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The Evidence of Gold Content for the Attribution of the Coins in the Name of Candragupta

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Abstract This paper uses the results of XRF metal analysis to shed light on the attribution of Gupta gold coins in the name of Candragupta. Two samples, including coins tested by Sanjeev Kumar and coins tested for this study, are merged and shown to be mutually consistent. In this way, a sample of 363 coins is constructed. We see that the so-called King and Queen coins seem to form a special group with much higher gold content than other types. The attribution of the coins with goddess on throne to Candragupta II is supported, with results of the correct sign although they are not statistically significant. The attribution of the so-called Belted coins to Candragupta III is strongly supported with results that are highly significant statistically.[1]

The attribution of the Gupta gold coins naming the king Candra or Candragupta present the numismatist with a particular challenge: to whom should the coins be attributed? The king lists that we know[2] record two different kings named Candragupta, the father (reigned about 319–50)[3] and son (about 376–415), respectively, of the king Samudragupta (about 350–76). In addition, over the last 30 years or so, scholars[4] have increasingly accepted the theory that there was a third king who also named himself Candragupta on his coins (about 447–56)[5], as these coins appear to have been issued *after* the reign of Kumāragupta I (about 415–47), the son of the aforementioned Candragupta II. We therefore have three potential kings to whom the coins naming Candra can be attributed. The fundamental arguments for attributing the coins are usually based on considerations of style, paying attention to how the designs evolved over time. However, considerations of style are open to differences of opinion, leaving us with a situation in which attributions remain controversial and subject to debate. To this day, therefore, there is no clear agreement on the correct attribution of at least some of the coins.

In a recent paper (Tandon 2020), I proposed a new approach that would apply statistical techniques to a measurable property of the coins: their weights. There is general agreement that most of the Candra-naming coins were issued by Candragupta II. The idea then is that, if a certain group of coins are theorized *not* to have been issued by that king, the weights of those coins should be different from the weights of the large bulk of the coins of Candragupta II. This test uses the widely made observation that Gupta coins seem to increase in weight over time. Using this approach, I was able to show that certain coins that so far have been universally assigned to Candragupta II, but which show stylistic affinity to the coins of Candragupta III, should in fact be reattributed to that later king. In the process, I also examined the question of the correct attribution of the so-called King and Queen type and also the coins naming Candra(gupta) which feature on the reverse a goddess seated on a throne. The weight data in all cases supported the attributions that I would have made based on style.

In this paper, I attempt to extend the use of statistical techniques to another measurable aspect of the coins: their gold content. The technique used to measure the gold content is X-ray fluorescence (XRF). This is a non-destructive method to study metal content, although it suffers from the drawback that it tests only the surface metal. Since gold is not very reactive with environmental contaminants, this may not be too serious a drawback when looking at gold coins.

XRF testing

For the study I tested 167 coins, which included coins of all the known Gupta kings except for Vainyagupta. The sample included four coins that would now be regarded as Hun issues, one of Toramāṇa (Prakāśāditya) and three of the 'Nameless' Archer coins.[6] All but one of the coins were from my own collection; one coin was from the collection of P. Hari Prasad, who kindly permitted his coin to be tested also.

The testing was carried out on a desktop X-ray fluorescence (XRF) analyser made by Olympus called the GoldXpert, which is optimized to test precious metals. Each coin was tested twice, once on the obverse and once on the reverse, with the two readings being averaged to get to an estimate of the metal content of the coin. The diameter of the test area used was 10 millimetres and each test was run for 30 seconds.[7] The analyser itself is a roughly 30-centimetre (1-foot) cube weighing 10 kilograms, making it relatively easy to use and transport if necessary. It is technologically similar to another Olympus-made analyser, the Delta hand-held analyser, which was evaluated by Gore and Davis (2016) in their thorough-going study of the XRF method to analyse the metal content of ancient Greek silver coins. Gore and Davis found that the Olympus machine performed on almost a par with the full-size spectrometers they tested in its measurement of the key elements, such as silver, gold, copper, iron, lead and bismuth. It did not perform as well in its ability to fully identify the trace amounts of lighter elements present.[8]

To check the accuracy of the analyser, I tested two coins of known metal composition: a modern (1989) United States $50 (Liberty/Eagle) gold coin and a modern (2001) US $1 silver

1 This paper has benefited from extremely helpful email exchanges with Ellen Raven. I also wish to thank John Deyell for sharing his transcription of Sanjeev Kumar's XRF results and for his detailed comments on an earlier draft of the paper, Ed Snible and Harold Edwards for helpful suggestions and P. Hari Prasad for allowing me to test his coin.

2 The best source for Gupta genealogy is the Bhitarī pillar inscription. For a complete summary of the genealogy and chronology of the Guptas, see Gupta (1974), 169–98.

3 The chronology is still somewhat unsure. I have relied largely on the chronology presented by Willis (2005).

4 The literature on Candragupta III is now quite large and growing. I have reviewed most of the early work in Tandon (2014).

5 This dating fills the 'gap' in Willis's chronology.

6 See Tandon (2015) on the assertion that Prakāśāditya was none other than Toramāṇa and Tandon (2018) for the argument that the 'Nameless' coins were also issued by the Huns.

7 I experimented with shorter and longer exposures but concluded that the 30-second exposure was perfectly adequate.

8 Such as Ti, Cr, Ni and Zn.

coin and found it to be reasonably accurate. On the gold coin, the instrument measured the gold content to be 91.81 per cent with a 95 per cent confidence interval of (91.67 – 91.95)[9], as compared to the US Mint stated content of 91.67 per cent.[10] Thus, although the actual gold content falls within the 95 per cent confidence interval of the estimate, we can note, at least on this evidence, a slight tendency for the analyser to overestimate the gold content. Similarly, with the silver coin, known to be 99.9 per cent silver according to the US mint, the analyser returned a reading of 100 per cent, with a lower bound on the 95 per cent confidence interval being 99.63 per cent.

The overestimation of the principal metal probably stems from the analyser's inability to identify and measure the quantities of trace elements, as was noted by Gore and Davis in their study. Small machines like the GoldXpert are not sensitive enough to accurately measure the minor trace elements. If there are several of these trace elements, as there are very likely to be in ancient gold, they could collectively add up to a noticeable percentage. Setting the content of all these elements to zero means that the estimated percentage of the elements that are measured will be overestimated. For example, suppose the actual composition of a coin is 90 per cent gold, 6 per cent silver, 3 per cent copper and 1 per cent trace elements. If the trace elements are all set to zero, we would actually be measuring only 99 per cent of the contents. The estimated gold content would then be declared as 90.91 per cent (= 90/99), an overestimate of roughly 1 per cent. The silver and copper would be estimated as constituting 6.06 per cent (= 6/99) and 3.03 per cent (= 3/99). Thus, we overestimate all the declared constituent elements by the same percentage, with the biggest absolute error falling on the main constituent element.

In a study of Kushan gold coins (Tandon, 2022a), I was able to confirm this tendency for the GoldXpert to overestimate the gold content by comparing my results with those of other studies. Figure 1 and table 1 show the estimated average percentage gold content of the gold coins of three kings, Vima Kadphises, Kanishka, and Huvishka, in three studies. Other than my own study, I looked at the results of Maity (1970), who used specific gravity (SG) to estimate gold content, and Blet-Lemarquand (2006), who used proton activation analysis. What I found was that the XRF results are higher than those from proton activation analysis, which are in turn higher than Maity's SG results, although the pattern of results is roughly the same in all three cases. I suspect that the Blet-Lemarquand results are the most accurate, given the use of sophisticated laboratory equipment, indicating that the XRF results are overestimates and that the SG results are underestimates. It is important to point out that the three studies analysed different sets of coins, of varying sample sizes, and that these differences could account for the differences in average gold content observed. However, I do suspect that there may be biases in the estimation techniques as well.

Table 1 shows the numerical values of the average percentage gold content and calculates the degree of over—

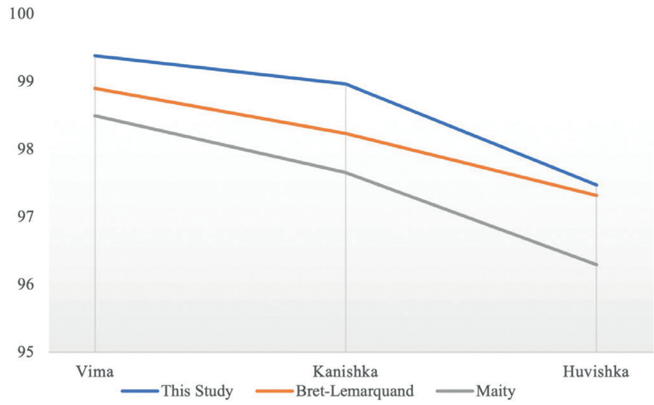

Figure 1 Average Percentage Gold Content: Three Kings, Three Studies (Source: Tandon, 2022a, Chart 6)

Table 1 Average percentage gold content in three studies and size of differences

	Vima	*Kanishka*	*Huvishka*
XRF results	99.38	98.97	97.47
Deviation from B-L	*0.49%*	*0.75%*	*0.16%*
Blet-Lemarquand (B-L)	98.90	98.23	97.32
	—	—	—
Maity	98.50	97.66	96.29
Deviation from B-L	*-0.40%*	*-0.59%*	*-1.06%*

estimation compared to the Blet-Lemarquand study, which varies from 0.16 per cent to 0.75 per cent. This is a small, but not insignificant, difference.

Having said this, it is important to note that, for my present purposes, the overestimation of gold content is of little significance. In what follows, I am focused on the *relative* gold content levels in different groups of coins, specifically, on whether the average gold content in different groups is the same or different. The fact that the *absolute* levels of gold content are slightly overestimated in all cases would not affect such comparisons.

Merging my sample with that of Kumar

Kumar (2017) published results of XRF tests he conducted on a sample of Gupta coins, and I thought it would be a good idea if possible to merge his results with mine in order to increase the sample size. In statistical analyses, the larger the sample size the more robust the results. So, I needed to see if my results were more or less in line with his so that I could merge the two samples. I expected that, in principle, the results ought to be similar, because Kumar used an instrument very similar technologically to the one I used, although his procedure was slightly different.[11]

Kumar's results were published in his book (2017, 93–6), and John Deyell had transcribed these results into an Excel file,

9 The analyser provides the estimate with a standard deviation; I then calculated the confidence interval based on the data provided.

10 Viewed online at https://www.usmint.gov/coins/coin-medal-programs/american-eagle/gold-proof.

11 Kumar used a hand-held analyser made by Thermo Fisher Scientific called the Niton X3t (Kumar 2017, 73). His procedure was slightly different from mine. He took five readings on each coin, two from different parts of the obverse, two from different parts of the reverse and one from the edge. Each reading lasted 10 seconds. Kumar did not tell us the diameter of the X-ray beam he used. I did not expect this procedural difference to matter much, and it turned out that it did not.

Table 2 Comparison of average gold percentage in Kumar and Tandon samples

	SK sample		*PT sample*		*t-test P-value comparing means*
King	*Average Au %*	*no. coins*	*Average Au %*	*no. coins*	
Samudragupta	83.729	54	84.276	39	64.47%
Candragupta II	82.152	76	82.543	50	50.02%
Kumāragupta I	75.745	36	75.790	35	97.54%

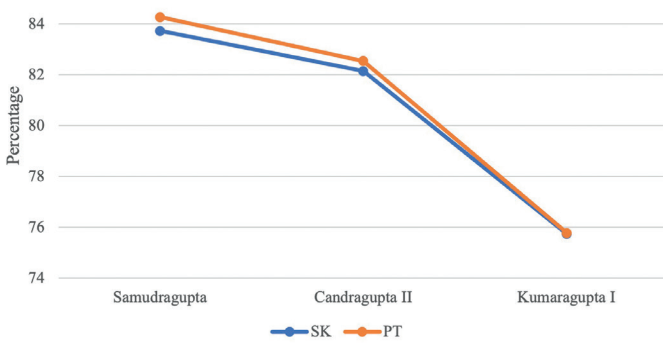

Figure 2 Average percentage gold content of three principal Gupta kings comparing results from Kumar and Tandon results

which he kindly shared with me. Results for a total of 225 coins were presented. Of these, 11 coins belonged to the post-Gupta period, 17 coins were of the repoussé type of Mahendraditya belonging to the Sarabhapuriya series,[12] 2 coins were fakes according to Kumar, and one coin was a half dinar, which I also regard as being of suspect authenticity. Excluding these 31 coins left 194 in the sample,[13] and these were the coins I included in my analysis. I of course reattributed Kumar's coins in ways I consider correct. Thus, the King and Queen coins and the Kāca coins were assigned to Samudragupta, the coins of Candra with the goddess on a throne were assigned to Candragupta II, and coins belonging to the 'Belted group' which I studied in my 2020 paper were separated and assigned (provisionally) to Candragupta III.

Because both the Kumar sample and mine contained very few coins of the kings after Kumāragupta, I decided to compare results only for the three kings for whom both samples were reasonably large and meaningful comparisons could therefore be made. Collectively the coins of these three kings account for 80 per cent of the coins in the two samples together. Table 2 and figure 2 summarize the results. We see that the results from the two studies are indeed very close to one another, and the statistical tests were very clear that we could not reject the hypothesis that they were drawn from the same population (i.e., that the average estimated gold content was the same in both samples). Detailed results are presented in appendix 1, but the table shows just how high the P-values[14] of the tests were; any P-value greater than 5 per cent is considered sufficient to say we cannot reject the null hypothesis. Here the P-values ranged from 50 per cent to over 97 per cent.

The appendix also shows scatter diagrams of the coins of the three kings, which provide a visual confirmation of the statistical result that the two samples are very similar. Thus, the studies were very much compatible with one another, and the results can be merged without hesitation. With my sample containing 169 coins and the Kumar sample containing 194 coins, we now have a total sample size of 363 coins.

Having established that the two samples can safely be merged, I created an Excel file containing the results of both samples, arranging the coins in roughly chronological order. The coins were arranged of course by king, in their proper order. Within the coins of Samudragupta, the King and Queen coins were placed first, followed by the other coins in alphabetical order by type. Within a type, the coins were arranged randomly. With the coins of Candragupta II, coins with the goddess on a throne were placed first, followed by all the others. Within these two groups, the coins were arranged in alphabetical order by type, and randomly within a type. The coins of Kumāragupta I were arranged in alphabetical order by type and randomly within each type. For Candragupta III, the belted coins were listed first (in the order belt – sash – sword), followed by the symbol coins (in the order sun – crescent – cakra – altar). The Horseman coins were listed last. The coins of Skandagupta were sorted by their weight standard. Coins of roughly 8.5 grams weight were listed first, in alphabetical order by type, and the 9-gram coins followed. The rest were simply arranged randomly by king. The Hun coins were placed after those of Budhagupta.

Figure 3 is a scatter diagram showing the percentage gold content of each of the coins, illustrated in the order of the list I had created.[15] In the figure, vertical dividing lines separate the coins of different kings. The coins of Candragupta III (CG 3) are divided into the Belted group and the Symbol group. The H stands for Hunnic coins. The other minor kings are not identified in the diagram. Looking at the pattern of dots, we see a slight tendency for the percentage gold content to decline over time, exemplified by the trend line drawn in the graph. In what follows, I will use that as a provisional marker for the temporal order of the coins, although this assumption is not necessary for the conclusions I want to reach. All I need to study is whether the average gold content for two groups is the same or different. We can turn now to the specific comparisons.

King and Queen Coins

I will examine the three questions about the coins in the name of Candra(gupta) in chronological order. The first question concerns the attribution of the King and Queen type. Figure 4 illustrates the type. The obverse features images, identified by the legends, of Candragupta and Kumāradevī. We know from

12 See Bakker (2019) for an argument why these coins should not be attributed to Kumāragupta.

13 This number is greater than the 179 coins for which Kumar gave summary results on p. 81.

14 The P-value is an estimate of the probability that two samples drawn from the same population would have a difference of averages as great or greater than the one we have in our study.

15 Detailed results for the coins in the Kumar sample are in Kumar (2017, 93–6) and those in my sample will be published in Tandon (2022b).

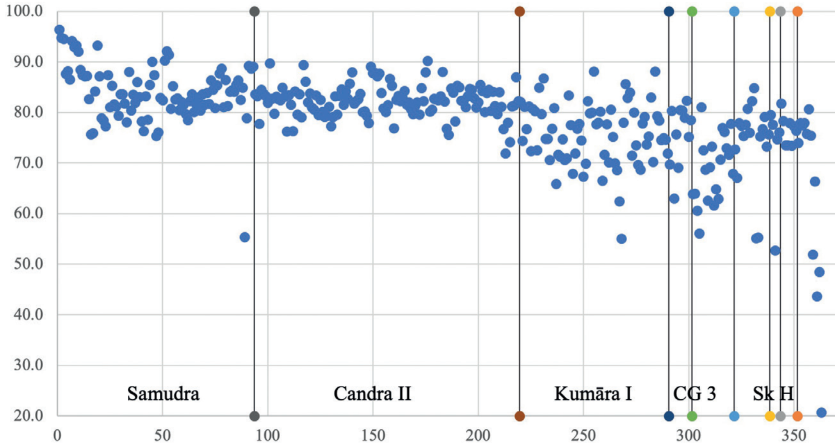

Figure 3 Scatter diagram showing the percentage gold content for each coin in the sample

the Allahabad pillar inscription that Candragupta I married the Licchāvī princess Kumāradevī. It mentions her as the mother of Samudragupta, who is described as *licchavyidauhitra*, the son of Licchavi's daughter. The reverse legend, to dispel any doubts about the identification, reads *licchavaya*. It thus seems logical to assume that this coin type must have been issued by Candragupta I, in celebration of his marriage. That is what all scholars believed once the coins were discovered in the nineteenth century. As far as anyone could tell, these were the only gold coins issued by that king, making them the first Gupta gold coins.

Allan (1914) argued, however, that the King and Queen type could not have been the first Gupta gold coins, because Samudragupta's standard type[16] is a close imitation of late Kushan types and therefore must qualify as earlier than the King and Queen type. In any case, the Gupta kingdom was rather insignificant at the time of the marriage being celebrated in the coin, and it therefore seems unlikely that Candragupta I would have been able to issue such a large number of gold coins. Allan therefore suggested that this type was probably issued by Samudragupta in honor of his parents. Raven (1994, 2010) emphasizes a different argument on the matter. By her careful analysis of the styles of the different coin types, what she calls their 'mint idioms,' she shows that the King and Queen coins and the clearly identifiable issues of Samudragupta cannot possibly be separated temporally; rather, they are obviously the products of the same mints at the same times, thereby supporting Allan's suggestion.

Figure 4 Gold dinar of the King and Queen type (Tandon collection no. 438.02, 7.50 g, 20 mm, die axis 1h)

In my study of coin weights, I showed that the weights of the King and Queen coins matched those of all other coins of Samudragupta very closely. In a sample that included 55 King and Queen coins and 369 other coins of Samudragupta, the average weights were 7.527 grams and 7.519 grams respectively; they were statistically the same. Under the widely held view and observation that the weights of Gupta gold coins rose over time, this result was incompatible with the notion that the King and Queen coins were issued earlier by Candragupta I. Thus, the weight study provided further support to Allan's argument.

Let us now see what the metal content study tells us. We would expect that, if the King and Queen coins were issued by Samudragupta, the average gold content in the King and Queen coins should closely match the average gold content in all other coins of Samudragupta. This is not, however, what we find. Figure 5 is a scatter diagram showing the percentage gold content in all the King and Queen and other Samudragupta coins in the combined (Kumar and Tandon) sample. We see that the percentage gold content appears to be considerably higher in the King and Queen coins, and this is borne out in the numerical data, summarized in table 3. The formal statistical test on whether the two groups belonged together (i.e., had the same mean) was soundly rejected. The P-value was vanishingly small (anything less than 5 per cent is considered strong enough to reject the hypothesis of equal means). The detailed statistical test results are in appendix 2, table A2. Thus, the statistical testing on gold content does not seem to support Allan's contention that the King and Queen coins were issued by Samudragupta.

For someone like myself, who strongly favours Allan's

16 This type has been called many things, including the standard type, the sceptre type, the javelin type, the rajadanda type, and the spearman type, because there is confusion about what exactly the king is holding in his (proper) left hand. Since Gupta coins are usually identified by what the king is doing (such as the horseman type, the lion-slayer type, the lyrist type, and so on), I find it odd that this type is named according to an object he might be holding. The Archer type is not called the Bow type, nor is the Lyrist type called the Lyre type. I propose that we find a new name to identify this type. In a discussion with Ellen Raven on the subject, I proposed that this type should be called the Sacrificing type, as the king is always sacrificing into the fire altar at left. This name has the benefit of avoiding completely the debate on what the king is holding, which varies quite a bit in its appearance. Ellen pointed out that the king is also sacrificing on the Chhatra type coins and proposed King-at-Altar type, although that suffers from the same problem. The search for a good name continues. Perhaps it should be called the Kushan type, or the Kushan imitation type.

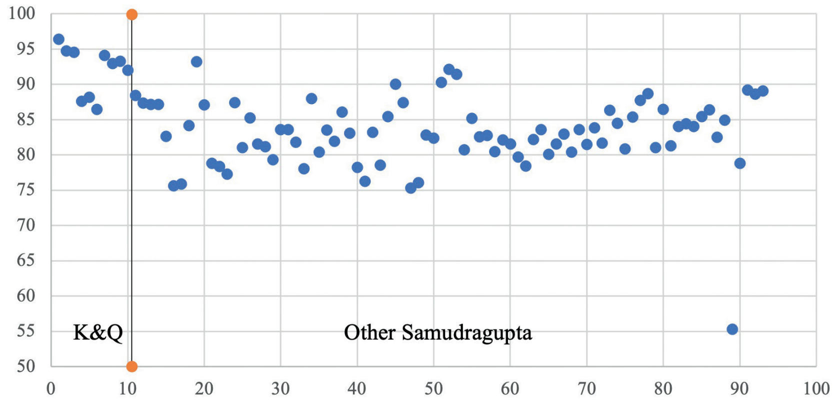

Figure 5 Comparison of the gold content in King and Queen and other Samudragupta coins

Table 3 Summary statistics on average gold content

Group	*Av. Au %*	*no. coins*
King and Queen	92.02	10
Other Samudragupta	82.99	83

view, this result is disappointing. Of course, proponents of the old view that the coins were issued by Candragupta I, would be delighted with this finding. The Allan supporters would be forced to look for other explanations for why the gold content of the King and Queen coins is higher than the gold content in Samudragupta's other coins. It is also possible that the result is an artifact of the small sample size of King and Queen coins, of which there were only 10 examples in the sample. In all statistical analyses, we would prefer to have large samples. At least 30 examples of each group would be considered desirable. Hopefully over time we can get more data for analyses of this kind.

One possible explanation for the higher gold content in the King and Queen coins is that perhaps it was regarded as a special issue and therefore merited a higher purity gold. In our sample, the average weight of the King and Queen coins is 7.49 grams, while that of all the other Samudragupta coins is 7.53 grams. A statistical test, however, shows that we cannot rule out the possibility that their average weights are the same. In my earlier study (Tandon 2020) where I had a much larger sample, the average weight of the King and Queen coins was 7.53 grams (based on a sample size of 55 instead of 10 in this study), while that of all the other Samudragupta coins was 7.52 grams (based on a sample size of 369 coins rather than the 82 in this study). Once again, the statistical test showed that we could not rule out the possibility that their average weights were the same. Thus the King and Queen coins are basically the same weight as the other coins of Samudragupta. This means that, given the higher percentage of gold, there is a higher average absolute amount of gold in the King and Queen coins than in all the other Samudragupta coins. The richer gold content then provides support to the idea that the coins were special.

Coins of Candra with Goddess on Throne vs other Candra coins

The second question I examined in my earlier paper was: should the coins naming Candra with a reverse featuring a goddess seated on a throne be assigned to Candragupta I, as suggested by Kumar (2017) or to Candragupta II, as is currently done by most, if not all, other scholars? The analysis of weights strongly supported the prevailing wisdom that the coins do indeed belong to Candragupta II. We turn now to see what the metal analysis would suggest. If the coins with goddess on throne were issued by Candragupta I, we would expect their gold content to be different from that of the coins with goddess on lotus or other coins of Candragupta II; provisionally, we would expect their gold content to be higher. Indeed, if the goddess on throne coins were issued by Candragupta I, their gold content ought also to be higher than the gold content in the coins of Samudragupta, who reigned after Candragupta I. On the contrary, if they were issued by Candragupta II, we would expect their gold content to be lower than that of Samudragupta's coins.

Figure 6 is a scatter diagram showing the gold content in each of the coins in the three groups Samudragupta, Candra with Goddess on Throne, and all Other Candra coins, presented in that order. The underlying hypothesis in arranging the coins in this way is that all the Candra coins belong to Candragupta II with the Goddess on Throne coins simply being early in his reign and the other coins being later in the reign. This is the order generally taken to be correct and is the order that was suggested by the analysis of weights in my earlier paper. But of course, the task here is to test whether that seems to be the correct order on grounds of the gold content also. Certainly, the scatter diagram seems to indicate that the order is indeed correct, as the Goddess on Throne coins seem to fit neatly between the coins of Samudragupta and the other coins of Candragupta II.

The formal statistical testing weakly supports the conventional view that the Goddess on Throne coins were issued by Candragupta II. I say 'weakly' because none of the tests for differences in the average gold content were statistically significant, but the averages were all in the expected order. Table 4 provides the summary statistics, and the details of the statistical tests are in tables A3 and A4 in appendix 2. What we see is that the percentage gold content is highest in the coins of Samudragupta (average 83.96 per cent), somewhat lower in the coins of Candragupta with goddess on throne (average 83.06 per cent), and lower still in all the other coins of Candragupta (average 82.20 per cent). Although these differences are small (and statistically not significant), they are all in the order to be expected if the Goddess on Throne coins were issued by Candragupta II early in his reign. The consequence of that is the gold content could be falling over time but at a very slow rate, and this is consistent with our

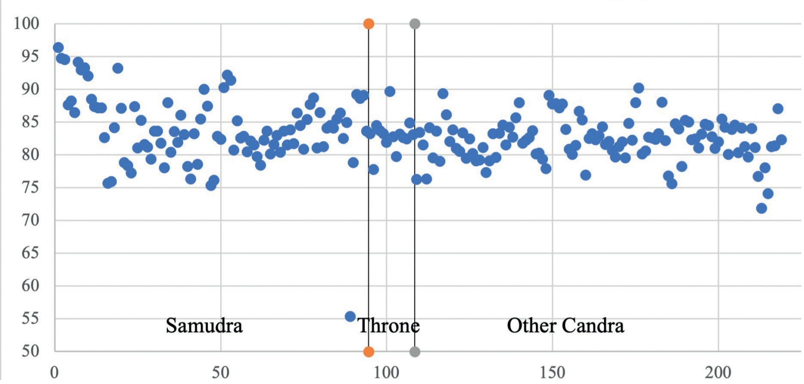

Figure 6 Comparison of the gold percentage of Samudra, Candra with Goddess on Throne and all other Candra coins

Table 4: Summary Statistics Comparing Samudragupta and Candra Coins

Group	*Av. Au %*	*no. coins*
Samudragupta	83.96	93
Goddess on Throne	83.06	15
Other Candra	82.20	111

data. The data is not consistent with the theory that the Throne coins were issued by Candragupta I.

Belted Coins vs Other Coins of Candragupta II

The main point of my earlier paper (Tandon 2020), indeed the reason why I started this research, was that I had discovered a group of coins, that had always been assigned to Candragupta II, which I felt on stylistic grounds belonged to Candragupta III. I called this group of coins the 'Belted group.' In my paper, I laid out in detail my argument for which stylistic features made this reattribution appropriate. Then I looked at the coin weights to see if they supported my suggestion. They did. Not only were the Belted Group coins significantly heavier than the other coins of Candragupta II, but they were also heavier than the coins of Kumāragupta I, thus strongly supporting the idea that they were issued after the reign of that king. Thus, the attribution to Candragupta III was supported by stylistic considerations and the analysis of weights. Here, I want to now examine whether the gold content data also supports this reattribution.

It does. Figure 7 is a scatter diagram showing the percentage gold content in the coins of the Belted group in comparison to the gold content in the other coins of Candragupta II. From the diagram, we can see that the Belted group coins have a lower gold percentage, with some coins having a gold content clearly lower than ever seen on any other coins of Candragupta II.

Table 5 provides the summary statistics of the numerical analysis. We see that the average gold content in the Belted Group (75.77 per cent) is far lower than the average gold content in the coins of Candragupta II (82.31 per cent). The details of the statistical tests are in table A5 in appendix 2, but I can summarize them here. The tests show that the difference in average gold percentage is statistically highly significant; the P-value of the one-tail test, which is the appropriate test here,[17] is 0.27 per cent. Any P-value less than 5 per cent is considered significant; a P-value less than 1 per cent is considered highly significant. Thus, the gold content data strongly supports the suggestion that the Belted Group coins are different and were issued after the reign of Candragupta II.

This is not enough. If the Belted Group coins were issued by Candragupta III, who ruled after Kumāragupta I, their gold content should also be lower than the coins of that king. So, we need to compare them. Figure 8 is a scatter diagram showing the percentage gold content in the coins of the Belted group in comparison to the coins of Kumāragupta I. We see once again that the Belted group coins appear to have, on average, a lower gold content, although the difference is not as marked as in the case of the coins of Candragupta II. This is to be expected, because the Belted Group coins were probably issued immediately after the accession of Candragupta III, who would have done so at the death of Kumāragupta I.

Table 5 provides the summary statistics of the numerical analysis; the details of the statistical testing are in table A6 in appendix 2. As we see, the average percentage gold content in the Belted coins (75.766 per cent) is indeed lower than the average percentage gold content in the coins of Kumāragupta I (75.767 per cent), although the difference is small. As one might expect with such a small estimated difference, the statistical test shows that we cannot reject the null hypothesis that the averages are the same (the P-value is 50 per cent). But note that the average gold content is indeed lower; if the coins were issued by Candragupta II, the gold content ought to have been higher. Thus, this data weakly supports the suggestion that the Belted coins were issued after the reign of Kumāragupta I.

As a final piece of analysis, I thought it would be useful to compare the gold content of the Belted group coins with the other coins of Candragupta III, both to see if the two groups have similar gold content as further evidence of my reattribution of the Belted coins and to uncover the possible order in which the

17 Recall that in a statistical test on averages, we have a 'null hypothesis' which is typically that the averages are equal (*i.e.*, that the difference in averages is zero) and against this we have an 'alternative hypothesis.' When the alternative hypothesis is simply that the averages are different (which it would be if we had no *a priori* reason to think one was higher than the other), we use a two-tail test. When the alternative hypothesis is that one average is higher than the other, so that the difference would be expected to be of particular sign (either positive or negative), we use a one-tail test. Here the null hypothesis is that the averages are the same, which would be the expected outcome if the Belted Group coins were issued by Candragupta II and were therefore like the rest of his coins. But the alternative hypothesis is that the Belted Group coins have a *lower* gold content, if they were issued by Candragupta III. That is why a one-tail test would be the appropriate one in this case.

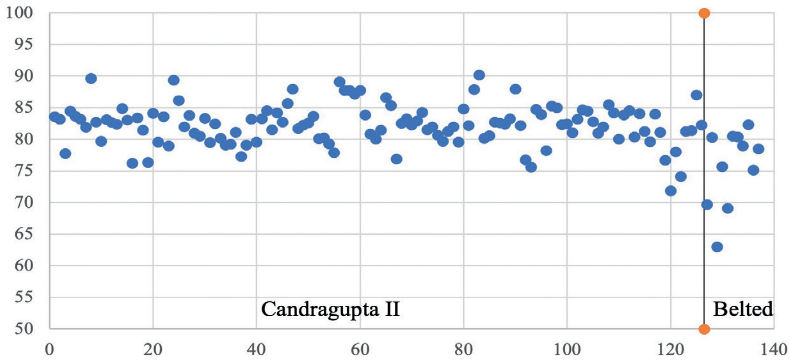

Figure 7 Comparison of the gold percentage of Candra II and Belted Group coins

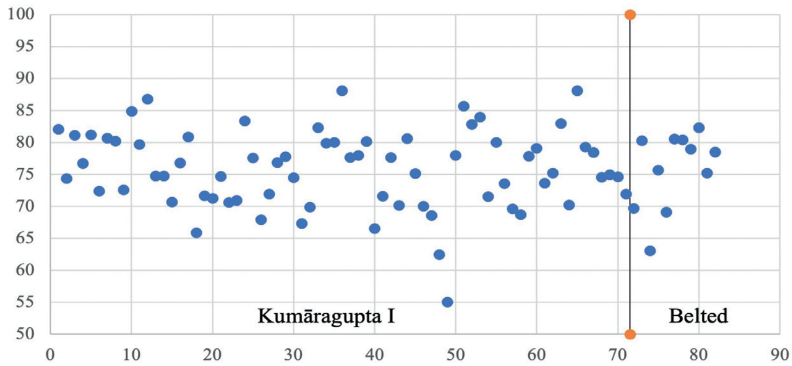

Figure 8 Comparison of the gold percentage of Kumāragupta I and the Belted Group coins

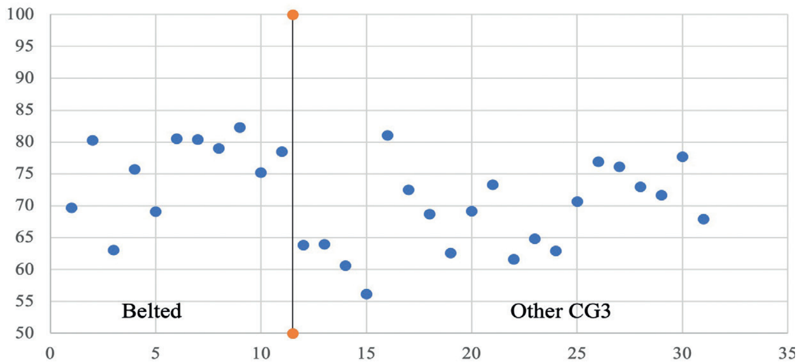

Figure 9 Comparison of the gold percentage of the Belted Group and other Candragupta III coins

coins might have been issued. My *a priori* expectation was that the Belted coins were issued early in the reign of Candragupta III, since they are closer in design to the coins of Candragupta II and Kumāragupta I. In particular, the addition of objects in front of the king's face seems to be a significant innovation that suggests a later date for the symbol coins. Given this assumption, the Belted coins should have a higher percentage of gold than the later coins of Candragupta III.

This is indeed what I find. Figure 9 is a scatter diagram showing the percentage gold content in the Belted coins compared to the other coins of Candragupta III. We see that the Belted coins appear to have a higher gold content than the latter group. This is seen more formally in the summary statistics, reported in table 7. The numbers show that the Belted group coins have a considerably higher gold content than the other Candragupta III coins (75.766 per cent to 68.736 per cent). The difference is highly significant statistically, as we can see from the detailed results presented in table A6.

Table 5 Summary Statistics Comparing Candragupta II and Belted Group Coins

Group	*Av. Au %*	*# coins*
Candragupta II	82.3071	126
Belted Group	75.7661	11

Table 6 Summary Statistics Comparing Kumāragupta I and Belted Group Coins

Group	*Av. Au %*	*# coins*
Kumāragupta I	75.767	71
Belted Group	75.766	11

Table 7 Summary statistics comparing the Belted Group and other Candragupta III coins

Group	*Av. Au %*	*no. coins*
Belted Group	75.7661	11
Other Candragupta III	68.7365	20

The P-value of the one-tail test of significance for difference in means is 0.34 per cent. I confess I found the size of this difference surprising and wondered what it might signify. A speculative explanation I came up with was that this is a sign that the Gupta empire was under some stress at this time. We know from the inscriptions of Skandagupta that the empire was facing an assault, probably from the Huns, and that at times things were very difficult from the Gupta viewpoint. However, Skandagupta was able to prevail ultimately. The low gold content during the reign of Candragupta III, who may well have been on the throne while Skandagupta was waging war as his general, may be a physical manifestation of the difficulties mentioned by Skandagupta.

Conclusion

The paper set out to use XRF estimates of the percentage gold content in various Gupta coins to help answer three questions of attribution of the coins in the name of Candragupta. The results showed that

- The attribution of the King and Queen coins to Samudragupta was not supported by the gold content data, although of course the evidence of style and coin weights remain persuasive. The gold content 'anomaly' requires explanation.
- The attribution of the Candragupta coins with reverses featuring a Goddess on Throne to Candragupta II (rather than Candragupta I) was weakly supported. The average percentage gold content of the Goddess on Throne coins was lower than that of the coins of Samudragupta, but the difference was not statistically significant. Nevertheless, the sign of the difference in average gold content was consistent with the attribution to Candragupta II and was inconsistent with an attribution to Candragupta I. Hence my earlier attributive conclusions based on style and weights are supported.
- The attribution of the Belted group of coins, identified in Tandon (2020), to Candragupta III was strongly supported. The average percentage gold content of the Belted coins was significantly lower than that of the coins of Candragupta II, suggesting that we can confidently reject the notion that the coins were issued by him. This conclusion strongly supports the evidence of style and weights.

References

Allan, J. (1914) *A Catalogue of the Indian Coins in the British Museum: Coins of the Gupta Dynasties and of Sasanka, King of Gauda*, London

Bakker, H. T. (2019), 'Observations on the history and culture of Dakṣiṇa Kosala', in H. T. Bakker: *Holy Ground: Where Art and Text meet*, Leiden/Boston, 235–82

Blet-Lemarquand, M. (2006): 'Analysis of Kushana Gold Coins: Debasement and Provenance Study', in F. de Romanis (ed.), *Dal Denarius al Dinar: L'Oriente e la Moneta Romana*, Rome

Gore, D. B., and G. Davis (2016) 'Suitability of Transportable EDXRF for the On-site Assessment of Ancient Silver Coins and Other Silver Artifacts', *Applied Spectroscopy*, 70:5, 840–51

Gupta, P. L. (1974) *The Imperial Guptas*, Varanasi

Kumar, S. (2017) *Treasures of the Gupta Empire*, [Mumbai]

Maity, S. K. (1970) *Early Indian Coins and Currency System*, New Delhi

Raven, E. M. (1994) *Gupta Gold Coins with a Garuḍa-Banner*, Groningen

— (2010) 'Samudragupta's King-and-Queen type coins in the patterning of early Gupta coin designs', *Journal of the Oriental Numismatic Society*, 205 supplement, Autumn, 31–9

Tandon, P. (2014) 'The Succession after Kumāragupta I', *Journal of the Royal Asiatic Society*, 24:4, October, 557–72

— (2015) 'The Identity of Prakāśāditya', *Journal of the Royal Asiatic Society*, 25:4, October, 647–68

— (2018) 'Attribution of the Nameless Coins of the Archer Type', *The Numismatic Chronicle* 178, 247–68

— (2020) 'Reattributing some (more) Coins of Candragupta II to Candragupta III', *The Numismatic Chronicle* 180, 361–92

— (2022a) 'A Hoard of Kushan Gold Coins from Swabi', in H. Wang and R. Bracey (eds), *Look at the Coins! Papers in honour of Joe Cribb on his 75th birthday* (Oxford)

— (2022b) 'An Analysis of the Metal Content of Gupta Gold Coins', paper presented at the International Numismatic Congress (INC XVI), Warsaw, 15 September, 2022

Willis, M. (2005) 'Later Gupta History: Inscriptions, Coins and Historical Ideology', *Journal of the Royal Asiatic Society*, 3rd ser., 15, 131–50

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Appendix 1
Detailed Results to Compare the Kumar and Tandon Samples

Table A1 Statistical test results with scatter diagrams comparing Kumar and Tandon results

Samudragupta coins

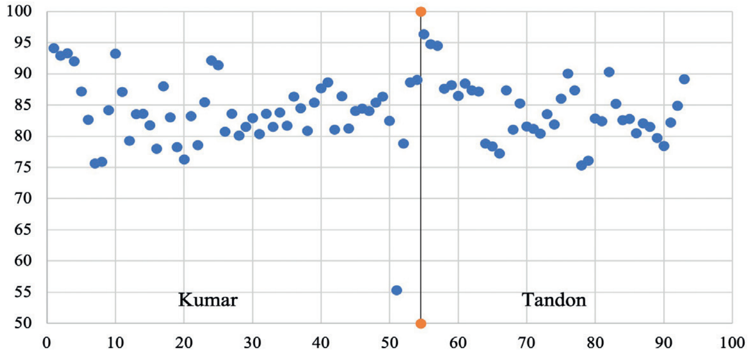
F-test two-sample for variances

	SK	*PT*
Mean	83.72852	84.27619
Variance	36.52531	25.04991
Observations	54	39
df	53	38
F	1.458102	
P(F<=f) one-tail	0.112211	
F Critical one-tail	1.668353	

t-test: two-sample assuming equal variances

	SK	*PT*
Mean	83.72852	84.27619
Variance	36.52531	25.04991
Observations	54	39
Pooled Variance	31.73339	
Hypothesized Mean Difference	0	
df	91	
t Stat	-0.462644	
P(T<=t) two-tail	0.644724	
t Critical two-tail	1.986377	

Samudragupta



Candragupta II coins

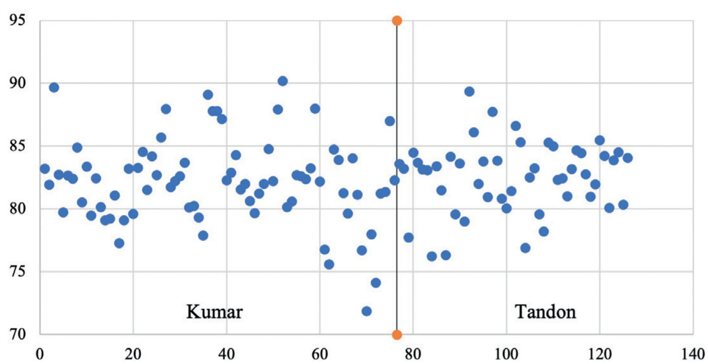
F-test two-sample for variances

	SK	*PT*
Mean	82.15158	82.5434
Variance	11.67359	7.756699
Observations	76	50
df	75	49
F	1.504969	
P(F<=f) one-tail	0.064005	
F Critical one-tail	1.555997	

t-test: two-sample assuming equal variances

	SK	*PT*
Mean	82.15158	82.5434
Variance	11.67359	7.756699
Observations	76	50
Pooled Variance	10.12579	
Hypothesized Mean Difference	0	
df	124	
t Stat	-0.676207	
P(T<=t) two-tail	0.500168	
t Critical two-tail	1.97928	

Candragupta II



Kumāragupta I coins

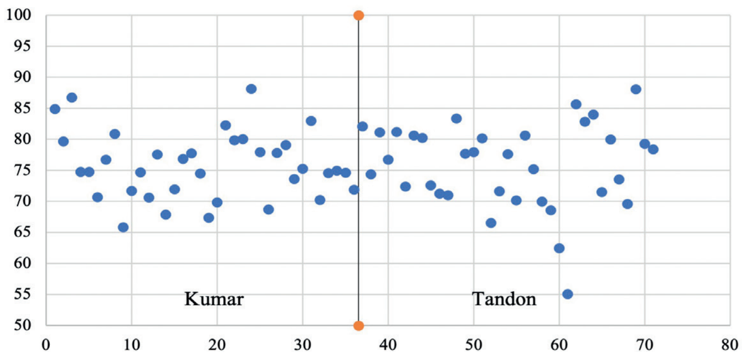
F-test two-sample for variances

	SK	*PT*
Mean	75.74472	75.79014
Variance	28.99025	47.45566
Observations	36	35
df	35	34
F	0.610891	
P(F<=f) one-tail	0.075931	
F Critical one-tail	0.567462	

t-test: two-sample assuming unequal variances

	SK	*PT*
Variance	28.99025	47.45566
Observations	36	35
Hypothesized Mean Difference	0	
df	64	
t Stat	-0.030897	
P(T<=t) two-tail	0.975448	
t Critical two-tail	1.99773	

Kumaragupta I



Appendix 2
Detailed Results of Statistical Tests

Table A2 Test results comparing King and Queen with other Samudragupta coins

F-test two-sample for variances

	Other SG	*K&Q*
Mean	82.98723	92.01713
Variance	25.14628	11.64674
Observations	83	10
df	82	9
F	2.159084	
P(F<=f) one-tail	0.104861	
F Critical one-tail	2.766068	

Since F < F critical, the variances can be assumed to be equal

t-test two-sample assuming equal variances

	Other SG	*K&Q*
Mean	82.98723	92.01713
Variance	25.14628	11.64674
Observations	83	10
Pooled Variance	23.81116	
Hypothesized Mean Difference	0	
df	91	
t Stat	-5.528283	
P(T<=t) one-tail	1.53E-07	
t Critical one-tail	1.661771	

Table A3 Test results comparing Samudragupta with Candra/Goddess on Throne coins (all throne vs other Candra)

F-test two-sample for variances

	All Throne	*Samudra*
Mean	83.064	83.95819
Variance	6.518458	31.46229
Observations	15	93
df	14	92
F	0.207183	
P(F<=f) one-tail	0.000997	
F Critical one-tail	0.456257	

Since F < F critical, the variances can be assumed to be equal

t-Test: Two-Sample Assuming Equal Variances

	All Throne	*Samudra*
Mean	83.064	83.95819
Variance	6.518458	31.46229
Observations	15	93
Pooled Variance	28.16782	
Hypothesized Mean Difference	0	
df	106	
t Stat	-0.605517	
P(T<=t) one-tail	0.273065	
t Critical one-tail	1.659356	
P(T<=t) two-tail	0.54613	
t Critical two-tail	1.982597	

Table A4 Test results comparing Candra/Goddess on Throne with all other Candra coins

F-test two-sample for variances

	Other	*Throne*
Mean	82.20477	83.064
Variance	10.53831	6.518458
Observations	111	15
df 110	14	
F	1.616687	
P(F<=f) one-tail	0.155261	
F Critical one-tail	2.181992	

Since F < F critical, the variances can be assumed to be equal

t-test two-sample assuming equal variances

	Other	*Throne*
Mean	82.20477	83.064
Variance	10.53831	6.518458
Observations	111	15
Pooled Variance	10.08445	
Hypothesized Mean Difference	0	
df	124	
t Stat	-0.983564	
P(T<=t) one-tail	0.163623	
t Critical one-tail	1.657235	
P(T<=t) two-tail	0.327245	
	t Critical two-tail	1.97928

Table A5 Test results comparing Belted with all other Candragupta II coins

F-test two-sample for variances

	Belted	*CG2*
Mean	75.76614	82.30706
Variance	36.91721	10.08182
Observations	11	126
df	10	125
F	3.661759	
P(F<=f) one-tail	0.000261	
F Critical one-tail	1.907226	

Since F > F critical, the variances can be assumed to be unequal

t-test: two-sample assuming unequal variances

	Belted	*CG2*
Mean	75.76614	82.30706
Variance	36.91721	10.08182
Observations	11	126
Hypothesized Mean Difference	0	
df	10	
t Stat	-3.52862	
P(T<=t) one-tail	0.00273	
t Critical one-tail	1.812461	
P(T<=t) two-tail	0.005459	
t Critical two-tail	2.228139	

Table A6 Test results comparing Belted with Kumāragupta I coins

F-test two-sample for variances			*t-test two-sample assuming unequal variances*		
	Belted	*KG*		*Belted*	*KG*
Mean	75.76614	75.76711	Mean	75.76614	75.76711
Variance	36.91721	37.54554	Variance	36.91721	37.54554
Observations	11	71	Observations	11	71
df	10	70	Hypothesized Mean Difference	0	
F	0.983265		df	13	
P(F<=f) one-tail	0.534021		t Stat	-0.000495	
F Critical one-tail	0.383215		P(T<=t) one-tail	0.499806	
			t Critical one-tail	1.770933	
		P (T<=t) two-tail	0.999612		
Since F > F critical, the variances can be assumed to be unequal			t Critical two-tail	2.160369	

Table A7 Test results comparing Belted with other Candragupta III coins

F-test two-sample for variances			*t-test two-sample assuming equal variances*		
	Other CG3	*Belted*		*Other CG3*	*Belted*
Mean	68.7365	75.76614	Mean	68.7365	75.76614
Variance	43.64322	36.91721	Variance	43.64322	36.91721
Observations	20	11	Observations	20	11
df	19	10	Pooled Variance	41.32391	
F	1.182192		Hypothesized Mean Difference	0	
P(F<=f) one-tail	0.406282		df	29	
F Critical one-tail	2.785445		t Stat	-2.913149	
			P(T<=t) one-tail	0.003411	
			t Critical one-tail	1.699127	
			P(T<=t) two-tail	0.006822	
Since F < F critical, the variances can be assumed to be equal			t Critical two-tail	2.04523	