56% of the axes in his study of Irish Early Bronze Age axes have no provenance at all. By comparison it was possible to locate the provenance of the Greenwell axes to a minimum of county level, indicating that this collection is slightly better contextualised than many. Rather than simply lamenting the limits of the knowledge and materials we have inherited from antiquarians, examining these axes for wear traces allows us to develop new understandings of them. It would always be preferable to have the contextual information

136 associated with any object of archaeological study but, in spite of this, it is worthwhile re-examining
137 these historic museum collections and carrying out metalwork wear-analysis on them.

138 In addition to being able to give some information about the provenance of the flat axes examined it
139 is also often possible to establish whether the axes were part of a hoard or buried alone. The flat
140 axes from within the collection are drawn from a range of typological types², geographical regions,
141 and find types (see Tables 1, 2a, 2b, 3 and 4). The data in Tables 1, 2a, 2b, 3, and 4 is drawn from the
142 British Museum's Collection data with supplementary information from the bibliographic sources
143 listed above.

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² The typological classifications used in the original sources are retained here – Schmidt and Burgess (1981) suggest that they might have offered slightly different classifications for some of the axes in Harbison (1969) but for the sake of clarity the original types have been retained.

Reg. No.	Primary Published Bibliographic Reference	Periodical BC	Typology	Country	County	Place	Find type
WG. 152 5	Harbison 1969; No 64	2500-2300	Lough Ravel	Ireland	Kerry	Beaufort, Cullinagh	hoard *
WG. 152 4	Harbison 1969; No 145	2500-2300	Lough Ravel	Ireland	Kerry	Stradbally	single find
WG. 152 8	Harbison 1969; No 8	2500-2300	Lough Ravel	Ireland	Kerry	Ardfert	single find
WG. 152 6	Harbison 1969; No 369	2500-2300	Lough Ravel (Ballybeg)	Ireland	Down	Dromore	single find
WG. 152 9	Harbison 1969; No 379	2500-2300	Lough Ravel (Ballybeg)	Ireland	Kilkenny	Gowran	single find
WG. 178 8	Schmidt & Burgess 1981; No 59	2300-2050	Killaha	England	Northumberland	Newbiggen, just outside the church entrance	hoard
WG. 152 7	Harbison 1969; No 526	2300-2050	Killaha	Ireland	Longford	Ardagh	single find
WG. 153 0	Harbison 1969; No 556	2300-2050	Killaha	Ireland	Roscommon	Croghan	single find
WG. 153 1	Harbison 1969; No 600	2300-2050	Killaha	Ireland	Cork	Mallow	single find
WG. 153 2	Harbison 1969; No 579	2300-2050	Killaha	Ireland	Meath	Kells	single find
WG. 153 3	Harbison 1969; No 531	2300-2050	Killaha	Ireland	Longford	Ballymacormack	single find
WG. 180 0	Evans 1881; page 43	2300-2050	Killaha	Wales	Caerphilly	Caerphilly	hoard
WG. 180 1	Evans 1881; page 43	2300-2050	Killaha	Wales	Caerphilly	Caerphilly	hoard
WG. 243 5	Harbison 1969; No 782	2300-2050	Killaha	Ireland	Longford	between Longford and Granard	unknown
WG. 178 9	Schmidt & Burgess 1981; No 186	2300-2050	Migdale	England	Northumberland	Newbiggen, just outside the church entrance	hoard
WG. 179 1	Schmidt & Burgess 1981; No 185	2300-2050	Migdale	England	Tyne and Wear	Wallsend	single find
WG. 179	Schmidt & Burgess 1981;	2300-2050	Migdale	England	North Yorkshire	Lockton; Pickering	single find

4	No 184						
WG. 180 4	Schmidt & Burgess 1981; No 187	2300-2050	Migdale	England	Northumberland	Alnwick	single find
WG. 179 5	Schmidt & Burgess 1981; No 71	2300-2050	Migdale	Scotland	Morayshire	Braemoray, Edinkilie, Grampian	single find
WG. 179 6	Schmidt & Burgess 1981; No 79	2300-2050	Migdale	Scotland	Highland	Nairn	single find
WG. 179 7	Schmidt & Burgess 1981; No 168	2300-2050	Migdale	Scotland	Moray	Lhanbryde, Mr Jack's Farm	single find
WG. 179 8	Schmidt & Burgess 1981; No 180	2300-2050	Migdale	Scotland	Moray	Dyke	single find
WG. 179 2	Needham, 1983: No NP 2	2300-2050		England	Northamptonshire	Kettering	unknown
WG. 179 3	Needham, 1983: No CA 28	2300-2050		England	Cambridgeshire	Littleport	unknown
WG. 179 0	Schmidt & Burgess 1981; No 229	2300-2050	Migdale (Biggar)	England	Northumberland	Stamfordham	single find
WG. 181 0	Schmidt & Burgess 1981; No 220	2300-2050	Migdale (Biggar)	England	North Yorkshire	Knapton	single find
WG. 179 9	Schmidt & Burgess 1981; No 234	2300-2050	Migdale (Biggar)	Scotland	Angus	Menmuir, Cottown Muir	single find
WG. 180 2	Evans 1881; page 43	2050-1700	Aylesford	Wales	Caerphilly	Caerphilly	hoard
WG. 180 3	Schmidt & Burgess 1981; No 316a	2050-1700	Aylesford	England	Northumberland	Sherburn Carr, Stamfordham	hoard *
WG. 181 1	Schmidt & Burgess 1981; No 312	2050-1700	Aylesford	England	North Yorkshire	Langton Wold	single find
WG. 154 2	Harbison 1969; No 883	2050-1700	Ballyvalley	Ireland	Antrim	Connor	probable hoard
WG. 154 3	Harbison 1969; No 884	2050-1700	Ballyvalley	Ireland	Antrim	Connor	probable hoard
WG. 154 4	Harbison 1969; No 885	2050-1700	Ballyvalley	Ireland	Antrim	Connor	probable hoard
WG. 153 4	Harbison 1969; No 822	2050-1700	Ballyvalley	Ireland	Meath	Athboy	single find
WG. 180 5	Schmidt & Burgess 1981; No 337	2050-1700	Scrabo Hill	England	North Yorkshire	Folkton VI, Barrow 235	hoard*

WG. 180 9	Schmidt & Burgess 1981; No 329	2050- 1700	Falkland	England	Northumberland	Ryall	single find
WG. 172 7	Needham, 1983: No GL 16	2050- 1700		England	Surrey	Kingston upon Thames; River Thames	unknown
WG. 152 3	Harbison 1969; No 446		Ingot axe	Ireland	Westmeath	Athlone	unknown

Table 1: Flat axes from Britain and Ireland held in the Greenwell Collection at the British Museum with associated published bibliographic and contextual data. Hoard * indicates that there are other parts of this hoard held by different museums.

Country	Number of Axes
England	14
Ireland	16
Scotland	5
Wales	3
TOTAL	38

Table 2a: Find locations for the 38 Flat Axes from Britain and Ireland held in the Greenwell Collection at the British Museum

Country	County	Number of Axes
England	Cambridgeshire	1
England	Northamptonshire	1
England	Northumberland	6
England	North Yorkshire	4
England	Surrey	1
England	Tyne and Wear	1
Ireland	Antrim	3
Ireland	Cork	1
Ireland	Down	1
Ireland	Kilkenny	1
Ireland	Kerry	3
Ireland	Longford	3
Ireland	Meath	2
Ireland	Roscommon	1
Ireland	Westmeath	1
Scotland	Angus	1
Scotland	Highland	1
Scotland	Moray	3
Wales	Caerphilly	3
TOTAL		38

Table 2b: Find locations at county level for the 38 Flat Axes from Britain and Ireland held in the Greenwell Collection at the British Museum

Find Type	Number of Axes
Single find	22
Hoard	8
Probable hoard	3
Unknown	5
TOTAL	38

Table 3: Find types for the 38 Flat Axes from Britain and Ireland held in the Greenwell Collection at the British Museum

As Table 2a shows the axes are drawn from across Britain and Ireland. The collection is unevenly geographically distributed with more axes from Ireland (likely a result of the large volume of metalwork in Ireland) and England (likely a collecting bias). In terms of the county spread (see Table 2b) there are axes from across much of Ireland, though elsewhere the collection is more limited. The prevalence of axes from Yorkshire and Northumberland reflects the life of Greenwell who lived and worked in the north-east of England. Table 3 shows that at least 22 of the axes were single finds and eight of the axes came from hoards – these axes were part of four separate hoards (with a likely fifth hoard coming from Connor in County Antrim, Ireland (WG.1542, WG.1543, WG.1544). In two cases, not all of the axes from a given hoard are held by the British Museum (indicated with a * in Table 1).

Table 1 gives information about the approximate date ranges for the axes – dating bronze metalwork remains a difficult task but these date ranges, based on Needham's (1998) chronology, provide a good estimate. The collection is weighted towards bronze flat axes from the period 2300-2050 cal BC. In Ireland developed flat axes (particularly type Ballyvalley) are thought to be more numerous than flat axes but in Scotland and Northern Britain flat axes (particularly type Migdale) are more numerous than developed flat axes (Schmidt and Burgess, 1981: 60). It is a particular strength of the collection that there are a good number of copper flat axes dating to 2300-2050 cal BC; all these axes are from Ireland which is not surprising given the low numbers of these axes elsewhere in Britain.

3.1 Methods

This paper follows the metalwork wear-analysis methodology described in Dolfini and Crellin (2016): it draws on experimental work to inform macro- and microscopic analyses of the surfaces of prehistoric axes. The paper draws on the existing published literature regarding metalwork wear-analysis on axes (primarily Dolfini, 2011; Kienlin and Ottaway, 1998; Roberts and Ottaway, 2003; Soriano Llopis and Guitérrez Sáez, 2009). During analysis no casts of the prehistoric axes were taken rather all the axes were observed in the British Museum using the naked eye and a Zeiss Stemi 2000

binocular light microscope and a Zeiss cold-light source with a “goose-neck” light guide to allow flexible lighting³. The analysis conducted broadly followed the same process described in Dolfini (2011): objects were visually inspected and the nature of corrosion was described (the subjective qualitative categories used differ from Dolfini 2011); objects were measured, photographed, drawn, and described; objects were microscopically examined at magnifications from x8 to x40; all microscopic traces and marks were recorded, on illustrations, in a datasheet, and photographed.

The data categories recorded (see Supplementary Material) during analysis were expanded from those listed for axes in Dolfini (2011: 1039, Table 2). During data recording for this paper mark descriptions were separated from mark interpretations – each category of data recorded related specifically to an observation and possible interpretations were considered following description (see Supplementary Material). The qualitative descriptive data recorded in the museum is provided in full in the Supplementary Material and a reduced and summarised interpretation of the data is provided in Table 4.

Additional categories for recording corrosion were created. A category focused on whether or not the blade was well enough preserved for the observation of use-wear striations was used to add more clarity to the data. Further categories for recording whether the axe showed corrosion differentials between the butt and blade and between the nominal front and reverse sides were also added: these categories are further discussed below in section 4.2.1.1.

In addition to recording wear on the blade, specific data categories were added to consider wear on the butt. Dolfini (2011: Table 2, 1039) notes one case of hafting marks in his ‘Wear traces - Other’ category but does not specifically record data regarding butt wear. Roberts and Ottaway (2003) and Kienlin and Ottaway (1998) both focus on the blade to interpret wear and neither paper recorded any wear to the butt of the axes. Research focused on lithic tools has found that the hafted and butt-end of tools often exhibit wear marks and can be informative about hafting and thereby use (Keeley, 1982; Rots, 2003; Rots, 2013). In Moyler (2008), the calculation of a wear percentage, based on presumed loss of material, takes into account the whole surface of the axe, including the butt (see for example Moyler, 2008: 82, Fig. 1). Given that a proportion of all axes have poorly preserved blades recording additional data about wear to the butt can help us add to the understanding we can gain about the prehistoric uses of metal objects. Butt wear was recorded in terms of rounding to the sides of the axe which would result from wear from hafting; striations associated with hafting (different from those associate with grinding); butt-end flattening (resulting from the butt-end of the

³ The axes have undergone various museum conservation and cleaning processes over the years and no further cleaning was carried out as part of this study.

axe impacting against the wood inside the haft); nicks to the butt; and butt asymmetry. These marks and their interpretation are discussed further in section 4.2.1.2.

Specific categories of data were also added to record marks to the axe that could be interpreted as resulting from intentional damage to the blade, body, and butt. There are some large marks, some incredibly numerous marks, some with unusual forms, and some in unusual locations which are not easily explained by usual wear processes. These marks are outside of what one usually observes and either too numerous, too severe or too unusual to fit normal wear categories. These marks are most easily and commonly interpreted as examples of intentional damage (for a parallel discussion of intentional damage to halberds see Horn 2011, and for swords see Melheim and Horn, 2014). Caution is urged with regard to an interpretation of intentional destruction: sometimes when it is clear that an object has been repeatedly hit by another object an interpretation of intentional damage seems appropriate. On other occasions the sheer amount of damage to the blade, or the form of the blade seems extremely unlikely to be the result of normal use and again intentional damage seems a more appropriate interpretation. In other cases, the evidence is much less clear cut: for example, there are a number of axes in the collection where the butts have been repeatedly hit by another object creating extensive notching. In such cases, interpretation is less secure – such marks could have formed from hafting. It is important that ‘intentional damage’ does not become confused with an interpretation of ‘ritual destruction’ which is damage on a very different scale.

4.1 Results

Table 4 gives an interpretive overview of the primary data (see Supplementary Data). The results of the analysis are discussed below.

Reg. No.	Condition	Blade suitable for observation	Front/Reverse corrosion differential	Butt/Blade corrosion differential	Casting Seam present	Two part mould	Hammering marks present	Patterns of grind and polish striations	Casting defects	Type of casting defect
WG.1523	Good	No true blade	No	No	No	Uncertain	No	No	No	NA
WG.1524	Medium	No	No	No	No	No	No	Not possible	No	NA
WG.1525	Medium-poor	No	Yes, reverse more corroded	Yes, butt more corroded	No	Yes	No	Yes	No	NA
WG.1526	Medium	Yes, in places	No	No	No	Yes	No	Yes	No	NA
WG.1527	Medium	No	Yes, reverse more corroded	Yes, butt more corroded	Yes	Yes	No	Yes, faint	No	NA
WG.1528	Medium	No	No	No	No	Yes	No	Yes	No	NA
WG.1529	Medium	Yes	No	No	Yes	Yes	No	Yes	No	NA
WG.1530	Good	No	No	No	Yes, slight	Yes	Yes	Yes	No	NA
WG.1531	Medium	Yes, in places	No	No	No	Yes	No	Yes	Yes - minor	Butt defect
WG.1532	Medium	Yes, in places	Yes, reverse more corroded	No	Yes	Yes	No	Yes	Yes - minor	Air bubble on blade
WG.1533	Medium	Yes, in places	No	No	Yes, slight	Yes	No	Yes, faint	No	NA
WG.1534	Good	Yes	No	No	Yes, slight	Yes	Yes, particularly on the butt	yes	No	NA
WG.1542	Poor-Medium	No	Yes, reverse more corroded	No	No	Yes	No (cannot be certain)	Not possible	No	NA

WG.1543	Medium	No (blade removed)	No	Yes, butt more corroded	No	Yes	No	No	No	NA
WG.1544	Medium	No	No	Yes, butt more corroded	No	Yes	No	Yes	No	NA
WG.1727	Good	Yes, in places	No	Yes, butt different colour	Yes, but partially ground away	Yes	No, but hammering destruction	Yes	No	NA
WG.1788	V.Poor	No	No	Yes, butt more corroded	Not possible	Not possible	Not possible	Not possible	Not possible	NA
WG.1789	V.Poor	No	No	No	Not possible	Not possible	Not possible	Not possible	Not possible	NA
WG.1790	Medium	Yes, in places	No	Yes, butt different colour	No	Yes	No	Yes	Possibly - corrosion pitting into air bubble	Air bubbles
WG.1791	Medium	Yes, in places	No	No	No	Yes	No	Yes, faint	No	NA
WG.1792	Good	Yes, in places	Yes, front more corroded	No	No	Yes	No	Yes	Possibly - corrosion pitting into air bubble	Air bubbles
WG.1793	Medium	No	No	No	No	Yes	No	Not possible	No	NA
WG.1794	Medium-poor	No	Yes, front more corroded	No	No	Yes	No	Yes	No	NA
WG.1795	Medium	No	No	Yes, butt more corroded	No	Yes	No, but hammering destruction	Yes	No	NA
WG.1796	Medium-good	Yes	No	No	Yes, partially ground away	Yes	No	Yes	No	NA

WG.1797	Medium-Good	Yes, In places	Yes, reverse more corroded	No	No	Yes	No	No - but other unusual marks	Yes - minor	Air bubble on blade
WG.1798	Good	Yes, in places	Yes, reverse more corroded	No	No	Yes	No	Yes	No	NA
WG.1799	Medium	Yes	No	No	No	Yes	No	No	No	NA
WG.1800	Poor	No (too porous)	Yes, front more corroded	Yes, blade more corroded (front side)	Yes	Yes	No (cannot be certain)	Not possible	Not possible	NA
WG.1801	Poor-Medium	No	Yes, reverse more corroded	No	No	Yes	No (cannot be certain)	Not possible	No	NA
WG.1802	Poor-Medium	Yes, in places	Yes, reverse more corroded	No	No	Yes	No (cannot be certain)	Not possible	No	NA
WG.1803	Poor	No	No	Yes, butt different colour	No	Yes	Not possible	Yes	Not possible	NA
WG.1804	Medium-good	Yes, blade edge gone but wear extends beyond	Yes, reverse more corroded	Yes, butt more pitted	No	Yes	No	Yes quite irregular	Possibly - corrosion pitting into air bubble	Air bubbles
WG.1805	Medium	Yes, blade edge gone but wear extends beyond	No	Yes, butt more corroded	Yes	Yes	Yes	Yes, faint	No	NA
WG.1809	Good	Yes	No	No	Yes	Yes	No	Yes	No	NA
WG.1810	Medium	Yes, in places	No	No	Yes	Yes	No, but decorative on the margins	Yes, faint	No	NA

WG.1811	Medium	No	No	No	No	Yes	No	Yes	Yes - minor	Air bubbles
WG.2435	Medium	No	No	No	No	Yes	No, but modern hammering	Yes, faint	No	NA

232 *Table 4a: Interpretive overview of the primary data concerning condition and production marks recorded for the 38 Flat Axes from Britain and Ireland held in*
233 *the Greenwell Collection at the British Museum. The primary data is available in Appendix 1.*

Reg. No.	Used	Blade with striations	Blade with nicks	Asymmetry	Blunt/Sharp	Breaks to blade	Sharpened for deposition	Butt wear	Butt rounding	Butt-end flattening	Butt asymmetry
WG.1523	NA	Not possible, no true blade	Yes, one small nick	No	Blunt	No	Not possible	No	No	No	No
WG.1524	Yes	Not possible	No	No	Blunt	No	Not possible	Yes	No	No	Yes, front left more worn
WG.1525	Yes	Not possible	Yes	Yes, front left more worn	Not possible	Yes, front right corner; front left-mid	Not possible	Yes	Yes - slight	No	No
WG.1526	Yes	Yes	Yes	Yes, front left more worn	Blunt - slight	No	Yes	Yes	Yes	No	Yes, front right more worn
WG.1527	Yes	Not possible	Yes, multiple	No	Sharp	No	Not possible	Yes	Yes - slight	No	No
WG.1528	Yes	Not possible	Yes	No	Blunt - slight	No	Not possible	Yes	Yes	No	No
WG.1529	Yes	No	Yes	No	Blunt - slight	Yes, three large chips	No	No	No	No	No
WG.1530	Yes	Not	Yes	No	Sharp	No	Not	Yes	Yes	No	No

		possible					possible				
WG.1531	Yes	Yes	Yes	Yes, front right more worn	Blunt - slight	No	No	Yes	Yes	No	No
WG.1532	Yes	Yes	Yes	Yes, front right slightly more worn	Blunt - in some areas	Yes - corner	No	Yes - slight	Yes	No	Yes - front right more worn
WG.1533	Yes	Yes	Yes	Yes, front right more worn	Sharp	No	No	Yes	Yes	Yes	No
WG.1534	Yes	Yes	Yes small	Yes, front right more worn	Blunt - slightly	No	No	Yes	No	No	No
WG.1542	No (hard to be 100% certain)	Not possible	No	No	Not possible	No	Not possible	No	No	No	No, front right more corroded
WG.1543	Not possible	Not possible	Not possible	Not possible	Not possible	Yes - blade cut off	Not possible	Yes	Yes - slight	No but there are notches to the butt	No
WG.1544	No (hard to be 100% certain)	Not possible	No	Yes relates to damage	Sharp - where blade present	Yes, one corner plus two large breaks	Not possible	No	Not possible - margins corroded	No	No
WG.1727	Yes	No	No	No	Sharp	No	No	Yes - decoration is worn off	Yes	No	Slight
WG.1788	Not possible	Not possible	Not possible	Not possible	Not possible	Not possible	Not possible	Not possible	Not possible	Not possible	Not possible
WG.1789	Not possible	Not possible	Not possible	Not possible	Not possible	Not possible	Not possible	Not possible	Not possible	Not possible	Not possible
WG.1790	Yes	No	No	Yes, front left more worn	Blunt - slight	No	No	No	No	NA	Yes, front right more worn (hard to interpret

											due to breakage)
WG.1791	Yes	No	Yes	Yes, front right more worn	Blunt	No	Yes	Yes	No	Not possible	No, it is the break that makes it asymmetrical
WG.1792	Yes	Yes	No	Yes, front left more worn	Sharp	No	Yes	Yes	Yes	No	Yes, front left more worn
WG.1793	Not possible	Not possible	Not possible	No	Blunt - slight	No	Not possible	Yes - slight	Yes	No	No
WG.1794	Not possible	Not possible	Not possible	No	Not possible	Not possible	Not possible	Not possible	Not possible	Not possible	Slight - but partly this is corrosion
WG.1795	Yes	Not possible	Yes, multiple, some possible destruction	Yes, front left more worn	Blunt - very	Yes, front right corner (small)	Not possible	Yes	No	NA	No
WG.1796	Yes	Yes	Yes, multiple and small	Yes, front right more worn	Sharp	No	Yes	Yes	Yes	No	Yes, front right more worn
WG.1797	Yes	No	Yes	Yes, front right more worn	Blunt - slight	Yes - front left corner (small)	Yes - where blade is well preserved	Yes	Yes	No	No
WG.1798	Yes	No	No	Yes, front left more worn	Sharp	No	Yes	Yes	Yes - slight	No	No
WG.1799	Yes	Yes	No	No	Blunt and Sharp	No	No	No but polished	No - slight evidence	No	No
WG.1800	Yes	Not possible	Yes	No	Blunt - in some areas	No	Not possible	Yes - slight	Yes - slight	No	Slight, front right more worn
WG.1801	No (hard to be	Not possible	No, two small nicks	No	Not possible	No	Not possible	No	No	No	No

	100% certain)		but likely accidental								
WG.1802	Yes	Yes	Yes	No	Not possible	Yes - left corner and mid blade	Not possible	No	Not possible	No	No
WG.1803	Yes	Not possible	Yes	Yes, front left more worn	Not possible	Yes, front left corner	Not possible	Uncertain - butt end has been damaged	No	Not possible	No
WG.1804	Yes	Yes	No	Yes, front left more worn	Not possible	No	No	Yes	Yes - particularly front right	No	Yes, front right more worn
WG.1805	Yes	Yes	No	No	Sharp	No	No	No	No	No	No
WG.1809	Yes	No	Yes	No	Sharp	No	Yes	Yes	Yes - slight	No	No
WG.1810	Yes	Yes	Not possible	Yes, front left more worn	Blunt - slight	No	No	No	No	No	Yes, front right more worn
WG.1811	Yes	Not possible	Yes, front left corner	Yes, due to front left missing corner	Blunt - slight	No	Not possible	Yes - slight	Yes - slight	No	No
WG.2435	Yes	Not possible	Not possible	Yes, front left significantly more worn	Not possible	Not possible	Not possible	Yes	Yes - strongly	No	No

234 *Table 4b: Interpretive overview of the primary data concerning use marks recorded for the 38 Flat Axes from Britain and Ireland held in the Greenwell*
235 *Collection at the British Museum. The primary data is available in Appendix 1.*

Reg. No.	Intentiona l Damage	Blade Intentiona l damage	Butt intentiona l damage	Body Intentiona l Damage	Modern re-use	Modern damage
WG.1523	Uncertain	Uncertain, one small nick	No	No	No	No

WG.1524	No	No	No	No	No	No
WG.1525	No	No	No	No	No	No
WG.1526	No	No	No	No	No	No
WG.1527	Uncertain	Uncertain, multiple nicks and plastic deformations	No	No	No	No
WG.1528	Yes	Uncertain- the blade corner damage may be intentional	Yes, corner butt nick	No	No	No
WG.1529	Uncertain	Uncertain - some of the breaks could be intentional	No	No	No	No
WG.1530	Yes	No	Yes, nicks to the butt	No	No	Yes, three nicks to the blade corner that are modern
WG.1531	Yes	No	No	Yes, surface damage	No	No
WG.1532	No	No	No	No	No	No
WG.1533	No	No	No	No	No	Yes there are some striations that cut through the patina
WG.1534	Uncertain	No	Uncertain, nick to the butt could be intentional, possible the butt has been intentionally squared off	No	No	No
WG.1542	No	No	No	No	No	No
WG.1543	Yes	Yes entire blade has been removed	Yes, there is a large chip from a heavy impact	No	No	No
WG.1544	Yes	Yes, one corner plus two large breaks all missing	No	No	No	Some scratches may be modern
WG.1727	Yes	No	Yes, the butt end is very abused	No	No	No
WG.1788	Not possible	Not possible	Not possible	Not possible	Not possible	Not possible
WG.1789	Not possible	Not possible	Not possible	Not possible	Not possible	Not possible

WG.1790	Yes	No	Yes, the butt appears to be asymmetrically broken	No	No	No
WG.1791	Yes	No	Yes, butt corner	No	No	No
WG.1792	No	No	No	No	No	No
WG.1793	Yes	No	No	Yes, split in two	No	No
WG.1794	Not possible	Not possible	No	No	No	No
WG.1795	Yes	Yes, the many chips to the blade (and butt) seem like destruction	Yes, butt cut off, then hammering and chipping	No	No	No
WG.1796	Yes	No	No	Yes, breaks to body	No	No
WG.1797	No	No	No	No	No	No
WG.1798	Yes	No	No	Yes, large incision on front	No	No
WG.1799	No	No	No	No	No	No
WG.1800	No	No	No	No	No	Yes - deep striations that cut through surface
WG.1801	No	No	No	No	No	No
WG.1802	Yes	Yes, two large breaks to the blade that are very unlikely to be from wear	No	No	No	Yes - some striations that cut through patina
WG.1803	Yes	No	Yes - butt has multiple nicks cut into it	No	Not possible	Not possible
WG.1804	Yes	No	No	Yes, to the margins	No	No
WG.1805	No	No	No	No	No	No
WG.1809	Yes	No	No	Yes, to the margins	No	No
WG.1810	No	No	No	No	No	Yes, deep scratch may be modern
WG.1811	Uncertain	No	No	Uncertain, some of the large scratches that cut through decoration could be damage	No	No
WG.2435	No	No	No	No	Yes, there is modern hammering, modern	Yes, there is modern hammering, modern

					damage to the blade, modern striations, modern cuts to the axe	damage to the blade, modern striations, modern cuts to the axe
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236 *Table 4c: Interpretive overview of the primary data concerning intentional damage of post-depositional marks for the 38 Flat Axes from Britain and Ireland*
 237 *held in the Greenwell Collection at the British Museum. The primary data is available in Appendix 1.*

238

4.1.1 Corrosion

Corrosion is the key variable in our ability to analyse and interpret information regarding the production and uses of prehistoric metalwork. Corrosion is highly variable across the Greenwell collection and even on a single axe. Detailed condition descriptions were produced whilst in the museum and these were used to inform the condition categories given in Tables 5, 6, 7 and 8. Table 5 shows the range of conditions found in the collection. Table 6 indicates the number of axes where the blade was wholly, or at least partially in good enough condition to record microwear.

Condition	Number of Axes
Good	7
Medium-Good	5
Medium	19
Medium-Poor	3
Poor	2
Very Poor	2
TOTAL	38

Table 5: Qualitative condition descriptions for the 38 Flat Axes from Britain and Ireland held in the Greenwell Collection at the British Museum.

Blade Condition	Number of Axes
Blade suitable for observation of striations	19
Blade unsuitable for observation of striations	19
TOTAL	38

Table 6: Assessment of the number of axes with blades suitable for the observation of striations for the 38 Flat Axes from Britain and Ireland held in the Greenwell Collection at the British Museum.

Table 7 compares the condition of axes found in hoards with those uncovered as single finds. In the Greenwell collection it is evident that those from hoards are in generally worse condition than those discovered alone. Hoards have a more complex corrosion environment as each axe will have a slightly different chemistry producing different corrosion micro-environments within the hoard.

Axes in hoards		Axes from single finds	
Condition	Number of Axes	Condition	Number of axes
Good	0	Good	4
Medium-Good	0	Medium-Good	3
Medium	1	Medium	14
Medium-Poor	3	Medium-Poor	1
Poor	2	Poor	0

Very Poor	2	Very Poor	0
TOTAL	8	TOTAL	22

Table 7: Assessment of the condition of axes with associated contextual information regarding their deposition in either a hoard or alone (n=30).

Unfortunately none of the earliest type Lough Ravel axes exhibit good preservation – these axes are made of copper rather than tin-bronze. The bronze flat axes dating to 2300-2050 cal BC and the developed flat axes dating to 2050-1700 cal BC both include a range of conditions but over 70% of the axes in these categories were classified as having medium or better condition.

4.1.2 Production Marks

The data regarding evidence of production processes in Table 6 indicates that only one axe can be confidently interpreted as having been cast in a one-part mould: unsurprisingly this is one of the earliest axes of Lough Ravel type (dated to 2500-2300 cal BC) (WG.1524). The other four Lough Ravel type axes (WG.1525, WG.1526, WG.1528, WG.1529) do not show casting seams but the symmetry between the two halves of the axe, on balance, is more like what we would expect from an axe cast in a two-part mould. The small axe-ingot (WG.1523) from County Westmeath in Ireland is hard to interpret due to its size and form and the author did not feel confident in interpreting whether or not this had been cast in a two part mould.

Raised profiles were observed on a number of axes – such profiles are indicative of casting seams (see Table 8). There is no apparent patterning in this data that indicates it was more or less common to remove casting seams on a certain type of axe or on axes from a certain geographical area. Axes from each of the three dating periods exhibit casting seams, including a Lough Ravel axe.

Casting Seams	Number of Axes
Seams present	10
Seams - partially ground away	2
Seams absent	22
Not possible to tell	2
TOTAL	36

Table 8: Interpretation of the presence or absence of casting seams. This interpretation rests on the observation of raised profiles on the margins of the axes. The axe from a one part mould (WG.1524) and the axe-ingot (WG.1523) are excluded from this data.

Hammering is indicated by patterns of small depression on the surface of the axe (see Figure 1). Hammering can be used as a decorative technique but also acts to increase the hardness (though also brittleness) of bronze metalwork. In experimental work Kienlin and Ottaway (1998: 27) found

that hammering (cold-working) increased the life-span of axes significantly and linked this to increased hardness. Hammering was very rarely observed on the flat axes from the Greenwell collection (see Table 9). Hammering is considered alongside other data regarding production, however, hammering can be used to repair axes and it can be hard to determine at what stage within the life-cycle hammering has occurred. Within this study two cases of destructive hammering and one case of post-excavation hammering have been recorded – such marks are not correctly associated with production processes but are informative about the individual histories of these objects. We assume that the majority of these axes were cold worked with hammering in order to increase their hardness, and there are cases where we can observe hammering marks (such as WG.1530, WG.1534, WG.1805) to support this view.

Figure 1: Micrographs showing hammering, scale bars all 2mm. Left: WG.1534 hammering on the blade of the axe. Mid: WG.1795 hammering on the butt – this hammering may represent a repair rather than a production mark. Right: WG.1727 decorative hammer marks between the body and the butt. Photo © R.J. Crellin. Taken courtesy of the Trustees of the British Museum.

Hammering evidence	Number of Axes
No hammering visible	28
Hammering visible	3
Decorative hammering visible	1
Destructive hammering visible	2
Modern, post-excavation hammering	1
Not possible to observe	3
TOTAL	38

Table 9: Interpretation of the presence or absence of hammering marks. This interpretation rests on the observation of patterns of small depressions on the axes.

Evidence for grinding and polishing of the axe to remove casting residues and change the appearance, colour and texture of the axe is interpreted on the basis of the observation of fine striations found on the body of the objects (see Figure 2 and Table 10). In the majority of cases

where such marks were observed, they were usually over a small area of the axe rather than the entire body of the object due to corrosion. It is of note that on many of the axes too poorly preserved for striations to be observed on the blades there were still often areas of the body well enough preserved to allow the observation of striations.

Figure 2: Grinding striations on the surface of axes. Both images taken at x12.5 magnification, scale bars 2mm. Left: WG.1544 grinding striations running diagonally across the image, note the contrast between the thickness of the decorative marks and the grinding striations. Right: WG.1790 grinding striations running diagonally across the image, disrupted in the lower part of the image by corrosion. Photo © R.J. Crellin. Taken courtesy of the Trustees of the British Museum.

Grinding and polishing marks	Number of Axes
Not present	5
Present	25
Not Possible to Observe	8
TOTAL	38

Table 10: Interpretation of the presence or absence of grinding and polishing marks on the body of the axe. This interpretation rests on the observation of areas of fine striations on the body of the axe.

Minor casting defects were confidently observed on four of the axes (WG.1531, WG.1532, WG.1797, WG.1811); in three cases these defects took the form of small air bubbles evident on the surface and in one case (WG.1531) there is a small, semi-circular area of metal absent in the centre of the butt-end of the axe – this probably resulted from the process of removing the excess metal poured into

the mould (see Figure 3). There are a further three cases (WG.1790, WG.1792, WG.1804) where the author feels it is likely that the pitting corrosion evident on the surface of the axe has occurred in, and obscured, pre-existing air bubbles on the surface. All of these casting defects are minor and, from what has been observed on the surface of the axes at least, unlikely to have affected the function of the axe. All of these axes show signs of wear indicative of use.

320

Figure 3: WG.1531 – removal of material from the butt, probably representing the removal of excess material after casting. Scale bar on micrograph 2mm. Photo © R.J. Crellin. Taken courtesy of the Trustees of the British Museum.

4.1.3.1 Use marks - blade

In spite of the corrosion it was possible to make a simple statement about whether or not the axe showed signs of use for 32 of the axes examined (see Table 11). The majority of the axes appear to have been at least lightly used and this is in spite of any casting flaws that may have been evident and includes evidence of use on even the very earliest axes. An axe was classified as showing signs of use if there was evidence from either the butt or the blade in the form of asymmetry, wear-striations, notching, bluntness or breaks that could be interpreted as deriving from active use rather than intentional damage (see Figure 4) (detailed data is given in Table 12). It is possible for an axe to have no striations visible on the blade due to corrosion processes but still show other signs of use. Confidently identifying an axe as unused is very difficult – given problems with corrosion it is more accurate to describe an axe as failing to show signs of use. The two axes identified in this study as not showing any signs of use are WG.1542 and WG.1801. WG.1801 is one of three axes found in the

Caerphilly⁴ axe hoard (Evans 1881: 43; Needham, 1978: 282-3) – these axes are in poor condition but the other two axes show signs of use including striations (WG.1802) and notches to the blade (both axes). WG.1542 was found in Connor in County Antrim (Harbison, 1969: 35) and is thought to have derived from a hoard though we cannot be certain (see Figure 1). One of the other axes also believed to have been part of the same possible hoard (WG.1543) is incredibly unusual having had the blade completely removed from the axe. The axe is extensively decorated and the blade has been removed following the pattern of the decoration (see Figure 5).

Interpretation of Use	Number of Axes
Used	30
No evidence of use	2
Not possible	5
NA	1
TOTAL	38

Table 11: Interpretation of whether or not the axe exhibits signs of use. This interpretation rests on the observation of multiple categories of evidence.

⁴ Also referred to as the Brithdir hoard.

345

346 *Figure 4: Micrographs showing wear to the blade of axes, all scale bars are 2mm. Top Left: WG.1799*
 347 *Flattening to the blade of an axe, observe the folding and associated wrinkling and plastic*
 348 *deformation. Top Right: WG.1795 Nicks to the blade from wear. Lower Left: WG.1533 Perpendicular,*
 349 *shallow striations running from the blade inwards, some of these extend over 2cm and are therefore*
 350 *indicative of splitting. Lower Right: WG.1792 Irregular striations, at 45 degrees to the blade. Photo ©*
 351 *R.J. Crellin. Taken courtesy of the Trustees of the British Museum.*

352

353 *Figure 5: Probable axe hoard from Connor, Co. Antrim. Left to Right WG.1542, WG.1544, WG.1543*
 354 *Note WG.1542 on which no signs of use were observed and WG.1543 where the blade has been*
 355 *removed from the axe. Photo © R.J. Crellin. Taken courtesy of the Trustees of the British Museum.*

Striations on blade	Number of Axes
Blade unsuitable	19
No marks observed	7
Marks observed	12
TOTAL	38

Notches, nicks and chips observed	Number of Axes
Blade unsuitable	7
No marks observed	11
Marks observed	20
TOTAL	38

Blade Symmetry	Number of Axes
Not possible to interpret	3
Symmetrical	16
Asymmetrical	19
TOTAL	38

State of blade at deposition	Number of Axes
Blunt	3
Blunt - slight or in limited areas	14
Sharp	10
Not possible to interpret	11
TOTAL	38

356 *Table 12: Indicators of wear on the blades. Striations on the blade are interpreted as forming during*
 357 *use, notches, nicks and small chips to the blade form as wear continues. Blade symmetry is a*
 358 *measure of how heavily an axe has been used – the more asymmetric the axe the more used it is*

359 *presumed to be as re-sharpening is presumed to result in asymmetry. Bluntness is a clear sign of use,*
360 *however this data has to be read cautiously as it is possible to re-sharpen a blunt and worn blade*
361 *(see discussion below).*

362 Bluntness can be cautiously interpreted as a sign of use (an axe could be deposited without ever
363 being sharpened – see for example axes from Langton Matravers (Roberts et al. 2015)), especially if
364 observed in conjunction with other indicators. Sharpness, however, cannot be interpreted as a sign
365 of no use as it is more than possible to re-sharpen a blade, following use and erase earlier use marks.
366 Indeed, it was possible to observe evidence of re-sharpening of an axe blade on seven occasions
367 (WG.1526, WG.1791, WG.1792, WG.1796, WG.1797, WG.1798, WG.1809) (see Figure 6). In these
368 cases the re-sharpening marks partially erased and cut across earlier wear marks and may be
369 interpreted as re-sharpening in preparation for deposition: this questions any simple assumption
370 that deposition occurred at the end of use-life and points towards more complex practices where
371 sharpness was deemed appropriate for deposition in some cases. The 13 ‘slightly blunt’ axes (see
372 Table 12) could all still be used as their bluntness is weak or only on small areas of the blade. In
373 contrast, the four axes classified as blunt (WG.1523, WG.1524, WG.1791) would be difficult to use in
374 the state they were deposited in.

375

376 *Figure 6: WG.1809 showing re-sharpening over wear. The nicks to the blade indicate wear and use,*
 377 *but overlaying these are parallel, regular sharpening marks which are inclined from the blade. These*
 378 *have ‘erased’ the earlier irregular striations presumed to be associated with the formation of the*
 379 *nicks to the blade. Photo © R.J. Crellin. Taken courtesy of the Trustees of the British Museum.*

380 Breaks to the blade were observed on nine of the axes (23.68%) (see Table 4). Breaks are presumed
 381 to form during heavier and more prolonged use. Excluding the one case where the entire blade was

broken off (WG.1543), in all other cases at least one corner of the blade tip has broken. A break to the blade tip may be accompanied by other breaks to the blade. Breaks to the blade tips are common if used in a standard hafting (rather than an adze hafting) as it is the lower corner of the axe that wears the most, loses the most material through use, and does the majority of the chopping work (Crellin and Purnell, in prep. a). Of the axes with blade breaks three are from certain hoards (WG.1525, WG.1802, WG.1803) and two are from the probable hoard from Connor in Co. Antrim (WG.1543, WG.1544).

4.1.3.2 Use marks – butt

As discussed in 3.1 recording detailed data regarding wear to the butt is not at present an established practice so the results presented here serve to illustrate how much we might be able to learn from such data and, of course, the need for rigorous experiments to support the results. In ten cases there were no observable use-marks on the butt of the axes. The number of axes which do not exhibit signs of wear on the butt is higher than the total number of axes observed as displaying no clear evidence of use (only three cases). In part, this appears to relate to the often poorly preserved butt end of axes. In seven of these cases it was possible to observe signs of wear on the blades of these axes. In many cases where the blade exhibited no striations it was useful to have data recorded regarding the butt to support interpretations of wear based on the symmetry and sharpness of the blade.

Butt rounding was recorded on 20 axes. Butt-end flattening was observed on one axe within the Greenwell collection (WG.1534) (see Figure 7) and has been observed by the author on a number of other axes held in museum collections. Table 13 shows the data for butt asymmetry. The figures differ from those for blade symmetry (see Table 12) which is interesting and suggest that the two categories of data may have the potential to help us better understand hafting and use (see further discussion in section 4.2.1.2).

Figure 7: Butt-end flattening on WG.1534 – note the folding and flattening of the butt and the associated plastic deformation. Photo © R.J. Crellin. Taken courtesy of the Trustees of the British Museum.

Butt Symmetry	Number of Axes
Not possible to interpret	2
Symmetrical	25
Asymmetrical	11
TOTAL	38

Table 13: Butt symmetry is a likely measure of how heavily an axe has been used – the more asymmetric the axe the more used it is presumed to be.

4.1.4 Intentional Damage

Table 14 shows the number of axes that were recorded as exhibiting marks that were particularly unusual and unlikely to have formed during usual wear processes – such marks have been considered and then interpreted as evidence of intentional damage. Table 15 shows where on the axes these marks were observed. Sixteen axes observed exhibited some evidence of treatment that has been interpreted as evidence of intentional damage – the presence of the ‘Uncertain’ category in this data reflects caution regarding the interpretation. Axes showing such evidence included copper and bronze flat axes and developed flat axes, and included axes from England, Ireland, Scotland, and Wales. Of the four axes that show damage to the blade one is from the Caerphilly hoard (WG.1802) and two from the potential hoard from Connor, County Antrim (WG.1543, WG.1544). All of these axes date to after 2300 cal BC. In contrast, the axes exhibiting damage (and in

one case destruction (WG.1793 is split in half)) to the body are from isolated finds. In only four cases was there damage to more than one area of the axe – WG.1528, WG.1543, WG.1791, and WG.1795.

Intentional Damage	Number of axes
Present	16
Absent	14
Uncertain	5
Not possible	3
TOTAL	38

Table 14: Axes exhibiting marks unlikely to have formed through the usual wear processes that may be interpreted as signs of intentional damage to the axe.

Intentional damage on the blade	Number of axes
Present	4
Absent	28
Uncertain	3
Not possible	3
TOTAL	38

Intentional damage on the body	Number of axes
Present	6
Absent	29
Uncertain	1
Not possible	2
TOTAL	38

Intentional damage on the butt	Number of axes
Present	8
Absent	27
Uncertain	1
Not possible	2
TOTAL	38

Table 14: Detailed break-down of axes exhibiting marks unlikely to have formed through the usual wear processes that may be interpreted as signs of intentional damage to the axe.

4.1.5 Post-depositional Damage

Evidence for post-depositional damage, presumed to have occurred after excavation, is interpreted on the basis of marks that penetrate through the patina on the surface of an object. Usually these occur as 'bright spots' where the metal is a shiny bronze colour rather than the more usual browns, greens, blacks and golds observed. One axe from the collection (WG.2435) showed extensive signs of modern use (see Figure 8). The axe is a Killaha type and was found in County Longford, Ireland. This unusual axe was asymmetrical at the time of deposition with prehistoric grinding marks evident on the body. There are nicks to the blade that are modern as well as a series of striations along the blade edge that appear to have been the result of hitting the axe against something. On the butt and the margins there are also a series of parallel indentations that penetrate through the patina. The axe has also been quite heavily hammered resulting in a very uneven surface – this hammering is unlike hammering more usually observed on any prehistoric axe and as such may also be modern. Taken as a whole the evidence suggests this axe has been re-used in modern times.

442

443 *Figure 8: WG. 2485 showing multiple forms of damage. The uneven and undulating surface is*
 444 *indicative of hammering which is probably modern. The incisions into the butt shown in the*
 445 *micrograph (top right; scale bar 2mm) are golden in colour and therefore modern. There are also*
 446 *multiple incisions into the margin of the axe (lower image) some of these are ancient (indicated by*
 447 *patina over the incision) but many appear to be modern (indicated by a bright golden colour). Photo*
 448 *© R.J. Crellin. Taken courtesy of the Trustees of the British Museum.*

449 In addition to this axe with signs of modern use, six other axes (WG.1530, WG.1533, WG.1544,
 450 WG.1800, WG.1802, WG.1810) showed signs of modern damage that penetrated the patina (see
 451 Table 4). In the main, this damage can be characterised as scratches to the body and margins of the

axes, and less frequently nicks to the blade that go through the patina. In many cases, it seems likely that the intention of the mark maker was to cut through the patina probably to work out what material the axe was made of.

4.2 Discussion

The axes in this study are arguably better contextualised than many axes from the same period held in other collections. This, as well as their typological classification, has facilitated this detailed analysis. Roberts and Ottaway (2003) reported that of the 54 axes in their study 43% were too corroded for microwear to be observed. Moyler (2008) does not report on the condition of the 143 axes in his study in a comparable manner. In this study, 50% of the axes had blades suitable for the observation of microwear. Roberts and Ottaway (2003: 123) argued that even in cases where the observation of microwear is not possible macroscopic observations can be informative about the axes – this is a view sustained in this paper. Whilst only 50% of the axes had blades suitable for microwear there were only five axes (13%) in this collection on which it was not possible to make an interpretation regarding use. In this paper, data regarding wear to the butt was recorded in addition to the standardised recording of wear on the blade as seen in Roberts and Ottaway (2003) and Dolfini (2011): adding in this additional data only serves to strengthen the amount that we can say about axes in spite of the difficulties regarding corrosion of copper-alloys.

Following the same methodology as Dolfini (2011) the presence, or absence of casting seams, and the symmetry of the body was used to interpret whether or not it was likely the axes were cast in open moulds. The findings in this area are particularly interesting: numerous open moulds for the production of flat-axes are known in Britain, particularly from north-east Scotland (Coles, 1968; Schmidt and Burgess, 1981: 52-4). This data remains difficult to reconcile with the form of the flat axes from the period. These moulds were generally carved into soft stone, such as sandstone, and some moulds show evidence of blackening and metal residues indicating use (Schmidt and Burgess, 1981: 52). Such moulds would produce axes with a plano-convex section rather than the more symmetrical section that we observe on the majority of bronze flat axes (and some earlier copper flat axes). Axes cast in such moulds would require significant finishing work to give them the more symmetrical profile commonly observed on the axes. Within the analysed material only a single axe could be categorically stated as having come from an open mould (WG.1524), a Lough Ravel axe from Ireland. Given that the shape of the known open moulds, particularly from north-east Scotland, most closely resembles the shape of a Migdale axe it is of interest that one of these (WG.1796) has only partially ground away casting seams and another (WG.1810) has evidence of decoration with hammer blows highlighting the symmetry of the two halves of the axe. In both these cases arguing

for casting in an open cast mould is difficult. With regard to the other nine Migdale axes, where there is no evidence of a casting seam but the body is symmetrical rather than plano-convex, it is possible these were cast in a one-part mould and significantly worked to produce a symmetrical profile but on balance casting in a two-part mould seems more likely for these particular axes⁵.

What is clearly evident in the data is the skilled finishing exhibited on many of the axes. Grinding and polishing marks are evident on at least some small portion of the surface of the majority of the axes indicating a shiny and relatively smooth finish was important. It is assumed that the majority of these axes were hammered to increase their hardness yet hammering marks are rarely observed in this collection, though they are used decoratively on some axes. Bray (2009: 61-4) has argued that the chemical composition data shows axes from MAII onwards were hammered and heated in Ireland but those of MAI were likely not. He also suggests that it may not have been until MAIII in Britain that axes were hammered. This study contains no British axes from MAI or MAII - I am therefore not suggesting these axes were not hammered but rather, that hammering was executed in such a skilful way as to leave very few traces and preserve the smooth surface of the axe. This emphasis on smooth and shiny surfaces may well link to earlier practices regarding the treatment of stone axes which were also often skilfully finished.

There are very few axes in this collection that show any sign of casting flaws, and for those that do these are minor. This can be interpreted in several ways, it may be that the collection is biased towards axes with fewer flaws as a result of antiquarian collection practices, though the range of corrosion conditions exhibited in the collection questions such an interpretation. Alternate interpretations include - axes with casting flaws were rare, axes with casting flaws may have been being recycled⁶ rather than used, or they may have been used but not selected for deposition in the ground. Where casting flaws are present, such as evidence of gas bubbles, the axes still exhibit signs of use.

Dolfini and Crellin (2016: 80) argue that our interpretation of use on copper-alloy axes is limited by the lack of experimental data. At present the majority of experiments have either chopped or split wood: use on other materials, use in combat⁷, or using the axe in alternate hafts (for example as an

⁵ The author has observed Scottish axes of Migdale type that show evidence of casting in one-part moulds elsewhere.

⁶ For discussion of the evidence for recycling at this time see Bray (2009: 66-7) which indicates recycling was known though not necessarily common practice everywhere but by MAVI 40% of deposited bronze shows chemical evidence of recycling.

⁷ See for example interpretations in, Högberg, et al, 2016.

adze) or for different kinds of woodworking has not been published. As a result this paper makes only simple statements about use. It is presumed that the microwear marks observed on axes in this collection result from woodworking. Moyler (2008: 85) argued that in the Scottish Early Bronze Age axes there is a trend indicating that later axes were more worn than earlier ones and that this may be a sign of either use on harder materials or their circulation for longer prior to deposition. In this paper, I have not tried to create a system for characterising wear as either light or heavy as I do not feel confident in the strength of these observations on the present evidence (see Crellin and Purnell, in prep. a). That said, if we look at axes which exhibit breaks to their blade which may be from heavy wear (not intentional damage), in combination with interpretations of their asymmetry and bluntness that support heavy wear, there are at least three axes which could be argued to be heavily used (WG.1532, WG.1795, WG1797), in addition WG.2435 was heavily used based on its strong asymmetry – these four axes are either type Killaha or type Migdale. A larger study would be required to support or question Molloy's interpretations.

One potential trend emerging from this study is the interesting combinations of axes that have been placed together within hoard deposits. Moyler (2008: 79-80) writes eloquently about the need to avoid categorising hoards as either Founders' hoards (made up of broken or worn out material presumed to be scrap) or Merchants' hoards (made up of unused objects ready for exchange) and the data in this paper (though it is limited and a study involving a larger sample of axes is needed⁸) supports this view. The hoard from Newbiggen is too badly corroded to be useful in the interpretation of wear; however, the hoards from Caerphilly and the probable hoard from County Antrim both contained a mixture of heavily worn and unworn axes. This combination questions the utility of terms such as Merchants' and Founders' hoards in the Early Bronze Age and points to the complexity of hoarding practice.

The heavily used axes would have appeared different to the naked eye from the apparently unused axes and perhaps those burying them even knew the histories of the used axes. In the case of WG.1543, the axe with the removed blade, the axe looks very different and that difference provides evidence of its unusual history. In addition a number of the axes in hoards⁹ also showcase evidence of what has been interpreted as intentional damage. I argue that axes with different histories, evidenced by their different appearances were brought together in hoards and that some of them were intentionally damaged prior to deposition. The sample in this paper is restricted and it would be foolhardy to offer any catch-all explanation for hoarding and deposition across a large geographic

⁸ The author is currently working on such a dataset

⁹ Intentional damage is also found on axes not buried in hoards

area and time frame. That said, I do not feel it is the case that the Early Bronze Age hoards in this study (or the single axe deposits) were a form of simple storage before future use, the combination of axes which visualised different histories in hoards, the preparation of some axes for deposition, and the intentional damage to other axes all indicate the complexity of hoarding practice at this time¹⁰.

There are numerous axes that were deposited without evidence of any intentional damage: such axes cannot be said to have been deposited because they were too damaged to remain useful. The variety of use-levels and surface damages exhibited by the collection indicates that conventions regarding the selection of axes for deposition may have been complex and geographically varied. Considering specifically the data regarding intentional damage it appears that from the outset some copper and copper-alloy axes were deposited in the ground having been subject to action which appeared to damage their surface. Caution was applied to this interpretation to try and record only cases that appeared to be aimed at truly changing and damaging the appearance of an axe rather than cases where the marks could have been created accidentally. Moyler (2008: 85) argued that for the Scottish axes those that were broken in the main showed evidence of casting flaws, such as cracks, hollows and air bubbles. He argued, therefore, that some of the fragmented Scottish axes he analysed broke during use and that in other cases technical knowledge was applied in selecting axes that already had flaws for deliberate breakage. In the case of WG.1793 (the axe broken in two) I saw no such evidence. In one case (WG.1790) I observed air bubbles on the surface of the axe which had been broken on the butt. In six other cases no evidence of casting flaws was recorded (WG.1543, WG.1544, WG.1791, WG.1795, WG.1796, WG.1802).

There are potential links between damaging and breaking axes and the treatment of other materials in the Bronze Age. Brück (2001: 156) has noted the specific fragmentation of materials deposited in hoards as well as objects placed in graves. She has also argued that the destruction of objects during the Bronze Age can be interpreted as symbolically potent and transformative drawing links with cyclical character of life (Brück, 2006: 91). Only one of the axes in this study was truly fragmented but there are a number of axes that exhibit damage to their blades, bodies or butts that may be interpreted as intentional. Whilst the breakage and destruction of swords, spearheads and socketed axes in the Later Bronze Age appears to be relatively common it may be that this is foreshadowed by intentional damage to Early Bronze Age axes that would not have rendered them functionless but would have changed their appearance and been marked upon their surface. Bradley and Ford (2004) discuss the case of two parts of the same sword deposited 3km apart on inter-visible hilltops in

¹⁰ The continuing analysis of a larger sample will, it is hoped, shed more light on this issue.

Staffordshire. This is a later deposit than the material discussed in this paper but highlights the knowledge with which many bronze objects were deposited – they were selected for deposition and that deposition was careful. This also appears to be the case in the Early Bronze Age – in the case of an individual axe the current paper cannot be used to identify why it is a specific object was removed from use and deposited but in the case of the hoards discussed we can see that axes with specific histories marked on their surface were being brought together.

4.2.1 Methodological development: recording and interpreting additional data categories

The implications and possible interpretations of the additional data recording employed in this study are discussed below.

4.2.1.1 Corrosion Differentials

Dolfini (2011) notes that having clear observations regarding the corrosion levels present on metal objects is important as it allows the analyst to look at the relationship between the amount of wear visible and the amount of corrosion products present. Analysis carried out in this study recorded differential corrosion in addition to qualitative observations regarding corrosion. Many axes exhibit differential corrosion across their bodies. In some cases there is a corrosion differential between the two sides of the axe (the nominal front and reverse) (31.58% (12 cases) in this study) and in other cases (also 31.58% (12 cases) in this study) there is a differential between the butt and blade of the axe (see Figure 9). Having observed this numerous times it was decided to record this data formally during analysis.

In the case of a corrosion differential between the front and reverse sides of the axe it is postulated that this is the result of post-depositional processes (for example, one side being deposited against a surface within a pit and one side being covered with backfill); we frequently observe that one side is far better preserved than the other and sometimes it is only possible to see wear on one side of an axe, recording this additional detail can help to further unpick the relationship between corrosion and wear during analysis.

The second corrosion differential often observed between the butt and blade is, I hypothesise, the result of hafting. I am not suggesting that axes with a corrosion differential were deposited with the haft in place but that the hafting process itself altered the surfaces of axes, perhaps through the use of binding substances, and that this, in some instances, created a corrosion differential post-deposition between the blade and the butt. Brandherm (2011: 25) observed differential corrosion patterns on Iberian halberds (indeed they were the most commonly observed marks in his study) and also related these marks to hafting (see also, Guitérrez Sáez and Martín-Lerma, 2015: 184). The

appearance of differential corrosion on the Greenwell axes is varied, in some cases the butt and blade are different colours; in some cases, the butt is clearly more corroded and, in others, the blade is. At present, this interpretation remains preliminary as I know of no published experiments that have considered why corrosion differs across the body of an axe. In spite of this it seems pertinent to record this data as it may allow us to learn more about hafting.

Figure 9 – Differential corrosion between the butt and blade on three axes. Left to right: WG.1525; WG.1805; WG.1790. With kind permission of the trustees of the British Museum. Image: R.J. Crellin.

4.2.1.2 Wear to the butt of the axe

Recording the wear observed on the butt of the axe resulted in additional helpful data for the interpretation of wear. When blades are badly corroded and, in particular, if the axe exhibits differential corrosion between the butt and blade where the blade is in worse condition, this data can help to elucidate something about the history of a given object. In this study, wear to the butt has simply been used as a means of considering wear and use in general; however, the potential here is more significant. Experiments are needed that focus on how it is that butts wear during different kinds of use and in different types of hafts. Use chopping versus splitting logs will produce a

different set of forces on the haft and the butt of the axe¹¹ and presumably therefore potentially different wear markers. Indeed, it is possible that use in different types of hafts may create different kinds of wear.

The potential to think about evidence for different forms of hafting and use links to the recording of data regarding butt asymmetry. This may prove to be a useful category of data in the future especially when read in conjunction with data regarding the blade symmetry. Interestingly there are 15 cases where either the butt is asymmetric and the blade is not, or vice versa. There are four cases where the butt and the blade are asymmetrical exhibiting wear on the same side, and two cases where the butt and the blade are more worn on opposite sides in this sample. Recording this data now lays the foundation for future interpretations of these axes following the much needed experimental work focusing on wear to the butts of axes.

5.1 Conclusions

This paper has presented metalwork wear-analysis on 38 flat axes from Britain and Ireland drawn from the Greenwell Collection at the British Museum. In addition, it has made two key suggestions for further categories of data to be recorded by analysts. Firstly, it was argued for more detailed recording of corrosion and in particular corrosion differentials on axes. Corrosion differentials between the butt and blade of axes in particular appear to be informative of hafting practices. Secondly, the paper argued that recording evidence of wear not only on the blade but also on the butt of axes is informative. The butt end of an axe wears as a result of hafting and the evidence left on the surface may be informative about particular types of hafting and use. Further experiments are called for in this area to support the interpretation of axe butts.

The axes analysed were one of the earliest forms of metalwork in Britain and Ireland which spread extensively and relatively quickly – indeed it is likely that the flat axe was one of the forms in which most communities came into contact with and used metal. Analysis of the flat axes shows that, in spite of corrosion, it is possible to make both macroscopic and microscopic observations about the production and use of many axes. In only five cases were the axes too corroded to allow useful analysis. In the main, the axes appear to have been cast in two part moulds and exhibit careful finishing processes that produce smooth and shiny surfaces which may link to earlier stone axes. Only three axes were identified as unused two of which are believed to have come from hoards. It has been suggested that axes had their own specific histories marked on their surfaces through use and evidenced by their different appearances. In the hoards analysed in this paper, it appears that

¹¹ During unpublished experiments conducted by the author splitting logs has driven the butt end of a flat axe into the foreshaft of a haft causing damage to the haft.

axes with different histories were being brought together for deposition. In the case of isolated singular finds many axes were deposited whilst still functional and some show signs of being re-sharpened prior to deposition whereas other show evidence of apparent intentional damage. Axes were clearly important objects at this time. Understandings of metal and metallurgy changed during the Early Bronze Age and the role and ontological status of axes was also shifting and complex; further metalwork wear-analyses of axes from this period will help shed new light on this research area.

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