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Form and flow: the 'karmic cycle' of copper

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ABSTRACT

The analysis and interpretation of the chemical composition of copper-alloys is one of the longest ongoing research projects within archaeological science. Beginning in the late 18th century these data have been consistently used to try and link objects with distinct metal sources. This paper argues the traditional provenance model for copper alloys is fatally flawed. Through pursuing a 'pure' source signal, chemical and isotopic datasets have been removed from their context and history. Social engagement with metal through processes such as reuse, recycling, and curation were rarely considered important by analysts. We offer an alternative model that unites the available legacy scientific datasets with process-metallurgy, archaeological and geographical context, and new conceptual approaches. Rather than provenance, we offer an empirical model of metal flow. Here objects are seen as snapshots of a wider metal stream; their final scientific characterisation including echoes of their previous forms and contexts. Through a series of case studies we highlight how the reinterpretation of existing datasets can disentangle the complex life histories of units of copper.

A document dated to the 12th year in the reign of Edward I (1284), translated from the original Latin by Riley (1875: 77), records the casting of a new bell at Bridgewater (Bruggewauter) in Somerset, England. It provides a detailed account of donations received from the parish and the expenses incurred by Richard Maydous, Philip Crese Erl, Gilbert le Large and Richard de Dunsterre. The document also lists, on the reverse, the sources of the metal used in the production of the bell:

> '*Metal for the bell. They answer for 180 pounds of brass, received as gifts, as in pots, platters, basons, lavers, kettles (cacabis), brass mortars, and mill-pots (pottis molendini). Also, for 425 pounds received from one old bell. Also, for 40 pounds of brass, received by purchase. Also, for 896 pounds of copper (cupri), received by purchase. Also, for 320 pounds of tin, received by purchase. Sum 1861 pounds. Of which there has been melted in the making of a new bell, 1781 pounds; and there are 80 pounds remaining over.*'

This list highlights an important problem with many traditional approaches to archaeometallurgy, which have assumed a simple linear relationship between the composition of ore sources and archaeological objects, since at least 605 lbs of the 1861 lbs of metal collected for the bell (*c.* 33% by weight) are being recycled. This figure may possibly be much higher if the 'purchased' copper, brass and even tin were also obtained from scrap, rather than freshly smelted metal. Clearly, if we were to carry out a 'conventional' provenance study of metal from the bell – using trace element composition and/or lead isotope ratios – we would be in danger of misinterpreting the results. To make this single object, copper from at least four different sources (the scrap brass, the old bell, the purchased brass and the purchased copper) is combined. Each has a potentially distinctive trace element 'fingerprint.' The scrap brass could be very variable indeed, depending on the life histories of the individual objects used, and even the old bell could itself contain recycled material from a previous iteration. Likewise, each of these sources of copper might bring in lead with different isotopic ratios, resulting in a mixed signal, which would correspond to no real source.

Although the Bridgewater bell provides an unusually clear illustration of this problem, the example is far from unique. Even defenders of a traditional model of evaluating provenance have to concede that particular assemblages are undeniably the result of collecting and remelting old metal artefacts. Pernicka (2014) for example discusses Late Bronze Age bun-shaped ingots from Switzerland, within which are partially melted pieces of identifiable objects (Rychner and Kläntschi, 1995). Similar and overwhelming evidence from both historic and prehistoric contexts has

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led us to fundamentally re-evaluate our approach to the interpretation of chemical and isotopic data from archaeological copper alloy objects. We would argue that, in focussing exclusively on the search for static geological origins or 'provenance,' conventional object-based perspectives have ignored the complex effects of human action on the chemical and isotopic composition of metal. Accepting that human interactions with metal (reworking, recasting, mixing and re-alloying) may weaken and ultimately destroy the possibility of provenance in a traditional sense does not, however, diminish the value of archaeometallurgical chemical and isotopic research. We need to move away from hoping that recycling was often unimportant (Pernicka, 2014: 258), an argument that is often framed through inappropriate analogies with the modern metallurgy industry. If we approach such studies of ancient metal from a broader perspective, taking a life-history approach to both objects and the metal from which they are made, then the dynamic composition of copper can provide us with the key to understanding structure in the data. In short it is possible to *empirically* assess the level and nature of metal recycling in the past, along with other types of social and practical interaction. Here we offer a framework which allows us to explore how people used and related to metal as a material in the past. For the first time in more than 60 years, we can begin to re-write the history of human engagement with this remarkable material. Perhaps invoking a 'karmic cycle' for copper suggests a more spiritual model than we intend, but we do believe that copper was frequently recycled, and that in some cases the previous lives of an object may have an influence on the form that such reincarnation might take.

1. A new paradigm: 'form and flow'

In order to visualise this model, and to emphasise how it differs from previous ideas that consider objects in isolation, we liken the flow of metal through society to that of a river fed by a number of springs, which runs out into a desert where it disappears. The extraction of copper from its ores, like a spring, creates a pool of material, which flows out as artefacts through a shifting social landscape, like a series of streams which may ultimately merge to form a river. Near to a source, individual communities may rely exclusively on a single 'stream' of copper, although they may alter it in a variety of ways. A new stock of metal entering the flow – the metal in circulation – will change the composition of the flow, just as the tributaries of a river contribute water with different chemical characteristics and sediment load. The composition of the metal in circulation at any one time and place is dependent on the balance of inputs from these 'tributary' streams. The relationship between an individual copper alloy object (with a specific 'form') and the generalized metal in circulation at a given time and place (the 'flow') can, therefore, be compared to the relationship between a bucket of water and the river. Water can be temporarily taken out of the river and kept in a bucket. While it remains in that container it will retain the properties of the river water at the time it was removed from the flow of the river. If the water in the bucket is returned to the river, it will alter to some small degree the properties of the water currently flowing in the river. In this analogy, a quantity of metal is 'scooped out' from the flow of the river of metal, made into an object of fixed form with a composition systematically related to that in the river (analogous to the bucket of water) and is then either lost, buried (to be archaeologically recovered) or returned to the river of copper to become available for future use as a raw material. We are left only with what has been taken out of the river. The concept of metal flow in archaeology has been emphasized by many scholars (Bradley, 1988; Needham, 1998; Jin, 2008; Pollard, 2009), but it is only now that we have developed a quantitative methodology to disentangle this complex dynamic system. The 'flow' of copper at any particular time and place is in reality made up of all the available copper objects at that time and place, and its precise composition is, of course, generally unknown to the users and will change with time as metal is added to or removed from the flow. Though specialized ingot forms may exist, we would highlight the potential for all copper objects to be melted and returned to the broader flow of metal. For societies which do not exchange metal, the flows of metal will be independent, like two parallel river systems, but exchange of metal will create linkages between them. The only evidence we now have for the composition of the flow of copper is the chemistry of the surviving objects made from it. In order to reconstruct this flow, we therefore need to think about the life history of the copper from which these objects are made. Individual objects and their assemblages crystallize out snapshots of the ongoing, overarching course of copper.

From this perspective, individual copper objects have three intrinsic 'attributes,' which are interrelated, but not necessarily dependent on one another:

- **trace element composition**, derived primarily from the copper ore source(s), but altered by human manipulation of the metal,
- **alloy composition**, defined by intentional action, as craftspeople choose to add minerals and metals to modify the characteristics of their material (fluidity in casting, colour, hardness, etc.),
- **form** (described by typology), imposed by humans and reflecting the socio-technological context of production.

There is a fourth (extrinsic) property, 'context', which frames the life history of the object, allowing us to situate its intrinsic attributes within the wider physical and social world. We argue that none of these intrinsic attributes are fixed in time, and are contingent not only on the life history of the object, but also on the life history of the copper metal prior to its incorporation into the object. Because we see individual objects being made by extracting metal from the stock in circulation, and, if not lost or deposited, possibly being re-made into new objects by being combined with metal extracted from the 'river', the biography of the metal flow transcends any individual object biography. Lead isotope composition, which might be considered a separate intrinsic characteristic, is in fact dependent on mixing between the lead isotopic signal(s) in the copper itself and the lead (if any) carried by the alloying elements, and is therefore encapsulated within the first two attributes.

Copper metal is extracted from an ore, refined, and turned into a block of relatively pure raw metal which becomes an input into the flow of metal. In theoretical terms we consider this a 'unit' of copper. It might be visualised as an ingot of copper, but this implies that all ingots are made from a single primary source, and this is not necessarily true. It also implies that 'finished' objects cannot act as ingots of metal, when the fact that they often do so has been demonstrated (Bray and Pollard, 2012). This unit of copper will then go through a series of transformations in shape, alloy composition and trace element composition (and also isotopic composition) as it flows through different societal contexts until it is ultimately lost or deposited into the archaeological record. The period of time between the 'birth' and 'death' of this unit of copper may vary from almost instantaneous (e.g., being made into an object intended to be placed in a tomb) to several centuries or possibly even millennia. The trajectory a unit of copper might follow is highly variable, and will depend on time and place (recycling and reuse may be much more common at certain times and places), and also the social context (some objects may be more highly valued than others in some contexts and therefore not recycled), although this social context may also change through time, even if the object itself does