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ABSTRACT

Mutability, the ability to change form and substance, is a key feature of glass and metals. Often, particularly in metals, this has been considered a frustration to archaeological and archaeometry study. This article assesses the typological, chemical and theoretic elements of reuse and recycling, reframing it as a potential not a pitfall. It presents brief case studies to illustrate the potential for understanding mutability in the past, using diverse archaeological data, and what this can elucidate about the movement, social context and the meaning of objects in the past.

TEXT

There is a growing awareness and interest in the mutability of artefacts in antiquity, particularly the practices of recycling. This is partly prompted by the increasing emphasis on contemporary recycling, but the archaeological record makes clear that recycling, as a range of alteration processes, has been practised since humans first engaged with material culture. Characterising recycling is essential in all areas of archaeology, as it may significantly alter some of our basic interpretational building blocks, namely concepts of material characterisation and provenance, value, identity, chronology and technology. These can be summed up as the basic 'what, when, where and how' of archaeology. If recycling is overlooked, these most basic of archaeological frameworks could be unsound.

While many of these ideas of mutability of artefacts are described independently, from Roman *spoila* (Kinney, 2001) to usewear (Crellin et al, 2018), there is little general theoretical discussion of the motivating factors and implications of recycling in the archaeological literature. The very term 'recycling', with its modern baggage, often simply creates more problems. Obviously, the social and economic symbolism of altering, mixing and reusing material can be radically different in different contexts. 'Recycling' is not a simple or monotypic process, though it is often given a single entry in technological schematics or *chaîne opératoires.* For example, in discussing the cycle of metal production we often see a simple loop from 'finished artefacts' back to workshop, labelled 'recycling' (eg. Ottaway, 2001). This simple acknowledgement is often then ignored in the discussion that follows. However, this is not so much caused by human behaviour in the past, rather a reluctance of modern scientists/scholars to engage with the broad and varied concepts of mutability (whether reuse, repair or recycling). Increasingly, our experience has been that doing so allows us a better lens through which to view chemical, typological and chronological data, even if still somewhat darkly. The acknowledgement of the archaeological reality of recycling as an important aspect of ancient technology gives us a new, more realistic set of questions which archaeological science can help to answer.

In this paper we present a brief discussion of different forms of mutability, with particular focus on case studies of glass in Roman/Post-Roman Britain and copper alloys in the British and Irish Bronze Age. We present varied lives of materials, and the changes they undergo between their initial manufacture into objects, to their final unearthing by archaeologists. Partly thought experiment, partly case studies: we aim to show how integrated archaeological and archaeometric approaches can create inroads into understanding the history of mutable materials as something more than either linear or incomprehensible.

The Problem of Recycling

There is a tendency in the modern mind to see recycling as a simple activity – similar waste objects (e.g. glass bottles or aluminium cans) are collected and returned to production centres for use as raw (recycled) material. Today recycling is associated with economic discussions of scarcity, and related ecological concerns over waste and environmental loss. This attitude both underplays the complexity of present attitudes to reduction, reuse, and recycling, and cannot be universally applicable in the past. In this paper we put forward a brief sketch of various 'sorts' of mutability, to highlight the variety of mutations that materials can undergo and how they can be identified and characterised. We assess recycling processes as a contributor of meaning to objects and materials - the interrelationship of time, form, function and ownership.

Time, Form, Function and Ownership

Recycling focuses attention on the interaction between form and substance through processes of alterations - not just of shape and material, but also of function and ownership. While 'ownership' is a complex term in the past (cf. Earle, 2000), and is demonstrably not equitable across time or regions, we here mean a socially understood association of objects with people, whether to a single person, group, or even mythical persons.

Within modern recycling, time, form, function and ownership are negotiated through financial markets, directed trade, and factory-based production. Meanwhile current archaeological debates tend to discuss concepts of materiality and biography of objects (Hoskins 2006, Hodder 2012, Jones 2012). Drawing on early work, such as that of Schiffer's (1972) 'lateral cycling' and 'recycling', and Kopytoff (1986) on the biography of objects, attention has been focused on the paths and life histories. Archaeologists have therefore tended to concentrate on the 'same' object as it accrues history and itself becomes a measure of change (Gosden and Marshall 1999), rather than the alteration and reuse of material.

Recycling connections are often apparent in archaeological approaches to object and assemblage life histories, but discussions like this are not even considered in some scientific studies. In archaeometallurgy, straightforward provenance interpretations of data are common, where the final object is assumed to be from a single geological source. However, the 'single provenance – single production event' technological model can be critiqued from several angles. One key example is the importance of time depth (Pollard et al., 2014; Swift, 2012). Whether or not physical alteration occurs, there are cases where the relationship between chemistry, form and time demonstrate the movement and flow of materials through different contexts.

Classes of mutability can be defined by considering the alteration and interaction of form, time, context and ownership. Recent work by the authors has demonstrated that the scientific study of materials can add more detail to histories and geographies of recycling – particularly by identifying chemical markers of change (see Bray and Pollard 2012; Pollard *et al.* 2014; Sainsbury 2018). We can think more temporally and dynamically when we link issues of typology, the conventional means of understanding changes in form, with scientific analysis of substance.

In modern terminology, recycling means returning objects to a 'raw' form so that they can be re-made into new, but a broader definition includes any object that has been modified from its 'original' or 'prime' shape, composition, ownership, or chronological context. It can also be taken to include object forms that persist beyond their initial currency – concepts and shapes that are 'archaic' but which are recycled through production using 'new material'. We prefer 'mutability' as a more useful umbrella term for a wide range of activities involving both form and substance. These processes can be driven by any number of economic, material, or social factors, and thus have a range of technological and social impacts. It is by blending a series of archaeological specialisms that we can begin to unravel recycling in the past.

Through proposing a broad and contextual definition of 'mutability', we are aiming to avoid a version of the 'presentist fallacy' (e.g. Killick and Fenn 2012: 561), specifically the dangerous assumption that modern value systems had similar meaning in the past. Explicitly, modern recycling is primarily based on economic concepts of value, global trade, and energy expenditure, which are often inappropriately applied to the past. Such a materially- (or environmentally-) deterministic definition needs extending to include the social context of recycling. Anthropological studies often stress, for example, the necessity of perpetuating the form of an object during reuse to retain an embodiment of spiritual power. As Swift (2012: 202) puts it, *"In each case, the decision to maintain, discard, deposit or transform the object would be made in relation to the perceived value and meaning of that particular object at that specific time"*. Such considerations give rise to different modes of ‘recycling’, in which the ‘scrap value’ of an object may not be the important factor, if it features at all. Unentangling such complex material-social pasts requires the collaboration of field, research and lab archaeologists.

Different Forms of Mutability

To discuss the interaction between mutability of objects, places and chronologies, we can consider two broad categories: one where the form of the object is changed (recycling), and another where is it not (reuse). Such a split grossly simplifies matters, but it allows pragmatic inroads to be made through bringing together various datasets and perspectives.

The first category, Recycling, has been problematically used in archaeology to encompass many things. While it is often used to mean complete destruction through remelting, this is not always the case. Due to this, we have chosen a broader definition; from a small physical alteration with an object continuing its original function, ranging to the complete obliteration of the original form, which then allows the material to be used again as if raw. As will be discussed, even full liquidity might not destroy or discount the ideological significance of an object’s previous life.

Meanwhile our definition of Reuse encompasses no physical changes beyond minor maintenance or decoration, but refers to change of purpose, place, owner or cultural significance in the artefact. We consider the passing down of heirlooms over long stretches of time, or the opportunistic, quick recovery and exchange of discarded items.

Recycling

The general archaeological invisibility of re-melting has limited discussions of possible motivations. To state the obvious: if the object has been completely remade, through a melting step, none of the original form (with its usual typological markers) remains.

However, by marrying chemical studies to social and artefact-based archaeology, such recycling behaviours can be inferred and reconstructed.

The trade in cullet glass, and the recycling of glass, is well attested during the Roman period. Contemporary authors discuss it (Statius, *Silvae*, I.6.73-74, Mozley 1928; Martial, *Epigrams*, I.41 and X.3, Shackleton Bailey 1990; Juvenal, *Satires*, V.47-48, Morton Braund, 2004), as do archaeologists and archaeological scientists (Silvestri 2008; Foster and Jackson, 2010; Freestone, 2015). This work indicates that one driver of glass recycling at the height of the Roman period was commercial. It is less energy consuming to melt pre-made glass than to form fresh glass, therefore less economically costly. While perfectly good new Roman glass could be made in the Western Provinces, and indeed a small portion was, the overwhelming majority of Roman glass was produced along the Levantine coast and Northern Egypt (Degryse, 2014). As the cost of transport to the rest of the Empire was significant, recycling and secondary production of glass was economically expedient.

Through geochemical characterisation we can see how carefully these recycling processes were organised. In the fourth century, colourless glass in Britain, but importantly *only* colourless glass, is of an older composition, and was recycled separately from other glasses (Sainsbury, 2019). Given our archaeological understanding of the time, this implies the availability of this glass, decoloured with antimony, became problematic and recycling the only convenient source.

The use and recycling of Early Bronze Age copper-alloys in Britain highlights how social and ideological choices can drive the retention or recycling of material. Combining material science, large chemical datasets and archaeological typo-chronology allows us to identify the different treatment of metal locked into separate categories of object. There is a stark chemical contrast between the ‘axe’ metal, ‘halberd’, and ‘dagger’ metal that relates to the chemistry of their original mining source, but also their social roles and people’s technological choices.

Towards the end of the third millennium BC in Britain and Ireland there are two chemical patterns in the copper in common use – [As, Sb, Ag][1] that was produced by the Ross Island Mine, County Kerry, Ireland, and [As, Ni], which at *this* time and context is probably Continental in origin. The majority of daggers are continental metal [As, Ni], while 90% of the axes and halberds are of Irish metal [As, Sb, Ag], and these are rarely mixed. Though usewear analysis should be applied further to early British daggers, the limited data that we have for those in Beaker culture burial often show extensive usewear, along with a distinct, separate chemical profile to the rest of the metal assemblage (Woodward *et al.* 2015, Bray 2015). This indicates long periods of reuse, as daggers were originally cast in France or Spain, then enter Britain as personal objects, which continue to pass down as heirlooms. Similarly, halberds show similar long histories of sharpening and then careful, ceremonial burial, though with the distinctive Ross Island chemical signature.

These reuse patterns are in clear contrast to the recycling (complete re-melting and recasting) that can be identified in the axe series. Thanks to laboratory experiments such as those of McKerrell and Tylecote (1972), we can assess the different behaviour of chemical elements during melting. Arsenic and antimony are vulnerable to oxidative loss, while silver and nickel are stable. This allows us to gauge the relative degree of re-melting that a unit of metal has undergone, compared to its contemporaries. The chemical signatures of the axes, cross-linked with their typological form, indicates the common re-melting and recasting into axes over several generations. In fact the Ross Island chemical signature persists in axes, with depleted arsenic and antimony, after the mine was closed due to flooding. Meanwhile the chemical signatures of the used and worn halberds (O'Flaherty 2002, O'Flaherty 2007) look relatively prime (very high arsenic and antimony), due to their long stretches of reuse, but importantly, not their melting and casting (Bray 2009, Bray and Pollard 2012). The social and technological context of axes and halberds result in different recycling and reuse histories.

[1] This is shorthand for copper that contains As, Sb and Ag as principal impurities, also referred to as Copper Space 12 (Bray *et al.* 2015; Pollard *et al*. 2018)).

Alongside these examples of broad trends in material recycling or retention, whether driven by ideology, economics or both, we must consider focussed recycling for a specific purpose. An obvious example is the recycling of deeply coloured mosaic glass tiles (*tesserae)* only for the purpose of giving colour to a new batch of glass. There is archaeological evidence of scavenging of these tesserae from mosaics (James, 2006), and the addition of these to a 'fresh' glass batch is chemically very apparent due to the unique composition of these tiles. Tesserae are more brightly coloured than most roman glass, also often opacified with high levels of antimony (around 4.5 wt%). The appearance of transparent coloured glass with elevated antimony, such as at Sion, points towards such an addition.

While antimony can also function as a decolourant (approximately 1 wt%), there would be no purpose in adding an opacifier/decolourant to glass that is intended to be clear but coloured. Experimental studies by Wolf *et al*. (2005) have shown that for even the very brightest colours that appear in this Late Antique church glass, the chemistry is explained by a maximum ratio of tesserae to bulk glass of 4:10 by weight. So only a small amount of tesserae need to be added to colour glass; a chemically apparent action, even when macroscopically invisible. A largescale study of glass from Britain has shown that much fifth and sixth century glass, while otherwise seemingly `fresh' production, has been coloured this way (Sainsbury, 2019). In each of these cases of recycling, the past lives of these objects would not be apparent without both an analysis of the artefacts, and a significant set of comparative data.

We must also consider how recycling alters the social and economic value of the same material. For instance, the creation of beads or amulets by piercing or melting individual glass sherds or tesserae is seen both in New Kingdom Egypt (Nicholson, 2011) and across Late Antique Europe (Swift, 2012; Cavalieri and Giumlia-Mair, 2009; Heck and Hoffman, 2000; Cool, 2000: 49-50; Henderson, 1987). In the first case, the resulting beads are contextually clearly low-status artefacts, made from a scavenged high-value material. By contrast, in Europe under similar recycling processes of bead production, the resulting objects are found in high-status graves. Finally, Roman period beads are made of *fresh* glass and were not seen as particularly high-status, often imitating real gems. Clearly the value and technological sequence of glass use is not consistent across these periods, and each case must be examined in context.

As well as defining recycling as material formerly in an object passing through a molten state, there are other processes that we must consider as 'recycling' rather than 'reuse'. There is the solid-state recycling such as that seen in copper by rough hammering and shaping. A rather traumatic example is that of the Auchnigoul Halberds, which were found in 1939, but were later brought to archaeological attention by Gordon Childe who found one bent and twisted to act as the 'earth for a wireless set' (Edwards 1940-1). Analogous practises are present in prehistory, such as the ongoing modification of greenstone axes as they were moved around Europe (Sheridan *et al*. 2011, 412). Such alterations can change the appearance, function, and style of objects.

Examples in glass include the placement of broken vessel glass into early mosaics, such as at Casa del Torello and Casa dello Scheletro (Sear, 1977), as well as the creation of lids for glass vessels from the grozing of broken bases (Price and Cottam, 1998).

Reuse

Reuse has long been acknowledged in archaeology but rarely as part of a larger analysis of mutability. It is often discussed under terms such as heirloom artefacts (Caple, 2010), scavenging (Gillings and Pollard, 1999), or trade (Renfrew 1975; 1977). While some forms of reuse or curation are immediately apparent, such as for objects that were never buried underground (e.g. the Lycurgus cup or the Portland vase), others are more complex. An integration of archaeometric and archaeological approaches can help disentangle these complex scenarios. For example, the metal or glass found as parts of hoards or burials can show a demonstrable variety in production dates, despite sharing a deposition date. The Yattendon hoard (Needham

1983 Br 8, Appendix 11, R1 and Coghlan 1970) contains axes and a rapier which date much earlier than the rest of the Late Bronze Age assemblage.

Assemblages of objects from various time periods, ‘out of their time’, is often apparent from form. Unfortunately, glass, even in burials, is often fragmentary. As such, typo-chronological identification is not always possible. Similarly problematic, some object forms are extremely long-lived and therefore relatively undiagnostic. However, applications of archaeological science can assist. Roman glass goes through several well dated major compositional changes which can aid the identification of retained and reused objects in later periods. For instance, when a database of compositional data from 4,000 sherds of English Roman and Early Medieval glass was analysed, many sherds from post AD 450 showed a composition that stopped being produced in the 2nd to 3rd centuries in Britain (Sainsbury, 2019). For many of the sherds, the compositions showed no obvious physical or chemical signs of re-melting, implying that objects were probably directly reused. The scavenging of glass vessels from unoccupied Roman sites is a known practice from Anglo-Saxon Britain.

Just as recycling can have multiple motivating factors, so can reuse. At Orpington, where there is a temporal gap between the Roman and Anglo-Saxon occupations, the later burials contain huge amounts of Roman materials, some traded, some scavenged (Swift 2012, 199). Grave 2 contained a continental Roman glass bracelet, dating to the early fourth century, while the rest of the assemblage indicates deposition post AD 450. Once again this highlights the complexity of concepts of ownership and time in the past. The presence of Roman objects in Anglo-Saxon graves is well known and better discussed elsewhere (White 1988, Eckardt and Williams 2003).

There is a clear practical and talismanic interest in earlier material in the Anglo-Saxon world, and a strong connection to idealised ‘ancestors’ (Caple 2010, Hunter 1974, Bradley 1998). Through the veneration of barrows or the prime place of Roman artefacts in Anglo-Saxon burials, there is evidence of reuse being motivated by more than just scarcity. This is not to say that such reuse was not also practically motivated.

These examples are relatively straightforward but there are more abstract forms of reuse. Example include copies of forms, which sometimes result in skeuomorphs, such as ceramic versions of metal shapes (eg. McCullough 2014), and later revivals, such as the 17th and 18th century copies of Roman glassware, flourishing after the rediscovering of Pompeii (Whitehouse and Gudenrath 2007). Some Early Saxon coinage directly copies high imperial Roman motifs, regardless of the original meanings of such images (e.g. early gold thrymsas: Skingley 2014).

Reuse and repair throws up problematic concepts such as the classical thought experiment of the Ship of Theseus (Plutarch *These*us 23.1, Perrin 1914). If each pane of a stained window is slowly replaced over time, maintaining the pattern, at what point is it no longer repair, but a new window? Does this change if the pattern is lost, but the glass remains the same?

Discussion and conclusions

Artefacts are more than static indicators of production, but rather integral parts of an interconnected and ever-changing social system. As Joy (2009) notes, moments of transformation are deeply illustrative, whether form, function, time or simply ownership. To identify, disentangle, and interpret these shifts requires a marriage of all the techniques at our disposal, particularly typo-chronology, archaeological context, and archaeometric analysis. This discussion aimed to highlight how often this collaboration indicates that objects and materials had long and complicated, re-used and recycled, lives in the past. This work is impossible without comprehensive programmes of artefact recording and cataloguing, and the collection of significant amounts of geological reference data and comparative artefact chemical data. Both high quality analysis of new samples with recognised standards, as well as the free dissemination of the raw data of such analyses, is vital. Online repositories and inter-laboratory collaborations should greatly benefit our study of complex material processes.

The complexity of the histories or biographies of objects and people must be engaged with beyond a theoretical level; on a practical and empirical one. This requires an approach to archaeological science that is not an 'archaeological bazaar' (Pollard and Bary, 2014), but a discursive interpretation of data *given the archaeological evidence*. The questions asked of material should be built together by analysts and specialists, and not only 'exceptional' artefacts analysed. Analysts need to be mindful that there are *human* processes that go into the creation of the numbers we see, and archaeologists need to know that simple linear interpretations of data are not always correct. This is vital in cases of prehistory, or periods with fragmentary practical literary sources, such as Anglo-Saxon England. Subtle changes in the chemical character of materials, context, and relative date are biographical fragments or life events, which can be stitched together. Though an exacting process, this seems more archaeologically relevant, avoiding overarching assumptions of 'single-source cast once' provenance programmes.

The mutability of artefacts is intrinsically linked to ownership and identity. Even in cases with a high degree of alteration of form, where an old object was completely molten and a new cast made, the old shape is entwined with the new owner's choice over the form, and the resulting shared identity. In cases where the basic type is retained, but the form changes, there is still complexity. The separation of 'axe-metal' and 'dagger-metal' in the Early Bronze Age implies an important ideological connection between the past and future of these objects. Was there a direct taboo about mixing? Was the social role and power of metal daggers so dominant that their potential as mutable raw material was not appreciated?

All of this is not to say, however, that all object transformations were considered this way. Each archaeological cast must be studied on its own merits and from its own data. Roman treatment of bulk glass cullet or mixed hoards of scrap and unrelated objects that become common in the Middle Bronze Age are very different to carefully retained and protected copper daggers from millennia before. In all cases, highly mutable materials, glass and metal, show a history that is intrinsically linked with recycling and reuse.

We must avoid making presentist assumptions about the ways in which recycling may have occurred. The consideration of mutability of artefacts that have no macroscopic signs of change is paramount. Despite the occasional lack of easy indicators, it seems that practically all materials were recycled or reused to some degree in antiquity. This happened in a variety of different ways to fit social, economic, geographic or temporal environments. By recognising that this mutability can cause specific changes or inconsistencies between form, composition, context and time, we can track potential reuse and recycling. These studies have particular consequences for the way we build typo-chronological frameworks – an understanding of substance, and the way that substance changes, is required. Typological studies need to think about the history of the materials of an object, as well as the form. By an intelligent marriage of *all* archaeological datasets, irrespective of specialty, we can use reuse/recycling concepts to help us infer the movement, social context and the meaning of objects in the past.

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