"Recycling economies, when efficient, are by their nature invisible".[1]
A first century Jewish recycling economy.[2]

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This article is dedicated to Beno Rothenberg the father of modern archaeometallurgy, an inspirational teacher and always a friend.

Introduction

> This innovation is timely, for ours are not as the days of old: in those days whosoever was a Biblical scholar, and also learned to wander at length and briefly in the field of Talmud, was considered a complete scholar; and we too are witness to the fact that such a person is sufficiently filled with the soul of his people and the spirit of his religion. This is not, however, the case in the present in which enquiry and interpretation have gained primacy – the enquiry is in all the depths and interpretation in all the directions, and whosoever is minded, will never again innocently proceed but will deepen his questions and elevate his research. Upon the ridges of the biblical field the sages of deep commentary lengthened furrows, and we, though we stand in their presence, cannot shut our eyes to the work that is being done around us, work that has no voice. A labour that will one day reach completion will come through contradiction to be both formed and perfected. While this critique has ventured to contradict – we, the lovers of our holy writ, have distanced our path from it. But that awful trend has almost passed, indeed, in our time scholars and their endeavours have been transformed. In our day mysteries from Genesis have already been uncovered, they have been unveiled and exposed to the sight of our eyes by the great digs that have been carried out in Egypt, Mesopotamia and in all of Palestine. Inadvertently, we see the objects as they are, all the ways of life of old as they were in truth, and not as they appeared in our imagination and thoughts. And there is no more room for contradictions and speculations and inventions, for we are not dealing with nought but what is actually in our hands, and so our step is ready, and we need judge only as we see fit.[3]
>
> Samuel Krauss 1922

This quote from Krauss' introduction to the Hebrew edition of his original German Talmudische Archaeologie,[4] which he titled קדמוניות התלמוד, is a testament to the scale of his vision and industry. And though one should never underestimate the magnitude of his labour and scholarly achievement we might, nevertheless, acknowledge how

[1] Needham, S. P., M. N. Leese, D. R. Hook, and M. J. Hughes. "Developments in the Early Bronze Age Metallurgy of Southern Britain." *Archaeometallurgy* 20, no. 3 (Feb., 1989): 384.
[2] The English translations of the Jewish sources are based on the Epstein, I. *The Babylonian Talmud*. London (Soncino Press) 1935, Danby, H., *The Mishnah*. Oxford: Clarendon Pr., 1933, and Neusner, J., and R. S. Sarason, *The Tosefta*. 6 vols. New York (Ktav) 1977. In many cases, however, these have been amended by Levene.
[3] Krauss, S., *Qadmoniyot ha-Talmud*, vol 1. Berlin (Binyamin Herts) 1922, p. III.
[4] Krauss, S., *Talmudische Arcäologie*, 3 vols. Leipzig (Gustav Fock) 1910-12.

naïve his prediction of what his interdisciplinary approach was soon to yield. We suggest that Krauss' principle of approach is not only still valid but one which needs to be embraced with greater enthusiasm and urgency by current scholars. Indeed, if there is any methodological criticism that might be levelled at Krauss and those who have followed in his footsteps, it would surely be the fact that his interdisciplinarity is weighted more on an interaction with secondary literature rather than the direct discourse and exchange between living practitioners of different disciplines. It is the sad truth that historians, philologists and archaeologists still do not work together often enough – this paper is the product of such collaboration.

In this paper we start by discussing why Ponting's analyses of first century Palestinian finds show a high level of control of the type of the copper alloy they made their utensils from is difficult to account for. We will then look at a section from the Mishna, a Jewish text that was redacted soon after the date of these finds that presents a list of the raw materials that were available to the metalworker at that time. This text provides some unique information about metal recycling that we will argue suggests the existence of a sophisticated industry of collection and sorting of as well as trade in disposed-of metal objects that we refer to at present as the 'scrap metal' industry; an industry that is, to a great extent, invisible to the archaeological approach. We will then argue that what we can learn from the Jewish texts about the way in which metal was recycled – i.e. collected, sorted and supplied back to the metalworker – in this period, and beyond, offers a possibility of explaining how the type of the copper alloy observed in the archaeological finds was controlled at that time. Finally, we shall use our ideas about the existence in late antiquity of a highly organised industry of what we call 'scrap metal trade' to explain a group of metal assemblages found in an early medieval workshop in Tiberias.[5] We shall argue that the best way to explain the different types of assemblages in the Tiberias workshop is that they were sorted according to grade, illustrating a fine ability to distinguish alloy in 'scrap' so as to control the products that were then to be re-made from it.

Copper alloys

Throughout Classical antiquity copper was alloyed with three metals: tin, lead and zinc. Of these metals, tin was the most important alloying component prior to the 1st century BCE, when zinc began to be alloyed with copper on a large scale to make a golden-coloured alloy today called brass. In antiquity this alloy was called *oreichalkos* by the Greeks and *aurichalcum* by the Romans. The occurrence of objects made from this alloy in excavated assemblages is of interest because it seems initially to have been reserved for specific uses such as coinage and, especially in the Roman world, military use.[6] Indeed, there is an increasing body of evidence to suggest that, from the 1st century CE, brass had become strongly associated with Roman Imperialism[7] and became increasingly the alloy of preference for decorative metal objects of many types across the Roman world and amongst groups who sought to emulate Roman styles and fashions. Tin continued to be alloyed with copper in small amounts (<10%) to make bronze and was used for many common artefact types. Larger amounts of tin (~20%) were added to copper to make special alloys reserved for special items, such as mirrors.[8] The addition of lead to copper-alloys can also be

[5] Ponting 2008.
[6] Bayley 1998, 19.
[7] Ponting 2002.
[8] Craddock 1985, 64.

of interest, first appearing early in the 1st millennium BCE, initially as an aid to casting, but increasingly as a cheap bulking agent during the Classical period, reaching the height of its use in Roman Imperial times.[9]

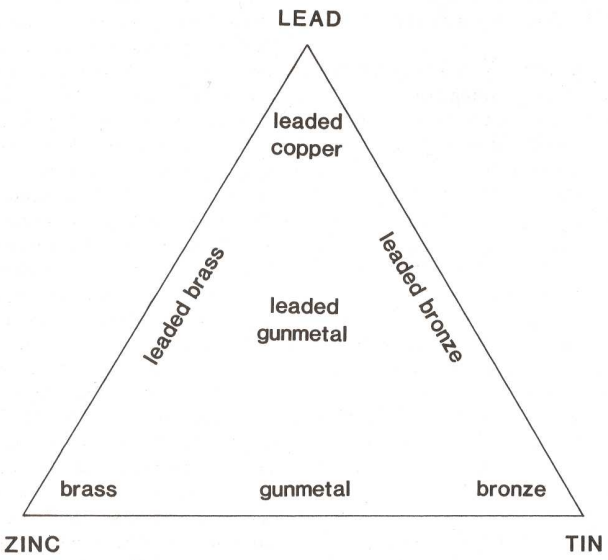

Figure 1: Copper based alloys: bronze, brass, leaded copper and leaded gunmetal (after Bayley 1998, 8).

Outside of the Mediterranean world of Classical antiquity the picture of copper-alloy choice and use is less clear. East of the Roman Empire the metallurgy of ancient Parthia is little studied, indeed, we have only managed to find a handful of analyses of Parthian copper-alloy coins from 1950[10] and nothing on other artefact types. The coins analysed are all made of bronze that is free of any zinc. However, it is known that alloys containing appreciable levels of zinc were being produced in northern India (Uttar Pradesh) as early as the first millennium BCE but these are rare. According to Craddock[11] the combination of textual and archaeological evidence suggests that brass was being made by cementation quite regularly in India by the later part of the first millennium BCE and that there is some (textual) evidence that may suggest that the technology to produce brass was introduced by Hellenistic invaders.

The sources of ancient copper and its alloying components has been a topic of debate for many years and much is known about the copper producing regions of the antique world. Palestine is a relatively poor region for natural deposits of the ores required for copper-alloy production; Feinan, Timna, the Sinai have been exploited for their rich copper resources from the earliest times[12], but sources of tin in the Eastern Mediterranean are elusive with only the Early Bronze Age site of Göltepe in Anatolia being well documented[13]. It is known that Afghanistan[14] has tin deposits as do regions of Central and Western Europe[15]. Lead is known to occur in Egypt but the silver-rich lead deposits of Iran are more likely to have supplied both lead and silver,

[9] Craddock 1985, 61.
[10] Caley 1950.
[11] Craddock 1998, 27.
[12] Craddock 2008, 96 and Healy 1978, 58.
[13] Earl and Özbal 1996.
[14] Moorey 1994, 252.
[15] Craddock 2008, 95 and Healy 1978, 60-61.

with the lead being essentially a by-product of the more lucrative silver extraction[16]. Zinc ores are also scarce, with the closest deposits being in south-west Anatolia. Both zinc and lead ores do occur in small amounts associated with some copper deposits in Northern Syria and it is these that most probably provided the metal for the sporadic production of natural brasses (such as the Nimrud bowls)[17] that occasionally appear in the first millennium BCE.

The raw materials for copper-alloy production were scarce and involved trade over great distances. Clearly the curation of the metal that was brought in and transformed into artefacts was of considerable importance and the fact that copper-alloys can be melted-down and re-cycled into new artefacts must have been heavily exploited as a result. However, evidence for recycling is difficult to find, being almost invisible to archaeology. Such evidence that exists is generally from earlier periods, but strongly suggests that recycling of copper-alloys was both necessary and commonplace. In particular, recycling appears to increase during periods of economic and social pressure and is often associated with temples and other structures of power and control[18]

Jewish vs. non-Jewish copper alloys?

Analytical work done on groups of copper-alloy metalwork from regions on the periphery of Roman influence generally show a gradual increase in the proportion of brass objects used as contacts increase and strengthen (often ending with conquest, as in the case of Britain).[19] Because of the increased availability of brass, the trace levels of zinc found in all copper-alloys also rise significantly due to the ease with which zinc vapour will contaminate other alloys through the re-use of crucibles and other tools[20]. It is therefore worthy of comment that copper alloy objects found on Jewish sites dated to the period immediately before the Great Revolt are free from zinc, whereas those from earlier Jewish sites and from later non-Jewish sites include brasses and other copper-alloys contaminated with zinc. The assemblages of metal objects retrieved from controlled excavations at Gamla, Yodfat and in the 'Burnt house' in Jerusalem have all been found to consist exclusively of bronze and copper with no brasses or other alloys containing significant levels of zinc (figure 2). Copper-alloy coins were also found (both in Gamla and in Jerusalem – arguably minted in both locations) that are also essentially free of zinc. This is strange as not only would brass objects be expected in assemblages of this period but that the presence of Roman brass in metal destined for re-cycling would, in usual working circumstances,[21] cause zinc to find its way into all copper alloys. This is clearly demonstrated in the analyses of copper-alloy objects from Roman Britain (figure 3). Dungworth's data from sites in Northern Britain shows how the zinc contamination of bronzes increases during the first century CE reflecting increased contacts with the Roman army and other groups regularly trafficking with the Roman world.[22] Indeed, brass objects form a significant part of an assemblage of metalwork from a 1st century

[16] Wolf et al. 2003, 418.
[17] Moorey, 1994, 254b.
[18] Karageorghis and Kassianidou, 1999.
[19] Hamilton 1996; Dungworth 1997.
[20] Dungworth 1996, 129.
[21] One would expect that through recycling at least small quantities of brass, and consequently zinc, would find their way into most produced alloys, even if through contaminated crucibles as is shown in Dungworth's analyses of British material and Beck et al's analyses of French material.
[22] Dungworth 1997.

BCE house in Jerusalem[23]. How it comes to be absent a century later from the copper alloys in Gamla, Yodfat and in the 'Burnt house' in Jerusalem is something of a mystery.

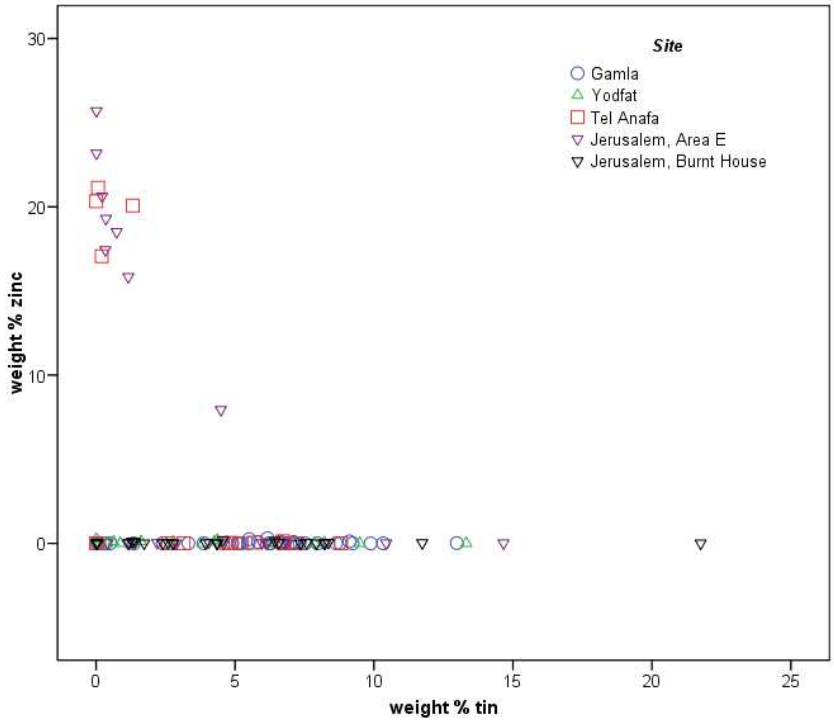

Figure 2: zinc and tin percentages in copper alloys in Roman Palestine.

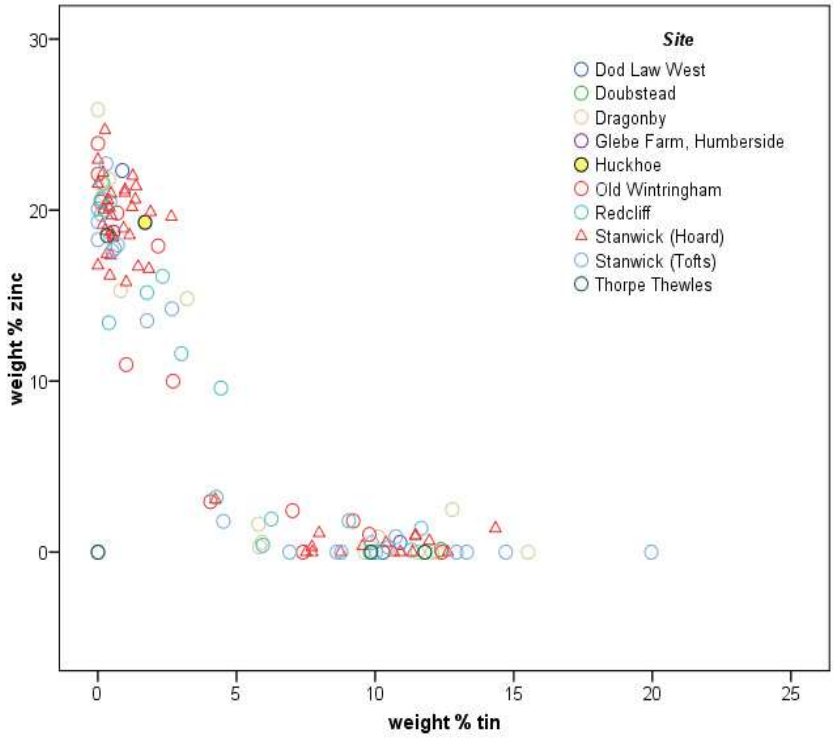

Figure 3: zinc and tin percentages in copper alloys in Roman Britain.

[23] Ponting 2006.

What then are the possible scenarios that could have led to a complete lack of zinc contamination in the Jewish assemblages in Palestine during the late second temple period?

1. That these metal artefacts were a collection of very old objects that predate the arrival of Roman brass.

2. That these metal artefacts were made in metal workshops that only used metal from ingots that had never been recycled and therefore could not have been contaminated with zinc.

3. That these metal artefacts were made in workshops that used recyclable materials, the alloy types of which they could distinguish to such an extent as to exclude brasses and other minor zinc contamination.

The first and second options are unlikely. The archaeological contexts of the objects and their typology clearly indicate that they are contemporary and common-place, the second option is highly unlikely given the level of re-cycling that is generally acknowledged to have been necessary to maintain metal supplies in the region. The third option seems the most likely but would require some qualification. In order for us to consider this third option feasible we must try and understand how a workshop could retain both its metal supplies and workshop environment free from even the smallest traces of zinc. Especially when the manufacturing cycle involves recycling which means that the metalworker would have to rely on there being extraordinary scrap sorting skills that would exclude not only the more obvious brasses, identified by their yellowish tinge, but copper alloy objects that themselves were made of recycled copper alloy objects that contained zinc.

To reiterate what has been stated above, the reason that traces of zinc find their way into other copper alloys is the fact that copper and its alloys are recyclable: objects made from this group of metals can be melted down or forged and thus remade/fashioned anew into other objects. And so it must be noted that although a portion of ancient metal supplies would have come from mining and smelting sites from which zinc was absent, for which there is ample evidence,[24] much of it came from recycling which would have included brass objects from the late Hellenistic period onwards and this would have increased with the arrival of Roman troops in the region. Metal objects that came to the end of their usefulness in one form were put back into the manufacturing cycle. As opposed to the industry of mining and smelting from which there remains ample evidence in the form of disused and abandoned mining sites, the activity of metal recycling, quite naturally, leaves barely a trace – except, of course, in the analyses of an object's composition. For the combination of elements found in recycled metals will be distinct from that found in metals extracted from particular ore sources which carry with them certain fingerprint combinations of ingredients. The traces of zinc found in 1st century CE British and European bronzes are the telltale evidence of such recycling.[25]

[24] Timna, Feinan and the Sinai all produce pure copper from relatively rich carbonate and sulphide ores that contain no zinc.

[25] See Dungworth 1997 and Beck et al 1985 for relevant NW European data sets against which to compare Jewish assemblages from Palestine.

The Mishna - Literary evidence for recycling

It has already been noted elsewhere that the classical corpus of ancient to late antique Jewish literature does not display an obvious concern with relating technical metallurgical information of a mechanical nature, at least not as its primary objective.[26] However, if one were to choose a section of text that comes closest to doing so it would undoubtedly be what is found in the tractate of Kelim chapters 11-14 that is in the order of Tohorot (Purities) of the Mishna (mKel 11-14). The tractate of 'Kelim', which might best be translated as 'utensils' or 'vessels', deals with the complex of rules intended to guarantee that utensils entering the inner parts of the Temple did not contravene its state of ritual purity.[27] This mishanic text has an equivalent in the Tosefta, though it is absent from the later Talmuds. Like other tractates from the order of Tohorot, the study of Kelim was largely neglected after the destruction of the Temple because it no longer had practical application, and many of the institutions and networks around it would have likewise disappeared. Thus it is lacking the later layers of interpretation and commentary that accompany other tractates, including commentaries which have often preserved older traditions.[28]

Of particular interest are mKel 11:1 and 3 in which we are presented with a confirmation of the part recycling played in the culture of the metallurgy of that period. The confirmation of the preponderance of the recycling of metal utensils is exemplified by the following rule:

> כלי מתכות פשוטיהן ומקבליהן טמאין נשברו טהרו חזר ועשה מהן כלים חזרו לטומאתן הישנה

> Utensils of metal, [whether] flat [in shape] or receptacles are impure (i.e. susceptible to impurity). If they broke they become pure (i.e. insusceptible to impurity). If again one made of them utensils they revert to their impurity (i.e. susceptibility to impurity) [29] (mKel 11:1)

Beyond the significance that this section has for halachic/ritual law it has the significance of reiterating the common-sense realisation that one of the most obvious properties of metal, that distinguishes it from other materials, is its recyclability – in the case of copper alloys this is mostly through re-casting, though in some cases re-forging is also a possibility. This affirms the fact that the metalworker was not dependant on the use of ingots fresh from the smelting sites to ply his trade. Rather, what we see here is that his was an industrial culture of recycling whereby any metal object that outlived its usefulness ceased to be that object per-se and reverted to being raw material – it was transformed, so to speak, from an object with a name and a specific function to raw material, i.e. 'scrap'.

The second rule regarding metal utensils is as follows:

[26] Levene and Rothenberg 2007, 7-27.

[27] See Neusner, 1974 and Douglas, 1993. The tractate of Kelim discusses a variety of categories of materials into which all utensils belong: earthenware (chapters 2-10), metals (chapters 11-14), wood, leather and bone (chapters 15-19), leather and clothing (26-28) and glass (chapter 30).

[28] We do, however, possess a small number of commentaries to aid us in our attempts to understand this text, most significant of which is the medieval gaonic commentary attributed to Hai Gaon (Epstein, 1982) and the commentary of Maimonides (Kafih, 1968).

[29] For a detailed discussion of this section see Levene and Rothenberg 2007, 36-41.

כל כלי מתכות שיש לו שם בפני עצמו טמא

> Any metal utensil that has a name of its own is impure (i.e. susceptible to impurity) … (mKel 11:2)

We provide this section to illustrate the sensibility behind the mishnaic taxonomy. As referred to in the comment to 11:1, the inherent recyclability of metal means that an object can be categorised in different ways according to whether it is still deemed to fulfil the function it was made for or not. In a moment it can be transformed semantically from 'utensil' to 'scrap', its function henceforth to be the potential to become what the metal-smith might choose to remake it into. This semantic change that we find easy to relate to is for the ancient Jew extended to a change also in the morphology of the material. Metal formed into a shape whereby it then can be used to perform a useful function was considered by the ancient Jew to acquire a state of susceptibility to impurity, or just referred to as 'impure' - טמא. Once such a metal object/utensil ceased to be considered functional then it became to that ancient Jew insusceptible to impurity, referred to succinctly as 'pure' – טהור. This could happen when an object broke, decayed, stopped being useful from age, etc.[30]

The following section, mKel 11:3, is the most significant for our discussion here:

> העושה כלים מן העשת ומן החררה ומן הסובב של גלגל ומן הטסין ומן הצפויין מכני כלים ומאגני כלים מאזני כלים מן השחולת ומן הגרודות טהורין רבי יוחנן בן נורי אומר אף מן הקצוצות משברי כלים מן הגרוטים ומן המסמרות שידוע שנעשו מכלים טמאין מן המסמרות בית שמאי מטמאין ובית הלל מטהרין

> One who makes utensils from [either]: the lump of metal, from the ingot, from the hoop of the wheel, from sheet metal, from the metal plating, from bases of utensils, from rims of utensils, from handles of utensils, from what falls in the process of metal work, from the filings and shavings, they are pure (i.e. insusceptible to impurity). R. Johanan ben Nori[31] says: 'Also from the cut bits of metal'. [Utensils that are made from] broken bits of [metal] utensils, from *scrap metal* and from nails that are known to have been made from [other] utensils are impure (i.e. susceptible to impurity). [Utensils that are made] from nails, the School of Shammai declare them impure, but the School of Hillel declare them pure.[32]

The fact that the raison d'être for this text was to provide metal workers with suitable guidelines to assure the goods produced in their workshops adhered to the requirements of temple ritual purity does not detract from what we perceive it to be: a list of raw materials that were available to the metalworker. This list is, to the best of our knowledge, unique for this period and region and must therefore be pivotal in helping us understand the metal working industry of the late Second Temple period. This is specially pertinent if we wish to consider, as suggested above, that the most

[30] Levene Rothenberg 2007, 136-44.
[31] First to second century CE.
[32] For a discussion of the halakhic significance a metallurgical and philological analyses of this text yields, and some notes on the various Hebrew terms in this text and their meaning see Levene and Rothenberg 2007, 148-62.

plausible way of interpreting the archaeological evidence is to take it as an indication that metalworkers were able to ensure that the scrap-metal they recycled did not produce coppers or bronzes that were contaminated by zinc. We shall start, however, by making some more general observations about this list with a view to see if we can learn anything about the nature of the metal supply industry that the workshops would have had to rely on. We will then consider if this passage and what we can learn from it can shed light on how the Jews of Roman Palestine managed to keep their copper alloys free from zinc in a way that others, such as in Roman Britain and Gaul, were not able to do or were not interested in doing.

One of the most obvious things about this list is the fact that it does not delineate the types of metal each of its constituents might relate to. This is an issue that has been partly discussed elsewhere;[33] indeed such an enquiry into the extensive lists of metal objects that exists in the tractate of Kelim in particular and the classic Jewish literature of antiquity to the medieval period more generally is a desideratum and one the present authors hope to address at some length in the future. For the purposes of this paper we need, therefore, not go in to such discussions in any detail that go beyond the needs of the theme dealt with here.

The most noteworthy aspect of this list for our purposes here is the fact that apart from the first two items, the 'lump of metal' and the 'ingot' the rest of the items are all clearly recyclables. Of the recyclables there are several categories we might distinguish: The first group 'the hoop of the wheel', 'sheet metal', 'metal plating', 'bases of utensils', 'rims of utensils' and 'handles of utensils' seem to all have in common the fact that they are not broken up but are identified by form and function. The second group 'what falls in the process of metal work' and 'the filings and shavings' are the by-product of manufacturing processes. And the third group the 'cut bits of metal',[34] 'broken bits of [metal] utensils', '*scrap metal*' and 'nails' seem to be what we would more commonly refer to as scrap; those objects and parts of them that have surpassed their life-cycle of usefulness, have become damaged, bits that have broken off, or such objects or parts of them that have been smashed or chopped up and piled up.

There is scrap and there is scrap - *grwt ym* גרוטים

As can be seen above we have translated the Hebrew term גרוטים (*grwt□ym*) as '*scrap metal*' yet have rendered it in italics, as we shall argue that the meaning of the Hebrew term differs in nuance from the meaning its English rendition has. Before even looking at the etymology of this word or considering what it might mean from looking at the way it is used in context elsewhere in the literature of the period we should consider its meaning in the list in mKel 11:3. Note that term *grwt□ym* appears within a list alongside the items 'what falls in the process of metal work', 'filings', 'shavings', 'cut bits of metal' and 'broken bits of [metal] utensils' which suggests that it is considered as distinct from them. Whereas we consider these other items as sub categories of what we call 'scrap metal' the text presents the term *grwt□ym* as an equivalent item and in no way privileged to its neighbours. So in the context of our list of raw materials *grwt□ym* can be distinguished as scrap metal that is not the by-product of a manufacturing process, it does not consist of parts of metal objects, and it is not processed scrap (cut or broken up). What is left is the disused object, this being

[33] Levene Rothenberg 2007, 141-44 .
[34] Admittedly, this category could encompass material that is the by-product of a manufacturing process.

a very specific type of scrap. In conclusion to what we have learned so far we might suggest that the contemporary English term 'scrap metal' covers a much wider variety of things than what the Mishnaic Hebrew *grwt□ym* encompasses. This is a semantic subtlety but one that indicates that the variety of items that we include as being defined by what we call 'scrap[35] metal' were not the same as those included in the term *grwt□ym*.

The word גרוטים (*grwt□ym*) is a plural noun and is loaned into Hebrew from Greek and attested in Hebrew only from its Mishnaic form of the language onwards. It is derived from the Greek *γρύτη*[36] which can mean either a **'**woman's dressing-case or vanity-bag', a 'workman's tool-bag', or 'frippery'. It is also used to denote 'smallness' in relation to fish.[37] One can possibly see some connection between the Greek and the Hebrew through the term 'frippery', maybe even its association of 'smallness', but this is a somewhat loose connection and it is clear that in Hebrew it acquired a rather different meaning.

What is more useful for us is to consider other contexts in which we find the term גרוטים (*grwt□ym*) used in texts contemporary or near contemporary with the Mishna. What follows is a discussion of what we can learn about the meaning of the term *grwt□ym* from it presence in context within the Mishna, Tosefta and Talmud and what this might tell us about the culture and practice of metal recycling that is implied therein.

The process of recycling starts at home, and the first stage of this is that point when a metal object ceases to be of use. We cite two text references that tell us that people had a dedicated pile of *grwt□a'wt* (scrap metal) to which they added such metal objects. In the Babylonian Talmud Shabbat 123a there is mention of a needle that has become defunct either through the loss of its eye or point that its owner is instructed to cast amongst his *grwt□a'wt*,[38] and in Babylonian Talmud in Bava Metsia 52b it conversely suggests that the owner of a sela coin (a silver tetradrachm) that had been damaged beyond a certain point may not be cast to his *grwt□a'wt*.[39] Both these references suggest that much like we have recycling bins for certain types of materials the same was true in antiquity. The disused, dysfunctional metal object lost the value that was intrinsically connected with its form and design, the needle you could not sew with and the coin that ceased to be recognised as such. Yet it was recognised that its intrinsic value as a raw material had not been lost.

What information then do we have about the next stage of the metal scrap in the greater process of recycling, how did it enter the trade cycle and how did this aspect of trade and industry look? Here too we present two text references where there is mention of *grwt□a'wt* (metal scrap) as a mercantile commodity. In the Babylonian Talmud Avoda Zara 53a there is a section that is concerned with what a man/merchant may do if he finds that he has in his possession a metal idol. What is interesting is the description of the way in which it was acquired; the text presents the

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[35] 'Scrap' being a word that in contemporary English is 'often confused with waste', http://en.wikipedia.org/wiki/Scrap.

[36] See Jastrow 1903, 266b who gives the meanings of the word as 'trash, frippery, broken ware.' See also Natan ben Jehiel 1878, 363, Krauss 1898, 183b-184a and Levy 1876, vol. 1, 358b-359a. Strangely this word is absent from Ben Yehuda.

[37] Henry George Liddell. Robert Scott. A Greek-English Lexicon. revised and augmented throughout by. Sir Henry Stuart Jones. with the assistance of. Roderick McKenzie. Oxford. Clarendon Press. 1940. http://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.04.0057%3Aentry%3Dgru%2Fth.

[38] אדם זורקה לבין גרוטאות, MS Oxford OPP. ADD FOL. 23 (366), Vatican 108 גרוטאותיו, 'his scrap'

[39] ולא יזרקנה בין גרוטותיו.

circumstances as follows: ‘if one bought scrap metal from heathens and found an idol amongst it’.[40] The implication here is that the merchant bought a job-lot of *grwt□a’wt* (scrap metal) amongst which there was a metal idol. We are not told who or what the heathen was but it is not impossible that he was, like the man with needle mentioned in the Babylonian Talmud Shabbat 123a (above), a person who sold on the pile of *grwt□a’wt* (scrap metal) he had amassed. Indeed, such piles might come about in bigger households, various institutions or workshops. The second reference is also from the Babylonian Talmud Bava Metsia 73a in which rules regarding cash investments in and loans to merchants who take advantage of price differences in different localities. As with the other references this aspect of the discussion is of less interest to us, what is of interest is the fact that one of the varieties of commodities that is discussed is *grwt□a’wt* (scrap metal).[41] So it seems that *grwt□a’wt* (scrap metal) was a commodity that was traded with and, furthermore, as the material presented so far suggests consists of a jumble of materials that have not been sorted out. One might just as well find in such a job lot of *grwt□a’wt* a needle or an idol. What also seems to be borne out of the examples presented so far is that *grwt□a’wt* are discernable objects, ones that are not in use but still recognisable as what they once were. Neither of the examples of *grwt□a’wt* are anything resembling mangled pieces of unrecognisable objects.

A text reference from the Tosefta Kelim Bava Metsia 1:3 adds another interesting aspect of the scrap metal trade in which a distinction is made between *grwt□a’wt* that came from abroad and those that have come from local sources.[42] This suggests a knowledge and/or perception of important differences between scrap metal from different sources and is discussed further later in this paper.

So far we have ascertained from the texts that disused metal objects were collected at source, in the home or any place where they were owned and used (Babylonian Talmud Shabbat 123a and Babylonian Talmud Bava Metsia 52b). Then at some point these assembladges were sold on (Babylonian Talmud Avoda Zara 53a). The word used to describe these assemblages of disused and unsorted metal objects is *grwt□a’wt*. We have seen that such assemblages of *grwt□a’wt* were a traded commodity. We have also seen that they were traded between towns domestically (Babylonian Talmud Bava Metsia 73a). The reference in Tosefta Kelim Bava Metsia 1:3 shows that they were also traded with across borders and over long distances.

A sophisticated culture of recycling

[40] הלוקח גרוטאות מן העובדי כוכבים ומצא בהן עבודת כוכבים, the Soncino translates לוקח as ‘brought’ which is amended here to ‘bought’ which is both a possible meaning of the root לקח (Jastrow p. 717) and is supported by the fact that the exchange of money is mentioned in this section later on.

[41] As it happens the Talmud advises against investment in *grwt a’ot* (scrap metal) as opposed to other agricultural produce. The reason is not given, however, one of the medieval commentators, the RABAD (Rabbi Abraham son of David, France 13th century), suggested that this was due to the fact that *grwt a’wt* were not a usual commodity in the sense that they were gathered only sporadically. This is not an entirely satisfactory explanation. We suggest that is more likely to be connected to either the control of the prices of metal or the fact that there is somehow not such a predictable or reliable price to such material before it has been sorted out properly and therefore one might not be able to predict, as with other produce, to the same extent one would the fluctuations of value as with agricultural produce – i.e. the price of apples in different regions etc. In any case there might have been a whole variety of reasons that are not apparent to us from the text. What it does tell us, however, is that it was a traded commodity and one which the lay person was not advised to speculate upon.

[42] הגרוטאות בין משל ארץ בין משל חוצה לארץ.

'Recycling economies, when efficient, are by their nature invisible in archaeological terms until the relevant metalworking sites with metalworking residues are located and investigated.'[43]

The evidence that we have produced thus far shows that at least in the case of the Jewish sources from the later part of antiquity and late antiquity there is some very compelling evidence for the existence of an organised culture and mercantile industry of metal recycling. On the one hand we have evidence for collection of disused metal objects and their being traded with, even over long distances, as unsorted assemblages. On the other hand we have the text of Mishna Kelim 11: 3 that presents a detailed and organised list of very specific types of metal for recycling that have clearly been sorted according to their usefulness for the metal-worker.

In juxtaposition to this evidence we have the copper-alloy assemblages from Gamla, Yodfat and in the 'Burnt house' in Jerusalem that show an ability of metalworkers to control their alloys to such a degree as to be able to exclude zinc traces all together.

We would argue that the literary evidence that we have presented above provides a probable explanation for how these Jewish metalworkers could control the type of their copper alloys by having a long tradition of a highly sophisticated culture of metal recycling.

Purity and susceptibility to impurity as an indicator of careful recycling

"It is hard to imagine that the detailed and technical descriptions of utensils and objects described in Mishna and Tosefta *Kelim*, both whole and broken, represent technological fantasies rather than material reality."[44] This statement might seem commonsensical but the transmission of these texts persisted despite the fact that after the destruction of the Jerusalem temple in 70 CE they had no practical use, and the fact that some of their meaning was lost.[45] Our attempt to recover a better understanding of these texts depends on the chance of coming across meaningful materials that we can cross match or compare, either in the form of other texts and/or archaeological finds.[46]

There are a number of things that we can deduce from the Kelim texts about the use of metals and their related industries in late second Temple Palestine from whence they originate. The most obvious is that the late second Temple Jews were concerned with issues of purity and impurity and furthermore, they had very specific and particular concepts/beliefs that relate to metals' susceptibility to impurity.[47] We

[43] Needham, Leese, Hook and Hughes 1989, 384.
[44] Schwartz 2006, 149.
[45] See the discussion regarding mKel 11:3 in Levene and Rothenberg 2007, 136 ff.
[46] For a discussion of the structure of the tractate of Kelim in the Mishna more generally se Levene and Rothenberg 2007, 142-43.
[47] The tractate of Kelim discusses a variety of categories of materials into which all utensils belong: earthenware (chapters 2-10), metals (chapters 11-14), wood, leather and bone (chapters 15-19), leather and clothing (26-28) and glass (chapter 30). These material categories are derived from the following biblical verses, though the Mishna elaborates much beyond the biblical text. Lev. 11:32 'And anything on which one of them falls when dead shall be unclean: be it any article of wood, or a cloth, or a skin, or a sack – any such article that can be put to use shall be dipped in water, and it shall remain unclean until evening; then it shall be clean'; Num. 31:22-23 'Gold and silver, copper, iron, tin, and lead – any article that [habitually] comes in fire – these you shall pass through fire and they shall be pure, except that they must be purified with water of lustration; and anything that does not [habitually] come in fire you must pass through water'; and Lev. 11:33 'And if any of those falls into an earthen vessel, everything inside it shall be unclean and the vessel itself you shall break'.

may also state with confidence that these concepts/beliefs were directly related to the material properties that this class of substance, namely metals (מתכות), displays. Material properties that are themselves characterised by them in relation to the processes and procedures of metal's use in manufacture and consequently the character of the industry these were carried out in.

One of the aspects in which metals are distinguished from other groups of materials that are discussed in the tractate of Kelim (clay, wood, stone, bone, metal, glass and dung) is the fact that it provides a list of the types of raw materials that the artisan, in this case the metalworker, would use in his workshop – the text of mKel 11:3 discussed above. This pericope provides a list of supplies that presumably would have been available to the late antique metalworker in Palestine. This differs to a great extent from most objects made from other materials that are discussed in the other chapters in Kelim whose processes of recyclability (where such exist) might well be referred to as 'reused garbage', the study of which has been referred to elsewhere as 'garbology'.[48] In contrast, the list of metal objects mentioned in mKel 11:3 represent well defined commodities for which the description 'garbage' does no justice; metal scrap has always had, as indeed it has today, a significant and enduring commercial value. Considering both current, recent historical, and what we have shown is implied from the Mishna, Tosefta and Talmud, practices of the collection, processing, supply and trade of metal scrap we would argue that the list in mKel 11:3 represents more than just an inventory of scrap that the metalworker might happen upon, but that it represents a list of recognised commercial wares that were the domain of established networks of industrial suppliers.

Early rabbinic texts such as the Mishna and Tosefta lead us to the assumption that the rules governing the ritual purity of utensils would have been adhered to. Furthermore, we must acknowledge that for this to take place that there would have had to have been an industry of manufacture with its suppliers of raw materials that would have catered for these rules. Indeed, we know that such rules were in evidence in some form already during the first Temple[49] and that these were the kernel from which the rather complex and detailed rules that we have in the Mishna, in the tractate of Kelim in the order of Tohorot, and other related materials in the Tosefta and Talmud eventually evolved. It is quite clear that for such rules as we find there to have been adhered to there would have had to have been an industry that could produce utensils that were ritually pure, could be maintained in such a state during their journey to the Temple, and could also deal with the recycling of impure utensils in a way that would assure that the impurity could be satisfactorily quarantined and eventually removed. As the mishnaic manual of Kelim clearly states this involved very clear rulings regarding the raw materials that were used (mostly recyclables – mKel 11:3). For this aspect to be maintained very reliable networks of supply would have had to be established and maintained. An example of such an industry is, of course, the stone vessel industry in the second temple period. Here, an entire industry developed to service the need for ritually pure vessels at a time when the Tosefta tells us that 'purity broke out in Israel'.[50] Vessels made of the local soft Senonian limestone (sometimes called 'chalk') were deemed not to contract impurity and so became popular during this period when particular attention was paid to the laws of ritual purity.[51]

[48] Schwartz 2006.
[49] See note 42 above.
[50] T Shabbat 1:14; JT Shabbat 1:3b
[51] Magen 2002.

The lack of zinc in the assemblages of objects from Gamla, Yodfat and the 'Burnt house' in Jerusalem may well have been the result of having such strictly controlled networks of scrap metal supply that were long established and still existed at the end of the second Temple period.

> But by late Second Temple times the laws of purity and their significance had been much elaborated by those Jews who came to see physical purity as a powerful metaphor for spiritual purity. In the first century CE purity was an issue of major significance for Jews of many different backgrounds and religious persuasions.[52]

Goodman points out that in the OT it is clearly implied that purity was connected to the Temple rituals and that it was recognised that being in a state of impurity was unavoidable and that there were rituals to remove it when needed. He contrasts this by stating that in "post-biblical texts pollution was sometimes treated as intrinsically undesirable."[53]

We know that on the one hand the rules pertaining to purity and impurity are ancient, and though they evolved over a long period of which the most detailed account we have is the latest, the mishaniac text; which, nevertheless, is sure to have sediments that would reflect earlier practice. A metalworking industry of supply and manufacture to support this is sure to have also evolved and is more than likely to have been significant by the late Second Temple period when pilgrimage, as various Jewish sources of the period attest, was very big business.[54] Evidence for a significant and long lived demand, are in themselves enough to imply the continued existence of an industrial network of supply and manufacture[55].

MKel 11:3 reveals the product list that the supply network would have consisted of. The supply and manufacture network would have had to be both a conservative one and a very skilled one in terms of the ability to sort out types of recyclable metal scrap. So much so as to be able to maintain supplies that were completely separate from that of the Roman metal industry and so remain completely zinc free. A contrast to this is the example of the British Isles that we have shown above, in which the arrival of the Roman sphere made its mark in the form of zinc traces in all forms of copper alloys. The ability to retain a completely separate industrial network in the east of the Roman Empire would have relied on the conservative and well established metal industrial sphere that had evolved to accommodate temple and related needs. An additional factor that might have helped keep at least part of this conservative supply and production sphere both separate from the Roman one and its brass related zinc traces is the fact that, as far as we know, the Persian sphere lagged behind Rome in terms of brass technology.[56] In fact, it has been suggested that Iranian production of brass starts only in the sixth century.[57] If

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[52] Goodman 2008, 288.
[53] Goodman 2008, 289.
[54] Goodman 1999.
[55] There is good archaeological evidence for a long association between metal recycling and religious centres such as the Bronze Age site at Kition, Cyprus. Karageorghis and Kassianidou 1999.
[56] There is so far no evidence for the Parthian zinc, contra Triester 1990.
[57] Forbes 1950, 284, 5, claims that the Persians were slow to catch on. Initially any brass that was there was imported from the west (as was apparently the case also in Egypt). "In Persia brass production seems to have started scale in the sixth century AD when it was exported to India ...". Allan (1979) deals with a later period but puts the use of brass as a common alloy to 1100 onwards.

this is indeed the case and some of the conservative supply networks that Jews who required 'purity'/'impurity' controlled bronze ware that are implied in mKel 11:3 were in the Iranian sphere then any such metalwork they acquired via these channels would have been zinc free. Indeed, these circumstances offer a likely scenario to explain the zinc free alloy patterns found in the Jewish contexts at the eve of the destruction of the temple.

The Tosefta Kelim Bava Metsia 1:3 which we mentioned above suggests the probability of exacactly such a scenario:

> העושה כלים מן הגרוטאות בין משל ארץ בין משל חוצה לארץ טמאין ר' יהודה אומר
> העושה כלים מן הגרוטאות של חוצה לארץ טהורין

> One who makes utensils from the *grwt□wt*, whether they are from this country or whether from abroad they are impure (susceptible to impurity). Rabbi Yehuda says: One who makes utensils from the *grwt□a'wt* from abroad they pure (insusceptible to impurity).

The '*grwt□a'wt* from abroad' are pure. What is interesting in this statement is the fact that Parthian supplies that would have been included in this as sanctioned for their purity would have also provided the metalworkers with zinc free alloys for recycling. What we see here is literary evidence of the fact that the Jewish metalworking industry of the late second temple period was concerned and particular about its metal supplies; which predominantly consisted of recyclable metal. The archaeological finds which are zinc free suggest that such concern and particularity was equally present in regards to the composition of the alloys of the material that came in these supplies.

Scrap awareness

The evidence that we have presented that is derived from both literary and archaeological sources suggests a very careful and aware culture of recycling, both in terms of sensitivity to the physical properties of the metals as well as their rules of ritual purity. They distinguish the varieties of types of what we call 'scrap metal' with a greater lexical range than the English term that we use suggests. To them *grwt□a'wt* has the much more limited meaning of 'metal object that has stopped being of use', i.e. it is of no use in its current form and despite being recognisable in its shape for what it used to be it reverts for them to raw material ready to be refashioned – recycled. Most of the rest of the list in mKel 11:3 which would come under the term 'scrap metal' in current English is not referred to in mishanaic Hebrew by such an all encompassing term. Once the metal is sorted it is not scrap to them it is what metal utensils are made from.

A medieval assemblage of 'scrap metal' – Tiberias

In 1998 the excavation of Fatimid (11th century CE) buildings at the foot of Mt. Berenice, on the outskirts of the modern town of Tiberias revealed what appears to be a copper-smith's workshop[58]. Beneath the floors of the building were found three large ceramic pithoi containing over one thousand copper-alloy objects together with

[58] Hirschfield and Gutfeld 2008.

over 200 kg of scrap metal. A sample of 103 objects from the hoard were analysed to establish the range of alloys used and it was found that over half of the objects were made of brass, 16% were made of bronze, 20% made of gunmetal and 10% of copper. Clearly brass would appear to be the alloy of preference by the 11th century. Curiously enough, most of the objects were incomplete or fragmentary; all the lampstands had been disassembled and there were large groups of separate handles, legs and other parts of objects that do not marry-up. The scrap metal comprises predominantly of cut-off handle-lugs and rims of large copper buckets; very few pieces of gunmetal or brass scrap have been identified. There is also a large amount of copper off-cuts from manufacturing processes. This is curious given the low proportion of un-alloyed copper amongst the objects and suggests that a fairly rigorous process of separation and selection was being applied. Additionally there are two brass jugs filled with metal turnings from finishing vessels on a simple lathe, however analysis of a sample of the contents indicates that these, to, are un-alloyed copper and do not appear to relate to any of the vessels in the hoard that are almost exclusively made of brass or gunmetal.

Possibly the most surprising element in the assemblage is the inclusion of 85 copper-alloy coins, of which 75 are Byzantine copper folles dating to between 1030 and 1078 CE. Of the 75 folles, 59 are of the type that does not bear an emperor's name, the so-called anonymous folles. All these coins are made of pure copper and were not part of the official Fatimid currency system of the time, which was exclusively composed of gold and silver denominations only. Therefore, the value of the coins to the hoarders would have been purely intrinsic and would explain their presence alongside other forms of un-alloyed copper scrap[59].

Because virtually all the identifiable objects in the hoard are essentially disassembled parts of complete pieces of copper-alloy furniture, equipment or table-ware and are accompanied by a large volume of cut-up scraps of metal, it is conceivable that the entire assemblage should be seen as scrap. This scrap, however, has been carefully divided-up and selected and there are few, if any, links between individual pieces. It may be possible to marry-up some of the lampstand elements and some of the legs form coherent groups, but generally speaking the hoard comprises of separate elements selected by a set of criteria that defies a modern rationale and brought together in Tiberias.

However, the problematic nature of interpreting the Tiberias hoard becomes much more understandable if viewed alongside the descriptions of the types of metal found in the documents discussed above (especially mKel 11:3). We find that in the Tiberias hoard we have represented four of the five categories of raw materials that were listed as being necessary for the production of utensils that would be regarded as halakhically pure. There is a lump or ingot of leaded-bronze, cut pieces of sheet-metal, bases, rims and handles of utensils as well as the two jugs full of shavings and a large amount of 'cut bits of metal'. Indeed, the only category not represented is metal 'from the hoop of the wheel' which is explained by the entire assemblage being restricted to copper-alloys whilst wheel hoops would have been only made of iron; a metal with which this particular industry was not involved. The fact that the make-up of the 11th century hoard of copper-alloy objects so closely matches the categories listed in the Mishna from the Second Temple Period is remarkable, more so given that many of

[59] The interpretation of other coin hoards as 'bullion' hoards is well documented, indeed, a larger hoard including anonymous folles from Turkey was similarly interpreted as a 'bullion' hoard with it being noted that 'this kind of collection could be found in coppersmiths' shops until quite recently' (Lowick et al. 1977, 16-17).

the objects in the Tiberias assemblage clearly originated in both Christian (the coins) and Moslem (style of and inscriptions on vessels) traditions. However, it seems likely that what we are seeing in the archaeological reality of the Tiberias hoard is the continuation of well established traditions of the recycling industry of the region, technological traditions of which we have an earlier example dating to the Second Temple Period in the form of the list from mKel 11:3. A list that was a product of a preoccupation with ritual purity that reflects, and inadvertently reveals, the very real concerns about the quality and composition of copper-alloys in a region where recycling was the mainstay of the metalworking industry.

Figure 3: Examples of some of the categories of raw materials listed in mKel:11:3 that are also found in the Tiberias hoard. From top left: sheet metal/metal plating/cut bits of metal, bases of utensils (examples of two types), rims of utensils (examples of rim and folded rims), handles of utensils (examples of ewer handle, spoon handle and table leg), and broken bits of metal utensils.

As we stated at the beginning of this paper, the recycling of copper-alloy metalwork is a human activity that is by its nature, invisible in the archaeological record and, because of this perhaps, it has usually been assumed that the majority of copper-alloy objects in the past were made from freshly smelted metal. This is implicit in most published works on ancient copper-alloy working; opening as they usually do with a discussion of ore sources, smelting technologies and the archaeological evidence for these. The recycling of copper-alloys is sometimes mentioned in passing as a likely explanation for the increased use of mixed ternary alloys (gunmetals) from the later

first century CE onwards, but then fades from the discussion.[60] Furthermore, the technique of lead isotope analysis, traditionally used to identify the ore bodies from which ancient non-ferrous metals were extracted, relies on the assumption of minimal recycling to work with the success to which the technique aspires and which is demanded of it by many archaeologists. Recycling makes things complicated for archaeometallurgists and archaeologists alike. However, apart from the fact that the recycling of a precious and scarce resource such as metal that is technologically demanding is likely to have been 'de rigueur' from the inception of metalworking and is clearly attested in the ethnographic record, there is a growing body of analytical and archaeological evidence that points to a widespread reliance on copper-alloy recycling. One of the earliest pieces of archaeological evidence is the group of ingots from the Cape Gelidonya wreck (Bronze Age) that includes two stylistically different ingots made of bronze rather than un-alloyed copper and which have been interpreted as being a class of ingot made from scrap[61]. The excavations at Kition in Cyprus have revealed Late Bronze Age workshops in the temple precinct where scrap bronze from votive offerings appears to have been recycled on a large scale.[62] The scientific analysis of copper-alloy artefacts suggests that low levels of arsenic in early tin-bronze objects indicates the recycling of arsenical coppers to make bronze[63] and, similarly, that the gradual reduction of tin contents observed in some quarters is indicative of recycling due to the loss of tin through volatilization every time the alloy is melted.[64] However, the topic has yet to be comprehensively scientifically studied, although some encouraging research is in progress. This study of textual data alongside archaeological data adds a further dimension to this discussion and provides that important human dimension often lacking in purely scientific investigation. Here we have the voices of the people who regulated the day to day activities of the producers and consumers of metal artefacts and which allow us a hazy glimpse into their minds and of their concerns and priorities.

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[60] For example Tylecote 1976, Healy 1978 and, more recently, Craddock, in Oleson 2008
[61] Muhly, Stech-Wheeler and Maddin 1977, 358.
[62] Karageorghis and Kassianidou 1999.
[63] Northover 2000.
[64] Gowland 1930, 511.

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