A STATISTICAL STUDY OF THE WEIGHTS OF OLD INDIAN PUNCH-MARKED COINS

BY

D. D. KOSAMBI

(*Fergusson College, Poona*)

THE punch-marks on old silver coins found in India have presented an unsolved riddle which has been attacked by a classification of the *obverse* marks. The efforts of Messrs. Durgā Prasād,[1] Walsh,[2] Allan,[3] in this direction will be valuable to future scholars, but as yet lead to no conclusion. The first two have paid some attention to the reverse marks also, while the third sometimes ignores them; the reason for this partiality to the obverse is that a group of five marks occurs systematically there, while the reverse may be blank or contain from one to sixteen marks.

The most important qualities of the coins in the ancient days were undoubtedly the weight and the composition. The latter has received very little attention, a coin or two being sampled from each new lot. The former is given as a rule, for every coin, but the statistical study of a coin group by weight does not seem to have been attempted.[5] The resulting confusion as to what standard of weight actually existed can be seen by consulting any of the above works; even Rapson[4] found documentary evidence too self-contradictory for use.

For the basis of a preliminary study, I took Walsh's memoir[2] on two Taxila hoards as fundamental. The work is full of oversights and mistakes, as I have shown in a note to be published in the *New Indian Antiquary*. Nevertheless, it is the only sizeable mass of data available to me, and I take all figures from Appendix XI, with the hope that no error of any importance enters into the weighing. Excluding the 33 Long Bar coins which approximate to Persian sigloi, and the 79 minute coins, all the rest, to a total of 1059 coins which seem meant to represent the same amount of metal, average 52·45 grains in weight. The 162 later coins (App. XII) of a single coinage average 52·72 grains. But the standardization of weights was not the same, as is shown by applying the z test to the variances of the two lots.

But even the main hoard of 1059 *kārṣāpaṇa* is not homogeneous. So, I classified them by the number of reverse marks and found the following data, in which the 64 double obverse coins have been omitted.

In Table I n is the number of coins with the number x of reverse marks given at the column head, and m the average weight in grains. One coin in the square 10-reverse mark class has been omitted, because it has a decidedly different history from that of the rest.[6] There exist coins with as many as 16 reverse marks, but counting the number of marks becomes difficult, and the total not tabulated being 15 square coins and 7 round, the table given below will represent substantially the most reliable portion of the data available to us.

It is seen at once that there is a regular drop in average weight with increase in the number of reverse marks. In fact, for the square coins, the linear regression can be fitted accurately enough by eye and is found on calculation to give the formula: $y = 53{\cdot}22 - 0{\cdot}212\,x$, where y is the average weight in grains and x the number of reverse marks. For round coins, the fit is not so good, though still satisfactory, the regression being $y = 53{\cdot}1 - 0{\cdot}214\,x$. That

TABLE I

	$x =$	0	1	2	3	4	5	6	7	8	9	10
Square	$n =$	224	128	132	85	64	46	21	25	10	9	8
	$m =$	53·26	52·93	52·74	52·47	52·53	52·17	52·03	51·67	51·40	51·47	51·01
Round	$n =$	58	34	29	28	25	10	13	8	9	3	3
	$m =$	53·35	52·84	52·75	51·90	52·29	51·67	51·82	52·23	51·23	50·10	51·20

is, practically the same line serves for both (Fig. 1).

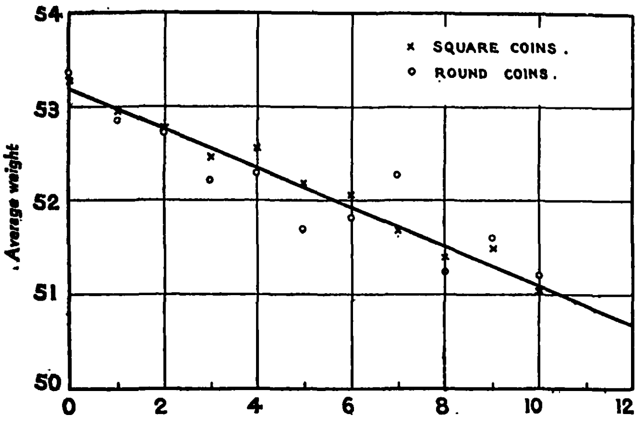


Fig. 1

The second result concerns the number of coins in each group. For simplicity, taking the sum y of both round and square with a given number x of reverse marks, the drop in number is exponential (Fig. 2). That is,

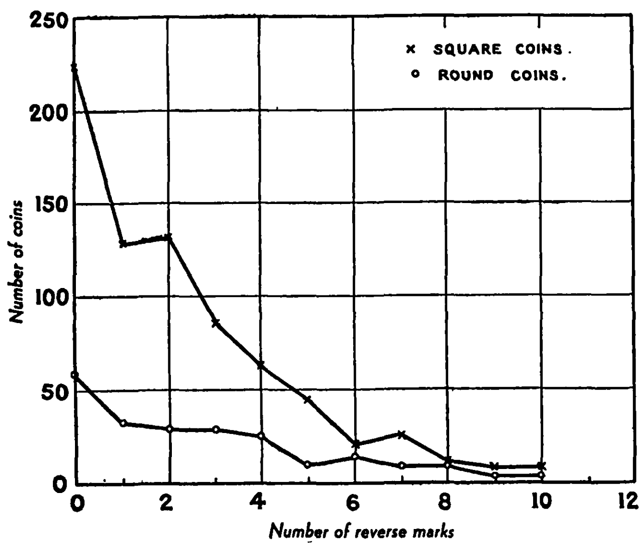


Fig. 2

the regression is given by $y = 283{\cdot}86\, e^{-x/3}$. This was obtained by taking the logarithm of the number of coins with each x, and fitting a linear regression. The divergence between the formula and the observed number is not significant by the χ^2 test, and the calculation obtained from the above table serves also for the omitted coins, giving, for $x = 0$ to 16, a value of χ^2 with P near 0·2; on the whole, a just tolerable fit.

These two results are quite startling. They show that the reverse marks—irregular as they might appear—were not distributed at random, for had they been so distributed, we should have obtained a Poisson distribution or something of the sort for the number of coins as a function of x; and the linear regression for weight would not have fitted so well. The only hypothesis that can account for our results is that *the reverse marks are checking marks stamped on by contemporary regulators or controllers of currency, at regular intervals.*

If accepted, this means that among the obverse marks, there might exist some symbols that specify the date of issue of the coins. This would, possibly, account for the fifth variable symbol found on the obverse. Even now, we have a sixty-year cycle with a name for each year, and there certainly existed an older 12-year cycle, still extant in Chinese and Tibetan tradition, which was converted into a sixty-year affair by associating twelve years with each of the five elements. This could account for one or two of the five obverse marks. One obverse mark is fixed: the sun symbol. If it is not votive, it might be a symbol of the metal itself. The next commonest mark is some form of the wheel, with (usually) six points of varying design. This *ṣaḍaracakra* is, in my opinion, not to be interpreted as a symbol of any deity, but as representative of the issuing authority, the *cakravartin* or king. The form of the points of the wheel, with perhaps one of the extra symbols, might be the ruler's personal monogram. This is borne out by the fact that in the few cases where the six-pointed wheel does not occur, we invariably get (with two exceptions) small homo-signs in their place (Durgā Prasād,[1] p. 41). That is, when the issue was not authorised by a king, it was authorised by a council of some sort.

Leaving these doubtful conjectures, we can use groupings by obverse marks for the purpose of weight analysis and compatibility tests, in particular the t test and the z test. I shall publish my results on this elsewhere.

Even in modern times, a certain amount of currency will be lost each year due to damage, hoarding, melting down, etc. This should, in stable times, be proportional to the actual number of coins in circulation. But when the coin does not represent full value in metal content, being just a token coin, with a rigorous control of weight by the examiners of currency, the formula for the number of coins surviving t years after issue would be given by

$$y = a\, e^{-bt} \left(\frac{1}{\sigma\sqrt{2\pi}} \int_{m_1 - r}^{m_1 + r} e^{-\frac{(x-m)^2}{2\sigma^2}}\, dx \right)$$

where: $m = m_1 - tm_2$
$\sigma^2 = \sigma_1{}^2 + t\sigma_2{}^2$

Here, a is a constant of integration, essentially the number minted. The legal weight, as also the average of freshly minted coins is taken as m_1, the variance at the mint as $\sigma_1{}^2$. The average loss of weight per year is m_2, and the variance of this annual loss, $\sigma_2{}^2$. The legal remedy, *i.e.*, the weight by which a coin may exceed or fall below the legal standard is called r in the formula.

When the coin is a source of metal, the first factor would account for most of the currency in circulation, particularly as the variances with modern technique of minting are very small. But with a token coin, and in any case after the passage of a greater number of years, the second factor would begin to dominate, and the coins withdrawn rapidly from circulation by those who check the currency. The phenomenon is similar to that often seen in biology, where a gene or culture of bacteria shows exponential *growth* till a threshold value is reached, when the situation changes entirely, the growth makes its own surroundings lethal, and further growth is either inhibited, or the whole of the variate vanishes altogether.

[1] *Journal and Proceedings of the Asiatic Society of Bengal*, New Series, 1934, **30**, Numismatic Number.

[2] *Memoirs of the Archæological Survey of India*, 1939, No. 59.

[3] *Catalogue of Indian Coins in the British Museum*, Ancient India, 1930.

[4] *Ibid.*, Andhras, W. Kṣatrapas, 1908, p. clxxvii *et sec*.

[5] The work of A. S. Hemmy, *Journal of the Royal Asiatic Society*, 1937, pp. 1–26 must be dismissed as mere trifling with an important subject.

[6] One coin in the 3-mark round lot should also have been so omitted, bringing the mean to 52·20, which would have fitted much better.

SULPHANILAMIDE AND DERIVATIVES IN BACTERIAL INFECTIONS

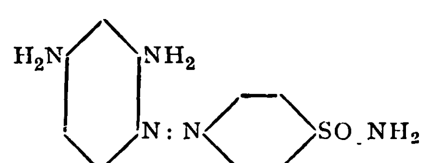
BY

K. GANAPATHI

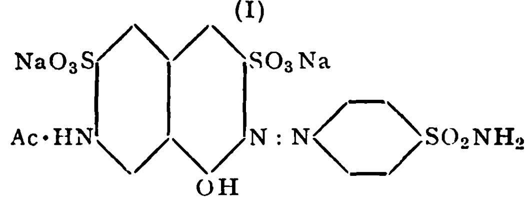
(*Haffkine Institute, Parel, Bombay*)

1. Prontosil and Related Dyes

DOMAGK'S sensational discovery[1] of the specific curative effect of 'prontosil' (I) in experimental β-hæmolytic streptococcal infections in mice, which is hailed as the "greatest discovery in modern therapeutics", appears to have been made in 1932 as a culmination of his researches dating from 1923–24 in the Elberfeld laboratories of the I. G. Farbenindustrie.[2] Regarding the hosts of compounds that must have been tested systematically in the course of this investigation, we are given no details. The discovery was announced on the 15th February 1935[1] only after it was confirmed by three years of clinical trials at the hands of the Rhineland practitioners, for "by untimely publication he did not want to give false hopes to doctors and patients".[2] This dye (prontosil) being of low solubility in water (about 0·25 per cent.), a more soluble form, "prontosil soluble" ("prontosil S", "neoprontosil", II) was introduced (as 2·5 per cent aqueous solution) for parenteral use, while in France, a carboxyl derivative of prontosil, "rubiazol" ("rubiazol C", III), synthesised by Gley and Girard[3] came into use.



(I)



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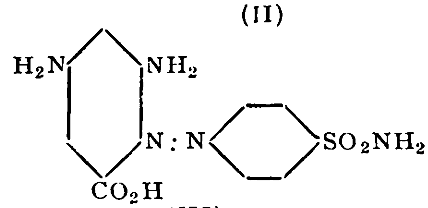

(III)