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Summary

A single set of alloy names to describe the whole range of copper alloys found in antiquity is suggested, based on those current in modern metallurgy. It is necessary to avoid names that are period-specific and to avoid using all the available names to describe a sub-set of the whole range of compositions. The adoption of a standardised nomenclature would minimise confusion in comparing the work of different analysts. Lead-tin alloys and precious metals are also considered briefly as is the use of ternary diagrams to display analytical data.

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## Introduction

From Bronze Age times onwards copper was seldom used on its own but was alloyed with one or more other metals to produce a range of alloys with very varied properties. In the past archaeologists have tended to refer to all these copper alloys as 'bronze', but with the advent of widespread compositional analysis this is seen to be misleading as only a proportion of copper alloy objects are truely bronze, ie an alloy of copper and tin. The composition of a particular object can be precisely defined by quantitative analysis which gives the percentage of each element present. Qualitative analysis identifies the elements present but not the exact amount. As with any other classification, the data provided by the analysis is only a first step and in order that the information may be used it is necessary to develop a terminology which identifies similar objects and groups them together with each group given a name that uniquely identifies it. It is with the choice of where to draw the lines between the different groups and the names to call them that the difficulties begin, as at present there is no single accepted terminology for many of the alloys that were used in antiquity.

## Alloy composition

From late Iron Age times onwards copper alloys contained deliberate additions of one or more of the elements tin, zinc and lead. Low levels of other elements were also present but they were accidental inclusions that occurred in the metal ores and were not removed from the metal during smelting or refining operations. These minor and trace elements may suggest a source for the metal or geographical areas of use, as has been done for the Bronze Age (eg Northover 1982, 59), though as yet this is a largely unexplored topic. Small amounts of the three main alloying elements may also be accidental inclusions deriving from the metal ores or from recycled scrap metal. In defining a nomenclature it is only the deliberate additions that need be considered, as the craftsman making or using the alloy would have been ignorant of the nature, and probably even presence, of most of the minor elements. These impurities would only have been noticed when they adversely affected the properties of the alloy; their presence was most likely to be recorded as low-quality metal rather than as a completely different type of alloy. In grouping analyses slight variations can be ignored as they would not have been discernible to the craftsman making or working the metal.

The craftsmen of antiquity had no means of performing elemental analyses as we do today but they usually had a good idea of the composition of their raw materials. Scrap metal was carefully sorted before it was recycled so that unwanted mixing was largely avoided. They would have relied on the properties of the alloys, their colour, hardness, malleability and ductility, all of which would have indicated to a trained eye the nature of the metal. Some alloys such as those with high levels of lead were well suited to casting, while others which were low in lead could also be wrought and were used to make objects from intermediate products such as sheet and wire.

The above discussion indicates that the names given to copper alloys have to reflect the varying amounts of zinc, tin and lead present in them. The alloys of antiquity have zinc contents of up to nearly 30%, tin contents mainly under 15% (but with some alloys with up to 25% tin) and lead levels that go up to around 25%. Occasionally alloys outside this range are found, but not in the form of usable objects (eg Craddock 1987). What is required is a single nomenclature covering the whole range of compositions, one that is equally applicable to objects of all periods so that a single analytically determined composition will bear the same name, irrespective of the date of the object.

## The preferred option

The first and in many ways the most satisfactory option is to use modern metallurgical names for alloys, although there are problems as not all the alloys of antiquity are in current use and some extrapolations are necessary. Copper-tin alloys are called **bronzes** and copper-zinc alloys **brass** (although some modern brasses contain far higher zinc levels than any ancient brass). **Gunmetal** is strictly a bronze with a few percent of zinc but this definition can be stretched to include all mixed alloys with significant amounts of both zinc and tin. **Leaded** alloys are those which also contain more than a few percent of lead. In modern practice the very high lead contents found in some antiquities are not normally used. There is no modern equivalent to the copper-lead alloys of the medieval period but **leaded copper** is an appropriate and unambiguous term, indicating copper with added lead in the same way that leaded bronze indicates bronze containing lead.

The most satisfactory graphical display of analytical results for copper alloys is on a ternary diagram, an approach pioneered by

Bayley and Butcher (1981) for Roman brooches. This depicts the relative proportions of the three alloying elements. The nearer a point representing a particular object is to a corner of the diagram, the higher the proportion of that element present. Figure 1 is a ternary diagram with the alloy names as defined above written in so that their relative compositions are clear; these are the names used in the present catalogue. It should be noted that points that fall close together on the diagram represent approximately the same alloy composition, providing the copper content of the objects is roughly constant. However, the ternary diagram only presents information on the relative proportions of the three major alloying elements present and contains no information on their absolute concentrations. It can show the groupings and spreads of compositions without the need to assign alloy names to individual analyses.

Figure 1 gives no indication of where the boundaries between the different alloys should be drawn, as there are no fixed divisions apart from those defined by the analyst. Often plotting analyses on a ternary diagram brings out clusters in the data, so that sensible boundaries can then be drawn between them. This approach may lack absolute precision (which is after all available in the raw analytical data) but avoids arbitrary boundaries splitting coherent groups of data.

The empirical approach of drawing lines between clusters is not ideal when attempting to define a universally applicable nomenclature, and so the boundaries shown on Figure 2 are suggested instead. Figure 3 shows these superimposed on the ternary diagram. They have been derived from consideration of alloy properties and made useful and usable divisions when applied to a large body of analyses of Roman metalwork (Bayley, forthcoming). Adding a given percentage of zinc to copper has only half the effect on the alloy's properties compared with the same amount of tin, so the brass-gunmetal-bronze divisions are not symmetrical. As a wide range of compositions is described as gunmetal, subdivisions into zinc-rich and tin-rich gunmetals may sometimes be helpful. Leaded alloys are those with more than 4% lead. Lower levels of lead would have had noticeable effects on the alloy's properties (Craddock 1985, 61-2), but were probably accidental rather than deliberate additions. Some metal was refined to remove even these low lead levels, for example where it was to be mercury gilded (Oddy et al. 1986, 7). Sometimes it is useful to subdivide leaded alloys into those with lesser amounts of the metal which could be wrought, and those with

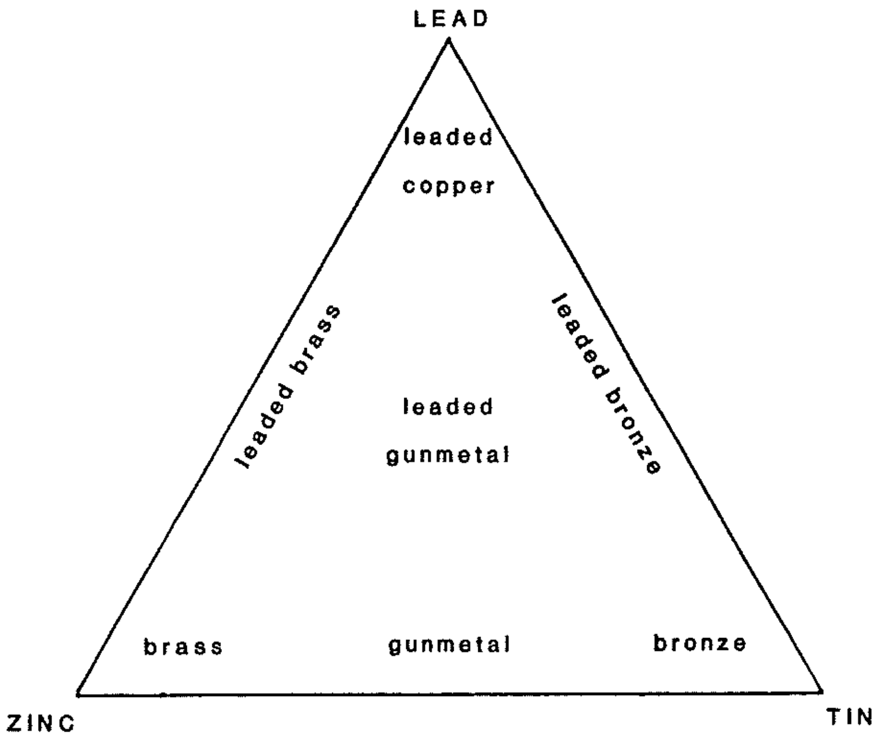


Figure 1: Ternary diagram showing the relative composition of copper alloys and the names assigned to them

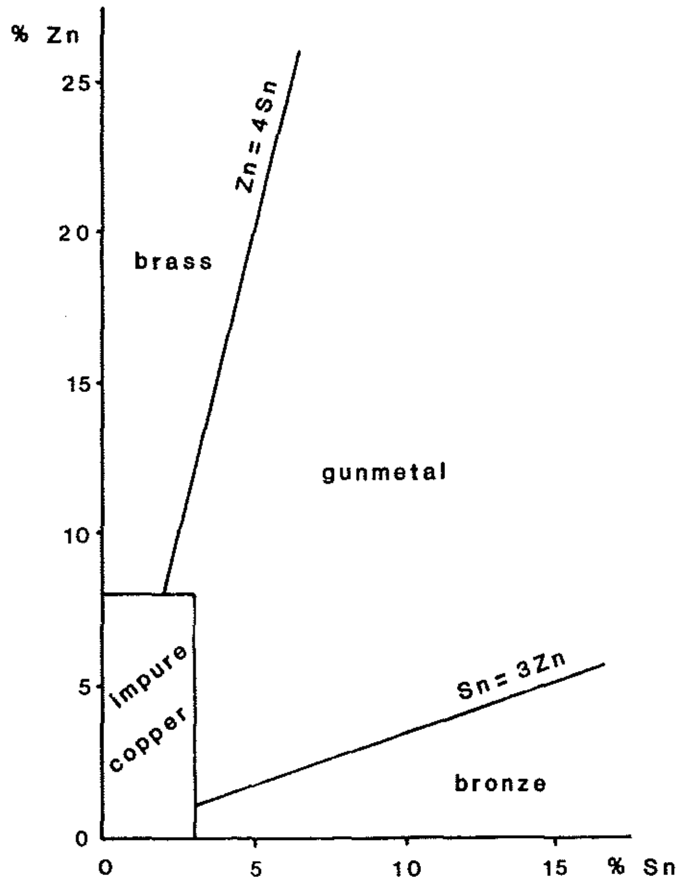


Figure 2: Graph of tin v. zinc showing the alloy name assigned to each range of compositions and the suggested boundaries between them

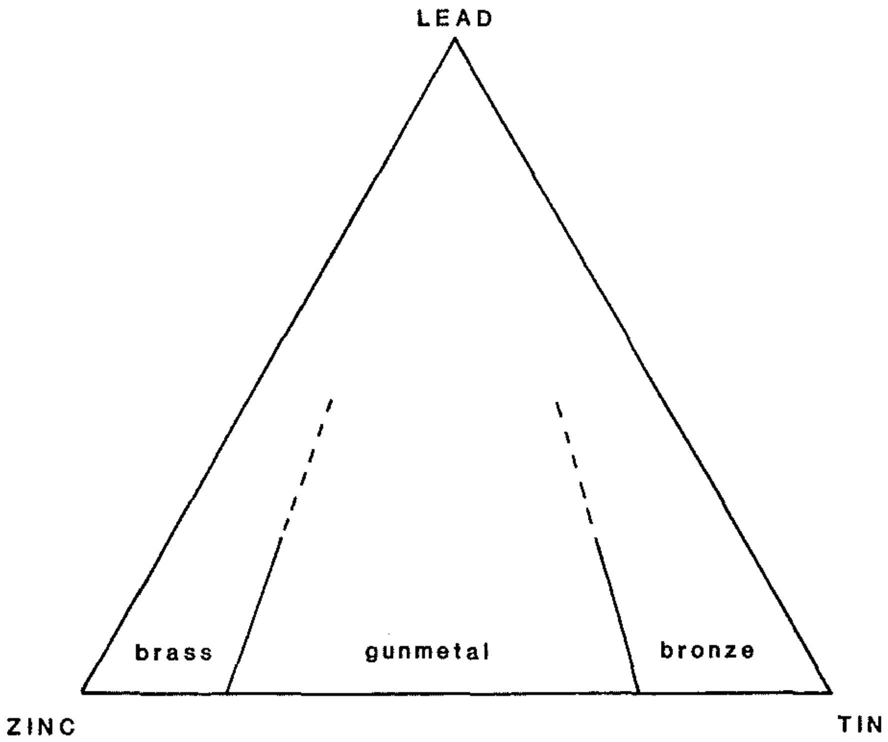


Figure 3: Ternary diagram with the boundaries shown in Figure 2 superimposed

much higher lead concentrations that could only have been cast. In these cases '(leaded)' alloys contain less lead than 'leaded' ones.

The one range of alloys which cannot successfully be displayed on a ternary diagram are those with low overall levels of additions which, relative to the whole range of copper alloys, are best described as impure copper. These alloys are almost unknown in Roman metalwork but are more frequently found at later periods. In this group are included those alloys with tin under 3%, zinc under 8% and lead under 4%. Normally only one of these elements is present in significant amounts and the copper content is usually around 95%. If it is necessary to display these results alongside those for alloys with larger additions, the method used by Oddy et al. (1986, 22) can be employed. The three variables for the ternary diagram are changed to zinc, lead and tin+copper, though this produces a rather different distribution of points on the diagram to that on Figure 1.

Brownsword (1987, 171) also uses ternary diagrams but weights the relative amounts of the three metals present to give better dispersion on the diagram, as he is dealing with only a limited range of compositions. It is therefore essential to check the scales and variables used in all plots before directly comparing them.

## Other possibilities

An alternative, though less satisfactory, approach to that oulined above is to use the terminology of antiquity to describe the different copper alloys. There are, however, two main difficulties in this. The first is that different names were used in different periods, reflecting the languages of the time, and the other is the problem of specifically associating the names in use with particular compositions.

If the main objection to the nomenclature already suggested is the anachronism of some of its terms, then the use of Roman terminology to describe medieval metals and vice versa is equally awkward. The second objection to ancient names is, however, a more serious one. In the past alloy names were not used consistently, so that often a single name covered a range of compositions and, conversely, a single alloy could have a number of names, often depending on the use to which it was put or the place it was made. As an example, the term 'brass' is now normally accepted as meaning a copper-zinc alloy with little or no other additions, though in late medieval usage 'brasse' could mean any copper alloy or, very rarely, copper alone with, if anything, a bias towards bronze (Blair et al. 1986, 85).

Surprisingly, there is little disagreement between modern analysts on what to call binary alloys such as brass and bronze (in their modern senses); here the anachronistic use of the term 'bronze', which was only introduced into English in the 17th century (Blair et al. 1986, 85), is overlooked. The main problem is with the mixed alloys and it is for these that the term 'latten' has gained a certain measure of popularity with those who analyse medieval metalwork. Cameron (1974) mentions the mid 15th-century instructions for the tomb of Richard Beauchamp, Earl of Warwick, which specify "the finest latten" should be used. By chance this monumental brass survives and has been analysed and shown to contain 8.2% zinc, 3.6% tin and 1.2% lead. This coincidence has been used to suggest that the alloy known as 'latten' in medieval times always had a similar composition and, conversely, that alloys defined above as gunmetals or zinc-rich gunmetals should be known as latten. While neither the composition nor the medieval specification of this particular monument can be questioned, a whole nomenclature should not be built round a single example.

The absence of a consistent correspondence between alloy name and composition in the medieval period has already been mentioned and the same is true of Roman terminology (Bailey 1932, 159). Recent writers are no less confusing as shown by the following contradictory statements about medieval alloy names and the range of compositions they represent. Brownsword (1988) defines latten as zinc-containing copper alloys which had a more or less golden colour and often contained some tin and/or lead too. Campbell (1987, 163) says "metalworkers used ... a variety of copper alloys, indiscriminately called latten, maslin or brass" and the glossary in the same catalogue defines latten as a "copper alloy resembling modern brass, but usually containing tin as well as zinc". Oddy et al. (1986) analysed Romanesque metalwork and they too consider maslin and latten to be similar alloys - but their definition is a quaternary alloy of copper containing at least 1% each of zinc, tin and lead - a very wide range of compositions. Some of the objects they describe as latten also appear in the *English Romanesque Art* catalogue (Zarnecki et al. 1984) but the alloy names assigned to them are different. A mourning Virgin (no. 231) is described as a brass, which was probably the intention of its maker as it contains some 16% zinc and only 2% tin and under 3% lead. Rather stranger is a doorknocker (no. 266) which is described as bronze but contains 10.3% zinc and only 2.3% tin!

While it is possible to argue that 'latten' is an appropriate term for mixed alloys of medieval date (though the range of compositions included seems to be open to debate), it is not a helpful term in attempting to establish a universal nomenclature for the copper alloys of antiquity. 'Gunmetal' at least has a specific modern definition and is no more anachronistic than 'latten' when applied to periods outside the high Middle Ages and thus is to be prefered.

Whatever nomenclature is adopted, it is important to define the terms used as, unfortunately, most analysts have their personal preferences and are unlikely to change instantly. A universally applicable nomenclature such as that suggested above should, however, be the aim in the longer term. Where they are dealing with a single period when only a limited range of alloys was used, the whole range of names suggested above may be applied to a subset of the copper alloy compositions of antiquity (eg Oddy et al. 1986) or appropriate historic terms may be used (eg Brownsword 1987). While the original papers carefully define the nomenclature used, other writers drawing on their work will simply copy the alloy names, a practice which is bound to lead to confusion as they are not usually directly comparable. Even where the same name is used for the same alloy (eg brass is universally used to describe a copper-zinc alloy) the levels of additions of other elements permitted may well be different. Oddy et al. (1986, 6) define brass as containing under 1% of both tin and lead, while Brownsword and Pitt (1983) have brasses with over 2% tin, and it is suggested that even higher tin contents may be acceptable as it is the zinc:tin ratio that is the main criterion, see Figure 2 above.

## Lead-tin alloys

Lead-tin alloys present fewer problems than copper alloys when it comes to their nomenclature, mainly because the possible range of compositions is limited. At either end of the range are the pure metals, lead and tin, while the alloys of intermediate composition are generally known as pewter. Other elements are rarely present above impurity levels. Most pewter contains more tin than lead but the proportions vary widely from a few percent up to over 50% lead. The other name that has been applied to these lead-tin alloys is 'solder', which does not describe its composition but its use, joining parts of composite metal objects. Both lead-tin alloys and pure tin were also used to give objects a tin-rich, white coating.

## Precious metals

Both gold and silver were used to make coins and decorative objects. The precious metal was normally alloyed with small amounts of base metals such as copper to increase its hardness, though occasionally the additions become a large proportion of the alloy which is then described as debased. Even when the precious metal is no longer the major element present, the alloy is usually described as gold or silver, as that was the intention of its maker.

Gold was also used to plate (coat) copper alloy objects. The deception was a visual one only, as the light weight of the object would betray its true bulk composition. Most gilded medieval objects were mercury gilded (Oddy 1981) and many of these were 'impure copper' (defined above). Other alloys, especially brasses, were also gilded (Oddy et al. 1986), though none of the gilded items included in this volume that have been analysed falls into this category. This bears out Theophilus' statement that "...unalloyed copper can be gilded more easily than brass" (Hawthorne and Smith 1979, 145).

Silver was used in a similar way to gold to plate base metal objects (eg SWA 81 nos. 893A-C), but the white metal platings normally found are tin or a tin-lead alloy.

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