Two thousand years of coinage in China: An analytical survey

S G E Bowman, M R Cowell and J Cribb

Introduction

The primary aim of this project was to provide an analytical survey of dated copper-based Chinese cast metalwork. The potential of coinage for this purpose is obvious and, in the case of China, made particularly opportune by the long tradition of manufacture of the copper-alloy cash coin. For almost two millennia the Chinese used this copper-based unit as virtually their only official coinage for day-to-day use. For much of this time the style and method of production of the cash remained essentially unchanged (1). Unlike the majority of Western coinages it was cast in its final form, instead of being struck, and this practice continued right up to the early 20th century.

The production methods used for cash manufacture were very conservative. We have a full account of the 17th century practice (2) but much the same process had been used since the Han dynasty (2nd century BC). The coins were cast in large numbers in batches in two-piece moulds arranged vertically. Moulds were prepared from fine sand re-inforced with an organic binder and contained within a wooden box. A pattern of 50-100 'mother cash' (either individually made or identical copies of a single master cash) were pressed lightly into the surface and then a second mould box was placed face down on top. An impression was thus taken of both sides of the mother cash pattern. The mould boxes were then turned over and separated so that the mother cash remained on the lower mould surface. A fresh mould box was then laid on this and again the pair turned and separated. In this way a series of two-piece moulds were obtained. After clearing channels between the coin impressions and making a central runnel, the boxes were fixed together in pairs and, following a preliminary firing, metal was poured in. The result was a 'cash tree' from which the coins were separated and subsequently cleaned up. A few fragmentary and complete cash trees have survived. The one illustrated here (Figure 1) although dating from the mid 19th century is typical of earlier examples.

In principle, the intention of this analytical survey was that the coins should merely provide a convenient dated series of metalwork. However, it has also been possible to use the analytical data to corroborate the numismatic study of the series, particularly the chronology of some of the later issues (3). There have been several recent analytical studies including Chinese coins (4, 5, 6, 7, 8) but they were restricted to comparatively short periods and no complete survey can be established from them.

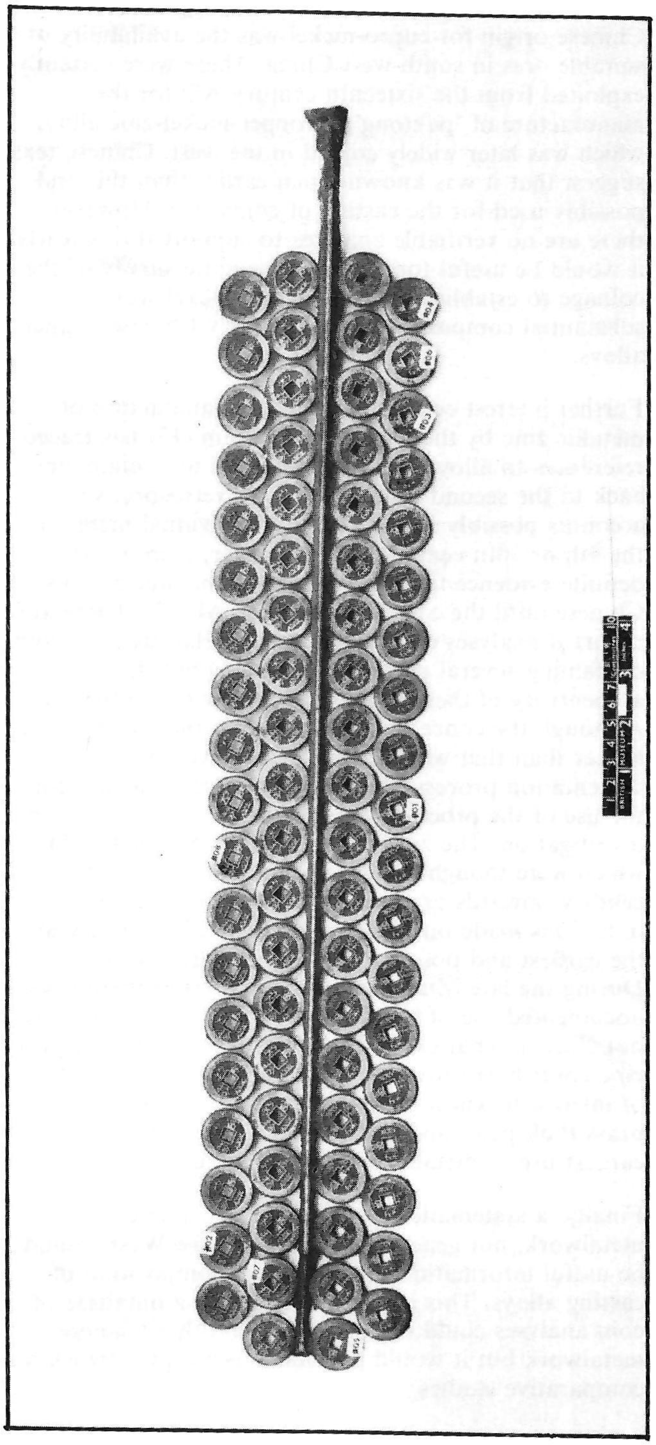


Figure 1: Tree of 78 brass Chinese cash, as cast, of the Board of Revenue Mint Peking dated 1905 (British Museum 1913, 10-11, 32).

There are a number of reasons why such a dated survey of metalwork would be of interest. One of these concerns the possible early use of more exotic metals and alloys some of which are alluded to in Chinese texts. For example, it has been suggested that the early use of cupro-nickel by the Indo-Greeks in Bactria during the second century BC was initiated by trade contacts with the Chinese (9) although this was refuted by Cammann (10). A more recent technical study of the Bactrian coinage provides data that are also opposed to the introduction of the alloy from China (11). Nevertheless, one of the reasons for suggesting a Chinese origin for cupro-nickel was the availability of suitable ores in south-west China. These were certainly exploited from the sixteenth century AD for the manufacture of 'paktong', a copper-nickel-zinc alloy, which was later widely copied in the west. Chinese texts suggest that it was known much earlier than this and possibly used for the casting of coins (12). However, there are no verifiable analyses to support this. Clearly, it would be useful for a more systematic survey of the coinage to establish whether or not nickel was a substantial component of typical early Chinese copper alloys.

Further interest centres around the manufacture of metallic zinc by the Chinese. Needham (13) has traced references to alloys that are presumed to contain zinc back to the second century BC with retrospective accounts possibly referring to the individual metal in the 9th or 10th century AD. However, there is no definite evidence for the isolation of metallic zinc by the Chinese until the early 17th century AD (2). There are reported analyses of 2nd century BC Han dynasty coins containing several percent of zinc (14) but the authenticity of these coins cannot now be confirmed. Although the concentration of zinc in these coins is no higher than that which could be achieved by the cementation process, this would be early evidence for the use of the process in the East and worthy of further investigation. The zinc coins analysed by Leeds (15) which were thought to have been minted from the 15th century onwards are now believed to be oriental imitations made outside China in the 17th century at the earliest and possibly the 18th or 19th century. During the late Ming and Ch'ing dynasties there is well documented use of brass for the cash coinage but it is not clear to what extent cementation brass and metallic zinc contributed towards its manufacture. It would be of interest to know precisely when the introduction of brass took place and if it is possible to identify the earliest use of metallic zinc in its formulation.

Finally, a systematic survey of dated Chinese metalwork, not generally available in the West, would be useful information on the typical composition of casting alloys. This is not to imply that a database of coin analyses could be used to 'date' other Chinese metalwork but it would provide a useful framework for comparative studies.

Analytical Techniques

Obviously, for a meaningful survey over such a long period of time, a large number of analyses are required to ensure that the data are representative. Since, in the first instance, the major alloying components were of principal interest rather than trace elements a rapid technique was required with moderate sensitivity. X-ray fluorescence (XRF) was therefore used as the principal analytical technique for all the coins but atomic absorption was subsequently applied to selected pieces to support the XRF data and extend the range of elements quantified. A Link Systems model 290 XRF spectrometer was used with a tungsten-target X-ray tube operated at 40 kV. A suitable area on the rim of each coin was normally selected for analysis and either scraped with a scalpel or abraded with silicon carbide paper to remove surface deposits of corrosion. Copper, tin, zinc, iron and lead were quantified in all coins and a selection were also analysed for nickel, antimony, silver and arsenic. The atomic absorption (AAS) analyses were carried out using a Pye Unicam SP9 spectrometer following the procedure described by Hughes et al (16) for copper-based alloys. Fourteen major, minor and trace elements were quantified. Samples for AAS were taken by drilling into the edge of each coin with a 0.75 mm drill bit and removing about 10mg of metal.

The limitations of XRF for the surface analysis of copper-based, particularly leaded, alloys have been noted (17) and segregation of lead in Chinese coins has been found by Sano and Tominaga (18). It was expected therefore that the accuracy of the results using this procedure would be compromised somewhat by inhomogeneities of the alloy. Replicate analysis and comparisons between XRF and AAS results on typical, not heavily corroded, coins indicate that the lead concentration will be subject to the greatest errors, typically +/- 10-15% relative as opposed to 5-10% relative for tin and zinc. This variation is less than the differences found between some of the coin groups and was considered acceptable for the purposes of this survey.

Results

General Trends

About 550 coins have been analysed in this survey covering a period from the Zhou dynasty, the 3rd century BC, to the end of the Ch'ing dynasty in the late 19th century AD. The coins were selected to provide as representative a spread of dates as possible. However, there are some periods when issues of coinage were severely restricted or curtailed completely, for example during parts of the 14th and 15th centuries, so that a complete coverage was not possible. During the period surveyed a number of mints were in operation throughout China which may not have always adhered to central minting policy. The investigation of possible regional variations in composition has yet to be examined however since the majority of the later coins included in the survey were selected from those attributed to or representative of the central mint at Peking.

The results show that, in general, issues before the 16th century are leaded bronze whereas subsequently they are brass. The general trends in the composition of the bronze coins are summarised in Figures 2 and 3 which display the average typical concentrations of lead and tin in the alloy (with bars indicating 1 standard deviation) for periods of a century or individual dynasties. It can be seen that for much of the period covered the coinage is heavily leaded bronze which is of course particularly suitable for cast metalwork. The lead content is typically in the range 10-40% and the tin content ranges up to about 16%. Although there are comparatively wide ranges in composition for coins issued over short periods, when these are averaged, some longer term trends become apparent. For example, prior to the end of the Tang dynasty in the 9th century AD there is a progressive increase in the amount of tin in the alloy but the lead content is rather erratic. After the Tang dynasty the overall trend is for the tin content to decline, except for one or two discontinuities. It is noticeable that during this period the trend in lead content is the opposite of that for tin, with the lead increasing at the expense of the tin and the copper. The progressive increase in the lead content may be related to the state of the Chinese economy because by adding lead there would be a saving in the more expensive copper and tin. It is significant that during the Song dynasty, when there are known to have been shortages of copper and greater demands on the coinage (19), the increase in the lead content is most pronounced.

The survey has also identified the point at which the coinage alloy changed from leaded bronze to brass, or more accurately a quaternary alloy containing substantial amounts of zinc, tin and lead. This change occurred during the years 1503 to 1505. The compositions of the coins during this critical phase are listed below in Table 1 together with the subsequent issues to 1566. Unfortunately only date ranges can be given for some of the coins in this table because the issues cannot as yet be more precisely dated. In addition, no coins seem to have been issued in the period 1505 to 1527 probably because of attempts to introduce a paper currency (20).

The results in Table 1 have been ordered to group together the brass issues and also to indicate an apparent trend in the composition of the bronze issues. The latter have been ordered by decreasing lead to tin ratio but the numismatic significance of this has yet to be investigated. Out of the nineteen coins analysed that were issued during 1503-1505, two (550 and 548) contain substantial amounts of zinc whereas most of the remainder are leaded bronze. All the coins examined with dates after 1527 are made of brass. The complete establishment of brass over leaded bronze for the cash coinage by 1527 is in accordance with near contemporary records such as Ku Tsu-Yu, writing in 1667, who notes that brass coins were used from 1520 onwards (21).

Prior to the 16th century zinc occurs only as a trace component of the alloy, generally less than 1%. This is a concentration which could have arisen through fortuitous association with copper or lead ores. The few exceptions proved on detailed examination to be of uncertain authenticity because of incorrect style, artificial patination or absence of internal corrosion.

Number	Date	%Copper	%Tin	%Lead	%Zinc
539⋆	1503-5	80	3.7	15.7	0.2
543⋆	1503-5	69	6.7	23.0	<0.01
549⋆	1503-5	77	5.0	17-2	<0.1
541⋆	1503-5	74	8.5	16.2	<0.01
547⋆	1503-5	72	9.3	17.8	0.1
426	1503-5	79	7.6	12.4	0.5
536⋆	1503-5	79	7.7	11.6	<0.96
538⋆	1503-5	74	10.6	14.8	<0.01
427⋆	1503-5	77	10.1	11.7	<0.1
542⋆	1503-5	81	10.0	7.0	1.6
544⋆	1503-5	82	10.7	6.8	1.2
546⋆	1503-5	84	10.8	4.9	1.0
21	1503-5	87	8.5	3.7	0.4
545⋆	1503-5	84	10.9	4.1	1.3
22⋆	1503-5	85	9.8	2.8	1.2
540⋆	1503-5	85	10.0	2.8	1.7
537⋆	1503-5	82	16.0	0.6	0.7
550	1503-5	66	7.4	10.9	16.2
548⋆	1503-5	69	7.8	9.6	13.3
430⋆	1527-66	82	3.2	0.8	12.5
429	1527-66	69	7.4	8.5	13.0
431⋆	1527-66	81	4.0	0.7	13.5
433	1527-66	70	5.5	7.2	16.0
428	1527-66	60	7.5	14.4	16.4
432	1527-66	70	5.5	6.5	17.4
20⋆	1527-66	69	7.4	5.2	17.8
19	1527-66	63	6.9	7.0	22.7

⋆ Analyses by AAS, remainder by XRF

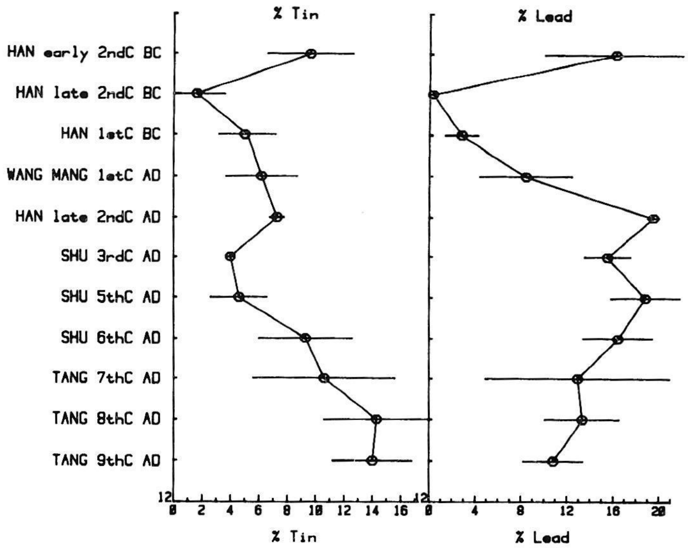
Table 1. Composition of coins issued during the transition from bronze to brass

The nickel contents were found to be similarly low and none was greater than 0.5%. Certainly no early cupro-nickel was identified and even during the late Ming and Ch'ing dynasties, when paktong was definitely being manufactured, nickel was never other than a trace contaminant of the coinage.

Brass Coinage

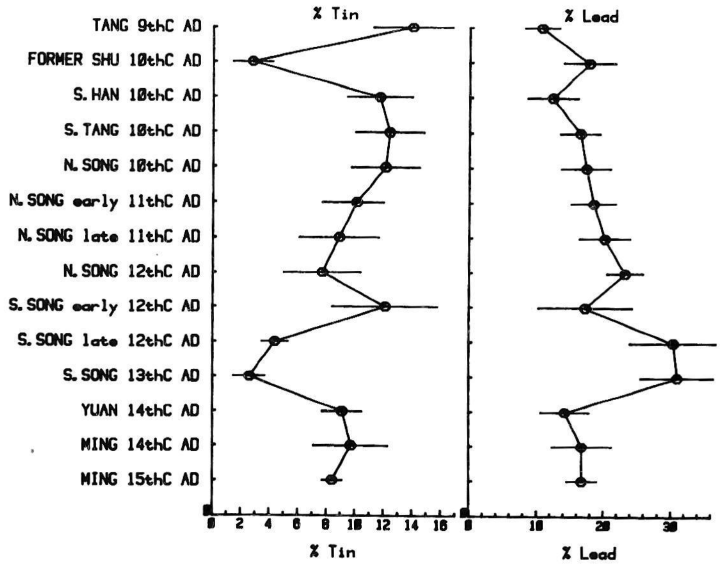
The primary source of contemporary information on the manufacture of the Chinese brass coinage is the **T'ien-Kung K'ai-Wu** written about 1637 (2). This gives precise details of the alloy used for the coinage, the method of casting and the preparation of the coins afterwards. The procedure referred to speaks of six or seven parts of copper alloyed with three or four parts of zinc, noting that about a quarter of the zinc is usually lost through vaporisation. Zinc was then regarded as a very cheap metal known as **wo chienn** or

Figure 2



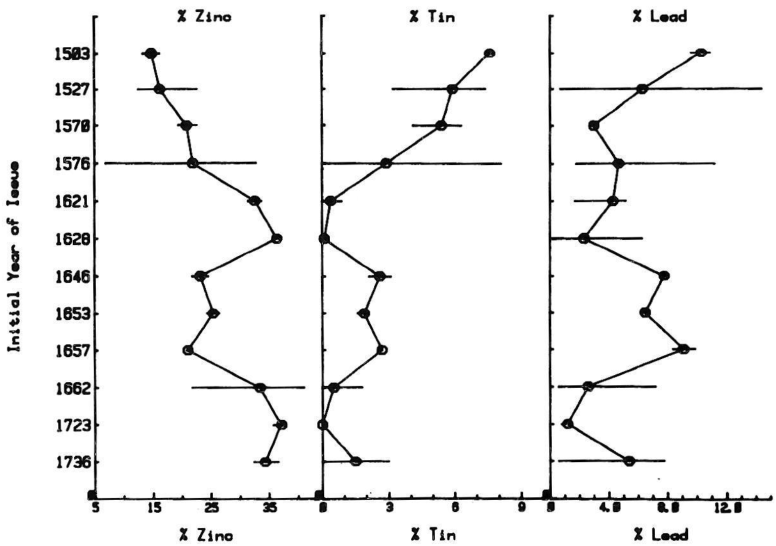
Bronze issues before the 10th century

Figure 3



Bronze issues after the 9th century

Figure 4



Brass issues from 1503 to 1736

poor lead and took the place of lead in effectively reducing the amount of copper in the alloy. In consequence, contemporary forgeries were reported to contain the most zinc with up to 50% of the metal. Clearly metallic zinc was available in the East at this time in substantial quantities and it is well known to have been exported to Europe at the beginning of the 17th century (22). In fact, the current results show that the brass coinage in China can definitely be traced back over one hundred years before this. What indication is there for the use of metallic zinc, as opposed to cementation brass, over this period? As we will show, the analytical data provide strong evidence for the availability of metallic zinc in China from the first quarter of the 16th century.

The main alloy composition of the brass coins issued from the 16th century to mid 18th century are summarised in Figure 4 by the means and ranges for zinc, tin and lead. This shows that the zinc content was initially only about 13-16% but, apart from some fluctuations, soon reached over 20%, and then by the early 17th century was 30-40%, which corresponds to the contemporary accounts. After the early 17th century the zinc content is occasionally reduced but not, it seems, below 20%. The wide, and apparently random, range in the zinc concentration over certain periods has some numismatic and historical significance which will not be explored in this paper. In addition to zinc the alloy also contained, at various times, substantial amounts of tin and lead, often totally 15-20%, whose concentrations are usually inversely correlated with the zinc. The presence of these metals is almost certainly connected with the use of re-cycled scrap, the possible inclusion of which is mentioned by Sung Ying-Hsing (23). In this context, it is significant that the tin and lead concentrations are highest in the earliest brass issues, with their relative proportions being similar to that in the near contemporary leaded bronze coins (see also Table 1). There would have been substantial amounts of earlier leaded bronze coinage available at that time and it would have been uneconomical to have refined this in order to extract the more valuable copper and tin components.

The concentrations of tin and lead in the early brass coins suggests that at least half of the metal used derived from re-cycled bronze. It may be conjectured that the zinc in these same coins was introduced via cementation brass which could have had a maximum zinc concentration in the range 28-33%. However, after dilution with at least an equal weight of scrap bronze (in some cases perhaps twice as much), the zinc concentration of the final alloy could not then be as high as that actually found in most of the coins. Hence, it seems more likely to the authors that zinc metal was added to the alloy in appropriate quantities and this applies even to the earliest brass issues in the period 1503-5. There may also be some historical evidence for the addition of zinc in that a different metal (described as 'good' or 'superior tin') was added to some of the issues of the **Hong Zhi** period (1488-1505) in the year 1505 (24) which is precisely the date of the first brass issues discovered here. If correctly interpreted, the original reference indicates that the amount of zinc added would have been about 12.5% which is similar to that found in the coins.

Summary

This survey has shown that the Chinese cash was usually manufactured from leaded bronze until the 16th century. Then, sometime during the period 1503-1505, brass coinage was introduced, perhaps alongside that of bronze, until from 1527 onwards all subsequent issues were made of brass. The composition of these brass issues indicates that metallic zinc was used in their manufacture, rather than cementation brass, and hence that zinc metal was available to the Chinese early in the 16th century. Whether this was manufactured in China or imported, perhaps from India, cannot be determined from these data but certainly it must have been available in considerable quantities. The composition of the coinage provides no evidence of early brass production using the cementation process although this does not guarantee that it was not used for other metalwork. Indeed, before the brass coinage was introduced, there is abundant evidence of brass of probable cementation origin being used for statuary metalwork in China (25).

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Biographies

Sheridan Bowman graduated in Physics from Oxford, where she also completed a D.Phil on thermoluminescence dating. She joined the British Museum Research Laboratory in 1976. The analytical work presented here was undertaken as a special project, departing from her primary work in dating, which has recently been in both radiocarbon and thermoluminescence.

Michael Cowell trained as an analytical chemist and has worked in the British Museum Research Laboratory since 1970. He has been mainly involved with the application of XRF, AAS and NAA to the study of ancient materials and artefacts. Recent work has included mediaeval pottery, Egyptian metalwork, cobalt blue glazes and a variety of coin studies from Celtic to Victorian.

Joe Cribb is curator of Far Eastern currency in the Department of Coins and Medals at the British Museum, which he joined in 1970. He recently published an illustrated introduction to the Chinese and British Colonial coinage and paper money in the Hong Kong Bank collection, 'Money in the Bank'.