Coin Weight and Historical Metrology

This revision of 1st June 2019 is just a series of small amendments to the May 2019 re-write.

This work was first published, on paper, in 2009 as a chapter of my *Early World Coins & Early Weight Standards*

I have retained the old page numbers, and append the old index, but both are now only very approximately correct. Revised sections include:

1) All the first 12 pages have been re-written– primarily drawing on the work done during the last 4 decades on pre-coinage weight standards by European archaeologists, most especially the work of Parise and followers. I found the Rahmstorf papers posted on Academia especially useful. Also papers by Gerald Finkielsztejn regarding the early (Hellenistic) coinage period. In this and later sections I am very grateful for a great deal of insights, comment and criticism from Ross Glanfield, via the Yahoo Numismet group.

2) A solution to the conundrum of Ibn Hazm's 84 grain dinar has been integrated. Many thanks to Michael Powell, Alberto Lalouf and especially Ed Hohertz for lots of help back in 2018 on that.

3) The revisions published separately to Academia in 2015 have now been integrated into the text

   They concern:

   a) Russian, Ottoman and Carolingian standards and

   b) The probable adoption of Troy and Sterling standards by Offa

4) A new suggestion for the origin of the Hindu gold-suvarna draws on work (from 2016) kindly supplied by Prashant Kulkarni, with some helpful comment from Meeta Rajivlochan.

5) The Kushan dinara weight has been corrected to 8.0g on advice from Robert Bracey

6) The early issues of the Shahi Spalapati Deva were checked and found to be c. 3.43g (by myself in 2010)

7) Splendid Viking weights from Russia posted and discussed by "Alexey" aka "GolemXV". Thanks to Yevgen Lemberg for the introduction.

I am sure there have been others – apologies for my fading memory. My wife Monica rooted out very many of my typing errors, but I am a hopeless case, and make them faster than anyone can keep up. Apologies for that too.

Please do write with comments and suggestions if you have any. Either directly via the Academia system, or via the Yahoo "Numismet" group, which still clunks along.

A further revision will follow this one when time permits. It will re-visit the questions surrounding the retreat from the modern study of historical weight standards. In 2009 (pp 159-162) this section focused upon errors arising from an excessively bullionist approach to coinage, and related assumptions about the laissez-faire characteristics of all pre-modern economies. Such errors were widespread early in the 20th century, and lingered in the USA within numismatics even later on in the century. However, a different set of errors, traceable I believe to Keynes, have found their way into current archaeological and anthropological thought, not least in the UK. Such went inadequately addressed in 2009, and I hope to correct that situation here before too long.

5. Coin Weight & Historical Metrology

Introduction: for the general reader

The chief aim of this study is to attempt to put before the general reader an overview of weight standards worldwide, and their influence on the fixing of coin weight standards throughout history, and on ideas about money before even that.

Behind this aim is the belief that all weight standards are something of an interconnected whole, spanning both millennia and continents. I hold that many errors of judgement that arise in piecemeal studies can be avoided if such an organic approach is given priority. Very many general principles connected to the way weight standard are maintained, and the way weight standards change, are prompted by this organic approach. Likewise very many pitfalls awaiting the incautiously optimistic must be dealt with. Rather than spell out these general suggestions in separate, abstract and inevitably arid theses, it seems to me simpler, clearer and more convincing to allow these to emerge alongside the facts of the history itself. Here I will give a brief taster of my logic, in the hope that it will illustrate for the reader the sort of approach I adopt and endorse, and thus, whether it is sufficiently to his or her taste.

Since a book written in English will mostly be read in countries where the weight standards themselves are rooted in English practices, here I will focus on those, and in particular the two versions of Troy weight used in modern times, one of which is generally called Troy, meaning something like official or monetary Troy, the other being the so called Apothecaries Troy.

Apothecaries Troy is a very simple system. It is also the system that a future archaeologist would very likely discover amongst our artefacts, if excavations were carried out in some remote future time. The sets of nested Troy weights that they would find would appear to be a pound of 16 ounces, split in a binary way - thus 16 ounces, 8 ounces, 4 ounces etc, down to the Apothecaries drachm, the 1/128th of the apparent "pound". Both apothecaries and bullion dealers, at least in silver, would rely upon such sets for the practical purposes of commerce.

troy set of 1588, 256, 128, 64, 32, 16, 8, & 4 oz

Official or monetary Troy is on the other hand almost bewilderingly complicated. It consists instead of a 12 ounce pound, each ounce comprising 20 pennyweights, each pennyweight comprising 24 grains. The "pennyweights" do not refer to any physical pennies we have a clear knowledge of, since the traditional Sterling penny weighed, in theory, 22.5
grains. Nor are the "grains" themselves representative of any real grains, in wheat or barley, that ever existed. It appears that in an older tradition there were 32 grains in a Troy pennyweight, of a kind that did somewhat approximate real wheat grains, and the heavier official sort of grain is just an arbitrary mathematical product of that, 4/3 times the weight.

How did the official system get so complicated? Well, I judge there are three matters to consider. Firstly, official Troy was much used by government scribes calculating money matters on paper, rather than merchants handling physical commodities. Duodecimal and decimal factors are just easier to manipulate in pen and ink calculation than binary ones.

Secondarily, if we delve just a little into the numbers - it emerges that this Troy 12 ounce pound comprised exactly 256 sterling pennies each of a reduced weight, 30 Troy wheat grains or 22.5 barley or Imperial/Troy grains. Thus the mathematics leads us in a circle, back to a pure binary number, and hints that practical men at the mint working with commodities wished to work much as other such men did elsewhere. Thirdly, the whole system creates a kind of mirror of itself, for there are 240 Troy pennies in an official Troy pound, and 240 Sterling pennies in a monetary pound, and the unwary can very easy mistakenly conflate the two. If, as many suppose, the government which first adopted this system was taking a seigniorage on metal of one ounce in every 16, then that tax on money was effectively camouflaged within the mathematics of the whole system. It hides that tax in its complexity of numbers, at least from the ordinary individual, back in the days when schooling was a rare luxury.

A Few More Important General Points

1) We are rarely fully informed about the weight system of any place or time prior to the later medieval period. **Throughout, this account is an attempt to guess at what most probably happened, based upon the available evidence.** What is presented here is thus a series of best guesses, the best conjectures I can offer, on the available evidence.

2) Evidence will emerge in the following study suggesting to readers that traditional weight systems were often maintained, not just for centuries, but for millennia. They are, at least sometimes, amongst the most extraordinarily enduring of all human institutions.

3) A weight system is more than just a weight standard. It is also a practice of dividing that standard up into subsidiary components, and of combining it into superior components, (as for instance Avoirdupois pounds are divided into 16 ounces, but added to make a stone of 14 pounds). Such mathematical systems of division and combination are almost as much a characteristic of a system as the absolute weight standard itself (eg avoirdupois lb = c. 454g), and indeed seem sometimes more resilient to change than the absolute standard of weight.

4) The two pan balance was the earliest and most reliable weighing instrument available to pre-modern man. Use of this device has interesting consequences, since given a standard weight (a particular piece of stone for instance), there are only a few operations that can be carried out with a two pan scale:

a) One can use the scale, plus the standard weight, to make duplicate copies of the standard weight.

b) One can put a number of these duplicate weights into one pan, so as to weigh integer multiples of the standard weight

c) Using fine sand one can create a weight of sand exactly matching the standard weight, and then tip some of this into the (emptied) second pan, until balance is again reached, and one then has two heaps of sand each weighing exactly half the standard weight. One then can then use this sand to calibrate a new stone to a half the original standard weight.

d) The process with the sand can be repeated, to make a series of lesser binary divisions of the standard, the quarter, eighth, sixteenth etc.ake approximate versions of 'non binary' weights.

e) One can make approximate versions of 'non-binary' weights. For instance one can through a series of steps construct $(^{1}/_{2} + ^{1}/_{4}) \times ^{15}/_{16}$ which at about 0.703 is quite a good approximation of $^{7}/_{10}^{ths}$ of the standard. But this procedure is quite time consuming, and always involves a residual error.

Much said in this brief account has been contested at some time or another, and the matters can only really be judged following the more detailed historical account that follows.

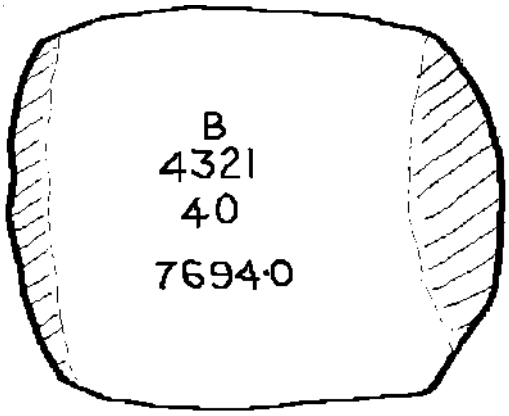
Finally, I repeat, all suggestions made are put forward here merely as the best explanation available given the known facts. Very little is certain in the history of weight standards.

The Earliest Origins of the Pound or 'Mina'

Written mention of weights post-dates the appearance of physical weights. Inevitably, the notion of weight pre-dates the first physical weight, and thus all physical or written evidence. This leaves us guessing about what seems plausible regarding mankind's earliest notion of weight. Here is a suggestion based upon some facts which seem at least relevant in indirect ways. Men, and even more likely, women, were harvesting wild grain to make a form of bread more than 11,000 years ago. Grain was apparently being cultivated for food 9,000 years ago. Measurement of grain quite possibly evolved in connection with its earliest use in food production and preparation. Since the harvest of grain was an annual event, it is also likely that measurement was used in connection with grain storage, concerning both the annual carry over of seed corn, and the assessment and apportionment of communal rations over the course of the year.

The simplest and most readily available measure of volume available to mankind, at least for a stuff like grain, is using a kind of cup made up of the two hands, when used to scoop up a small heap. My own trials of this with modern wheat grain suggest this amount of grain weighs about 250g. In addition, many authors[1] have estimate the average human daily bread ration at about 500g, thus approximately double that amount. These two physical measure arise out of the basic facts of human beings themselves, and might well be connected to the prominence of 500g and 250g standards in Europe, Persia, and China, as will be accounted below.

The Earliest Egyptian Standard and its Influence

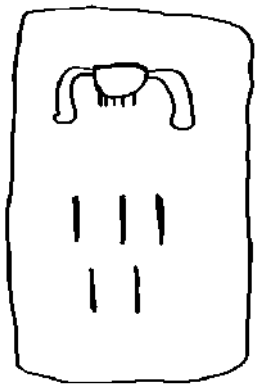


"40 Beka?" c. 3,800 BC? (498.6g)

Early in the 20th century Petrie claimed that an assemblage of stones found in a grave, apparently dating to perhaps 3,800 BC, was a set of weights.[2] The items have clearly been shaped, the one illustrated being cylindrical with rounded ends. The inscription, presumably in Petrie's own hand, decodes as follows: "B" indicates Petrie thought it conformed to what he called the "beqa standard". This had a median of about 13g with a range from about 12.2 to 14g. The name of the standard Petrie took primarily from a set of much later weights, of around 700 BC, inscribed in Hebrew with that word. Those later weights apparently conform to a slightly lower standard somewhat close to one half of this: 6g. Since the word "beqa" actually means "half", there is some sort of sense in rather arbitrarily asigning the name "beqa" to very much earlier items, but the arbitrary nature of this decision should be borne in mind. The word has biblical precident also, which no doubt influenced Petrie's thinking here. "4321" is merely Petrie's reference number assigned in his catalogue of weights.[3] The numeral "40" indicates his assumed denomination, thus 40 beqa. "7694" is the weight in (Imperial/Troy) grains, thus 498.6g. Knowledgable early 20th century readers would quickly spot that Petrie's beqa was a passable approximation of 4 Troy pennies, that is to say 128 Troy wheat grains, and thus that the illustrated weight is quite a good approximation of 16 Troy ounces (497.7g). That chain of ideas was brought out more explicitly by Skinner. Without doubt the sort of thinking that linked this very ancient Egyptian item to traditional British weight standards has had an exaggerated influence on the opinions of some amateur British 20th century enthusiasts. At the same time, it has come to be equally neglected by subsequent generations of professional archaeologists. The truth is not the property of either of these somewhat tribalistic groups, it belongs to the evidence.

The claim that we can follow Petrie and assign such very early dates to these items and call them are weights, has been thrown into some doubt by Rahmstorf.[4] Primarily because no parallel finds have subsequently been reported from more modern excavations, but also because the "set" itself is not very internally consistent. These criticisms are of course valid, but perhaps not all that weighty. Curiously little has been published, on any sort of ancient Egyptian weights since Petrie's days. Further, a lack of internal consistency concerning weights is common in weights we know to be mutually contemporaneous (eg English Late medieval lead weights.[5] Even weights from a single grave can lack consistency (eg the

early Anglo-Saxon grave finds[6]). The items are clearly manufactured for some purpose, and Petrie's suggestion seems the most plausible.



A typical 5 beqa weight c. 1850 BC with the "nub" = gold hieroglyph (61g)

The Early Egyptian "Beqa" Standard

We may be more confident of the use of the beqa standard in Egypt from around 2,600 BC onwards,[7] with evidence from both surviving weights and indeed, for the chronology, from wall paintings depicting a set of weights from that date.[8] Skinner agreed and lists known examples of inscribed "beqa" weights down to c. 1450 BC.[9]

Known denominations of stone weights from the "beqa" standard system tend to be binary below the unit, but decimal above it, and include:

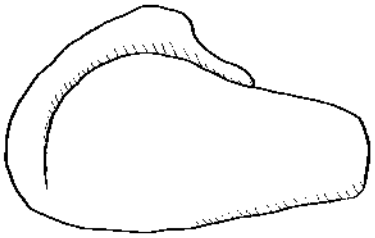
$^1/_{16}$, $^1/_8$, $^1/_6$, $^1/_4$, $^1/_2$, 1, 2, 3, 4, 5, 6, 10, 20, 30, 40, 50, 100, etc. up to 2000 beqa.

Skinner adds three interesting hypotheses about the beqa. Firstly that it ultimately derives its standard from a binary assemblage of cereal grains - exactly 256 of them. He goes on to explain the large variation in the standard as involving two separate peaks (at c. 12.4g and c. 13.2g, but with a wider spread still) as being created by the choice of lower weight wheat grains, or on other occasions, higher weight barley grains. Finally, he suggests that although the beqa increasingly fell out of favour in Egypt, it contued to be remembered, either locally in Egypt, or elsewhere, right down to the coinage period and the issues of Aegina. All of this is plausible, but we suffer from a woeful lack evidence, for or against it. The mathematical equivalence clearly implicit in Skinner's suggestion is this:

40 "light beqa" = 40 Aegean staters =
40 x 256 near physical wheat grains =
10,240 (Troy) grains = c. 497g (16 Troy oz)

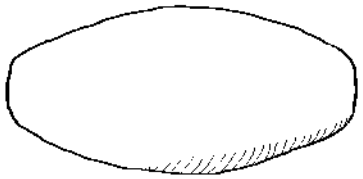
That system certainly seems to appear under the Arabs around 700 AD. That the system "existed in 700 BC and probably millennia earlier"[10] was the holy grail of many an amateur enthusiast, while simultaneously being anathema to many a professional archaeologist. For my own part, I find it an attractive suggestion but needing further corroboration.

The Persian Weight system[11]



Generic Mesopotamian "sleeping duck" weight

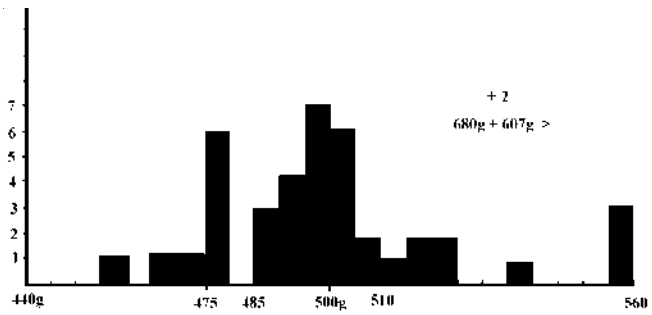
Weights seem to appear quite soon after 3,000 BC in Mesopotamia.[12] Common forms are the rather odd sleeping duck form, and even more often, the spindle. Both come in many sizes.



Generic Mesopotamian "spindle" or "sphendonoid" weight

From the very beginning they conform to a "shekel" of around 8.3g. Text confirms that a King Shulgi of Ur, c. 2095-2047 BC, standardized the Sumerian weight system on the basis of a pound, or mina that weighed around 500g, based upon 60 shekels of around 8.3g. Skinner references three weights inscribed in the name of Shulgi himself: they imply minas of 500.2g, 498.7g and 496g respectively. Fourteen centuries later the Babylonian king Nebuchadnezzar, 605-562 BC, tracked down a specimen of Shulgi's double mina, and made a copy of it, to act as an imperial standard. An inscribed copy of that copy survives. It implies a mina of 489.2g. Another weight is known of just a little later that is inscribed as 'of the palace of Darius', and it implies that Darius 522-486 BC made his mina 500.2g.[13]

Below is a histogram of 44 Sumerian, Babylonian, Assyrian and Persian inscribed weights, spanning the period from Shulgi to Darius, according to their implied mina standard.[14] Given due allowance to the time span and diversity of sources, the weights point very clearly to a standard of close to 500g being maintained throughout the whole period. Given the close correspondence between the best attested weights of Shulgi, Nebuchadnezzar and especially the palace weight of Darius, I am inclined to dismiss the outlying weights of around 475g and 560g, as deriving from either different standards, or from incompetence or dishonesty by manufacturers or local officials.



Mina standards of Ancient 'Persian' inscribed stone weights

While enquiring into the origins of the c. 500 gram mina we might, by chance, have solved an even more profound question, that of the origin of counting systems. It seems quite possible that the earliest organized farming communities, who set aside grain to tide themselves over the winter, were the first people ever to need to count in an 'open-ended' way; using a 'ladder' system. That is to say, they were the first to find the route to expressing arbitrarily large numbers. The suggestion seems initially plausible, and rather surprisingly we do have evidence that lends at least partial support to it. For if we enquire into the derivation of the word 'mina', which first appears in texts in the early 3rd millennium BC, we find its literal meaning is 'count'. At their root then, the ideas of 'counting', 'unit' and 'pound' all seem to be the same. Surely this hints that the origin of the notion of weight is tied into some counting process, perhaps the one suggested above.

A further piece of evidence giving support to this line of reasoning is the perplexing adoption of base-60 counting by the very ancient inhabitants of Mesopotamia. To this day we measure 60 minutes to the hour, 60 seconds to the minute, for reasons no historian records. A similar preoccupation seems to give us, via the same Babylonians, 360 degrees in a circle. If weighing and counting arose side by side in assessing the grain harvest, it would be very natural to round the year off to approximately 360 days, and make this a 'great unit', a man-year of food. And it would also be natural and convenient to break this up into half-a-dozen sacks of c. 30 kg (a talent) each, a size that could easily be manhandled. Thus the pound of circa 500g would perhaps go 10 to a bowl full, 6 of which went to a sackful, or talent, six of which in turn would make a man-year of food. Thus the fact that there are approximately 360 days in a year, combined with the fact that 30 kg represents a manageable sack to carry, and that a half kg of grain represents a man-day's ration, all conspire to push mankind towards sexagesimal counting, in the context which might represent the very origins of counting itself.

Thus, we might reasonably guess that in the first farming communities of the fertile crescent, perhaps 10,000 years ago, the mina, a kind of 'pound', first came into being. It expressed approximately twice a two-cupped-hands-full of grain, or one man-day's rations, and played a key role in assessing, sharing and storing the harvest. The set of higher value counting units might have included sacks, and man-years of grain, allowing numerical counting up to multiples of 360.

The mina was divided into 60 parts we will call 'shekels' but which in early times were called 'gin'. The mina multiplied by 60 was a talent, in early times called a 'gun'.

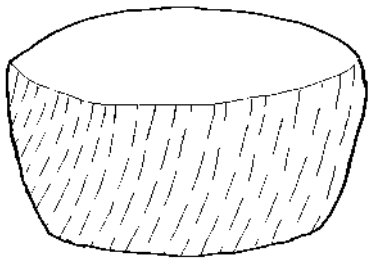
1 'gun' (talent)	= 60 mana (mina)	= c. 30 kg
1 mina	= 60 gin (shekels)	= c. 500g
1 shekel	= 180 se (grains)	= c. 8.33g
1 se		= c. 0.0463g

It seems however that the shekel divided up into 360 parts, that is, into half-grains or 'half-se'.

Weights calibrated to this Mesopotamian/Babylonian/Persian standard seem to appear before 2000 BC as far East as the Indus Valley and as far West as Egypt. Standardisation in Mesopotamia apparently ran ahead of developments in Egypt. It seems possible that a move towards a 40 "beqa" c. 500g mina in Egypt at some stage echoed this Mesopotamian initiative. Perhaps even more likely (as we shall see shortly) is the development of a 64 x 7.8g shekel c. 500g mina in the very early Aegean/Minoan system.

As we shall see also, the very ancient Mesopotamian/Persian weight system stayed in use well into the coining period, being applied to the Achaemenid darics of Sardis etc right down to the conquest by Alexander, c. 330 BC. There are indications that this c. 500g mina also influenced the commercial weight systems of a good number of subsequent Hellenic cities, and that it may have been revived in Persia in connection with later Sasanid coinage. All this will be investigated further below.

The Syrian "Deben/Qedet" Standard



Generic Egyptian "loaf" shaped deben standard weight. Note that we also commonly find eg spindles, and (in the Aegean) spools, and yet other shapes to this standard

Beginning in the 1970's a narrative, initially constructed by Parise began to emerge, primarily amongst professional archaeologists located in continental Europe. That account brings to the fore a different, c. 470g Mina. This c. 470 g mina is plausibly described as emerging in Syria perhaps by 2,400 BC, and spreading into Egyptian use sometime after 2000 BC,[15] ultimately largely displacing the earlier "beqa" standard.

There can be little doubt about the existence of such a c. 470g mina, but equally, we seem to have no firm ideas as to where it came from. Three possibilities spring to mind. Firstly, it may be just a kind of parallel of the 500g mina, emerging independently, but at roughly the same size and for the same reasons. Secondly, it could be a direct commercial derivative of an earlier 500g standard, merely the commercially accepted version of the 500g standard itself, eroded in use. Thirdly, it could be a politically adjusted version of the 500g standard, specifically, 15/16 of it, with a reduction associated with tariffs or standardised interest payment, or some such. I have an open mind on this question.

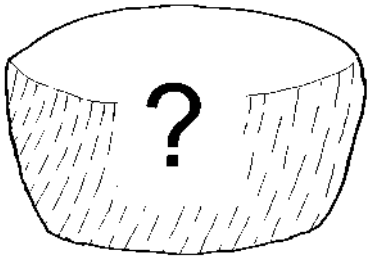
What cannot be doubted is that the early 470g mina system primarily had a somewhat decimal structure. It equates to 50 units of c. 9.4g "qedet", or 5 units each of 10 qedets, such 10 units being called a "deben". We get excellent site specific verification of this structure from a sealed context: the multiple weight sets found from a c. 1300 BC shipwreck near Uluburun.[16] The denominations seen in the Ulburun sets seem to be primarily decimal, and include:

1, 2, 3, 5, 10, 20, 30, 50 unit (c. 9.4g) weights

The same standard and structure is found very widely in Syria, Egypt and the Aegean. Late in the pre-coinage period we begin to find hoards of scrap silver, apparently weighed, sealed, and bagged up, hidden in jars by Phoenician merchants. These seem to have been traded to at least two separate weight standards. Sometimes they seem to indicate a mina of c. 500g,[17] in line with Persian mina. At other times a different 'mina' this time of about 450 grams,[18] which would seem to be an

eroded version of this mina of 5 deben. There will be much more to add concerning this "eroded Syrian" standard of c. 450-460g in what follows.

"Hittite" and "Karkemish" shekels



Thus far we have been setting out conclusions put long since by Petrie, Skinner and a host of others. The Parise publications however went beyond the indubitable use of a c. 9.4g x 50 = 470g decimal standard. It added two associated standards: one associated with a 'Hittite' shekel of c. 11.8g - going 40 to a 470g mina, the other associated with Karkemish - a shekel of Karkemish being c. 7.8g - going 60 to the mina of c. 470g. Thus three regional shekels were in use in the Levant, all of which shared a common 470g Mina. (Parise dubbed the best known Syrian shekel, of c. 9.4g going 50 to c. 470g, the shekel of Ugarit.) This three standard model has been promoted by many others subsequently, perhaps most notably by Rahmstorf.[19] The unit shekels were not themselves new suggestions. Petrie, for instance, found all these units statistically amongst his own (chiefly Egyptian found) weights. What Parise added was a reinforcement of the common association of the units with a single mina.

Parise[20] produced both old weights and texts indicating these c. 11.8 and c. 7.8g standards existed and were used in conjunction with a 470g mina, but the evidence given was slender. The sort of very solid evidence from old weights, underpinned for instance by a widespread use of a special form of the weight, or a widespread regional adoption of a standard, or even a set of weights from a good sealed context (as got for the 9.4g standard at Uluburun) are all lacking for the two other Parise standards. Almost all excavations of ancient cities will throw up anomalous seeming finds of individual weights, and having three theoretical standards to play with will inevitably make it easier to explain such anomalies, but that in itself rules against, not for, accepting such anomalies as compelling evidence. The Cape Galinodya shipwreck for instance gave us a number of anomalous seeming weights, which might be explained using the Parise hypothesis, but this author did not see anything there that compelled its acceptance.

Bearing the above in mind, this study will move cautiously forward accepting the existence of these mysterious standards, largely on the basis of the sort of statistical work pioneered by Petrie. In each case caveats should be born in mind, as follows.

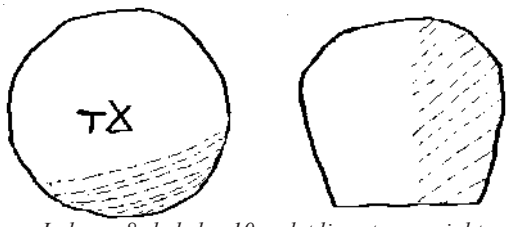
Concerning the so called "Hittite standard", c. 11.8g, it is important to have in mind that modern archaeology has spent decades excavating huge ancient Hittite cities, and has left almost no reports of finds of old weights at all. That seems a very odd situation indeed. Statistics rather strongly suggests a c. 11.8g standard lurks amongst the great mass of ancient weights from the Levant. But archaeology gives us very little confidence the standard is in an important sense "Hittite".

Concerning the so called Karkemish standard, c. 7.8g, we shall see below that there is a very similar standard to this, in the very ancient Aegean weight system. However, that is not a splitting of a c. 470g mina into sixty shekels. It is the splitting of a heavier mina, in the 480g to 500g range, and splitting it in a binary fashion, into 64 pieces. This raises a range of possibilities when we are faced with any isolated find of a weight to this sort of standard. Which is it? It could be an Aegean standard shekel weight in that different system. It could a genuine "Karkemish" standard weight. Or, it could act across both system, used in conjunction with a set of Aegean or Karkemish weights to convert the set, additively or subtractively, from one to the other.

Actually, we do have literary reference to what seems to be a c. 7.5g sniw (or Shat) standard in Egypt around the 12th century BC.[21] But below we will see clear evidence for a possible precursor, a Minoan c. 7.8g standard, already existing by that date, as in effect a 'quarter ounce' to a c. 500g mina.

Actually, further evidence comes from what may well be an ancient weight set in the Goulandris museum[22] which seems to adhere to a c. 7.7g standard. Those weights are suggested to be 1, 2, 3, 4, 7 and 8 shekel pieces. This does not clearly point to a 60 shekel mina, if anything, by the inclusion of an 8 unit, it seems more closely associated with the binary division of a "Minoan" 480g-500g mina. Thus, to recapitulate, where apparently strong evidence to a c. 7.8g shekel emerges elsewhere, we are left at best perplexed as to which of the two minas, (500g/64 or 470g/60) it should be associated with.

Weight Conversion and 'JILs'



Judean 8 shekel = 10 qedet limestone weight top and side view (91g)

It seems appropriate to say something next about an extraordinary group of so called JILs (Judean Inscribed Limestone weights), as they amplify much of what was said in connection with the Parise hypothesis. The JILs were primarily made and used in the Judea region from c. 700 BC down to 586 BC. They were the subject of an important in depth study by Kletter. Here I accept Kletter's largely empirical determinations but reject some key parts of his interpretation of them.[23] The weights are quite well standardised and their primary unit seems to to be a local shekel to a c. 11.33g standard. The primary set of weights denominated in these shekels runs:

1, 2, 4, 8, 12, 16, 24, 40

Thus the mina indicated is 40 x 11.33g = c. 453g. It appears quite possible that this derives from a much earlier (so called) c.11.8g "Hittite" standard, but that over the course of a thousand years or more, the standard has eroded by 3% or 4%, and its mode of division has moved from a rather decimal to a rather binary expresion. However, we immediately hit a complication which is plausibly unravelled by Kletter - that the inscribed weights for the denomination 4 and upwards are (apparently) inscribed in an Egyptian (Hieratic) script, and accord with a lower standard of the qedet of c. 9.06g. That is to say, they constitute a sub set which can also be read as:

5, 10, 15, 20, 30 and 50 units

where the unit is a (rather low) Egyptian/Ugarit c. 9.06g qedet. Again this would show a reduction in the more ancient standard, around 3.6% in this case, thus not much out of line with variability in other indicators. Further, when expressed in qedets, the ancient decimal structure is retained.

To that extend then it seems to partly corroborate the Parise hypothesis. There was a mina split alternatively into both 50 Syrian/Egyptian units and 40 heavier Judean units. It does not of course answer our problem as to whether that heavier weights has some Hittite parentage. However, if we apply the further part of the Parise hypothesis to the JILs, we find the possibility that, if a 453g/60 = c. 7.56g unit was also posited then the subset:

3, 6, 12, 18, 24, 36, 60 would also be generated

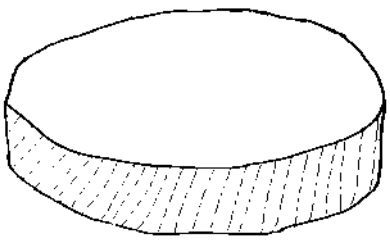
Thus the JILs could conceivably be used as a sort of universal tool kit for weighing to all three local weight standards, according to a version of the Parise hypothesis. All one would need to add are a few additional smaller weights, to the 9.06g and 7.56g standards, in order to complete the various "sets". And the reason for raising this is that, at least at first sight, exactly such smaller weights do seem to exist amongst the JILs. Petrie long since spotted these as denoting a variety of different shekels, calling them Peyem, Necef and Beqa respectively according to inscriptions actually found on them. Some problems of detail arise however when we start to look at the average weights of these items.

Kletter judges the average "peyem" standard to be c. 7.82g. That is an excellent fit for the much earlier Karkemish shekel postulated by Parise, but in connection with her c. 470g mina. For a later c. 453g standard we would expect c. 7.55g. (Kletter takes the rather idiosyncratic stance that this peyem is just the name for the local fraction of the JIL standard, the 2/3rd piece - but that hits exactly the same problem). Turning to the Necef pieces, Kletter determines the average to be c. 9.66g. Petrie had wanted to make these a kind of qedet, but the average looks too high for that, and does not really fit the Parise hypothesis at all. Finally Kletter determines the Beqa pieces weigh on average to a c. 6.0g standard. Again this is way too high, if this beqa is taken as a half unit to suit this version of the Parise hypothesis, we would need 11.33g/2 = 5.67g.

The alternative put up by Kletter is to merely make the beqa simply the name of the half shekel, which also ought to be 11.33/2 = 5.67g, which is just as problematical.

Where does this leave us? Readers must decide for themselves. I judge the JILs do tend to corroborate the Parise hypothesis in a way, but with a number of so far inexplicable and rather exasperating conundrums.

The Minoan/European Weight Standard



Aegean lead disc weight

Weights in a variety of materials and fabrics, from Crete and elsewhere in the Aegean, were analysed by Evans in 1906, and he found a standard unit of about 65 grams amongst them. This work was extended in 1992 by Petruso.[24] He recorded nearly 200 weights from the Aegean region, mostly made of lead, found variously on Crete, on islands such as Chios, and on the Greek mainland, at Mycenae and elsewhere. Similar weights have since been found at Thebes. Using this material Petruso extended the unit upwards, by a factor of 8 to a kind of mina which he figured at around 483g. He also extended it downwards to 1/8th, a kind of shekel of c. 7.5g. The weights seem to date to the period 1700 to 1200 BC. They include:

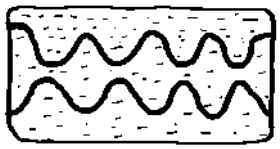
$^{1}/_{64}$, $^{1}/_{32}$, $^{1}/_{16}$, $^{1}/_{8}$, $^{1}/_{4}$, $^{1}/_{2}$, 1, (mina)

Thus under the mina, (roughly!):

7.5g, 15g, 30g, 60g, 121g, 242g, 483g

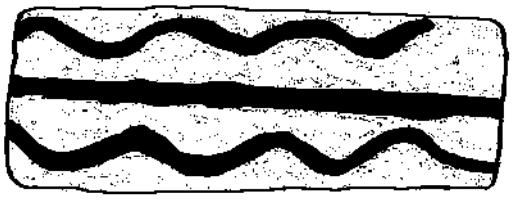
In addition we find weights which seem to represent: $^{1}/_{24}$, $^{1}/_{12}$, $^{3}/_{16}$, $^{6}/_{16}$, $^{12}/_{16}$, and $^{3}/_{2}$ minas. These extra weights include a couple of duodecimal fractions, and a subsidiary 12 ounce pound with its half and quarter (where 'ounce' is here taken to mean the sixteenth part of the mina). Petruso also found contemporary Linear B texts which do not tally very well with the basic denomination structure. They report a talent of 60 mina, a half talent of 30 mina, a mina, its half and its $^{1}/_{24^{th}}$. Thus the textual record lacks the predominantly binary structure that we see in physical day to day usage, as represented by the surviving weights. The archaeological investigator Petruso found this puzzling, but the discrepancy here in practice seems a familiar one to any with a more general interest in metrology, being one seen between scribes and merchants even in 19th century AD contexts, mentioned in the introduction above.

Some might feel Petruso was a little too much of a stickler for a particularly exact sort of statistical accuracy. If his weights are examined, the minas and other heavier weights often run to a standard of 500g or more. If we look at the use of lead weights in commerce in more accessible periods in history, we find it quite normal for them to to be a little under weight on average. Thus I feel no offence against rationality is made by the assumption that these are most probably weights theoretically calibrated to an ultimately Babylonian standard of c. 500g. What we can say even more confidently is that they have an essentially binary structure, that is to say, a pound comprising 16 ounces, just as we would normally have it in modern times. As such it was almost unique in those very ancient days. Elsewhere in the Near East the switch from decimal to binary type weight systems seems to occur much later, early in the coining period, some time around or after 500 BC. And then of course, a reverse switch back over the 19th and 20th centuries



Bronze Age weight from N.E. France c. 1500 BC?

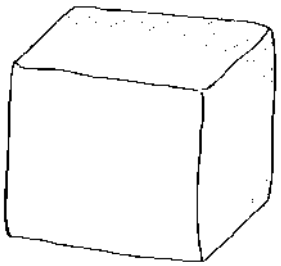
Soon after Petruso's publication, evidence emerged that a system apparently deriving from Aegean/Minoan practice had spread into Bronze Age Continental Europe. A catalogue of weights from Germany and its environs apparently fitting this pattern were published by Pare in 1999.[25] The weights are few and rather variable, but Pare himself postulates the standard of these weights rather directly follows from Aegean practice, thus on this account being a binary division of a c. 500g Mina.



The Salcombe weight, discovered off Devon (in 2007?)

Finally, some time after 2004, a single weight, or at least a metal item strikingly similar to those published by Pare, was found in the sea off Salcombe, Devon.[24] The continental weights it apparently copies are often rather elegant items, bronze with an undulating inlaid copper wire. This English find is much cruder, or perhaps has been damaged in the sea, but seems clearly to be intended to serve that same purpose. Found amongst the cargo of a ship which appears to have foundered around 1200 BC or earlier, the weight today weighs 29.8g, and thus fits well with the Aegean/Minoan system of Petruso. Thoughtful readers might have noticed that the Aegean weight system bears a striking resemblance to the modern Troy Apothecaries weight system, and that the item in question here is not such a bad fit for a modern Troy ounce (31.1g)! Of course, we are a long way away from offering evidence that this very ancient weight is linked to recent practice. Perhaps this is entirely an amusing co-incidence? Perhaps it is just very corroded in the sea? We will investigate the evidence concerning possible links later in the text.

Indus Valley Weights



Generic cubic weight in chert, Indus Valley

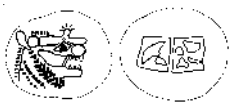
One final very ancient system remains, that of the Indus Valley civilization. The weights are distinctive in form, the great majority being rather attractive cubes of banded chert. They develop very early, apparently initiated around 2,800 to 2,600 BC.[25] They are also the most carefully maintained standard of any of the very ancient weight systems. However, the system is so closely integrated with subsequent Hindu coin issue, that it makes sense to postpone further discussion and resume it in connection with Hindu coinage itself.

Weight in the Coining Period

The current best guess is that coins first appeared at Sardis around 615 BC. Some political aspects of this change to coin use I dealt with in other chapters of Early World Coins,[28] but there seems to be a further general point to be made, more intimately connected to coin use. With the exception of the Aegean/European system, all ancient weights tend to be denominated somewhat according to a decimal system, or in the Mesopotamian/Persian case, sexagesimal. This is out of step with subsequent ancient, medieval and early modern practice. During the fully historical coin using period, weight systems, in Europe, and beyond, tend towards top down binary splits of a mina type weight. That was the system I learned as a child in the UK, and which persists yet in the USA: a pound, of 16 ounces.

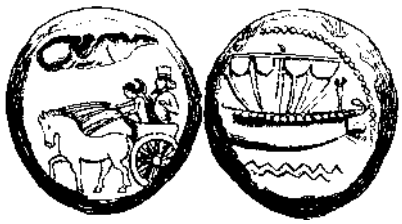
As far as I can tell, the general switch in approach to the structuring of weights happened quite close to the period when coins, and thus retailing and markets first came to the fore. As if the earlier decimal systems had best fitted the clerical bureaucracies of the very ancient command and control economies, but the practicalities of the new market places needed something more intimately associated with weights and scales, rather than stylus and clay, or pen and papyrus. Aspects of this will become clearer as we start to investigate coin weight itself.

First Coins and the Syrian "Deben/Qedet"



(1) *Lydian 1/3 Stater c. 615 BC c. 4.7g*

I have found no record of pre-coinage weights from Sardis. This does not mean none were ever found, the reporting of weights for many periods henceforward has attracted rather limited general attention in the past, and I have no easy access to detailed excavation reports themselves. It is widely believed that the 4.7g issues of Sardis, which seem to qualify as the world's first coins, were 1/3rd staters, thus yielding a stater of c. 14.2g. That being the case, the most plausible interpretation is that they used the same standard we see emerge somewhat later amongst the coins of the Phoenicians and then the Ptolemies, accounted next.



(21) *Sidon double shekel c. 425 BC c. 28g*

We can say more about the issues of the Phoenician cities. Above we accounted a very early mina, from well before 2,000 BC, of about 470g, which comprised five deben each of 10 qedets, thus each in turn of c. 9.4g. We also drew attention to what appeared to be a corresponding but apparently reduced version of this mina standard amongst the JILs with a weight of c. 453g. We further noticed what appeared to be a find of hack silver bagged up apparently to meet that reduced standard. In 2015 Finkielszteijn published a small group of weights from Tyre[29] which accord with a reduced mina of c. 454.4g, split in a binary fashion into halves, quarters and eighths. This accords rather well with the coinage of the region, making the well known double shekel a kind of one ounce to it. Finkielszteijn also draws attention to other weights from Tyre, Marathus, and Aradus which stick close to the old c. 470g mina, and were perhaps divided in the more traditional near decimal way into 9.4g shekels. However, Further, the binary weights of Tyre accord well with the much better studied contemporary commercial lead weights of Athens. Analysis of data on those in 2011 by Pakkanen[30] gave a near identical mina value of c. 453g, on a series of weights that very clearly were split on a binary basis down to the sixteenth, or "two ounce" piece.

What to conclude? It seems simplest to see the early coinage period as a period of transition, where in Phoenician

and other hands, the old 'decimal' 470g mina is both tending to fall to a new lower standard, and to develop a new binary top-down denomination structure. A rather confused period of flux apparently. Further light seems to be thrown upon this matter by the coinage of Phoenician Carthage.

Carthage gold/electrum Stater (c.9.3g vs c. 7.3g)

The gold coinage of Carthage, although becoming somewhat debased, retains much the same types despite a very big change in the weight standard. During 350-320 BC or so the coins weigh close to 9.3g. During the period 310-290 BC they look much the same but weigh 7.4g. Easy enough to explain if we follow the lines laid out above. Prior to c. 310 they employ a high weight qedet, and thus a mina of 50 x c. 9.3g = c. 465g. Post 310 BC we find the quarter ounce of that same pound predicts 465g/64 = 7.27g. A pretty good fit, so all explainable by a move from a decimal bottom-up to a binary top-down denomination structure. This leaves us with Phoenician Carthage out of line with Phoenician Sidon of course, over the absolute standard of the 50 qedet mina, but that seems to fit with the ambiguity of the lead weights mentioned above and below, and is not an implausible metrological situation to come across in itself.

(33) *Ptolemaic Silver Tetradrachm, 283-46 BC c. 14.2g*

Meanwhile in Egypt, Ptolemy I initially followed Alexander in striking to Attic standards, but after just a few short years, in 295 BC, reduced the standard to c. 14.2g. At first sight this looks like the sort of thing noted at Sidon earlier, and Carthage later. The old (qedet x 50) giving a c. 470g mina was long established in Egypt, so again the most likely precedent seems surely to be a binary splitting of a reduced "Phoenician" mina, actually the one already in use in Egypt for about 1,700 years. That is to say, a "half ounce" tetradrachm yielding a reduced mina of c.14.2g x 32 = c. 454g. Just the sort of result seen in lead weights below, from Tyre and Athens.

However, we should consider an alternative possibility, arising from strong suggestions that Ptolemy I closed the Ptolemaic economy in 295 BC, which seems to have very interesting (possible) consequences. Howgego thinks it "even plausible"[31] that Ptolemy I began to exchange Athenian Tetradrachms (c. 17.2g) one for one with his own new 14.2g coins at a hard border in that year. If so an interesting new possibility emerges. If five Attic Tetradrachms are melted and reminted, they create near enough exactly six of the reduced weight Ptolemaic tetradrachms. Thus while the new standard was broadly in line with very old Egyptian tradition, it was even more in line with a 1/6 = c. 17% profit on a money tariff at the border for the Ptolemaic dynasty. Odder still, a little after c. 270 BC, Ptolemy II began the issue of an enormous gold coin, the mnaieion, of 100 drachms value and 27.8g weight.

This coin is frequently called an octadrachm, but note that of course 2 x 14.2g = 28.4g, which is a little higher. It has

Ptolemaic mnaieion, c. 270 BC, c. 27.8g

also been suggested that a new 13:1 silver:gold exchange rate was adopted by the Ptolemies, which would dictate a 100 drachms mnaieion of 25 x 14.2 g = 355g/13 = 27.3g. Again, apparently not quite right. I will propose here a different suggestion. Anyone arriving in Egypt with 100 Attic tetradrachms, converting them into Ptolemaic teradrachms, converting that again into a gold mnaieion, and then leaving again, would almost exactly hand in 16oz attic in silver for 1oz attic in gold. Thus a 16:1 gross exchange rate for Egypt, which, being gold rich and silver poor would work much to its advantage, especially given the low rate of gold, 10:1, imposed by Alexander himself. At that time Attic weight was still arranged to the decimal system created, it seems, by Solon. If this were to be the case, then the mnaieion would seem to be the very first coin issued to a binary attic standard. There is something seductive about this idea when one goes a step further and notes its curious similarity to the issue of full Troy ounce gold bullion krugerrands by gold rich South Africa in the 20th century.

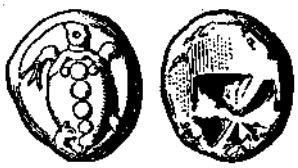
Whether or not this is true, as we will see, the apparent more widespread adoption of a binary form of Attic follows very closely on the heels of this, across the Mediterranean, at Rome.

(34) *Ptolemaic copper deben 246-21 BC, (up to 96g)*

This is not the place to go into the mysterious complexities of Ptolemaic silver/copper bimetallism, but it is worth drawing attention to the oddity of some of the huge coppers struck by Ptolemy III. The largest of them seem to be stuck at around 94g, thus quite possibly at the full very ancient Syrian Deben, belatedly perpetuating its original, decimal, form.

In following the trail of the qedet/deben system, we have got rather ahead of ourselves, thus we must now backtrack about three centuries, to pick up the start of a different set of developments.

The Aegina Stater and the Egyptian Beqa



(6) *Aegina silver 'turtle' c. 535 BC, c. 12.4g*

Coinage spread like wildfire after its apparent inception at Sardis. Mitchiner guessed[32] it arrived at Aegina about 545 BC. Other Greek cities took it up even earlier, but we turn to it first because its seems the Aegina standard was a very important measure of weight value in the Aegean, at least in the late pre-coinage period. (Evidence for that will be given shortly, when we consider the birth of the Euboean and Attic systems). Now, there is no doubt that the weight of the Aegina "turtle" is a good fit for the very ancient Egyptian "beqa" standard. The question before us is - is that intentional, or mere co-incidence? Petrie seemed to think it intentional, as did Skinner, McDonald and Bosak, amongst others.

Regarding positive evidence for an intentional association: firstly, the c. 12.4g unit is quite a good fit for the sort of c. 500g mina (x 40) that we find from early times in the Aegean. Meanwhile it is a poor fit for its main rival, the c.455/470g (5 deben) Syrian mina. What little work had been done on commercial weight during the coinage/historical period shows that a c. 500g mina was quite prominent. Tekin in Turkey surveyed Eastern Hellenic cities[33] and found just seven with enough surviving known weights to postulate the standard. A majority, four of the seven: Lysimachia, Kyzikos, Kolophon and Ephesus seem to adopt just such a c. 500g standard. Meanwhile Finkielsztejn draws attention to a couple of very idiosyncratic Phoenician standards. One, at Marathus[34] seems to rely upon an eccentric denomination of 44 of the 11.3g local shekels (see JILs above) as a way, it seems, to specifically define a c. 500g standard. The other applied by the agoranomos Herodos[35] makes innovative use of a 144 denomination of the c. 3.5g "drachm" of a binary Syrian mina to make another version of a c. 500g mina. Since the Aegina drachm was widely recognised, and a 500g mina apparently simultaneously widely used, it is more or less inevitable that it was understood to equate 40 such shekels by those involved in international trade. But that is as far as we can go.

Turning now to the gaps in the evidence - they are without doubt big. For instance, I have found no clear evidence at all concerning the weight standards used alongside the coins at Aegina itself. Further, Skinner cited no firmly dateable Egyptian beqa weights later than c. 1450 BC, thus about 800 years before we start to hear about the Aegina shekel standard.

Where does this leave us? A kind of shekel in a system that builds downwards in a binary fashion to 256 (more or less) physical wheat grains, and upwards by a factor of 40 to make a man-days food ration is inherently plausible for very ancient Egypt and for ancient Aegina. As we shall see, a very similar 'Troy' system exists clearly enough in later periods. It is a suggestion that has proved very attractive to the independant and scientifically minded.[36] On the other hand, very frequently the modern professionally trained archaeologist will take a determined stand on narrow epistemological grounds - pointing merely at the gaps in the evidence, and putting no alternative in place by way of explanation. Readers must decide for themselves. I merely remind that - absence of evidence is not evidence of absence.[37]

The Attic Drachm and Euboean Standards

(15) *Athenian silver 'owl' tetradrachm c. 17.5g*

Two well known but contradictory ancient texts give accounts of the doings of Solon with regard to weight standard. These apparently relate to a period a little before the adoption of coinage at Athens. They read:

Androtion on Solon: *For he made the mina to consist of a hundred drachmas, which before had contained only seventy-three, so that by paying the same amount of money, but money of lesser value, those who had debts to discharge were greatly benefited, and those who accepted such payments were no losers.*

Aristotle on Solon: *he carried through his abolition of debts, and after it his increase in the standards of weights and measures, and of the currency. During his administration the measures were made larger than those of Pheidon, and the mina, which previously had a standard of seventy drachmas, was raised to the full hundred. The standard coin in earlier times was the two-drachma piece. He also made weights corresponding with the coinage, sixty-three minas going to the talent; and the odd three minas were distributed among the staters and the other values.*

Both accounts were written long after Solon was dead, they are mutually contradictory, and probably both somewhat garbled. Nevertheless, in the light what was said above, it seems possible to figure out a very simple story of what most probably happened. The mina of 100 drachms mentioned by both authors is very probably the well known Attic standard subsequently followed by Athenian owl coinage, with a drachm of c. 4.37g and thus mina of c. 437g. If we accept the alternative standard of Pheidon as equating to 70 different drachms, but follow Androtion in applying it to the same mina,[38] then we have a drachm of c. 437g/70 = c. 6.25g. If we then follow Aristotle in making the old standard double this we have c. 12.5g. That is near enough the theoretical standard of the coin of the Aegina mint, controlled by Pheidon, as derived above. The peculiarities of the 73 drachm mina and the 63 mina talent make little sense in the texts, but seem rather easy to explain, once we examine the associated commercial lead weights. These seem not to the Attic nor the Aeginan coining standard, but rather to the reduced Syrian/Phoenecian 5-Deben standard described earlier. Others write of a 105 drachm mina - working in Attic drachms, (thus c. 459g) but that would equate well enough with the same mina expressed as 73 old Aegina drachms (thus c. 453g), especially given the lower Attic coin standard usually met in practice.

Athenian lead mina weight - typically c. 453g

The notional story told here then runs that a c. 500g mina initially found in Mesopotamia was transfered by the Minoans into Bronze Age Aegean culture. That came to be expressed as 80 Aegina drachms by the late pre-coinage period. Perhaps in connection with some sort of tariff system, Euboa adopted a reduced version of this mina, set at 70 Aegina drachms, thus about 437g. It was Solon himself who then created the Attic drachm, in connection with his famous reform. We get support from the fact that there is no strong evidence for the existence of Attic weight at all, before the coining period. The very first Attic standard coins however seem to be the electrum issues of Samos. Mitchiner guesses the earliest Samos issues are c. 575 BC, while putting the earliest Athenian issues at c. 535 BC. Thus the story would most easily unfold if we assume some influence of Athenian policy upon Samos immediately prior to the period of coin issue, perhaps driven by a need felt at Samos to distance itself from the practice of its rival Miletos, who had adopted the standard of Sardis to the East.

What we may say with more certainty is that the highly productive silver mines at Laurion, owned by Athens, allowed Athenian four drachm c. 17.2g 'owls' to dominate the international trade of Ancient Greek states, and indeed coinage events much further afield. However, and this is rather strange, Attic weight had very little influence on commercial weight standards anywhere, even, as we have seen, at Athens itself. It seems to have arisen solely as a measure of coin value, and was hardly adopted for any other purpose, except for one very important caveat, which will arise below, that of the Roman commercial and coining system. Thus through the apparently pre-historic decision by Euboa, to fix its mina at 70/80 of the more general Aegean system, a fundemental 7:8 conversion factor seems to have come into being which still appears to dog Anglo-French metrological relations (for instance) at the end of the 18th century, two thousand five hundred years later.

The Sumerian Shekel and the Daric

Gold 'Daric' c. 513 BC+, c. 8.3g (this type c. 500 BC+)

In contrast to all the above, there is no mystery at all about the weight standard of the Persian gold daric. The Mesopotamian mina was formally fixed at close to 500g with a division into 60 shekels by 2,100 BC or earlier. In the British Museum there is a palace weight of Darius himself which weighs 500.19g. His gold darics are a good approximation of that 1/60th of that standard.

There is little more to say directly about that fact, but it does provide an opportunity to suggest a solution to a famous but puzzling text in Herodotus (IV 166). The text suggests that Darius tried to make himself famous by doing something no one had ever done before. That was to make his gold coins of the 'utmost purity'. Herodotus further suggests that the satrap Aryandes sought to upstage Darius, by making his own silver coins more pure than his master's and that Darius eventually had Aryandes executed for his conceit. Taken at face value this is a very puzzling story, in part because it seems highly unlikely that Aryandes, or anyone else, was striking any coins at all in Egypt at that time. Further, the gold and silver coins struck by Darius do not seem to be exceptionally pure.

As mentioned, Darius struck coin which rather exactly replicated the very ancient Mesopotamian shekel, of c. 8.33g. Several rulers had struck at Sardis before Darius launched his daric, but none before him struck to what Darius perhaps thought (correctly) was the true and most ancient standard. The gold daric follows on from the gold issue of Croesos, which weighed just a little less at c. 8.16g. The simplest way to explain this situation seems to be that Croesos applied a small seigniorage, of about 2%, to his gold coin, and Darius took great pride in abolishing it. A similar argument follows concerning a belated raising of the weight of the silver siglos from c. 5.35g to c. 5.55g by Darius himself. We might easily imagine it was this during this short period of a reduced weight siglos that Aryandes made his quip.[39]

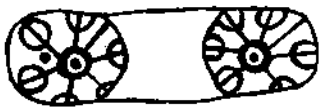
The earliest coins of Sardis and Ionia were struck in impure natural alloy, electrum, and many suspect it was normally further adulterated, to lower the gold content. If so they may never have been tariffed at their intrinsic value. The silver coins of such as Aegina and Athens seem to be rather pure by the standards of the day, but as we shall see, arguably fall, just like those of Croesos, a little short of the expected full standard. Since in those days Egypt issued no coin, all payments from Aryandes in Egypt very likely would be in full weight of metal, which might easily, one might suppose, provoke the situation where the quip was made. That completes the suggested contextual basis of the Herodotus text. All in all, it seems quite possible that Darius abolished seigniorage to match Aryandes, and thereby became a precursor of John Locke, demanding coin should exactly replicate its full declared intrinsic value by weight.

Coins and the "Hittite" (or "Khoirine") Standard

(78) *Darius silver siglos, c. 520 BC+, (this type c. 486 BC +), c. 5.55g*

As mentioned above, Darius struck a silver siglos, but at a different standard to his gold coinage; after an early adjustment, c. 5.55g. This is widely taken to be a kind of half shekel with a corresponding shekel being c. 11.1g. A great deal of ink has been expended with the aim of fixing this standard to customary valuations of gold and silver within Persian practice. This relies upon text again found in Herodotus, and assumes a gold to silver value ratio of one to13.33, with a special silver mina of 666g being created, and thus a corresponding coin valuation ratio of 20 sigloi to the daric. That approach seems to me correct, but incomplete. Bimetallism was a political hot topic in the 19th century, and Victorian ideas about Persian financiers sitting down and designing a new standard from scratch according merely to rates of exchange seems a little implausible. Above we saw Rahmstorf following Parise in strongly supporting a very early "Hittite" shekel of c. 11.8g. Further we saw the possibility that such a standard persisted, in an eroded state, in Judea, at c. 11.33g. It is tentatively suggested here that a practice of

weighing silver to very ancient "Hittite" standard was also inherited by the Persian regime. Erosion over time there was perhaps coupled with tweaking and that tweaking was the real input of ancient economic thought, creating a new 11.1g standard for silver as above. Initially this suggestion might seem far fetched but for a further fragment of evidence.



(615) *Taxila bent bar, c. 485 to 315 BC? c. 11.5g*

The Taxila bent bars were the first commonly used coinage of Afghanistan and NW India. Mitchiner follows Allen in the British Museum Catalogue, judging them to follow Persian metrological standards, associating them with the double siglos. This idea does not really work, because some issues, at least, seem to average about 11.5g. Whilst it is common enough to find coins issued below their full theoretical standard, due to seigniorage or other fiscal reasons, it just does not make sense for them to routinely weigh above the theoretical standard. Here instead it is suggested that the rather mysterious very early so called "Hittite" standard did exist, theoretically fixed at around 11.8g. Petrie had early spotted it in his data but called it a Persian "Koirine". Further it is now suggested that local versions of the standard were perpetuated in rather widespread localities. Reasonably exactly at c. 11.5g in the bent bar coinage of Afghanistan, but brought into line with the deben after 700 BC in Judea (11.33g thus 4:5 to the deben), and in a form that is both eroded and tweaked by Darius, (11.1g, thus 3:4 to the daric) in that last case specifically in connection with silver use in a bi-metallic system of coinage.

Italy (Campania) & the Minoan/Aegean Standard?

Naples didrachm c. 300 BC

This, the last of the suggestions linking a group of coins to a pre-existing standard is perhaps the most tentative. Back in 1911, Head judged the (sometime) achieved standard of the much of the early coinage of the Campania region of Italy as being 118 grains, that is to say, c. 7.65g. His convoluted attempt to explain coin weight in archaic Italy in terms of the Corinthian version of Attic seem unconvincing.[40] Rather importantly, it fails to mention (!) the 118 grain standard he himself favours for the physical coins. In other parts of his text[41] he introduces a Phocaïc/Campanian standard which does match this c. 7.65g standard.

Thus it seems we have to reject earlier explanations of this Campanian standard. As we have seen archaeological work done since Head's day has brought to light a new possibility - dubbed here the Minoan/European standard. That yields a quarter ounce or didrachm of c. 7.55g to 7.8g, a rather good fit for the coin series here mentioned.

Although this suggestion is lodged upon somewhat shaky foundations looking backwards, it seems to gain support from subsequent developments, within Roman coinage, as we shall see below.

Standards, Seigniorage and Croesus

Before we move on further into the coining period we will pause to take stock a little. Above, an attempt was made to attach some of the earliest coins to pre-existing weight standards. As we shall shortly see, this effort leaves the weights of even some very early coins unexplained. I judge the difficulties arise only in part from the paucity of evidence surviving from such a distant period. They also arise from the nature of the exercise itself, that of creating a national monetary standard, an exercise which tends towards deliberate complexity and indeed obfuscation.

Let us go back to the pre-coinage model of weight standards in the Levant, proposed by Parise and recently promoted by Rahmstorf and others. The model, perhaps correctly, suggests three linked monetary zones, all sharing a common mina of c. 470g, but in each case divided differently, into shekels of 1/40, 1/50 and 1/60 of that standard. The reader is led to believe in archaeological writings[42] that this was an attempt to simplify international trade. That the states mysteriously somehow started out with diverse staters and sought to assist the ordinary citizen by seeking unification at the mina level, and above. That approach seems to me politically naive. Simplifying trade is easy, merely get all the partners to use the same system. The Parise model if correct was more plausibly constructed for exactly the opposite reason. It does make international trade at a big scale simple - since all of it can be carried out in a universal mina. However, the pre-modern man in the street was more likely to be familiar with smaller shekel sized amounts of luxury items, such as, of course, gold and silver. Within the Parise model, standards are systematically constructed to complicate, rather than simplify, matters for the many. They tend towards international incomensurability. The independent states of the ancient world were frequently involved in military conflict, but they were surely even more frequently involved in economic conflict. Nor are they at all unique in that respect. As I write these words international tariff disputes, concerning the USA and China, and also the UK and Europe, dominate the news media. Surely it was ever thus, and the diversity of ancient metrological systems is just a different facet of the same fundamental situation?

The coming of coin added a second tier of complexity to the situation. Many believe the very first coins were frequently made from a kind of electrum deliberately adulterated with additional copper. That is to say, they were secretly tariffed at a value above their mere metal value. Certainly the levying of a seigniorage charge on coin, elevating its value above the bullion value, has been the norm for much of subsequent history, probably most of it. This being the case, we will expect to find four different approaches to weight standard inherent in coinage.

Firstly, there will be cases where coin is stuck to some full metrological standard. This was the announced policy in England after 1666, ceasing in 1816 in the case of silver. Above, it was suggested that Darius adopted a similar policy. In such cases, even the costs of coin production have to be met from general taxation.

Secondly, there will be cases where a small charge is levied merely to cover the mint cost in making the coin, the brassage. It was suggested that we saw something like that above, under Croesus. We will see something similar below at Athens, Aegina and Campania. It was certainly common enough in later times, for instance at the medieval mint of Venice.[43]

Thirdly, there are further cases where the system of weight itself seems clearly contrived so as to yield a fixed relationship between the face value of coin and its intrinsic (or international) bullion value. Many believe, as do I, that we find such systems in medieval Islam, in the English sterling and the Carolingian systems. Much more will be said about this situation later in this text.

Finally, a fourth situation very commonly arises where seigniorage is somewhat arbitrarily driven by political expediency, that is to say, something like a state driven system of inflation. In this last case , the relationship between the weight (and purity) of coin may well become arbitrary and complicated, often with constant changes. Many coins fall into this category, but they are not considered in this text.

Accuracy & Diversity in Ancient Greek Coins

It seems appropriate to tackle the topics of accuracy and diversity in ancient coin weight standards together, as they often come that way in discussion. What quite often happens is an attempt to discuss important matters concerning diversification of weight standards is derailed by casual and dismissive comment concerning accuracy.

Firstly then, concerning accuracy of standards, the ancients met no problem at all in estalishing absolutely accurate primary standards. One needs only the political power to specify that some particular very resistant stone or metal item represents the unique true standard, and that standard is then completely established, in so far as anyone, ever, can determine it.[44]

Making good reproductions of the primary standards is a different matter, concerning the accuracy of available scales. Skinner determined[45] that by 600 BC the best scales could weigh to two parts in a thousand. That is to say, one gram in 500g on the mina, or 0.01g in 5g on the drachm. That seems to me about right. Even in mass produced items like coins, some Islamic mint masters in the 8th century (at Wasit and Baghdad) managed 0.02g on 2.93g with very few slips.[46] Thus the anciently achieved accuracies are perfectly adequate for the determinations offered in this text. By and large, the sort of inaccuracies we routinely come across in ancient weights and coins are very much larger than this. They do not arise from stultified technological development, but rather from problems of competence, communication or financial self interest, or, often enough most likely, a combination of all three of these.

Nineteenth and twentieth century scholars have made reasonably accurate determinations of a large number of the weight standards exhibited by ancient Greek coins. Here is a list, taken from Kraay[47]

Achaea	circa 8.0g
Aegina	circa 12.2g
Asiatic	circa 13.3g
Attic	circa 17.2g
Campania	circa 7.5g
Chios	circa 15.6g
Corcyra	circa 11.6g
Corinth	circa 8.6g
Euboea	circa 17.2g
Miletos	circa 14.1g
Persia AU	circa 8.35g
Persia AR	circa 5.55g
Phocaea	circa 16.1g
Phoenicia	circa 7.0g
Samos	circa 13.1g

As we have seen - some of the standards listed above seemed to spring directly from pre-coinage metrological systems; interpretations have already been offered for them. Note further, that Kraay seems to be attempting to establish empirically the standards coins achieved, rather than theoretical underlying standards. Consider for instance Euboean, Attic, and Corinthian, which seem all to have the same root. Skinner[48] and Grierson[49] both fix that standard higher, making a tetradrachm of 17.5g or equivalent. This seems to fix the Persian standard of Darius at a theoretical 500g, and to fix the Euboean mina at exactly 7/8ths of it. Kraay however fixes the observed weight of the earliest issues 0.3g lower, on average. On the basis of theories outlined above we would estimate the Aegina standard at 500g/40 = 12.5g, and Campanian at 500g/64 = 7.8g. Again Kraay's observed weight of the earliest issues in both cases are c.0.3g lower, on average. The medieval mint documents of Venice point to an actual cost of producing silver coin from silver bullion, the "brassage", of about 2%. The variations calculated above are in the region of 2% to 4%. That is to say, way higher than can be explained by mere technological problems, but very much in line with what one would expect if mint masters were allowed to recover their costs by a small remedy to cover brassage.

Having dealt with relatively minor variations due to accuracy of scales, and slightly bigger ones arguably due to brassage, we are still left with major variations between cities, due, as proposed earlier, to a kind of interstate/interclass economic conflict, expressed as both conflicting weight standards, and probably related currency exchange, tariff and seigniorage arrangements. Evidence for, or against, this conclusion is of course scanty, but text concerning legislation at Olbia[50] especially seems to point to something like this.

Stepping back from theory and addressing the practical problems of figuring out what denomination some arbitrary small ancient Greek coin is, we need to bear in mind that variations might arise:

i) Due to their being the product of different primary standard weights.

ii) Due to their sharing a common standard but it being sub-divided differently

iii) Due to a different seigniorage being applied

iv) Due to being derived via gold/silver ratios from a special 'subsidiary' electrum or silver pound

v) Due to the weight of pure metal being the prime consideration in a less than pure coin

The diversity of possible sources of variation make it clear that we must put little weight on any particular mere guess that we make about the metrology of a particular coinage within the doubtless complex and highly competitive situation, if we have no corroborative evidence aside from the weight itself. So when it comes to many matters associated with Ancient Greek coinage, (such as, for instance, even the origins of the Phokian electrum standard of circa 16.1g), I fear the matter may be, and may ever remain, a mystery.

The Later Development of Attic weight

(15) *Athenian silver 'owl' tetradrachm*

To recap: a tetradrachm of circa 17.2 grams (1/25th of the Euboean mina) was the most important of the early Greek coining standards. The standard seems to have been used for coins very early, with the electrum issue of Samos. A couple of decades later the system appeared at Athens, in the shape of coin of c. 8.6g, used for silver, in the series usually known as 'wappenmunzen'. Text suggests this standard was created earlier by Solon from a mina known as 'Euboic', thus by the early Athenians themselves.

It seems possible that the Euboeans had earlier created their mina by applying a 2oz tariff to a widely used and pre-existing 500g mina (originating in Mesopotamia?) but that is just plausible speculation. We have evidence neither to corroborate nor contradict it. If we consult ancient texts we find Herodotus suggesting that the Babylonian talent equalled $^{7}/_{6}$ of the Euboean talent. (H. III 90). Calculating the Babylonian talent on the basis of a 500g mina this seems to imply an Attic mina of c. 429g and a tetradrachm c. 17.16g. The difference from our theoretical figure is small; it seems that Herodotus was taking his estimate of the Attic mina from physical coins, and thus making it about 2% short of our theoretical estimate. Other sources complicate the picture. Cunningham[23] quotes Xenophon valuing the siglos at 7.5 attic obols, thus an overvalued Attic tetradrachm of 17.76g. Further, he quotes Hesychius valuing the siglos at 8 obols, which suggests an undervalued Attic tetradrachm of 16.65g. We might suspect that these ancient authors were quoting the rates at money changer's tables: the ancient equivalent of 'tourist rates'. Thus I would always recommend caution in the use of isolated and fragmentary ancient comment as evidence for ancient weight relationships, unless the ancient author himself was scientifically minded, and was carefully explaining the topic. There is some mathematical evidence hinting that Roman weight, at least, might in some way derive from an ancient Egyptian 40 beqa version of the circa 500g pound, evidence deriving from a consideration of the grain structure of the Roman pound. This will be given below.

The Athenian coinage was primarily issued in its chief unit, the tetradrachm of c. 17.2g, but smaller denominations exists to the following standards:

Binary: $^{1}/_{4}$, $^{1}/_{8}$, $^{1}/_{16}$, $^{1}/_{32}$, $^{1}/_{64}$

'Duodecimal': $^{1}/_{12}$, $^{1}/_{24}$, $^{1}/_{48}$, $^{1}/_{96}$, $^{1}/_{192}$

where the 'duodecimal' divisions are really better understood as a further set of binary divisions, of the $^{1}/_{12}^{th}$ part of the tetradrachm. Superficially, in totality, they might be taken to represent the influence of an Egyptian/Aegean binary mathematical tradition, with what might be interpreted as an additional Babylonian duodecimal element. They perhaps represent two different classes of people. The wealthy, who figured their accounts in the c. 17.2g tetradrachm and its binary divisions, and their financial inferiors, who figured their accounts in diobols of c. 1.45g and its binary divisions. This metrological division seems to echo a similar break in the binary ladder of division we saw in connection with Lydian and allied standards, between the shekel and the trite.

The standard subsequently became the most prominent Greek coining standard, as the highly productive silver mines at Laurion, owned by Athens, allowed Athenian c. 17.2g 'owls' to dominate the international trade of Ancient Greek states. Later, Philip of Macedon adopted the same standard for his gold, striking at c. 8.6g. And most important of all, Alexander the Great subsequently adopted a version of it, when coining his vast holdings of silver and gold, the loot arising from his conquest of Persia.

(27) *Alexander's silver tetradrachm*

As a coining weight Attic became enormously important, influencing Seleucid, Parthian, Bactrian, Indian and early Sasanid coin issue. It seems also to have been widely used in accounting the weight/value of silver dishes and the like in both Ancient Persia and Afghanistan.[51] Oddly however, it was almost never used in Greece or further east as a basis for commercial weight. As mentioned above, Athens for commerce apparently used a Syrian/Phoenicia mina of c. 455g. The only site where archaeology clearly discovers a series of weights to an Attic standard seems to be Olympia,[52] and that may be due to what we might postulate to have been a kind of specialist provider position concerning international payments.

Now looking forwards in time, if we re-divide the Attic pound of circa 437g up into 16 ounces anew, this brings into being a new companion 12 oz pound, a pound of c. 327g. As we will see, exactly such a weight does become a very important commercial weight in the West. It is the commercial and often enough the coining weight standard of the Roman Empire. This derivation of Roman weight from Attic is again conjectural, but seems to have been assumed by some since ancient times, and I am aware of no rival suggestion.

Alexander apparently abolished a Persian 13.3:1 silver/gold ratio, replacing it with a simple 10:1 relationship. He also produced a very carefully regulated coinage, with a tetradrachm close to 17.2g, and drachm of c. 4.3g. Note that a silver 'siglos', if struck at a rate of 120 to a c. 500g mina would weigh 4.17g. Thus when we see the coins of Alexander's successors, such as the Seleucids and the Bactrians drift down a little in weight, it is not clear whether this was to match the typical weight of worn coin in circulation, or whether the standard was deliberately tweaked closer to the expectations of Persian subjects. Either way, a slightly low weight theoretical drachm of circa 4.24g seems to have evolved under the Seleucids, which perhaps re-emerged to influence Islamic metrology centuries later.

Anonymous versions of Alexander's tetradrachm continued in production until about 190 BC. At around that time a new coin, the Cistophoric tetradrachm, appeared at a number of towns in what is now Western Turkey. Its weight was carefully regulated to c. 12.6g, which looks rather like three quarters of a late version of Alexander's Attic weight. It has been plausibly

(39) *Cistophoric silver tetradrachm*

suggested that this was a semi-fiduciary issue,[53] valued the same as 2nd century BC Alexander type tetradrachms, but intrinsically worth 25% less.

Etymology and the Origin of Euboean Weight

As we saw above, prior to the introduction of coinage at Athens tradition suggests that Solon made two parallel sets of changes to existing practices there. One was aimed at reforming the metrology of Athens, the other at offering debt relief to its poorer citizens. We have only a much later account of these actions, which perhaps gives a garbled account of what was actually done, but it does raise the possibility that the metrological changes and the debt relief were linked. The idea of a linkage becomes more attractive still when we notice that in ancient Greek the word for 'interest' derives from the word 'to weigh'. These observations point to the possibility that interest charges on loans in Late Bronze Age Greece were taken by weight. In other words, that they were recovered by manipulating the relative weights of a 'debtor's mina' and a 'creditor's mina'. In particular, it is possible for instance that bullion hacksilver was loaned out at 12.5% interest by making the loans in minas of c. 435g, but the capital plus interest were retrieved as minas of c. 500g. The use of such weight driven calculating mechanisms need not be restricted to interest rates. It is just as easy to conceive that taxes, such as import duty, might be 'assessed' directly by use of the scales, with weights appropriate to the scale of charges levied.

In connection with these matters, mention should be made of an unusual system of payment recorded in an ancient Indian text, the Arthashastra[69] (passage 2.19.29) The surviving version of the Arthashastra seems to have been composed around the 3rd century AD, but is widely assumed to contain elements from very much earlier sources. Since the passage in question bears no relation to its surrounding text, nor to any actual, nor even easily conceivable payment system based upon coin use, it seems logical to assume that, like the account of Solon's doings, it records a practice recalled from the pre-coinage era.

The text records four different versions of the 'same' weight, a 'drona'. In effect what the text says is that a 'revenue drona' should be fixed at $^{16}/_{16}{}^{ths}$ of the full standard, a 'trade drona' at $^{15}/_{16}{}^{ths}$, a 'payment drona' at $^{14}/_{16}{}^{ths}$, and a 'palace drona' at $^{13}/_{16}{}^{ths}$. This isolated fragment from the Arthashastra represents a rather alien thought pattern, where price difference is created, not by changing the numerical price, but rather by changing the standard that quantity is measured in. It seems almost a kind of doublethink. We find something similar in a prehistoric Persian tradition of making a 'royal' mina weigh double a common mina, and in Warring States China, in the practice of using 'long' weights for loaning, and 'short weights for taxing. There is no reason to suppose such ideas are directly related to each other. But they give us a clue about how similar financial operations, using scales, may have evolved in parallel in the Bronze Age.

If this line of thought is broadly correct, it could explain the origin of the various subsidiary pounds, which might perhaps be related to early Bronze Age hierarchically structured weight and payment systems. The evidence is sketchy. The fact that the Attic pound closely resembles $^{7}/_{8}{}^{ths}$ of the Persian mina may have some other explanation, and may indeed be just a coincidence. I mention the matter here in the hope that some future metrologist may bring further evidence into play, bearing upon the origins of these very ancient and apparently mathematically related metrologies.

Roman Weight standards

Roman coining weight standards were carried forward somewhat seamlessly into Byzantium, and from thence into Medieval European traditions. Roman coin metrology is usually presented in modern literature as a set of done and dusted facts, which can be stated without further comment or support. In point of fact ancient literary sources are sparse and incomplete. A very influential and lengthy account does exist, but from a late date, recorded by Isidore, Bishop of Seville, c. 560-636.[24] Surviving weights, and the coins themselves, tend to support his account, which runs:

1 pound (libra)	= 12 ounces
1 ounce (uncia)	= 8 drachms
1 drachm	= 3 scruples
1 scruple	= 2 obols
1 obol	= 3 siliquae

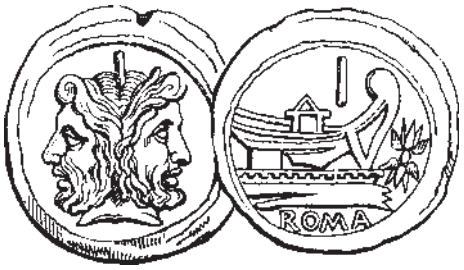
There have been numerous attempts to fix the absolute standard of the Roman coining pound or 'libra' on the basis of extant coins and weights, with most results falling in the range 320g to 329g. This level of variation does not seem to me to have much theoretical importance. The Roman Empire stretched for thousands of miles and lasted, all told, for perhaps two thousand years. The state regularly came up against enormous economic challenges, and set against this backdrop, a variation of less than 3% in a standard directly associated with practical payment systems hardly surprises. For the purposes of this study the theoretical Roman pound will be fixed at c. 327g, based upon the following prior and posterior considerations.

Arguing from prior considerations, we have seen that Darius fixed his mina at very close to 500g. And that at some stage the Athenian mina was calibrated very close to, possibly exactly at, $^{7}/_{8}{}^{ths}$ of this. Since a sixteen ounce Attic mina and the twelve ounce Roman libra are commonly taken to share a common ounce, this line of reasoning suggests a theoretical value of 328.1g for the Roman pound. Above we suggested an extention of this argument. If the Ptolemaic mnaieion was indeed an intentional Attic ounce in weight, that may also be involved in the matter. Note especially episode when Rome first came to strike coin in gold, its "oaths" and "eagles": the time of the second Punic war. The eagle type especially suggests the Ptolemies were perhaps somehow backing Rome in this struggle. The weight standards of the coins are quite close to being quarters and eighths to a 'mnaieion' ounce

Arguing from posterior considerations, it will be suggested below that Medieval Paris Troyes weight was intended to represent $^{3}/_{2}$ Roman pounds, that is to say, 18 Roman ounces. We know that the Paris Troyes pound weighed near exactly 489.5g from early modern times. Calculating backwards from Paris Troyes gives a Roman pound of 326.34g. That a difference of less than a gram in a theoretical standard should develop

over 1,000 years or more should give us no grounds for concern. Thus we will fix our 'theoretical' Roman pound at c. 327g, for the purposes of further discussion. Skinner found it impossible to reconcile the differences exhibited in surviving Roman weights, but suggested a weight initially of about 329g eventually falling to 324g, on the basis of coin weights[54].

The earliest Roman money seems to have been random lumps of copper, circulating according to an agreed weight system. Later this was replaced by hefty cast copper ingots apparently weighing a full (Roman) pound each. These ingots fairly rapidly reduced in weight, down to a size that could conveniently be used as a coin, the 'As'.



(59) *Republican Rome, copper As*

There are considerable difficulties in dating the various reductions in weight of the Republican copper As, and in determining whether it circulated as something akin to a full weight coin, or rather, as a kind of fiduciary token. However, there is less difficulty in seeing what metrological system was used to determine the ever reducing weight of the various Asses, which over time set standards (in Roman ounces) of (amongst others) twelve, six, three, two, one (illustrated above), and finally, half an ounce.

(58) *Republican Rome, silver denarius*

Initial issues of silver denarii were apparently struck at six to the Roman uncia, thus c. 4.5g. The weight of subsequent issues of denarii is highly variable, but the average comes close to 3.9g, thus seven to the uncia. It seems possible the curious variability in the weight of these coins was devised to disguise the fact that the average weight had been reduced. If so, it seems possible that a fiat element of value had been built into the coin, which were on that account tariffed at 1/6th oz, but weighed, on the average, 1/7th oz, (or $^{1}/_{84}{}^{th}$ of a Roman pound in ancient literature, and as numismatists commonly have it).

Republican Rome, gold c. 217 BC, c. 6.64g

Gold coin appears during the second Punic war, around 217 BC. The weight looks as if it was intended as a quarter of an Attic ounce, which is not at all an Attic stater of course. It may, as indicated earlier, reference the weight of the earlier Ptolemaic mnaieion as a quarter to that ounce, as mentioned above. Subsequent gold issue is sporadic until the late Republic, and only becomes a regular part of the Roman coinage with the reforms of Augustus. A single reference by Pliny[25] sets the weight of the aureus as 40 to Roman pound, a value (circa 8.2g) that some late Republican aurii seem to match or even surpass. However, the issues of Augustus seem to be closer to 7.8g in weight, and some authorities, such as Mattingly,[26] prefer to fix the standard at 42 to the pound, a figure which better matches the coins themselves.

Why on earth would anyone pick such a strange fraction as $^{1}/_{42}{}^{nd}$ part of a pound to fix a denomination on, or for that matter, its half - $^{1}/_{84}{}^{th}$? An obvious metrological hypothesis would seem to be that the values of $^{1}/_{42}{}^{nd}$ lb (7.8g) and $^{1}/_{84}{}^{th}$ lb (3.9g) actually represent logical choices within some alien metrological system, and are only represented within Roman metrology rather arbitrarily by these strange fractions, $^{1}/_{42}$ and $^{1}/_{84}$. The mathematical logic of binary, decimal, duodecimal and sexagesimal fraction are all readily comprehensible, but fractions of $^{1}/_{42}$ and $^{1}/_{84}$ seem strange and arbitrary amounts to favour. A clear solution to that problem appears directly from our previous account. Recall the very earliest European pound mentioned above, associated with Crete and Mycene, which seemed perhaps to weigh c. 500g and be divided up in a straightforwardly binary manner. Simple arithmetic shows that the $^{1}/_{64}{}^{th}$ of such a pound, the quarter ounce, would weigh c. 7.8g. Likewise the $^{1}/_{128}{}^{th}$, or $^{1}/_{8}{}^{th}$ ounce would weigh c. 3.9g. That is in a system in place perhaps a thousand years before Rome was founded. That same system might very well have existed in Hellenised Italy before the Romans ever considered striking coin, in the standard of Campanian as accounted above. Thus it seems quite possible that these early Roman weight standards directly represent key elements of an earlier, and more universal Mediterranean weight system, and only yield rather arbitrary fractions when transposed into the Attic standards. It suggests the possibility that, alongside the official sub-Attic standard used for copper at Rome, a different and more ancient system was acknowledged for the precious metal coinage, perhaps with an eye to wider international circulation, outside Roman territories.

As we have seen the Campanian stater/didrachm weights slightly lower, at c.7.5g or c. 7.65g (according to the two rival accounts of Kraay and Head). However, we have also seen that that is consistent with the charging of a small brassage charge being applied at the mint. If, as is postulated here, the Republican denarius was tariffed very significantly above bullion value for internal use, there would be no need to find any brassage so as to fix it to an alternative external international standard of 1/64th of a very ancient 500g pound.

We will meet with this intriguing 3.9g standard three times more in important European contexts, and it is the global totality of this evidence which is striking. Although not strong enough to validate a metrological theory of a continuously existing very ancient binary 500g weight system in Europe, the evidence seems strong enough to make the idea worth holding in mind. It is of course possible that any apparent relationship between these prominent early denarius and aureus weights is illusory, and that both derive independently from (say) some forgotten attempt to fix say gold/silver and silver/copper rates in the market place. But we have even less evidence supporting that thesis.

(64) *Imperial Silver Denarius (after Nero)*

The binary denarius, struck 8 to the uncia, mentioned above appeared under Nero. At c. 3.40g it went 96 to the pound/

libra. Perhaps by the time of Nero, Rome itself had a somewhat global reach and had no need for an alternative international standard. However, elementary calculation shows that Nero's denarius was a simple binary fraction, the 128th part, of the Attic coining mina. The significance of this reform is perhaps also best understood in the light of the Eastern expansion of Rome, into traditional 'Greek' spheres of influence. The denarius would retain this weight throughout the rest of the period of issue, it disappeared in the inflationary debasements of the 3rd century AD.

(60) *Imperial gold aureus*

Just as Nero seems to have regularised silver into an Attic system (128 to an Attic silver pound, thus an eighth ounce) thus too he seems to regularise the gold aureus at c. 7.3g, thus 60 to that same Attic ounce. Presumably some compromise with prevailing gold:silver exhange rates was part of that reform process.

Later Roman and Byzantine issues continue to respect the c. 327g pound. The silver siliqua of Valens at c. 2.27g went 144 to the pound. The c. 6.8g hexagram of Heraclius 610-41 went 48 to the pound. The solidus, initiated by Constantine the Great 306-37 went 72 to the pound of 327g, theoretically at c. 4.54g.

(74) *Gold Solidus c. 4.54g*

To recap, we now have commercial and monetary weight hand in hand for copper (only) under the Republic. After Nero, we find the silver denarius hand in hand with commerical weight. But the gold solidus only takes on that central role long after the copper and the silver systems have collapsed.

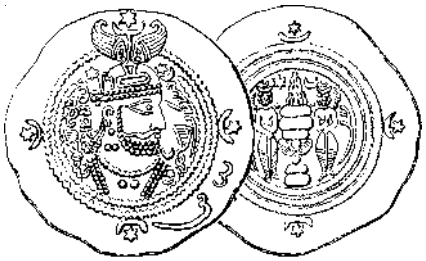
There is a strange and fascinating set of relationships recorded by Isidore of Seville concerning Roman standards, which warrant further attention. Isidore records that an ounce is equal to:3 (siliquae) x 2 (obols) x 3 (scripulus) x 8 (denarii), and since the siliqua or carat, the seed of the carob tree, is widely figured at 4 wheat grains (= 3 barley grains) and the Roman coining pound is 12 ounces, this gives us the 6,912 grains in the ounce that we expect. Isidore also confirms that the solidus comprises 24 carats (siliquae). But he then goes on to specify a different sort of 'Greek' pound which he calls a 'mina'. This is equal to 75 solidi, thus 1800 siliquae, thus on the customary account, 7,200 wheat grains. Theoretically it should weigh 75 x 4.54g = c. 340g. As Isidore points out, this is also 100 "drachms" or rather denarii, since the denarius weighed c. 3.4g. Since there are 72 solidi in the coining pound, this 'mina' is 75/72, or about 4%, heavier than the coining pound. It seems possible that it might represent the weight of gold bullion equal in value to a pound of coin. When we enquire into Roman commercial weight, we find numerous claims concerning local uncia weights that do indeed seem to conform to a heavier standard.[55] The truth of that matter seems still unclear. As we will see below, this whole matter will lead to a very odd situation indeed.

We saw above that the most important weight standard in Syria, Egypt and the Eastern Mediterranean in very early times conformed to a c. 470g mina. We saw ample evidence that that changed in two ways over time, essentially into a mina of c. 455g, divided in a binary fashion into what amounts to 16oz. This rather exactly matches the sort of ounces mentioned by Isidore, they are the ounces used much later, in medieval Rome and Florence, and many hold that they spread from there, first to British Imperial and then to US customary. We will have much more to say on all that later in the text of course. For now note that in essence, we have two possibilities. Either one standard (ultimately 16oz = c. 454g) developing over 4,000 years, or two co-incidentally near identical standards, one developing over about 2,000 years, another over 1,600 years - with a six hundred year gap in the middle? I have seemed to see two positions taken. One perhaps exaggerates the evidence for continuity (including by Petrie, Skinner and Connor). The other however, does not seem to me to take on board just how odd such a postulated 'mere co-incidence' looks.

Sasanid Coin weight

Roman weight standards were maintained in the shrinking territories of Byzantium down to its fall in the 15th century, but both Western Europe and Persia adopted new standards during the early medieval period, systems apparently directly or indirectly influenced by the metrological reforms of the Umayyad Caliph 'Abd al Malik. In order to set the scene for those crucially important reforms however we must now return to the development of metrology in Persia after Alexander.

As was mentioned above, Alexander's conquest of Persia swept away the Lydian 13.3 **:** 1 silver to gold ratio. He fixed gold silver ratios at 10 **:** 1. An obvious consequence of this act is that both gold and silver coin could now be conveniently pegged to the same standard. He also launched a new 'drachm' of circa 4.24g, the Attic origins of which was discussed above. In the longer term gold coinage disappeared from Persia almost completely. During the period 200 BC to 226 AD Parthian rulers mostly struck silver drachms often weighing 4 grams or less, but which never the less are generally assumed to be a degraded version of Alexander's 'Attic' drachm. The new Sasanid dynasty which came to power in 226 AD seems to have restored the standard of the Persian drachm more accurately to about Alexander's 4.24g standard. However, a couple of centuries later, under Peroz 459-84, the standard seems to have been deliberately revised downwards, to around 4.13g.[56] Efforts to standardise the drachm at this new weight are apparent for the rest of the Sasanid period, especially with regard to the huge issue of well made coins issued in the later part of the Khusru II's reign.



(111) *Late Style Khursu II Silver drachm*

We saw earlier that Darius chose to strike 60 gold darics to a mina at circa 8.33g, and also (separately) had chosen to make 120 silver sigloi from a mina. Combining these two

traditions leads us immediately to expect a full weight silver drachm of c. 4.17g, which is quite a good fit for the coins .

The Sasanids famously associated themselves with the restoration of ancient Persian religious and cultural values, and the coinage reform of Peroz is best understood in that context. It looks like a fairly rigorous attempt to replicate the aim of Darius, and to carefully strike coin close to full weight according to the best ancient standard. Actually, it is perhaps worth noting that 121 x 4.13g = 499.7g. In the light of what was said above concerning minting costs, brassage, then if we allow the mint master one coin in the mina to cover his costs, we get a very exact fit indeed. Thus the coin commonly called a late Sasanid drachm might better be called a Persian mithcal, or a Sumerian half shekel.

The First Islamic Weight System

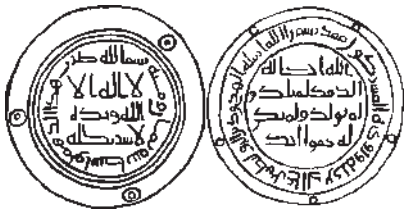
Our excursion into pre-coinage weight systems bears fruit when we consider the system that the Umayyads created. The canonical Islamic weight system of the later Umayyad and early Abbasid Caliphs is perhaps a hybrid of earlier Persian and Egyptian practices. Understanding its nature is the vital step, for anyone attempting to get to grips with the coin metrology of Medieval Europe.

In the early post-conquest period the Arabs issued versions of the coins of the previous Byzantine and Sasanid rulers. Around 698 AD Caliph ‘Abd al Malik reformed the types and metrology of the coinage, producing distinctive iconoclastic dirhems and dinars. Such coins survive in large numbers, and by examining them we discover that the weight of the issues at the main mints were very strictly maintained. There can be no doubt that the intended weight of the gold dinar, struck at Damascus, was very close to 4.24g. And the new silver dirhem, at least those specimens struck at the main mints of Wasit, Damascus and (a little later) Baghdad, were very close to 2.92g.[28] As usual we have no direct record of how these new standards were arrived at, but in this case, and indeed in most cases henceforward, we can make confident guesses.

(391) *Umayyad gold dinar*

Regarding the gold, although the Umayyad dinar of 4.24g replaced the functions of the Byzantine solidus, theoretically weighing 4.54g, the weight is different. If we now accept that metrological standards frequently have great life expectancies, we have no difficulty in finding an origin for this standard. 4.24g is a very well known weight in metrological history, it is the commonly seen version of Attic, under the Selucids et al. At a time when Arab rulers were anxious to rid themselves of imposed Roman customs, I see no difficulty with the idea that scholars at Damascus searched their histories for the ‘true’ or ‘original’ weight standard of the region, and discovered that a thousand years earlier, before the Roman occupation, this sub-Attic standard had been maintained. ThisHellenistic version of Attic weight could easily be determined by the early Arabs from surviving examples of the plentiful coinage.

The Arabs inherited their early empire from two separate regimes, the Byzantines in the West, who had founded their economy on gold and copper coins, and the Sasanids in the East, who had used a different metrological system and based their economy almost entirely on a silver coinage. The Arab reform of gold coin happened in 77 H (around 698 AD), but a year or two passed before the first reformed dirhems appeared in 79 H. Since these dirhems were central to a new and rather novel metrological system, we may imagine that that year or so was filled with debate over how to reform the silver standard.



(393) *Umayyad Reformed Dirhem*

The weight of the new silver dirhem, at c. 2.92 grams, seems a completely new and immensely influential departure.[57] To understand it, we will have to reprise all we have learned about earlier Egyptian and Persian metrological systems. And in order to corroborate this understanding, we will have to examine its apparently enormous influence upon the medieval systems of weight used widely throughout Medieval Europe. Moving through the matter methodically we will:

1) outline the proposed metrological system itself
2) indicate relationship to the earlier Egyptian beqa system
3) indicate a relationship to the earlier Persian system
4) list the evidence for the use of this system in early Islam
5) sketch the relationship to Medieval European systems

The system of metrology adopted by ‘Abd al Malik in 79 H. (c. 700 AD) for his silver coinage was abandoned by the Caliphate about 140 years later. It seems to be the one we understand as the traditional English Troy and Sterling weight systems, and since the nomenclature of the original system in Islam is rather alien to English readers, English equivalents will be used here.

The hypothesis presented here is not new, versions of it have been aired by 18th, 19th and 20th century scholars.[58] The version put forward by Skinner in 1967 was the most sophisticated up to that date, and forms the basis of this new, and I hope, final and conclusive defence of the thesis.

For the purposes of simplicity throughout the current chapter, all grains will be understood to be troy wheat-grains unless stated otherwise. This was a type of grain known and used in England up to the 12th century at least, with an absolute value of c. 0.0486g. We begin by outlining the troy system, as it survived in England into modern times.

Troy weight: A Troy pound contains 12 Troy ounces,
which each contain 20 Troy pennyweights,
which each contain 32 Troy wheat grains

Thus 12 ounce Troy pound is 7,680 wheat grains or c. 373g

Alongside we have

Sterling weight: A sterling pound contains 12 Tower ounces,
which each contain 20 Sterling pennyweights
which each contain 30 Troy wheat grains

A 12 ounce Tower pound is 7,200 wheat grains or c. 350 grams

Thus, by definition, a Sterling pound is exactly $^{15}/_{16}{}^{ths}$ of a Troy pound, and likewise, a Sterling penny is exactly $^{15}/_{16}{}^{ths}$ of a Troy penny. There are a number of little mathematical ‘tricks’ hidden in these figures.

Firstly, if we analyse the Troy pound in terms of sterling pennies, we find that there are 256 of them, an exact binary multiple. This makes it especially easy for a practical metrologist to break Troy pounds up into sterling pennies. A bar of silver need only be repeatedly cut in half.

Additionally, when explaining these figures quickly, in summary, it is quite easy to conflate the binary structure of the Troy penny (32 grains) with the binary structure of the troy pound (256 Sterling pennies). In doing this one skips the 'missing' sixteenth, or two grains, in each Sterling penny. A convenient oversight if this sixteenth constitutes a tax or imposition of some sort.

Further, mint accountants might treat a 256 sterling penny troy pound as 16 'ounces' each of 16 pennies, so that one 'ounce' may be held back in seigniorage, whilst 15 'ounces' are paid back to the silver consignee. The structure of the systems means that the consignee would hand over 240 (Troy) pennyweights, and gets back 240 (Tower) pennyweights. Once again any impost is camouflaged by the mathematics of the system.

All the above relies primarily upon the simple fact that

15 x 16 = 20 x 12

and upon ambiguities concerning the dual ounces and the dual pennyweights.

The structure of the Troy/Sterling system outlined above derives from English traditional measures. That proposed for 'Abd al Malik in 700 AD differs in just one very small detail. Rather than using a (Troy) penny of 32 grains, it uses a 'bullion dirhem' of 64 grains. Likewise Sterlings of 30 grains are replaced by 'coin dirhems' of 60 grains.

Thus it seems the Islamic bullion pound was:

12 ounces of 10 dirhems of 64 grain

the coin pound

12 ounces of 10 dirhems of 60 grains.

Troy's relationship to Ancient Egyptian Metrology

Modern troy weight seems related rather directly to the ancient Egyptian Beqa system, as proposed by Skinner, in two separate ways. Firstly, 16 Troy ounces equals 497.7g which is a good approximation to a mina of 40 beqa (c. 500g). Thus Troy and the Ancient Egyptian standard have a 'common ounce'. More surprisingly however, they turn out to have a common grain too, since 16oz Troy is 32 x 20 x 16 = 10,240 grains, and the Egyptian mina was 256 x 40 = 10,240 grains. In other words, the two pounds are all but identical. The main difference is the order in which the factors are customarily expressed, since 16 oz Troy is 2^6 x 10 x 2^4, whereas the beqa mina is 2^8 x 10 x 2^2. The only other difference is that in England Troy is normally quoted in the 12 oz version, the Egyptian 40 beqa mina equates to a 16 oz version of Troy.

Troy's relationship to Ancient Persian Metrology

Troy weight is less directly related to ancient Persian weight, but there are two important similarities. Firstly, of course, 16 ounces Troy at 497.7g is a good approximation to the Persian c. 500g mina. Indeed, if we figure the Late Sasanid drachm of Khusru II at 4.17g then 120 x 4.17 = 500g, which is a very good fit indeed. It seems possible that the standard for Troy weight was in fact taken from these late style drachms of Khusru II, preserved by Arab scientists and passed on by Jewish scientists into the early medieval European tradition. Secondly, the 12 ounce Troy bullion and coining pounds both divide up into 120 dirhems, in exactly the same way that the Persian mina apparently split into 120 sigloi under the Sasanids. Of course the weight is not the same, the new drachm or 'dirhem' being reduced by $^3/_4$ in the case the bullion standard, and $^3/_4$ x $^{15}/_{16}$ in the case of the coin standard. However, this perpetuation of Persian sexagesimal practice within Islam allows us to explain why there were, until very recently, 240 pennies in an English pound. It is in essence because, allowing for these reductions, the penny equates to half a dirhem, which was itself a reduced siglos, which is to say half a shekel. Thus the penny appears at root to be a species of quarter shekel. And there have been 60 shekels in a mina for 4,000 years. Unravelling the reductions in the weight of the Persian/Sasanid shekel, or mithcal, will help us unravel some of the mysteries of early Islamic metrology, and early Islamic financial history.

Troy and 'Abd al Malik's Dirhem: the Evidence

The case being defended is that English Troy weight was inherited in mysterious ways from the Medieval Islamic past. Here is a list of the pieces of evidence suggesting that Troy weight is the system of weight introduced in 700 by 'Abd al Malik in connection with his silver dirhem issue:

Evidence from the Coins

As mentioned above, Caliph 'Abd al Malik fixed the weight of his gold dinar, struck at Damascus around 698H, at c. 4.24g. The silver dirhem on the other hand weighed c. 2.92g. This fact was carefully determined by Skinner based upon examples of the coins themselves, and as far as the main mints of Damascus, Baghdad and Wasit go, for the first 120 years, there can be no doubt that he was very close. I have checked this matter myself, and also had the result independently verified by others. This finding is surprising at first sight, since a host of scholars have published the weight of the dirhem incorrectly as 2.97g. The reason for this wide spread error will emerge below.

Having established that the first dirhem weighed very close to 2.92g, we immediately see that this rather exactly equals two sterling pennies, with a coin dirhem in line with the Sterling or Troy coining pound. 120 x 2.92 = 350.4g. In fact, on the basis of an exact weight standard got from Umayyad dirhems one is tempted to suggest that the Islamic equivalent of a Sterling pound should be adjusted to c. 350.5g and the version of the 16oz Troy pound, called in Islam the ratl kabir (great pound) to c. 498g.

A second point to note is that if we take a theoretical weight for the Sasanid drachm of c. 4.17g, and multiply it by $^7/_{10}$, then we get 2.92g. Thus seven-tenths of a Sasanid drachm is a good approximation of the weight of an Islamic dirhem. There is no surprise in this. We have got our drachm weight by taking 500g/120, and our dirhem weight by taking: 500g x $^{12}/_{16}$ x $^{15}/_{16}$ x $^1/_{120}$. If so the Sasanid drachm multiplied by $^{12}/_{16}$ x $^{15}/_{16}$ is the dirhem by weight, and $^{12}/_{16}$ x $^{15}/_{16}$ is 0.703; a good approximation of seven-tenths.

Evidence from Early Egyptian Glass Weights

The most recent survey of the Egyptian early Islamic glass weights is by Morton.[59] Amongst the glass weights are a significant number inscribed 'dirhem of two-thirds' which have caused much confusion in modern literature.[60] These were standardised at about 2.82g. This is exactly $^2/_3{}^{rds}$ of the weight

of the gold dinar, but it is also just a little, 0.1g, below the official issue weight of the silver dirhem, c. 2.92g. It seems likely these weights were created for the purpose of checking the dirhems in circulation. Clipping of coin was a very common abuse in the early Islamic period, and these weights seem to be designed to assist in rejecting coins which had lost more than about 3.5% of their metal value. If this suggestion is correct c. 2.82g defines the lowest legal weight of a dirhem, which differs from both its expected (theoretical) and actual issue weight. In addition to this rather confusing "dirhem of two-thirds", Morton identified four other weight standards:

i) The "Umayyad" standard: These weights were officially issued from sometime before 90H (709 AD) to about 165H (781 AD) by Umayyad officials in Egypt. They represent a ratl or pound weighed about 444 grams, which was divided into 12 ounces. Firstly, it should be noticed that this is a reasonable approximation for a mina of 5-deben, which we saw well entrenched in Egypt in Ptolemaic times, and indeed much earlier still. Later medieval and early modern sources regularly refer to a commercial pound used in Islamic Egypt of 144 dirhems. This pound was still in use when Lane wrote in 1860.[61] At that time it weighed 444.4g. Lane fixed this dirhem as 64 wheat grains (or 48 barley grains). That yields a wheat grain of 0.0482g which differs by only 0.8% from the English Troy wheat grain. Thus the simplest assumption would be that the very ancient mina of 5-deben, of c. 454g, was still in use in Egypt in early Islamic times. Further that it was calculated as a pound of 12 ounces, each of 12 dirhems, where the dirhems were for all practical purposes, troy dirhems, of 64 troy wheat grains, or two Troy penny weights.

If I again follow Isidore, then the 5-deben standard was adapted to the Roman weight system by fixing it at 100 solidi, whilst it was adopted into the Islamic system by fixing it at 144 ("bullion" or Troy) dirhems. The discrepancy between the two versions is about 10 grams, 444g vs 454g, thus a little over 2%. If our reconstruction of prehistoric events outlined above is correct, starting at the original Babylonian c. 500g mina, the Roman '5-deben' theoretically represents:

$$^{7}/_{8} \times {}^{12}/_{16} \times {}^{1}/_{72} \times 100 = {}^{700}/_{768} = 91.1\%$$

Whereas, starting at the original Babylonian c. 500g mina, the Islamic '5-deben' theoretically represents the much simpler:

$$^{64}/_{10,240} \times 144 = 9/10 = 90\%$$

So we have a little over 1% of a theoretical gap, and in practice a further 1% gap has appeared over many centuries of independent developement. Since the actual weight of an early Byzantine solidus seems to be about 4.44g, there was little or no difference in practice.

ii) The Ratl Kabir ('Great pound') was the official standard in Egypt for at least 10 years after about 165H (781 AD). No ounce weights survive; we must judge the system from the ratls, and half and quarter ratls. These point towards a pound standard of 490g to 500g. This of course equates very well with our very ancient fundamental pound weight, maintained in Persia since before 2,150 BC, and in line with 40 Egyptian beqa since earlier times still. Perhaps its adoption by the Arabs in Egypt represented an attempt to unify weight standards across the whole Caliphate, based upon the very ancient standards of Persia, where the caliphate had by then established its capital (Baghdad). We will interpret it here as directly equivalent to 16 ounces Troy (modern estimate 497.6g).

iii) The 'Syrian' Ratl. This pound is known from a small number of specimens, at least some of which date to the middle of the second Islamic century (around 760 AD or so). Most specimens point towards a weight of 345 to 350g. This is a very good fit for the Islamic coining pound (ie Sterling or Tower pound), of 120 coin-dirhems (240 Sterling pennies)

Thus when we examine the glass weights of the Umayyad and Abbasid period we find evidence for a commercial pound based upon a bullion dirhem of two troy pennyweights which remained in use until very recent times, plus further weights consistent with the prominence of both troy and tower weight systems in early Islam. A further system, iv), is seen in the glass weights, but it apparently came into use in the 3rd century AH. It points to an abandonment of the system described here, so we will postpone discussion of it until the appropriate place in the text.

The Evidence from English Texts

If weight standards were carefully maintained over long periods, and there is a correspondence between Islamic and English troy weight, this correspondence ought to be preserved and reported in early literature, and in fact it is. As mentioned above, in 1860 Lane noted that in Egypt:

a kambah (wheat grain) was $^{1}/_{64}{}^{th}$ of a dirhem
a habbeh (barley grain) was $^{1}/_{48}{}^{th}$ of a dirhem
the habbeh = $^{127}/_{128}$ of an English (troy barley) grain
the dirhem = $47^{5}/_{8}$ to 48 t. b. grains = 1.984 to 2 troy pennies

This was on the basis of an Egyptian commission which had reported in 1854 and which standardized the 'dirhem al-kayl at 3.0898g. However, much earlier than this we find Arbuthnot,[29] writing in 1727, quoting the reports made by John Greaves who travelled in Egypt around 1640 '(*Egyptian*) *grains are almost the same as ours, 48 of our grains exceeding 48 of theirs, or their dirhem, only by 0.18 parts of a grain. Consequently our pennyweight exceeds their half dirhem, by 0.09 (not a tenth of a grain.) And so our Troy ounce = 20 pennyweights, is not two whole grains more than 10 of their dirhems = 480 of their grains, and therefore may very well pass for one of those various ounces of Aegypt, and which consisted of 10 dirhems*' Greaves goes on to remark that the Cairo Ratl of 144 dirhems makes 6912 Egyptian grains, and 6886 troy grains - thus *'differs so little from our Averdupois pound'*. Thus we find an awareness of the correspondences of English Troy (and Avoirdupois) and Islamic Egyptian weight systems as far back as English records can take us.

The Evidence from Islamic Texts

The lynchpin of this whole argument however is a short passage found in the early 15th century writings of al-Maqrizi, only recently translated[62] (1994). Concerning the reforms of 'Abd al Malik, al-Maqrizi wrote '*he set the weight of the dinar at 22 Syrian qirats minus one habbah, and that of the dirhem at exactly 15 qirats, one qirat being equal to 4 habbahs*'. This gives a dinar of c. 87 habbah, and a dirhem of 60 habbah. We know the dinar was c. 4.24g, so this gives a habbah of 0.0487g. Thus 60 such habbah weigh c. 2.92g. It is surely clear that al-Maqrizi is describing a dirhem that weighs almost exactly two Sterling pennies, which is part of a system which makes a coin dirhem equal to 60 habbah, where the habbah corresponded almost exactly with our Troy wheat grain. Given the fact that the dinars and dirhems of 'Abd al Malik so exactly fit al-Maqrizi's specification it is hard to doubt that he correctly transmitted exactly what 'Abd al Malik did.

Thus it seems unreasonable to deny that 'Abd al Malik oversaw the synchronisation of his coinage with what we now call the Troy system. This was based upon a c. 500g mina, or Ratl Kabir, treated as a 16 oz pound, and a corresponding 12 oz pound deriving from it, of c. 373g. Each of the ounces was divided into 10 (bullion) dirhems, weighing 64 grains.[63] A second pound, of c. 350g, consisted of 12 ounces of 10 (coin) dirhems each of 60 grains, or 2.92g respectively.

We can only guess why this happened. The most likely reason is that the Arabs imposed a seigniorage of $^{1}/_{16}^{th}$ on the new silver coinage. In which case a man who delivered a ratl of c. 375g of silver (120 bullion dirhems) to the mint at Wasit got 120 coin dirhems weighing c. 350 grams in return.

If this assumption is correct then we may imagine that elements amongst the Persian population were not best pleased with this new departure. The hypothesis mentioned above was that Late Sasanid practice resurrected the tradition founded by Darius, that coin circulated at full weight. So a new 'short weight' coinage, imposed against hallowed tradition by an Arabian foreign invader might not have found favour in early Medieval Persia. It is this insight, or rather a matter of its understandable official suppression, that I believe leads us to an explanation of the mystery and confusion which have surrounded the matter ever since. We can only hypothesise about what 'Abd al Malik's intentions were, so we can only hypothesise about what consequences it brought about. But the following facts at our disposal seem to point to the following conclusion.

Firstly, hoards of Persian silver coin recovered from one or even two centuries after 'Abd al Malik's reform still contain a large proportion of old Sasanid dirhems, by now in a worn, clipped and thoroughly unsatisfactory condition. Clearly there was some impediment to getting this obsolete and substandard coin back to the mint where it could be regularised under official dies. The most likely explanation would seem to be that a black market appeared where individuals sought to avoid paying a seigniorage tax by settling their accounts in bullion, by weight of silver, rather than by count, in official dirhems.

Secondly, clipping of coin became rife, not only of obsolete Sasanid dirhems, but also of new Umayyad and Abbasid dirhems, reducing them from the c. 2.92g standard set at the mint. It should be born in mind that clipping is a kind of 'popular crime'. The passing of wholly counterfeit coin depends upon the outwitting of the victim by the culprit, and tends to be an occasional event. In contrast, the regular passing of clipped coin usually depends upon the recipient being to some degree complicit with the passer of the coin, and indeed the clipper himself. The signs of significant clipping on a coin cannot easily be overlooked by an observant party to a transaction. Thus signs of general clipping of the coinage in the circulation lead one to suspect that some degree of popular resistance to the government coinage, or its taxation policies, was under way.[64] The issue of the glass 'dirhem of two thirds' weights in Egypt seem very likely to be associated with this clipping affair. They were apparently standardised at $^{2}/_{3}$ of a dinar weight, thus $^{2}/_{3}$ x 4.24 = c. 2.83g, ie about 3% below the actual weight of the dirhem. It seems likely that regulations of some kind allowed payees to reject coins that fell short of a c. 2.83g standard. (Similar regulations have been passed into force elsewhere in medieval times, allowing 10% underweight coin to circulate in Medieval Venice, and perhaps even coin short by 12.5% to circulate in Medieval England).

Third, and most important of all, during the first half of the 9th century AD (3rd H), Islamic authorities more or less stopped producing fixed weight coinage.[65] Mints continued to put out round discs of silver and gold that looked like coins, were called 'coins', and were stamped to show they were of a of a guaranteed metal quality. However, they were no longer struck to any fixed weight standard, and are best viewed, not as coins, but rather as a species of circulating bullion, or small 'ingots'.[66] This is an extraordinary event, more or less unique in world financial history. I believe it is best explained by assuming that the Arab Caliphate, after about 140 years of perseverance, finally threw in the towel and stopped attempting to raise a $^{1}/_{16}^{th}$ seigniorage on its money. The circulation of silver bullion, which in an unorthodox manner re-established something like the ancient Persian tradition of a 'full weight' coinage, seems to have dominated Islamic practice for about four centuries thenceforward, down to the time of Saladin, and even later in Egypt.

Thus it is argued that metrological troubles lay at the very heart of early Arab political problems. Our near complete lack of information on the matter from official sources tends, in my view, to reinforce the contention that this was an extraordinarily sensitive issue. This reform, coming unannounced sometime in the later 9th century AD seems to have given birth to a new definition of the dirhem, a definition in terms of the traditional dinar weight of Damascus. Known as the dirhem of 'seven-tenths', this weight represented $^{7}/_{10}^{ths}$ of the weight of the canonical dinar. A dirhem of $^{7}/_{10}$ x 4.24g = 2.97g. This dirhem is subsequently very widely mentioned in medieval sources.

Polyhedral Weight

Large numbers of uninscribed polyhedral bronze weights are found throughout almost all the Islamic territories. They are regulated to multiples of the 2.97g value, most commonly at 10 dirhems thus c. 29.7g.[67] We also get glass weights from Egypt that fix upon the same standards, some of which are inscribed, which seem to date to the mid 3rd century AH/later 9th century AD.

Since the matter is not mentioned at all in contemporary texts we have to try guess why the metrology was reformed in this way in the 9th century. It seems that Islamic authorities abandoned using two separate rates for the dirhem, a coin rate of 2.92g, and a bullion rate of c. 3.11g. Instead a new single rate was fixed, at c. 2.97g, which 'split the difference'. No doubt this presentation oversimplifies the lost details of the reform, but it seems surely to capture its mathematical bones. The very large number of apparently unofficial but nicely made polyhedral brass weights must derive from this later period, and reflect the fact that anyone engaged in trade would need their own set of weights, in order to settle everyday transactions in a society where money was weighed rather than counted.

The final class of glass weights mentioned by Morton also seems to belong to this later period. Following Balog he calls it an 'Abbasid ratl'. It seems to conform to a ratl standard of about 380g. Early Islamic sources discuss ratls of 128 dirhems, $128^{4}/_{7}$ dirhems and 130 dirhems.[68] We can make

good sense of these texts according to the dirhem definitions outlined above. Firstly, since it seems clear that early Islam was using what we are calling 'Troy' weight, it follows that:

12 troy oz = 120 bullion dirhems = 128 coin dirhems = 374g

As with English Troy sets, collections do not seem to contain weights specifically dedicated to this standard, but half and quarter ratl kabir weights were produced, so the weight could be quickly made up simply by using one of each. However, once the dirhem was redefined at 2.97g, it seems that a new 128 dirhem pound was brought into being, correspondingly raised to the new standard, 128 x 2.97g = 380g. This is the new standard exemplified by the weights which Morton dubs 'the Abbasid' ratl standard. Once we recognise this, it is an easy step to explain medieval references to a 130 dirhem pound. 130 x 2.92 = 379.6g, thus 130 of the old, weight regulated dirhems approximate very well to the new 380g pound. The third version of this ratl in texts, that of $128^{4}/_{7}$ dirhems, is almost as easily explained, since it equates to a further convenient definition of the 'same' weight, in terms of the dinar, $128 + {}^{4}/_{7} = {}^{896}/_{7} + {}^{4}/_{7} = {}^{900}/_{7}$ dirhems and ${}^{900}/_{7} \times {}^{7}/_{10} = 90$ dinars. Ninety dinars actually weight 90 x 4.24g = 381.6g. Surely this indicates that practical minded mathematicians of the 9th century did not quibble about the odd gram or two when seeking a day to day definition of the pound in terms of the dinar? (1.6g in a pound of 380g would be undetectable on most scales existing in the 9th century, although of course the numerate portion of the population would be just as mathematically aware of the difference as we are today.)

An important propaganda point in favour of selecting a dirhem of ${}^{7}/_{10}$ of the mithcal (an alternative name for the weight of the dinar of Damascus) was that tradition could be cited in its approval. As mentioned above, the Sasanid standard drachm was called a 'mithcal' by Arabs in Persia. Further, according the relationships inherent in the Troy system, the c. 2.92 coin dirhem was by definition 0.703 of the Sasanid mithcal, (if by convention, as assumed here, they share a common c. 500g mina, or 'ratl kabir'). By conflating the Damascus circa 4.24g dinar mithcal, with the Sasanid c. 4.15g mithcal, the change over from a c. 2.92g dirhem to a 2.97g dirhem could be easily be hidden from any who lacked a sophisticated insight into the different weight systems.[69] The new weight system would be lent a long established but spurious pedigree.

In summary, the new 2.97g dirhem of circa 830 AD was ${}^{7}/_{10}$ of the Damascus mithcal (of 4.24g), and the old 2.92g dirhem of 698 AD was ${}^{7}/_{10}$ of the Persian mithcal (of c. 4.15g). Somewhere around 860 AD (even the exact date of the change is unclear, during the political and economic hiatus of the early 9th century) few people likely owned a scale that could distinguish these weights, and few of the Damascus dinars in circulation had anyhow escaped the clippers attention. Thus for the bulk of the population the move from a dirhem of 2.92g to one of 2.97g probably went unremarked. However, it had important consequences for metrology, or at least, our understanding of it. The c. 2.92g dirhem is a logical extension of the largely binary pound/grain system in use in Egypt (and further afield) for thousands of years. The simple and rather elegant mathematical logic of the Troy system was lost, or at least obscured, with the change to an arbitrary approximation of the dirhem as ${}^{7}/_{10}$ of the dinar of 4.24g. This is especially so if, as has been suggested above, the dinar of 4.24g itself derives from a rather arbitrary weight standard ('reduced attic') created by Alexander's successors.

The above account departs from what we read in most modern literature. Modern historians for the most part have incorrectly taken the c. 2.97g value for the dirhem as representing the reform of 'Abd al Malik himself. Thus they have for the most part failed to see that the English sterling penny of c. 1.46g is very probablythe half of the true original Arab dirhem of c. 2.92g. Thereby the simple story of Euro-Persian metrology has been garbled, and then mislaid. Genuine understanding has been kept alive only by more practical minded scientists, like Greaves and Skinner, who saw through to the underlying patterns of the weights and their mathematical relationships.

This completes the account of major developments in early Islamic metrology, developments which became highly significant in the evolution of subsequent Medieval European standards. It will be convenient now to turn to those European matters. In due course we will return to survey later metrological developments in Medieval Islamic Persia, India and Central Asia.

Medieval European Weight Systems

Dark Age metrology

When Islam threw off Roman rule, it appears that it made a conscious attempt to return to more ancient, and more rational standards; it defined a new bullion dirhem as a simple binary multiple of a fairly realistic standardisation of the wheat grain, and it also reconnected its metrological calculations with the very ancient circa 500g 'ratl kabir' (great pound). There are hints that something similar may have happened in post-Roman 'barbarian' Europe. The evidence is not so clear cut, so any conclusions should be viewed as tentative hypotheses. However, what follows does appears to be the simplest storyline consistent with the available facts. The dominant coin weight of the late Roman Empire was the gold solidus struck at 72 per pound b thus weighing 24 carats, that is to say "96 (Roman) wheat grains". As we saw above, a Roman wheat grain would weigh ${}^{35}/_{36}$ of the Troy wheat grain, so for most practical purposes they can be considered the same.

The first noticeable change we find after the Romans quit NW Europe is that the more westerly Byzantine mints start to strike a triens denomination in gold. This represented ${}^{1}/_{3}$ of the solidus, so would contain 32 grains. This also might represent a preference amongst the new rulers of Europe for a simple, traditional, binary coin weight.

(157) *Anglo-Saxon Triens or Thrymsa*

The next change that we see is a reform to the standard of the Merovingian gold coin. Around 570 a 'new version' of the solidus appears, weighing around 3.9g. Theoretically the Roman solidus should perhaps weigh 4.54g, (but in practice c. 4.4g was the standard generally seen in actual coins). Most authorities treat the reform to 3.9g as a matter of 'slippage', new coin being struck to the weight of the worn and clipped short weight old coin found in circulation. Fiscal necessities might easily drive a state in this direction, and I am in no position to rule that such a suggestion is wrong. However, there is an alternative possibility, which I shall pursue here. 3.9g is the inevitable outcome of splitting the 500g pound in a binary fashion. The sixteenth part of that pound is a troy ounce of circa 31g, and the eighth part of that ounce is 3.9g.

We have already seen that use of a 500g standard, split in a binary way, was very likely in use in the Aegean by around 1,800 BC, and that much later, a c. 3.9 gram standard for the denarius existed in Republican Rome, even though it was alien to the Roman coining system that it is widely assumed that the state officially applied. So it is at least possible that the Merovingian reform respected such a simple archaic system, a system which was perhaps remembered in Mediterranean trade, or amongst Rome's early neighbours, or in Europe beyond the frontiers of the Roman empire. This latter suggestion, of an archaic 3.9g (60 Troy barley grain) Merovingian solidus, which would yield a c. 1.3g triens, or primitive Germanic 20 troy barley-grain penny, is close to that championed for many years by Grierson.[70]

A significant number of balances and associated metal objects survive in English Anglo-Saxon graves from c. 600 AD. Many nineteenth and early twentieth century researchers saw in their irregular physical standards early versions of the English Troy penny of c. 1.56g.[71] If this is correct it seems to suggest that the primitive Troy type system that apparently spread into Europe in the Bronze Age was, or became, denominated bottom up in wheat grains, and also, remained in place beyond the Roman frontier for two millennia. Right down to the Dark Age migrations. A romantic, or perhaps rather, a beguiling notion. It seems to me a plausible suggestion, but as yet one with inadequate corroboration.

In 1990 an archaeologist, Scull,72 re-examined seven groups of items, associated with balances from early Anglo-Saxon graves. The items did not include any purpose made sets of weights, and showed little metrological consistency. Applying the controversial sophisticated statistical 'Kendal' formula he derived two standards. One was 1.30g to 1.33g. Scull pointed out that that might be a third or 'tremis' to a contemporary Merovingian gold issue of circa 3.9g. It would of course also be Grierson's 'Germanic 20-grain penny'. Early Anglo-Saxon sceattas tend to weigh up to 1.2g, and thus somewhat themselves point to a theoretical circa 1.3g 'penny' . The second posited standard was to circa 1.51g to 1.58g, which matches either a Roman tremis, or 32 (physical) wheat grains, ie a Troy penny. We have however nothing to corroborate such a proposed higher weight 32 grain troy-type "penny"at that date. Perhaps an alternative approach, surveying only purpose made weights, regardless of their historical find context, might one day lead to more consistent and reliable results?

Scull's findings point us towards two associated possibilities. First that the apothecaries's drachm, the binary $^{1}/_{128}^{th}$ part of the 16oz troy c. 500g pound, might have been continuously preserved from prehistoric times in North West Europe, beyond the frontiers of the Roman empire. Second, that the Merovingian adoption of the apothecaries's drachm as its gold standard was not a mere matter of slippage. The groups of weights Scull studied preserved the two separate weight systems side by side, not as one melding into the other. On this analysis they appear to be: firstly, a 'heavy' or 'bottom up' binary 'penny' - the Troy penny got from taking 32 wheat grains; secondly a 'light' or 'top down' quasi-binary penny, got by taking ($^{1}/_{128}$ x $^{1}/_{3}$) of the c. 500g troy pound.

Although this dual system, if correctly identified, is developed by a mathematically different method than that implemented by 'Abd al Malik, it could be used in a somewhat similar way. Perhaps as a pair of coin and bullion weight standards, or as buying and selling weights for bullion (which, after all, is a somewhat similar notion). At $^{1}/_{6}^{th}$ the 'seigniorage' or profit taken in switching between these standards is much larger than the $^{1}/_{16}^{th}$ taken at Baghdad, but this too would not be surprising in a Dark Age context.

An analysis by Blackburn of weights found at Torksey, a Viking camp set up in Lincolnshire in 872, seems to reinforce Scull's conclusion. These weights apparently represent two sorts of 'halfpennies', of roughly 0.65g and 0.8g.[73] As we will see below, this finding does not quite match the standards maintained by Viking weights in Scandinavia, but it fits well with Scull's findings concerning the two standards found in Anglo-Saxon weight sets, of near three centuries earlier. This seems to offer further evidence that the Merovingian change in weight standards was not mere 'slippage', but did genuinely involve a change to another, parallel and well established, weight system.

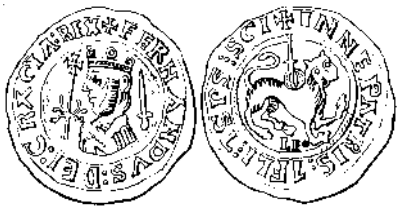
It is noteworthy that in practical commercial activities it is often much quicker to cut a sample of any commodity into two equal pieces, rather than setting about accurately weighing out pieces or potions separately. Thus a binary 3.9g standards may represent a formalisation of a rough and ready practice of making up small packets of stuff, such as medicinal powders, which were held in bulk in 500g units.

Moslem Spain

Moslem armies invaded and occupied Spain soon after 710. Initially the new territory seems to have been integrated into the universal coinage system of the Umayyads, striking silver dirhems that much resemble those of the east, and seem to weigh the same, canonical, c. 2.92 grams. However, Spain fell out of the political orbit of Eastern Caliphate very quickly. After the separation, the number of dirhems issued increased, but their fineness fell, and crucially for this study, their weight changed too. Thus if we look at the dirhems of al-Hakam, 796-822, we find they seem to weigh on average about 2.65 grams.[74] The weights of the coins are in general too variable for us to say with much confidence what exactly the target was. However, whatever the intended theoretical weight was, it was surely less than the canonical c. 2.92 grams.

In this connection a well preserved medieval weight from Islamic Spain, inscribed 'seven mithcals' and weighing 27.67 grams[75] represents what appears to be crucial evidence. Two things immediately spring to mind about this weight. First, if the piece is at all competently made, these mithcals cannot be canonical mithcals of c. 4.24 grams, since 7 x 4.24 = 29.68 grams. Second, all other things being equal, seven is a rather peculiar number of mithcals to fix on to make a specific weigh. There are perhaps a number of ways of solving these two little puzzles, but the most appealing is surely this: according to the most basic symmetry of later Islamic metrology, seven mithcals equal 10 dirhems, which in turn equal an ounce, or 'wuqiyya'. Further to that, 27.67 grams is a rather good approximation of an ounce; but not an Islamic ounce, a Roman ounce. At $^{1}/_{12}^{th}$ of 327grams this should be 27.25 grams. Taking the rather vague indication of the 9th century dirhems alongside the more precise indication of this weight we can hypothesize as follows: after a failed attempt to impose a completely Islamic metrological system upon the distant province of Spain, a compromise arose. The Islamic structure, of 10 dirhems to the ounce, and twelve ounces to the pound, was adopted, but newly calibrated to the old pound and ounce of Roman tradition. Thus the 7 mithcal weight equates to 10 dirhems, or an ounce, but to a Roman, not an Islamic ounce.

The c. 2.65g dirhems become tenths of a Roman ounce, just a little lighter than the expected c. 2.72g that a "Roman standard dirhem" should weigh.



(240) *Spanish Maravedi*

Three other well defined and important coining weight standards used in medieval Islamic Spain are: the maravedi, the dobla and the c. 1.54 gram 'dirhem'. We will attempt to account for these in turn, taking first the gold c. 3.88 gram morabetino, or maravedi. Islamic gold dinars in early Islamic Spain seem for the most part to weigh a little over 4 grams, a weight which seems to arise by slippage from the canonical standard of 4.24g set in Damascus. A carefully maintained c. 3.9g standard only appears late in the day in the Islamic states, under Muhammad ibn Sa´d, 1147-1171, at Murcia. However, it was then enthusiastically taken up at Toledo by the Christian ruler Alfonso VIII, 1158-1214. One logical reason for the emergence of this weight could be that it represents exactly a 'Roman mithcal', since if the traditional 10:7 ratio is applied to a 'Roman' dirhem then we get 2.73g x $^{10}/_{7}$ = 3.9 grams. However, if we accept this logic, we are then left wondering why this weight seems to be more popular with Christian than Moslem rulers. Perhaps the tendency to estimate the Roman ounce and pound high in early Islamic Spain, seen in the 7 mithcal weight and elsewhere, was to create a kind of 'roman mithcal' which replicated the rough standard actually seem in most circulated (and slightly clipped) gold dinars of the early caliphs, which were in practice a little over 4 grams. Gold 'morabetinos' struck by subsequent Christian rulers are described as struck 60 to the Tower mark (ie 350g x $^{8}/_{12}$ x $^{1}/_{60}$ = 3.88g) in English texts. As such it is of course is another appearance of our old friend, the apothecaries' drachm. Given the influence of Ibn Sena (Avicenna) upon medieval medical practice in Europe, it seems possible that it was through the influence of his teaching that this 'drachm' was popularised within later European pharmaceutical practice.

(408) *Almohad dirhem*

The very common square silver 'dirhem' of the Almohades was widely used in Islamic Spain and North Africa, struck from around 1160 to 1300, and probably later still. It seems to be intended to weigh 1.54g to 1.56g, a very good approximation of the Troy penny, (of 32 wheat grains, i.e. c. 1.56g) or half a 'troy' or 'bullion' dirhem. We showed above that the Troy or bullion dirhem of around 3.12g was very probably in use under the Umayyads in Egypt in the 8th century AD, and that it was still in use there from the 17th through to the 20th centuries. Thus it would seem to have a continuous existence in Egypt, and so it is no great surprise to find this very influential silver coin, weighing exactly a Troy pennyweight, being widely used further along the coast of North Africa.

(241) *Spanish 'dobla'*

Finally, the Almohades struck gold to the so called 'dobla' standard, c. 4.6g, from around 1130. I know no reason to believe that this had anything directly to do with the 4.62g mithcal standard that arose later and far away in the Timurid East (see below). Nor does not seem have any other precedent, in Islam or elsewhere. Thus its appearance is a bit of a mystery. It has been suggested that it represents exactly $^{1}/_{100}{}^{th}$ of the Spanish pound used for international trade, and by most Spanish colonies. This pound, of 460 grams, is widely thought of as a 'Cologne' pound. But deriving this 4.6g standard from $^{1}/_{100}{}^{th}$ of Cologne weight gives us a small problem, since the Cologne pound, as we shall see, is an extension of the Troy/ Tower system, being 15 troy ounces, thus c. 467g. A seven gram discrepancy is small, but greater than one would expect.

Alternatively, it has also been suggested that the coin was an attempt to restore a mithcal of 24 carats. Traditional Islamic texts state that the dinar should weigh 24 carats, an opinion which is sometimes attributed to the Prophet himself. These traditional statements presumably relate to the pre-existing Roman/Byzantine 24 carat/96 grain standard, which theoretically equalled circa 4.54g.

It seems such ideas were in circulation within Moslem Spain. Ibn Hazm (994-1064) was mocked by Ibn Khaldun for holding that the dinar should weight 84 grains.[76] As we shall see shortly, Charlemagne had apparently already created his new "new Roman" grain of c. 0.0532g by 794. 84 of those grains is quite a good fit for real physical solidi of 24 ancient Roman carats. That is to say, the weight of the 'dinar', or Roman solidus, that was actually in circulation in the lifetime of the Prophet Muhammed. Once the idea of a high weight 24 carat dinar became popular a further development seems quite plausible. The Almohades perhaps sought to boost revenue by building on the mathematics of this argument - but using not Roman nor Carolingian but the heavier Troy/Kayl carats of 'Abd al Malik. Thus yielding a 24 carat dobla theoretically of 4.66g. In practice c. 4.60g seems to me most likely to derive from this religiously orthodoxy argument. But it is not impossible that both a religious justified 24 carat dinar, and an internationally convenient concordance with the Cologne pound, both played a part.

The Carolingian Empire

It seems probable that the tendency towards broader thinner flans that appeared in France with the coinage of Pepin derives from Arab and ultimately Sasanid traditions, rather than anything from the European Roman past. A further change, in metrology, associated with Charlemagne's recoinage of around 794 seems to make the penny even more of a hybrid of Eastern and Western traditions. It should be noted that this change coincides with what apparently amounts to an adoption of the Easten tradition in England (according to many prominent commentators over several centuries). Both changes follow a trade rift between England and the continent (a sort of hard Brexit) at a time when the Anglo-Saxon mathematician Alcuin of York was attempting to advise both parties.

(209) *Carolingian penny*

During the 1960's three important studies of Charlemagne's weight standards appeared in rapid succession, by Grierson (1965), Miskimin (1967) and Morrison (1967).[77] The paper by Morrison seems to have attracted most subsequent attention, and that is unfortunate, since we are now in a position to say that in his somewhat overlooked piece, Grierson most likely solved the problem of Charlemagne's metrology.

Grierson combined four facts to reach his conclusion. Firstly he considered the Paris wheat grain, known to be fixed throughout the later medieval and early modern period at c. 0.0532g. This is mathematically fundamental to French metrology. Calculating upwards in a purely binary fashion it yields, at 2^{13}, a pound of 16 ounces weighing c. 437g. Secondly, relying upon French traditions concerning 15 and 16 ounce pounds, and on the analogous structure of the English Troy and Tower pounds, he then postulated a secondary Carolingian 15oz pound to the same ounce standard, a pound of c. 409g.[78] Independent of this postulate, we know that Charlemagne struck 240 pennies to his pound, and that his surviving pennies weigh circa 1.7g. This too yields a coining pound of circa 409g. Thus it seemed probable to Grierson that Charlemagne created two pounds, one of 16oz for goods in general, and perhaps bullion in particular, and a second one of 15oz for coining purposes.

Relying upon our earlier analysis of 'Abd al Malik's reform of the dirhem, we can now reinforce Grierson's analysis of Charlemagne's reform of the penny, coming just a century later, and give a better account of how it probably came about. Firstly, the mathematics applied by Charlemagne, involving a 16 to 15 ratio of bullion to coin, seems to derive from Arab practices accounted above. Charlemagne ruled whilst coin metrology at Baghdad still directly reflected 'Abd al Malik's standard, and he was in direct contact via emissaries with the court of Harun ar-Rashid at Baghdad. However, the physical ounces that Charlemagne based his standard upon were not Islamic but Roman ounces, since 409g is 15 Roman ounces and 437g is 16 Roman ounces. Indeed 437g is the very ancient Attic mina. What Charlemagne did was to apply a fully binary version of Arab mathematical/fiscal policy, creating a 15 ounce pound of 240 pennies, but fixing his ounce at the Roman standard ounce. He did this in a thoroughly scientific fashion, creating an unprecedented theoretical grain of 0.0532g within a new, perfectly binary system. Nor should we overlook the charming fact that, in theory and in practice, the new circa 1.7 gram penny it generates is precisely one half of the standard Imperial Roman denarius of circa 3.4 gram instituted by Nero ($^{1}/_{96}^{th}$ of the Roman 12oz pound).

Charlemagne and Harun ar-Rashid were political allies, and there was a considerable exchange of gifts between their courts. An old French tradition relates that amongst Harun's gifts was a set of Arab weights, upon which Charlemagne based his standard. A great deal of effort has gone into conjuring up a very ancient Oriental weight standard of c. 409 grams to justify this tradition. As mentioned above, Head[40] postulated unsubstantiated manipulations of the ancient standards of Lydia (Croesus) in order to justify a 409g standard. Much later, Miles[79] claimed to find a c. 409g standard amongst the glass weights of Egypt. Looking more carefully at a larger number of weights, Morton revised this estimate very substantially, down to c. 380g. Thus both Head and Miles seem to have been indulging in a bit of metrological wishful thinking. What Charlemagne got from the Arabs was not an absolute standard, but a metrological philosophy. His coin weight, like his coin design, represents a synthesis of eastern and western practice.

How then did Charlemagne arrive at this system? In part it resembles the Islamic Spanish system as accounted above, in taking Roman ounces as the basic unit of construction. However, the Carolingian reform seems more original and sweeping. Using Roman ounces, the Islamic metrological philosophy was extended to its ultimate conclusion, yielding a new, and entirely artificial, perfectly binary grain. My guess would be that this system was created for Charlemagne by the shadowy 'Radanite' Jews.

Throughout the Dark Ages, despite the lack of a Roman peace, trade continued between East and West. Spices, perfumes, silks and such like were carried West, largely paid for by slaves carried East. Prior to the Moslem conquest of the East Mediterranean seaboard, control of this trade seems to have been shared between 'Syrian' (ie Byzantine) and Jewish traders. After the conquests, in a period of military confrontation between Islam and Christendom, the Radanite Jews came to dominate the trade. As Islam became the focus of scientific progress and scholarship, these Jewish travellers became the chief transmitters of new eastern ideas into less advanced courts like that of Charlemagne. Records clearly show that Charlemagne's dealings with Harun ar-Rashid relied upon Jewish intermediaries. Christian clerics at Charlemagne's court complained about the intellectual atmosphere of open house that prevailed under their influence, and it seems most likely that Charlemagne's hybrid coin metrology was created by one of these sophisticated Jewish intellectuals. There will be a good deal more to say about the Radanite Jews shortly, in connection with both Scandinavian weight standards, and with the sterling pound and penny.

Before moving forward, it is worth noting that on the above account, Spain, the southern neighbour of the Carolingian empire, adopted a dirhem nominally of 2.72g. Since the Spanish ounce would be exactly the same as the Carolingian ounce; the Spanish (ie Roman) pound could be counted out using 192 Carolingian pennies ($^{12}/_{15}$ x 240). On our understanding that equates to 120 of the proposed Spanish dirhems, thus 8 Carolingian pennies, theoretically, exactly equal 5 Spanish dirhems in weight.

Early Medieval Scandinavia

Huge numbers of Islamic dirhems have been found around the Baltic, associated with weights which have an Islamic appearance. Umayyad, Abbasid, and Samanid dirhems dating from the 8th, 9th and 10th centuries are all found on the sites of medieval Scandinavian settlements.

Scandinavian octahedral (Viking) weight

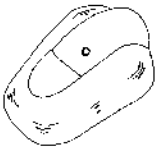
Summary of the Main Hypotheses Concerning the 'Great' or 'Troy' Pound of c. 500g - see Text for Full Details

c. 8,000 BC?  +  ≃ **500 grams**

A person needs about 500 grams of grain a day for basic subsistence. It so happens that two hands cupped hold about 250 grams of grain. Thus it seems quite possible that prior to storage, in very early times, each harvest would be measured, using two hands cupped as a measure of a 'unit', where each primative 'pound' represented two such units, or alternatively, a day's survival for a group member.

c. 4,000 BC? 

The two pan scale was most likely developed to accurately weigh gold. The nature of the device dictated that a binary weight system would prove most convenient. In Egypt a 256 grain standard, of c. 13 grams, called a 'beqa' was selected. It directly follows that 40 such beqa would best approximate a 500g pound, which would therefore equate to 10,240 grains

c. 2,150 BC 

The Babylonian King Shulgi seems to have been the first to create a widely recognised standardized great pound, maintained and distributed in the form of stone 'sleeping ducks'. Surviving examples indicate his pound weighed around 502g.

459 AD 

The Sasanid King Peroz revived the Babylonian pound of c. 500 grams, and the traditional Persian practice of dividing this sexagesimally, into 120 drachms. As these each weigh c. 4.15g, his pound was c. 498g.

699 AD 

'Abd al Malik adopted the existing 498g Sasanid 'Great' pound. However, he figured it in the Egyptian way, as comprising 10,240 grains (each of course arbitrarily fixed at 0.0486g). This pound was treated as 16 'ounces', each of 640 grains. He then proceeded to create a subsidiary pound, especially for the purpose of the bullion trade, of 12 such ounces. This bullion pound obviously contained 7,680 grains, which rather neatly divided up into 120 bullion dirhems (12 ounces of 10 dirhems) each weighing 64 grains in a rather traditional Egyptian way.

However, he then apparently went on to take a $^{1}/_{16}{}^{th}$ in seigniorage away from the bullion pound to make a coining pound. This could be done by striking 128 dirhems weighing 60 grains from each bullion pound, but retaining 8 dirhems as seignorage, and returning 120 dirhems to the original owner of the silver. These 120 coins comprised a coin pound, of 12 ounces, each of 10 dirhems, each of 60 grains = 7,200 grains. Two parallel systems were thus created, each of 12 ounces of 10 dirhems. In the bullion system the dirhem was 64 grains, in the coin system it was 60 grains. The whole excercise is a wonderful melding of Persian and Egyptian sexagesimal and binary arithmetical practices.

792 AD 

Offa seems to have transplanted this Islamic system into England, perhaps under the name 'Esterling', in 792/3 AD. The bullion (Troy) and coining (Tower) pounds were as in Islam. A penny, theoretically of 1.46g, was used in place of a dirhem of 2.92g, thus a whole system now hinged on the fact that 15 x 16 = 240 = 20 x 12. Charlemagne created a very similar system at the same time - but using a weight standard taken from a half denarius of Nero, rather than a half dirhem of the Abbasids. The opposing systems came about during a rift in relations between England and Continental Europe. Presumably to do with tariffs.

It should not be assumed that the importation of dirhems from Persia into Scandinavia spanned this long period. As mentioned above, old coins long remained in circulation in early Islamic Persia, perhaps due to a reluctance of some to pay seigniorage on reminting. Stratigraphic analysis from excavation seems to suggest that, regardless of the issue date, these dirhems came across the Caspian sea and up the Volga, reaching the Baltic during the period 850 to 950 AD. At that time Viking residents of Scandinavia had not yet taken to coin use, and Moslems had already reverted to circulation of bullion by weight. Thus it is no surprise to find that these dirhems were traded by weight. This conclusion is supported both by the many irregular sized 'make-weight' fragments of dirhem that have been recovered, and also by the numerous weights recovered from around the remains of medieval settlements.

Large numbers of these weights have been examined in recent years by Sperber.[80] He concluded that they belonged to two separate systems, united by a common 'ounce' or 'ora' of c. 25.4g. The oft met suggestion that this ora was just a poor attempt to replicate the Roman ounce, theoretically of c. 27.25g, was rejected by Sperber, who interpreted it instead in association with the two parallel weight systems.

The ora rather aligns quite well with six Islamic mithcals, or gold dinars, since 6 x 4.24g = 25.44g. The exact weight associated with the Viking ora however remains controversial. A specific kind of small weight, made of iron coated with copper or bronze, seems to be found widely, and to be carefully regulated. Well preserved specimens from the Moscow area [81] point to an 'orteg' of 8 grams, thus an ora of 24 g. Meanwhile a few very well made heavier weights from Sweden indicate a six ora at very close to 150g, thus an ora of c. 25g. Wallace in Ireland has championed two standards apparently relying upon Irish Viking lead weights to support a higher value of 26.6g, but the background work seems still to be unpublished. Joakim Schultzén has attempted to suggest a sort of dual standard tied to trading fees which seems to me a promising line of enquiry, but that still lies outside mainstream thought apparently.[82] Sperber himself argued that the Vikings recognised an ounce as equating to six mithcals, but also to a subsidiary 'market dirhem' standard, a dirhem weighing $^{2}/_{3}$ of a mithcal. Thus the ora, according to this system, would divide into 6 x $^{3}/_{2}$ = 9 'market dirhems'. As was shown above, such c. 2.82g weights, or 'dirhems of two-thirds' were well known in Islam itself, from the inscribed Egyptian glass weights. We need not however believe that this standard was adopted directly from that Islamic practice. Recalling the discussion of Islamic glass weights above, it seems likely that, in Egypt at least, a weight of $^{2}/_{3}$ dinar (c. 2.82g) was adopted as the lowest acceptable weight of a dirhem for legal tender. Since the dirhems in question usually weighed on issue around 2.92g, this practice opened the way for enterprising individuals to try to clip 0.1g off all the dirhems that passed through their hands, and the surviving circulated dirhems from the Umayyad and early Abbasid period seem to indicate that something very like this actually happened quite a lot. Thus Scandinavians may have got a notion of a c. 2.82g dirhem directly from examination of the old, dishoarded, and frequently slightly clipped dirhems that came their way.[83]

The second standard Sperber himself claimed he called the 'Swedish/Islamic system. It consisted of taking the same 6 mithcal ora but this time splitting it in a straightforward binary fashion. It produces a novel set of weights based on an Islamic standard, but new in itself. Amongst the divisions we find a 'lod' of 3 mithcals, a 'bullion dirhem' of about 3.2g, a 'penny' of about 1.6g, and a 'halfpenny' of about 0.8g.

These two standards again bring to mind the twin bullion and coin dirhems of 'Abd al Malik, but with a 'charge' not of $^{1}/_{16}^{th}$ (2.92g vs 3.11g) but of around $^{1}/_{9}^{th}$ (c. 2.8g vs 3.2g). We saw something similar suggested in the pennies of Charlemagne, and in the pennies of Anglo-Saxon England, which perhaps adopted dual weight systems. Whether such a dual systems existed and how, if so, it is to be interpreted in the day to day workings of the pre-coinage economies of Scandinavia, remains obscure. The postulated Scandinavian 'dirhems' do however have a rather remarkable and unexpected mathematical property. 128 examples of a 3.2 gram dirhem, that is to say, 16 of these 'Swedish/Islamic ounces', weigh quite close to 409g. As we have seen, that is Charlemagne's coining pound of 240 pennies. The Franks were neighbours of the Vikings to the South; as was Islam to the East. The utility of this double correspondence might not have been lost on Viking traders.

A full account of the postulated equivalencies created by this (possible) set of coincidences runs as follows.

The Attic pound (c. 437g)
= 128 Roman Imperial denarii (c. 3.4g)
= 256 Frankish pennies (c. 1.7g) x $^{15}/_{16}$
approx: Charlemagne's 240 penny coining pound (c. 409g)
= 128 'Swedish/Islamic dirhems' (c. 3.2g)
= 16 Swedish/Islamic ounces' (Ora) (c. 25.6g)
= 32 lod (c. 12.8g)
= 96 Damascus mithcals (c. 4.24g)
= 144 'Islamic market dirhems' (c. 2.82g)

This somewhat hypothetical system seems to get a degree of validation from the traditional Russian weight system being reckoned as:

Funt 409.517g x 1/32 =
Lot 12.797g x 1/3 =
Zolotnik 4.266g x 1/96 =
Dolia 0.0444g

Thus the Funt is the same as Charlemagne's coining pound, 15 Roman ounces. The Lot is half of Sperber's projected Ora, the Zolotnik an Islamic mithcal. This last deduction is well corroborated by the name, which translates as "golden one". The Zolotnik is apparently tweaked a tiny amount upwards, presumably because in Russia a version of the Roman ounce was taken very exactly as 27.3g, and given priority when fixing the absolute standard. Just as important is an apparent fit of Ottoman weight standards within this system. Sperber's claim of a 3.2g 'Swedish/Islamic' dirhem within Scandinavia remains controversial, but that it constituted the Ottoman dirhem seems much better corroborated:

Lidra 320.7g x 1/100 =
Dirhem 3.207g x 1/16 =
Kirat 0.2004g

Further, it seems rather likely that this Lidra derives from an earlier Byzantine 'logariki litra' of around 320g.[84] Thus the Russian standard Funt split in a binary fashion yields 3.200g, hardly different from the Ottoman dirhem of 3.207g. But at a practical level, a convenient decimal possibility apparently came to the fore, with the canonical Islamic dirhem being tweaked up from 3.125g to 3.207g and the canonical Roman (12oz) pound being tweaked downwards from c. 327g to 320.7g.

Inalcik puts the origins of these Islamic standards back at least to the Seljuq period, and they seem to arise rather naturally as a convenient practical decimalisation of the earlier, and in some ways more elegant, fundamentally binary system apparently introduced by Charlemagne. These sorts of proposed international equivalences seems to come as a surprise to many readers today, and talk of them is not infrequently scorned, especially amongst younger academic writers. They are not however particularly surprising nor innovative in the context of traditional metrological studies of previous generations. For instance, the significance of the correspondence of Carolingian and Islamic standards, brought to the fore with the c. 408g pound, was addressed back in 1834 by Saigey.[85] This correspondence still looms large inthe works of Witthöft,[86] However, both these authors assumed the ultimate origin of the 408g pound and its family of equivalencies was within Islam. A consequence of the recent unwelcome development in attitudes is that traditional conclusions are no longer being challenged and corrected by new archaeological findings. If we examine the work by Morton on early Islamic glass weights, we find no trace of a c. 408g pound in the earliest Islamic weights. It does possibly appear in Islam in association with a weight dated to 226H (c. 840 AD), but that is about 50 years after the standard was apparently adopted by Charlemagne, in 793/4 AD when he introduced his 1.7g penny. Thus, on the evidence as it now stands, the c.408g pound, so crucial to money conversion between important Roman and Islamic weight standards, first appears in Europe rather than Islam, at Charlemagne's court, quite possibly created by "Radonite" Jewish merchants trading and advising there, and not, as Saiger and Witthöft and others formerly held, as a fundamental standard of Islam itself.

English Sterling weight

(169) *Sterling penny*

Details of the Troy/Tower system were laid out earlier, in connection with the coinage of 'Abd al Malik. The Troy system of weight, (with a 64 grain dirhem/32 grain penny), seems to have been employed in Egypt from at least the reform of 'Abd al Malik, right down to metrication. Thus it might constitute the model for the English system at almost any date after about 699 AD. However, the associated subsidiary Tower system, employed in the production of the 60 grain canonical dirhem, was apparently in use for a relatively short period within Islam, being discontinued around 850 AD with the 7/10^{ths} mithcal of c. 2.97g being preferred after that date. This would give us a much shorter window of best opportunity for the dual system to be transplanted in its fully ramified Troy/Tower form. Within that interval of about 120 years there is just one date that springs immediately to our attention, that is the reform of the weight of the penny by Offa in 792/3. A recent review of the metrological evidence by Naismith[87] makes Offa's new penny a possible fit for the sterling c. 1.46g/30 grain standard.

The coins are not particularly consistently made, leaving that evidence somewhat ambiguous. However, three pieces of historical evidence also seem relevant. Firstly, that Offa's penny reform of 792/3 coincides very closely with Charlemagne's reform of 793/4. Secondly, both in turn follow on closely from Charlemagne's Admonito Generalis of 789, which made a commitment to the reform of weights to some true standard, very possibly the standard of biblical contexts. Finally, both courts were influenced by Northumbrian scholars of York, Alcuin and his contemporaries. Given the evidence of Islamic influence associated with Charlemagne's reform, there seems to be a strong case for something similar occurring with Offa. One might immediately ask why then did the two rulers go down separate paths?

Reports of failed marriage contract and a two year long 'hard Brexit' at that time indicate a wider political rift opening up. Not a unique out turn in the long history of English/Continental relations or even their proposed metrological reforms. The case for the adoption of Troy/Tower in England in792/3 is not watertight. However, if we agree with the quite large body of scholars who have held, for 3 centuries now, that English Troy came from Islam, then 792/3 would seem to be the most likely date of that event. The probable reason for the borrowing would be an Anglo-Saxon quest by Alcuin of York and his associates for the true original biblical standard of Moses (Leviticus 19:35-7 etc), at a time when Islam held the Holy Land, and had itself recently adopted very ancient Egyptian standards.

The Crypta Balba Museum in Rome owns a very official looking weight inscribed CAROLI PONDUS,[88] at one time the possession of Athanasius Kircher. In the late 19th century Blancard[89] discussed it, he interpreted its weight as being closer to the old Paris weight standard than any German possibility. Soon after he was rather fiercely criticised by an Italian scholar, Capobianchi,[90] who argued that the weight was not to a German or French standard, but to an Italian one, the Ancient Roman. The fact that this would make it a very weird 7 ounce Roman weight did not deter him. More than a century on it is still described that way in the museum catalogue. Nobody ever seems to have noticed that the weight actually weights 186.42g - thus almost exactly 6 English Troy ounces – half a Troy pound. It seems possible that at some stage in the proceedings prior to the rift Charlemagne considered using Troy weight himself. That possibility might assist us in understanding what seems to be a rather early adoption of what appears to be sterling weight at Cologne.

It might be objected that we have little evidence for the continuation of use of these standards in the coins of the later Anglo Saxons. But the standards of those coins are notoriously complex, to the point of incomprehensibility, and thus themselves indicate no obvious alternative – the basic practical Troy system may just have continued in use in official contexts, behind the scenes. A further problem is that when the Tower system emerges clearly under the Plantagenets in the form of the sterling penny, there is little sign of an accompanying bullion Troy system. However, Connor already pointed towards an explanation of that matter, that abuse of the dual standard by tax officials led to its suppression for official purposes, post Magna Carta, but prior to Henry VII. This revision of my original text brings it more into line with the conclusions of both Skinner and Grierson as regards the reforms of Offa, but with a new historical and textual basis, the search for conformity to scripture, which now seems to me rather credible in the Anglo-Saxon context. A further reform of the penny took place around 1083.

The pennies in question, William's 'Pax' issue, generally weigh low, about 1.38 g, but the weight of the penny was subject to just minor adjustments thenceforward, during the couple of centuries in which we know Sterling weight was (re)introduced. Prior to William I the weight of the penny fluctuated quite widely. Thus the initial standardization of weight seen in the 1083 issue seems to be the most plausible candidate for the return of the 'English' penny to the sterling standard. This fits with the etymological evidence.[91] Recent work by Lyon,[92] drawing upon unpublished work by Brand, suggests that in some areas late 11th century tax payments were collected at a rate of £1 1s 2½d in the pound. This seems a very odd surcharge until one notices that such a 6% addition applied to 'Pax' penny payments would bring the payment up to the standard of a full Sterling pound. Thus it seems probable that sterlings, and the Sterling pound, were known at that date (240 x 1.46g = 350g). 12th century penny issues of c. 1.42g represent better approximations to the Sterling standard. Remaining minor deficiencies probably arose from either fiscal or competency reasons, but we lack any indication of which, as so often in historical metrology.

We do not get a good clear textual account of the English Troy pound until a statute of Henry VII in 1496, which defined a Troy pound as 5760 (barley) grains, subdivided into 12oz of 480 grains, or 240 pennies of 24 grains. A clear definition of the Tower pound, as eleven and a quarter Troy ounces, does not appear until the Tower pound was itself abolished in preference for the Troy pound in 1527.[93] However, some mint documents from the 13th century seem to indicate the taking of a sixteen pence charge on coining Sterling quality bullion. This would correspond to a theoretical ideal of giving a Tower pound of pennies in return for a Troy pound of bullion.

English metrology has been thrown into much confusion by '*The Assize of Bread and Ale*', traditionally associated with legislation of Henry III, of 1266. That definitively states that an English sterling penny should weigh 32 grains. But metrologically that stipulation appears wrong. I suspect the misrepresentation was deliberate, and was rooted in political and fiscal expediency.[94]

No official English standard weights produced for the mint before the 1850's are known to exist. However, copies of earlier standards exist, and the cross referencing of these with texts, with the weights of English coins, with early continental coins, and with surviving continental weight sets, show clearly that the tower pound has hardly varied from 349.9g since at least the 14th century.[95] Thus English records reveal a replica of the early Islamic weight system gradually emerging out of the mists of ignorance, and when at last it is fully visible, it turns out to be near exactly the same.

This presents us with two possibilities, either England inherited its system ultimately from Islam, or the matter is a complete coincidence. And the near exact fit of both the absolute standard, and the associated rather complicated mathematical grain, ounce and pound structure of both Troy and Sterling pounds, surely puts the possibility of coincidence beyond the bounds of reasonability.

Although Troy weight is not mentioned in any surviving document before the late 14th century, writers very shortly after that date already considered the origins of Troy weight to be lost in the mists of time. According to a very popular 'history' created in the 14th century, the British nation was founded by a Trojan named Brutus, and it seems likely that it was correspondingly believed that Troy weight was the standard that said Brutus brought from Troy with him. Since this opinion has been subjected to ridicule from time to time by modern scholars, there is some amusement to got from the deduction laid out here, that in many ways, Troy weight turns out to be, not much younger than the sack of Troy , but in its ultimate origins, very much older.

The earliest etymological gloss of 'Sterling', the very well established name of the tower pennyweight, dates from around 1300 . Walter de Pinchbek claimed then that the Sterling standard got its name because Sterlings were originally made by 'Eastmen'.[96] Just how this bears on our account will be discussed under Cologne weight below.

Setting aside the etymological conundrum of the word 'sterling', enquiring minds have suspected that England got its weigh standards from Islam since at least the early 18th century, as previously mentioned. This now seems very probable, although questions remain about the extraordinarily complicated manipulations of the penny weight during the later Anglo-Saxon and early Norman period. Soon after 1066 William I brought over the 'Jews of Rouen' to assist in the financial management of his new realm. The standardisation upon Sterling weight in 1083 followed with little delay. If we investigate the associations of the Jewish Talmudic college at Rouen, we find that around 1000 AD it sought out qualified masters from a senior Talmudic college at Troyes.[97] The origins of Troy weight are popularly said to have been at a great market held at Troyes and founded by Charlemagne. In fact we have no record of such a market being held before 1100. However, a scholarly Jewish colony certainly existed at Troyes much earlier than that, perhaps as a fixed outpost of the Radanite trade. Quite likely the mathematically elegant and politically expedient system of metrology laid out by 'Abd al Malik was still known to these Jewish intellectuals, as was a likely transplantation of it to England, and Cologne. Troyes weight, (see below), contrary to much conventional wisdom, seems to manipulate the Carologinian system of weight, using the same grain, but a new pound of 18 Roman ounces, to just a little below 16 oz English Troy (63/64). If this is correct, England did not get Troy from Troyes, rather, Troyes got its weight (more or less) from England.

It should be borne in mind of course, that although the metrological system underlying coining in England remained almost static from the introduction of Sterling until the adoption of the metric system, the weight of physical English silver penny did not. Prior to 1279 we have few records of mint intentions, but in 1279 the Sterling penny was below 1.44g, in 1412 it fell to 0.97g, in 1464 to 0.78g. These changes reflect an inflationary process rather than a metrological change. The rather direct link between metrology and the physical pennyweight was broken in the troubled 14th and 15th centuries, and the restoration of a link, between the heavy silver 'crown' or 5 shillings and the Troy ounce, in 1552, lies beyond the scope of this study.

Cologne Sterling weight

(297) *13th century Cologne (style) penny*

Henry II of England, 1154-89, granted special privileges to visiting Cologne merchants. From around 1170 we find English records suggesting that Cologne used an 8oz mark of c. 233g,

composed of 160 pennies. Simple mathematics shows that these pennies were for all practical purposes Sterlings, struck at a rate of 240 to 350g (ie the English 12 oz tower or sterling pound). Examination of Cologne pennies themselves reportedly[98] shows that a standard of 1.47g had been set much earlier, in the times of Otto I (936-73), and was quite well maintained down to the late 13th century.

It is this fact that has clouded the etymological argument concerning the word English 'sterling' for so long. It seems to many to refer to a pound of the 'Eastern men', but did it refer to an Eastern pound of Cologne, or an Eastern pound of the Arabs? The truth is surely that Cologne very likely got its standard from remnants of the Radanite Jews much as England did, and both look to an ultimate Arabic source for the standard itself. Once it is seen that England and Cologne both might have got their standard ultimately from an 8th century Islamic source, the etymological questions about the derivation of the word 'sterling' no longer has any great significance. Quite possibly, both readings contain an element of truth.

Like the English penny, the Cologne penny fell away from the full standard in later centuries, but Cologne standard weight itself remained rather constant. Estimates of the Cologne pound in the 17th and 18th centuries put it in the region of 466.5g to 467.5g. This is a good approximation of troy/tower even after 6 centuries of potential divergence, since 15oz Troy = 16oz Tower = 466.5g. Interestingly, in later centuries at least, Cologne did not divide its pound into grains in the English/Islamic way. An early 18th century source[99] mentions a division into 16 ounces of 8 drachms of 76 grains (thus deliver 16 oz troy = c. 499g = 10,376 grains = 2^9 x 19!). Early 19th century sources mention another alternative division of Cologne weight following Roman practice into 12 ounces of 8 denarii of 6 obols of 12 grains, yielding a grain similar to, but not quite the same as, the Paris grain.

Venice Sterling weight

(261) Venice Matapan

Around 1200 Venice launched a heavy silver 'grosso' of c. 2.19g with a fineness aiming at 98.5%. It is immediately clear that this coin weighs 3/2 Sterling pennies. Further, documentary evidence shows that from around this date silver was traded in Venice in the form of a mark (8oz) of 109.5 grossos.[100] Converting this measure to a 12 ounce standard, one finds it yields near exactly 164 grossos. Since the grosso is 1.5 sterlings in weight, this 12oz pound theoretically comprises 246 sterlings.

Frequent mention of the 'esterlin' denomination in early Venetian document suggest that Sterling silver was well known there, and elementary mathematics suggests that the Venice 12oz pound may have been a kind of heavier companion weight to the Sterling pound, also denominated in sterlings. In Islam, and England, we have seen the operation of a pair of pounds, Sterling/Tower and Troy, of 240 and 256 sterlings, thus with a gap of 16 sterlings, or 1/16th between them. The mathematics of the Venice pound suggest an alternative pair of pounds, of 240 and 246 sterlings, with a slender seigniorage theoretically added to the Sterling pound of just 6 sterling pennies, or about 2.5%. This deduction fits quite well with the low level of seigniorage known to have been charged at the Venice mint in later medieval times (sometimes only 2%).

Paris/Troyes weight

In France the primary system of weight used in connection with coinage which survived from medieval into modern times is called 'Paris' or 'Troyes' weight. Here we will call it 'Paris'. Traditional medieval European metrology is bedevilled by two misleading myths about the Paris weight system. The first is that Charlemagne got it from the Arabs. As we have seen, this is false, or at least, very misleading. The second is the naming of a venerable set of Paris weights (now at Conservatoire des Arts et Métiers) as the 'Pile de Charlemagne'. The set of weights in question implies a mark of c. 244.75g. dividing into 8 ounces of 8 gros of 3 denier of 24 grains. As we have seen, these are not the weights of Charlemagne. In fact the weights probably date from the reign of Louis XI 1461-83 or his successor Charles VIII 1483-98.[95]

Thus we will reject these two myths, and instead work to the more probable idea that although Paris derived from the standards of Charlemagne, it represents a revision, better aligning French weight to the international Sterling standard of the later medieval period. This assumptions yield rapid results. Firstly: 244.75g/ 8 x 8 x 3 x 24 = 244.75/4,608 = 0.0531g Thus for all practical purposes Paris weight was still based upon Charlemagne's grain.

Secondly, 16 Paris ounces equal circa 489.5g, and 489.5g x 2/3 = 326g, thus the Paris 16 oz pound, or livre, is a good approximation of 18 Roman ounces. Given the prominence of the Roman ounce within Charlemagne's weight system, this can hardly have passed unnoticed in a system that replaced it, so we should assume that 16 of these new ounces was deliberately fixed at 18 Roman ounces.[101]

Thirdly, 12 Paris ounces weigh 489.5g x 0.75 = c. 367g, and 367g/1.46g = 252 (very nearly). Thus a Paris 12 ounce pound is a very good approximation for 252 sterlings. Since the Tower pound is 240 sterlings, it follows that the Paris ounce is very close to 21/20 x the Tower ounce.[102]

Thus it appears that the Paris ounce is a cleverly conceived standard which is readily convertible to the Roman and Carolingian standards (9/8) and simultaneously to sterling standard (20/21). Likewise, 16oz Troy x 63/64 = 16oz Paris.

How the Paris/troyes system came into being is rather more of a mystery. The gap between English troy (16 oz = 497.6) grams and Paris troyes (16 oz = 489.5 grams) is small, just 1/64, as small as the difference in the spellings of the names, so to speak. Much scholarly time has been spent trying to derive English Troy from French Troyes, but if our conclusions are correct, this time has been wasted. English Troy is far the older of the two systems. The most likely explanation of the origin of Paris/Troyes is that at some point in the medieval period, 18 Roman ounces, c. 489.5 grams, was adopted, at Troyes and at Paris, as a convenient approximation to the Troy 16 oz pound, but in a way that would assist conversion to the Carolingian system, fettered to Roman ounces. England was tied to the Islamic system, adopting an apparently more ancient tradition, getting its standards (somewhat mysteriously, but more accurately), from the Baghdad 'ratl kabir', and thus the mina of Darius and of great ages before that.

An important coin weight which seems to bear little resemblance to anything laid out above is that of the medieval French gros tournois. The weight of this coin was fixed at a

seemingly arbitrary $^{1}/_{58}^{th}$ of a Paris mark, thus: $^{8}/_{16}$ x 489.5g x $^{1}/_{58}$ = 4.22g. Fortunately we have contemporary texts which tell us that this equates in silver value to exactly 3 English sterling pennies: as follows: 3 x 1.46 x $^{92.5}/_{96}$ = 4.22g

(218) *Gros tournois*

(since sterling silver was 92.5% fine, Paris 96%). Trying to find such a solution without the guidance of contemporary texts would be like looking for a needle in a haystack. This is an excellent reminder of how coin weight can diverge from metrology for complex reasons. It is easy to suppose that similar calculations underlie some of the metrologies of Ancient Greek coins, but in that case contemporary texts are all but lacking, confounding our attempts to unravel ancient mint master's intentions.

Sterling Weight in Later Medieval Europe

It is universally acknowledged that the sterling or 'esterlin' standard became very influential right across Europe in the 13th century. Popular authorities such as the *Oxford English Dictionary* suggest that this widespread acceptance was due to the reliably high silver content of the contemporary English penny, at c. 92.5% fine. To some extent this may have been true, on the back of the huge issues of Henry III and Edward I, in the Low Countries and beyond in the later 13th and 14th centuries. But as we have seen, the sterling or 'esterlin' standard was popular earlier and further afield than that. Spufford tried to explain the popularity of the esterlin standard in Venice around 1200 by the elevated fineness of the English silver penny, coupled with its continental distribution via the crusade and ransom of Richard I.[103] That suggestion does not seem plausible. The silver pennies of Richard I, 1189-99, were not issued in the great quantities seen under later monarchs. And since Venice opted for a coining silver fineness of 0.965, why would they have been impressed by an English sterling standard of merely c. 0.925? The same is true of Paris. We have seen that the Paris troyes standard seem to have been conceived to acknowledge the importance of the sterling standard, but again, Paris struck grossi at 96% fine, so could hardly have been in awe of the English c. 92.5% standard.

The popular understanding that English sterling pennies set an enviable high standard for silver quality seems to be misconceived. Rather Sterling was a useful international standard of weight, with a sterling or Cologne pound of c. 350g, and its corresponding penny, of c. 1.46g. Cologne appears to have stood by this standard more consistantly than England under the Anglo-Saxons. The suggestion by numerous British authors that say Paris or Venice favoured sterling because of the financial clout of the medieval English mint seems to tend towards nationalistic chauvinism. Sterling, or Cologne, was a near universal system of weight, likely spread throughout Europe, perhaps under the influence of Jewish scholars and financial advisors, due to its convenience.

That is why we find traces of it everywhere, at Cologne, Venice, Paris and London. The only strange fact before is: why has this matter has been so thoroughly forgotten? But that too is nothing new in metrology, intimately associated as it is with stealth taxes, got by seigniorage.

Today we associate sterling silver with 0.925 purity, but if Brand[104] is correct even this is a misunderstanding. Medieval documents suggest that the English standard was initially 0.937, that is to say $^{15}/_{16}^{ths}$ fine. This in turn suggests that in England an imposition of $^{1}/_{16}^{th}$ in fineness was taken atop one of $^{1}/_{16}^{th}$ in weight: those who knew this probably did not advertise the matter.

Florentine Weight

(265) *Gold florin*

Florence began to issue gold coins in 1252. Gold issue had been more or less laspsed in European commerce for 500 years prior to this. The new gold 'florins' weighed 3.54g, thus 128 made a 16 ounce pound of 453g.

The Florin became enormously popular, versions being struck in Germany, Scandinavia, Hungary and elsewhere. The Venetian gold ducat which appeared in 1282, was set at $^{1}/_{67}^{th}$ of the Venice mark, yielding a coin of 3.56g. Clearly this had nothing to do with Venetian metrology, and everything to do with creating a rival for the florin. A very similar weight issue appeared in France in 1475. Called the 'Ecu au Soleil' and struck at $^{1}/_{70}^{th}$ of the French mark, its weight was just a little lower at c. 3.5g. Further reduced it appeared in Spain as the escudo, or $^{1}/_{68}^{th}$ of the Spanish mark (c. 3.38g).

The arbitrary fractions: $^{1}/_{67}$, $^{1}/_{70}$, $^{1}/_{68}$, came about in an attempt to express an alien standard in a local system. The gold florin itself however is a simple binary fraction of a traditional Florentine pound, of c. 453g. This weight does not have a Sterling basis, the Florentine pound equates equally arbitrarily to about 310 sterlings. So we are faced with the problem, where did this Florentine pound come from?

The origins of the Florentine c. 453g pound are puzzling. As we shall see, there is stong evidence that it went on to influence English Avoirdupois, British Imperial and US customary weight. Further it closely resembles the sort of sub-Syrian/Phoenician standard found in Classical Athens and a number of Phoenecian cities in the Levant. Both Petrie and Skinner wished to connect the dots here, believing that a kind of provincial c. 453g pound continued in use throughout the Roman period. Their physical evidence for this looks rather thin, almost wishful thinking, as far as I have been able to discover.[105] However, the textual evidence, from both the 4th century Syrian Epiphanius and Isidore of Seville, in the early 7th century, is clear about a 100 denarius libra. Isidore is clear about the weight of his denarius (about 3.4g, as being $^{3}/_{4}$ of his contemporary solidus). He is just as clear that there were two Roman pounds, one the version we know well, of 96 denarii thus 327g for 12oz, but the other of 100 denarii, thus c. 340g for 12oz. This latter yields the Florentine ounce we are looking for and thus a 16oz of 454g. Connor, like Skinner and Petrie, makes reference to a well preserved set of Roman weights in the British Museum,[106] indicating an ounce of 28.4g and a 16oz pound of 454g. Like Skinner, Connor relates these weights to the standards locally preserved at Florence and Rome from antiquity down to the adoption of metric standards in 1818.

At that time the two cities assessed their 12 oz pounds at 339.55g and 339.16g respectively. However, the weights Connor points to are all rather small ones, perhaps for some specialist pharmaceutical purpose?

As previously mentioned, during the European Dark Ages, a weight standard quite similar to this Florentine standard was preserved in Islamic Egypt, the standard commercial ratl of 144 bullion dirhems, which theoretically should weigh c. 448g (surviving weights indicate c. 444g in practice). However, the version at Florence seems to derive from the theoretical weight of 100 Roman solidi of 4.54g. This theoretical evaluation of the Roman coining pound, at Florence (c. 327g) is almost exactly the same as the version implied if we assume Paris (Troyes) represents 18 Roman ounces; it is the one preferred in this study. What to say in conclusion? This particular matter of proposed very ancient continuity remains intriguing, but needing more corroberation.

The florin, or rather its twin, the ducat, became widely used and eventually cloned within Islam under the name 'ashrafi'. In about 1419 the Mamluqs began to strike gold to a 3.5g standard.[107] According to most accounts, this imitated the Venetian ducat, which itself had imitated the florin. However, as things stand, that puts the cart before the horse. If medieval Florence got its weights from Egypt, via either Ancient Rome, or early Islam, then the popularity of a 3.5g standard in Islamic Egypt might well be because it exemplified a natural division of a weight standard long established there.

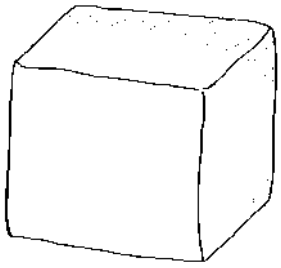
In the Islamic world the 3.5g coin got the name 'ashrafi' from the laqab of the Egyptian Sultan Barsbay 1422-38, who popularized its use. The Persian Aq Qoyunlu dynasty adopted the denomination in the reign of Hasan, 1453-78. The Sefavids also adopted it (from about 1501 to 1521), as did late Timurids, Moghuls, and even the Central Asian Shaybanids for a brief spell. The Ottomans adopted it, renamed a 'sultani', around 1477, and it remained in use in Turkey at a c. 3.5g standard, down to the late 18th century.

Turning to events in the West, it does seems likely that the English Avoirdupois pound weight of 453g derived directly from Florentine standards, due to the influence of Lombardy merchants on English wool trading in the 14th century.[108] At the time, Italian bankers were active in retrieving large debts amassed by Edward III during his continental military forays. Connor hints that a reduction of near 10% in the commodity pound, from Troy c.497g to Avoirdupois c. 454g , was imposed at that time, and it seems possible that such impositions lay behind unrest which culminated in the peasants revolt of 1381. If such is the case, it might go some way to explaining the curious silence of official sources regarding the whole matter.

One of the earliest surviving sets of official English weights, at Winchester, dated to 1353, was calibrated to this standard. Earlier 13th century English weights and documents neither recognise nor refer to such a pound. Dictionaries routinely mislead on this matter, suggesting that England somehow got Avoirdupois weight from France. But neither the term nor the weight standard had any prominent usage in France. There can be no doubt that today's customary pound in the USA is the English Avoirdupois pound. Thus it seems very likely that the American customary pound in the 21st century is the coining pound, of 128 florins, of 13th century Florence. And it is possible, as detailed above, that it might be traced back much further, to a 5-deben mina traded in the Eastern Mediterranean more than four thousand years ago.

The most obvious explanation of events in Florence at the birth of the florin is that a traditional trade pound for general commodities of c. 453g was already established there in the 13th century. Perhaps gold, being used as a commodity rather than a coinage metal in the earlier Medieval period, was bought and sold to this standard. So when gold was first struck up into coins, it retained the standard of this trade pound, distinguishing, and indeed distancing it from the common silver currency, which was by then widely and customarily figured in the 'Troy' or 'Sterling' system of weight.

The Hindu Weight System



Generic cubic weight in chert, Indus Valley

The very ancient Hindu metrological system much resembles the earliest metrological system of Ancient Egypt. This might indicate that it was adopted from Egypt in remote prehistory, but it seems more likely that the two cultures both came up with similar rather convenient solution to the same problem, independently, on the back of very much more ancient shared understandings.

More than 1500 weights have been excavated from Indus Valley sites, buried between c. 2,600 BC and 1500 BC.[109] The initial excavation and analysis of these polished cubes of chert was carried out by Hemmy, under Marshall, and subsequent work has corroborated the findings. The weights were carefully regulated to a standard that hardly varied during the whole period, individual weights typically being within 2% of the mean. The commonest weight, the 'standard unit', averaged 13.71 grams. The denomination structure of the weights is mostly binary up to 4 units, and decimal above that, thus:

$^1/_{16}$, $^1/_8$, $^1/_6$, $^1/_4$, $^1/_2$, 1, 2, 4, 10, 20, 40, 50, 100, 200, 500, 800

Marshall subsequently excavated a much later site, Sirkap,[110] inhabited in the last centuries BC and early centuries AD. He found 54 stone weights there, this time in the form of stone balls. Twenty-five of these stone balls came from a single find, buried under a shop along with a mass of jewellery, perhaps hidden just ahead of the Kushan conquest. Many of the balls had apparently been carefully weight adjusted, by having little holes drilled in them, and small lead plugs added. Analysis of the stratification suggested that the hoard was buried during a phase of destruction around 36 AD. The calculated standard unit of these later stone weights was 13.705 grams, with the set from the jeweller's shop showing a denomination structure of:

$^1/_4$, $^1/_2$, 1, 2, 4, 16, 32

Clearly, both in magnitude and method of division these later weights fit the Indus Valley pieces very closely. Despite being separated by near 2,000 years, they share almost exactly the same standard, and a very similar binary structure. Marshall went on to point out that the $^1/_4$ unit, of 3.425 grams, was very close indeed to the weight of the Imperial punchmarked coins[111] issued by the Magadhan and Mauryan rulers throughout much of India from around 400 to 180 BC.

Having identified these coins as very probably the quarter units of the Indus Valley standard, we can begin to investigate the literary traditions associated with the weight system.

(638) *Mauryan Punchmarked coin*

Manu, apparently writing in the 2nd century BC,[112] says for the purposes of weighing silver two ratti seeds was equal to one 'rupya mashaka', and that 16 such 'mashakas' constituted a 'dharana' or 'purana'. 'Purana' means 'old' and in the context of the second century BC it surely refers to the ubiquitous and recently discontinued Magadhan Imperial punchmarked coins, which existed in vast numbers and had been the staple unit of trade in the empire for a couple of centuries past. So it appears that the Mauryan punch marked coins were made to a 32 ratti weight standard.

(633) *2-ratti mashaka*

Further, we do get coins apparently calibrated to Manu's 2-ratti mashaka standard. Now, the ratti is a poisonous bright red seed, with a black dot at one end; ratti seeds I have examined average 0.107g in weight.[113] Thus both Mauryan coins and Indus Valley weights seem to be simple binary extrapolations of this ratti seed weight; the standard Marshall designated a 'unit' being 128 such seeds (128 x 1.07 = 13.7g). With an average weight of about 0.107g, the ratti seed weighs a little over double the weight of Egyptian grains, so Marshall's 'unit' was a little heavier than the higher limit for the Egyptian beqa, 13.5g, but quite similar. Thus it is possible that at some point a 128 ratti unit directly replaced a 256 wheat or barley grain unit in North Indian usage. Although individual ratti seeds inevitably vary in weight, they quite possibly represent a more consistent standard than the wheat grain. Also the gunja plant, on which these seeds are found, grows wild all over India, whereas grain was not so widely available in the tropical South, in ancient times. In summary then, both the weights themselves, and text from Manu, point towards the Indus Valley civilization establishing a weight standard based upon 128 ratti seeds, but it is possible that 256 physical barley grains were used to give a very similar standard in early times.

Let us turn now to a different text, the Arthashastra. The surviving version was apparently composed around the 2nd or 3rd century AD, but rather clearly derives from very much earlier texts, as Kangle himself held in his 1969 translation.[114] In it we find the same definition that we found in Manu: sixteen (silver) mashakas make a dharana. Alongside this we find an extended metrological nomenclature, with binary definitions which fit the pattern seen in Hemmy's stone weights. Using Manu's identification of the dharana with the purana coin, of c. 3.4g, the following table correlates the definitions given in the Arthashastra with the inventory of weights excavationed.

Base unit	ratti seed	0.107g	1
2 rattis	1 mashaka	0.214	2
4 mashakas	1 masha	0.855g	8
4 mashas	1 dharana	3.42g	32
4 dharanas	1 suvarna	13.7g	128
2 suvarnas		27.4g	256
4 suvarnas		54.8g	512
8 suvarnas		109.6g	1,024
10 suvarnas		137.1g	1,280
20 suvarnas		274.2g	2,560
30 suvarnas		411.3g	3,840
40 suvarnas		548.4g	5,120
100 suvarnas		1371g	12,800

One ambiguity in the Arthashastra, concerning the use of the words masha/masharka, is amended in this table in the light of the testimony of Manu, and others. This was presumably just a transcriptional change/error in the extant copy of the book.

Thus we discover from the Arthashahtra that Marshall's 'unit', at least in the 4th century BC, was called a 'suvarna'. Since the Arthashastra calls all these units 'dharana' we can reasonably assume that 'dharana' just meant something like 'weight' at that time. Thus the specific 32 rattis weight, adopted for coinage purposes, was so fundamental to the ancient Hindu weighing system that the Arthashastra merely calls it 'weight'. Over the centuries coins adhering to the 32 ratti weight get variously called: karshapanas, tankas, jitals and (perhaps) pagodas. But some tankas, and some pagodas, were clearly coins struck to different standards. And some jitals were struck to alien Islamic standards. So it would be best to create a standardised terminology here, fixed for the purposes of this study. I will rather arbitrarily name the 32 ratti weight a 'dharana'. Thus over the centuries different rattis standards and different terminologies will arise, but for the purposes of this study we will identify the structure of the basic Hindu metrological system in this way

1 masha	= 8 rattis		
1 dharana	= 4 mashas	= 32 rattis	
1 suvarna	= 4 dharana	= 16 mashas	= 128 rattis

Before moving on to build upon this basic Hindu metrological framework, we should perhaps attempt to answer the question, how did the standard remain so constant, for so long? We have evidence that in Persia inscribed weights made around 2,100 BC were sought out, read, and replicated by scribes living around 600 BC. Those preserved inscribed examples of standards greatly helped the maintenance of consistency in Persia. Indus Valley weights are uninscribed however, and it seems much less likely that official scribes at the Magadhan court had access to preserved weights from the much earlier civilisation, far away on the opposite side of the subcontinent. More likely what survived was the practical tradition of using 128 ratti seeds to fix the standard. Individual seeds vary in weight of course, but the inevitable averaging that comes from using a large number of seeds, coupled perhaps with just a little luck, apparently kept the system well adjusted.

We can glean a further piece of information from the Arthashastra (2.12.24). Silver coins were debased by the addition of copper, plus a 'hardening' agent. The exact proportions are unclear, but probably a make up of something like 75% silver, 20% copper and 5% hardening agent was intended. What little modern metallurgical analysis I have found suggests that this 25% debasement is roughly correct. The important point to note is that the state could very likely have gained a significant seigniorage from this substantial debasement of the silver coinage, which would obviate any need to extract a seigniorage by manipulating the weight of the coinage. Thus the coins could be issued at full weight according to the official metrology. In conjunction with this, it is interesting to note that the sort of small weights made for commercial use, such as are common in Roman or Islamic culture, seem to be almost unknown from early historic India. This is probably because the standard coin itself functioned as a weight, and this in turn likely explains why the quarter suvarna was itself called merely 'dharana' or 'weight'.

The Hindu subsidiary gold 80 ratti weight system

This Hindu binary weight system, based upon the ratti seed, and a suvarna of 128 rattis, was almost certainly in existence before 2000 BC, and, as we shall see, it continued to exert great influence over Indian metrological thought, and Indian coinage, until at least the 17th century AD. But matters had already become more complicated by the start of the historical period. The account in the surviving versions of the Arthashastra is somewhat garbled. But it can be clarified by readings from the later texts of Manu, Hemadri, and Sangraha.[115] All these texts suggest that, alongside the prehistoric binary 'silver' weight system laid out above, a second system existed, especially for gold, and copper. This system was also based upon the ratti seed, but included a'gold-masha', fixed at 5 rattis, and a 'gold-suvarna' of 16 of these gold-mashas, therefore equalling 80 rattis. Further, the surviving version of the Arthashastra specifies the ultimate weight of the gold-suvarna in rattis, but not so the silver system outlined above.[116] I judge this suggests a late amendment of the text, at a time and place where gold and silver weight standards had diverged. The coins indicate that initially, or at least, in the Mauryan period, gold and silver shared a common ratti, of c. 0.107g.

So we have a system of weights for gold, mentioned in the Arthashastra, but missing from the Indus Valley weights. Thus it very likely came into being sometime after 1500 BC, but before the 3rd century AD, the latest date that the relevant passages in the existing version of the Arthashastra could have been composed, it seems. This system was calculated on an 80 rattis standard, which rather unhelpfully it also called a 'suvarna'. How did this come about? The important point to note is that the earliest Indian coinages are exclusively in silver. However, a small number of early gold coins have very recently come to light.[117] Fortunately, they seem to be very carefully made, and to a very exact standard of c. 2.15g. If we treat these as 20 ratti coins we have a ratti c. 0.1075g - thus almost exactly that of the Indus Valley and the Mauryan issues. If we then construct an 80 ratti gold-suvarna from that same standard we have 8.6g, that is to say, exactly an Attic stater, of the type found under the Bactian Greeks. Gold to an Attic standard seems to have been introduced by Greeks into Afghanistan about 250 BC. Back in 2009 I followed Codrington in associating the 80 ratti gold-suvarna with the Persian daric, but this new evidence seem to shunt it clearly to a later date, sometime in the period 250- 180 BC in all probability. Ancient texts suggest that copper coin was weight regulated on the same basis as gold.

(639) *Mauryan cast copper*

The copper issues of the Mauryan period are distinctive, uninscribed cast pieces. Superficially the weights of these appear highly variable. However, consideration of the fabric reveals that a small proportion of surviving cast copper issues are of much better manufacture. These probably represent early official issues, which are swamped by a deluge of crude and incompetent unofficial later copies, probably products of the disintegration phase of the Mauryan economy. If we focus upon the 'official issues' we find an apparent standard of 3.8 to 4 grams.[118] Given the standard of care generally seen in the production of copper coin down the ages, this seems an adequate fit for a theoretical 40 ratti/c. 4.3g standard. A 40 ratti standard will become very important in our later discussion, but like most Indian standards is given a host of different names over the centuries. So we will again arbitrarily fix a name for it here: a 'gadyana'. The gadyana seems to equate to a South Indian 'bean', the 'kalanda' of quite variable weight. Nevertheless later texts widely associate this bean with 20 madata seeds. And the madata seeds is in the same places conventionally figured as 2 ratti seeds. Thus our suggested terminology follows long held Indian metrological conventions, as follows:

1 masha = 8 rattis
1 dharana = 4 mashas = 32 rattis
1 gadyana = 40 rattis
2 gadyanas = 80 rattis = 1 gold-suvarna = attic stater

The Indo-Greeks and the 'Greek-ratti'

Around 180 BC an offshoot of the 'Greek' state of Bactria made conquests in North-West India. The new ruling dynasty, the Indo-Greeks, abandoned the traditional Hindu fabric of the punch marked coinage and created in its place a thoroughly Greek looking coinage, the silver coins of which are described in modern catalogues as a 'tetradrachms' of c. 9.68g and its fourth part, a 'drachm' of circa 2.42g.[119]

(696) *Menander 'tetradrachm'*

Although these coins look very Greek, their weight standard is not, and this fact is usually glossed over under the rubric the 'Indo-Greek standard'. It is clear from Marshall's finds at Sirkap that the invading Indo-Greeks had direct access to traditional Hindu weight standards. As we have seen, those Hindu standards were maintained by stone weights at the shop in Sirkap, and of course elsewhere too, throughout the whole of the Indo-Greek period and on to the close of the Indo-Scythian period, the date when Marshall's weights were buried. Since the Indo-Greek 'tetradrachm' is not derived from any well known Greek standard, logic suggests it will most likely follow a pre-existing Indian standard, and in the light of the above exposition of earlier Hindu traditions it is easy to see how this might be so.

Greek coining traditions tended to recognise a denomination called a 'stater' valued at 2 'drachms', each of which in turn was valued at 6 'obols'. Likewise the Persian coining tradition recognised a related denomination here called a 'shekel' which split into 2 'sigloi' which split in turn into 6 'daniks'. The Attic obol weighed about 0.73g and the Persian danik around 0.93g. Clearly Indo-Greeks traders, for practical purposes, would tend to identify the traditional Hindu masha, of c. 0.855g as being a species of 'obol'. So it was an obvious step to make a new 'Indian-stater' or 'Indian-shekel' that consisted of 12 of these 'obols'. However, twelve mashas should weigh 10.27g, not the 9.68g we find used for the Indo-Greek 'tetradrachm. $^{9.68}/_{10.27}$ x 12 = 11.31 mashas. Thus we do not have an exact fit between the expected 12 masha standard, and the actual standard we find the Indo-Greeks

employing. However the shortfall is not great, being around 6%, or $^{1}/_{16}^{th}$. Further, the new Indo-Greek coins were struck in near pure silver, not the c. 75% alloy used by their predecessors, the Mauryas. Thus is seems quite possible that the new Indo-Greek tetradrachm represented a 12 masha piece, but less a $^{1}/_{16}^{th}$ or so by weight, perhaps to allow for seigniorage.

Turning now to a much later text, written around 1020, a carefully considered piece by the Islamic scientist Alberuni, we find him identifying a weight he calls a tola, which according to his sources had already, in his day, been a fundamental Hindu standard from time immemorial. The tola that Alberuni refers to was a weight of 12 mashas, (thus 96 rattis). So we know that a weight of 12 mashas, called a tola, became very prominent in Hindu metrology long before Alberuni wrote. But we find no mention of either a tola, or a 96 ratti piece, in the Arthashastra or other ancient Hindu text. The tola appeared somewhere in between. The most likely point at which the tola might have entered Hindu metrology seems to be with the eruption of the Indo-Greeks and the creation of their new heavy "tetradrachms".[120] There does not seem to be any obvious alternative candidate. This 'tola' standard completes the set of weight denominations we need to explain most metrological developments in Hindu India.

1 masha	=	8 rattis		
1 dharana	=	4 mashas	= 32 rattis	
1 gadyana	=	40 rattis		
2 gadyanas	=	80 rattis	= attic stater	= gold-suvarna
1 tola	=	3 dharana	= 12 masha	= 96 rattis
1 suvarna	=	4 dharana	= 16 masha	= 128 rattis

The reader may perhaps have noted that, if the above speculation is correct, the Indo-Greeks created exactly the sort of problem in Hindu Metrology that we saw in 'Abd al Malik's system, and later between the Troy and Tower pounds. That is to say, just as we had two dirhems, and two pennyweights, one for bullion, and one for coin, separated by $^{1}/_{16}^{th}$ in weight, so we are going to have two tolas, again separated by just $^{1}/_{16}^{th}$ in weight. Given the problems we encountered sorting these matters out in connection with Early English and Early Islamic texts, resolving it with certainty in connection with early Hindu metrology, where we seem to have no relevant texts at all, seems too much to ask. All we can say is that, at the time of the creation of the tola, on the balance of probabilities, such a situation seems the most likely.

(697) *Indo-Greek drachm*

The Indo-Greeks also issued prolific quantities of the quarter to this new 12 masha coin. In part this was likely done to echo the Attic drachm, the quarter piece of the tetradrachm of Alexander and many other Greek states. But since the new three masha 'drachm' contained 2.42g of pure silver, this new 'drachm' could directly replace the old, somewhat debased, punchmarked karshapana (which theoretically contained 3.4g x 0.75 = 2.55g of silver) on a one for one basis. This would yield a slim profit to the mint, without much disturbing day to day commerce in the market place.

If the above line of reasoning is correct, then by their reforms the Indo-Greeks created a new slightly lighter ratti . It would weigh c. $^{15}/_{16}$ of the old ratti, thus c. 9.68/96 = 0.1008g, or for most practical purposes, 0.1g. As we will see below, this is what seems to have happened. Most likely over time Hindus continued to use their coins as weights, and a new theoretical ratti of 0.1g became the norm, defined by the Indo-Greek coinage. For convenience we will call this new lower standard the 'Indo-Greek ratti' or 'Greek ratti' for short.

We find corroboration for this line of thought in the weights Marshall found around post Indo-Greek Sirkap. The set he found in the jeweller's shop mentioned above were a pure binary extrapolation of the ratti seed, even more pure than the binary/decimal weight sets from Mohenjo Daro. But elsewhere in Sirkap a few none binary weights turned up, six in all. In Marshall's opinion they were intended to weigh 11, 13, 13, 60, 60, and 60 mashas. Allowing for possible incompetence and/or dishonesty in the construction of such unofficial weights, they suggest the same as the coins, that a duodecimal unit, a tola of 12 mashas, became a significant part of the Indian metrological system during the period of Greek rule in the North West. These non-binary stones are best interpreted as one and five tola weights.

The collapse of central rule away from North Western and Western India led for the most part to an abandonment of all but copper coin, and as copper coins were rarely made to a particularly exacting weight standard it is hard to draw any conclusions regarding metrology from them. Continuing silver use in the North West until the first century AD, and for much longer in Western India, followed the 'drachm' standard through Scythian, Western Satrap and Gupta times. Over the centuries the 'drachm' weight drifted slowly downwards, perhaps tracking the rate of wear in circulation. It slowly parted company from the Greek 3 masha standard of c. 2.4 grams, so that a 3rd cent AD Western satrap 'drachm' weighed about 2.2g, and a 5th century Gupta 'drachm' about 2.1 grams.

The Kushan Dinara

In Central and NW India silver coinage more or less collapsed into base metal around the start of the first century AD. About a century later, the Kushan ruler Vima Kadphises created a vast new empire, including much of Northern India and Afghanistan. He chose to create a completely new coinage for this empire, in gold and copper.

(719) *Kushan gold dinara*

The new gold coin seems to have been called a 'dinara' and weighed almost exactly 8.0g.[121] It is widely reported to weigh about the same as the contemporary Roman aureus, but there must be some doubt about that. There is surprisingly little agreement about the weight of the aureus. Perhaps late in the reign of Julius Caesar, or early in the reign of Augustus it did weigh 8 grams. But most put the average for Augustus lower, perhaps 7.86g. Further, it had fallen to about 7.3g by the time of Nero, 37-68 AD. Thus it would be a strange sort alignment to make, in around 90 AD in India. As we saw above, Hindu tradition already prescribed the issue of a gold-suvarna coin weighing 80 rattis. If we apply the hypothesis that the predominant weight standard in Kushan times was the above Greek-ratti, then the Kushan gold dinara, if a gold

suvarna, should weigh close to 80 x c. 0.1g = c. 8.0 grams. Exactly what we do see. Thus any suggestion of a Roman origin starts to look unlikely. More likely the weight arose from purely local considerations, being the traditional gold suvarna of 80 rattis. Further, I do not think anyone has ever considered the possible relationship between Kushan and Chinese metrology. Since the Kushans had their roots far to the east of India, and the tradition of a gold/copper bimetallism is strikingly similar to the money forms of Han China, with no precedent in Europe, Persia, or India, it would seem obvious to consider such a possibility. As we will see below, gold in China seems to have been weighed at that time in liangs, or Chinese ounces, where an ounce was 240 millet seeds, and 10 seeds weighed circa 0.66g. Thus the Chinese ounce at that time seems to have been around 15.8 grams, and the half ounce c. 7.9 grams. So one could as readily argue that a standard Hindu gold weight of 80 rattis was tweaked to coincide with a Chinese half-ounce, than that it was adapted to match Roman standards. From the fragments of information we have, it would seem possible that Vima might fix his gold standard with the intention of launching a new world currency, intended to unify all the world's metrological systems. But actual evidence that he did do this is lacking, and thus a new look at the data might lead to a much less exciting conclusion, that the Kushan standard was a purely Indian affair, based entirely upon a pre-existing Hindu 80 ratti/c. 8.0g gram standard.

It is worth pointing out that whilst for the mathematically adept international trader the Kushan dinar might be very convenient, for the Hindu man in the street things were getting more than a little complicated. Remember his coins probably doubled up as his weights. Under the Mauryas there were 3 coins (each of a dharana) to the 'tola' (of 12 mashas) but 4 to the chief weight, the suvarna (16 mashas). Under the Greeks we find that four standard coins ('drachms') apparently still make up the standard weight, but that standard weight has become the tola. Under the Kushans a new gold standard appears that is, at 8g, more or less equal to the 80 ratti 'gold-suvarna'and a rough approximation of 3 of the old Greek 'drachms'. Meanwhile the Kushan coppers follow Attic standards! It would not be surprising to find that Hindu ideas about metrological standards in general, and their nomenclature in particular, became confused amongst less numerate individuals.

Gupta Gold Issues

According to the account in Allan the Gupta dynasty around 400 AD issued its gold dinara at about 8.1g. The weight was raised once more around about 500 AD, this time to about 9.5g. And it seems that, regardless of which of weight standard was applied, both these coins were called either a 'dinara' or a 'suvarna' in a rather promiscuous manner in early medieval texts.

(752) *Gupta gold dinara*

The earlier standard seems hardly different from that of the Great Kushans, but the latter standard, that of c. 9.5g makes no sense as a gold suvarna at all. Our best guess is that it is an attempt to fix the dinara, not at a gold suvarna of 80 rattis, but at a tola of 96 rattis. Applying the Greek ratti, this of course should weigh a little more, c. 9.60g. So the fit is not as good as one would like, but no simple alternative explanation presents itself. Sangraha, who wrote in the 9th century AD, defined a dinara as containing 192 yava (grains), which in a Hindu context probably equates to exactly 96 rattis.[115] This suggests that these late Gupta gold dinaras may well have been fixed at a tola in weight.

For reasons that will emerge later in our account, authors such as Thomas, writing in the 19th century, incorrectly identified this c. 9.5g coin as the very ancient gold-suvarna of 80 rattis. Such a calculation implies a ratti of c. $^{9.6}/_{80}$ = 0.12g. But that standard, as we will see below, is a different 'heavy weight' or perhaps 'Islamic-ratti'. Such a standard perhaps did exist at a very early period, in connection with the Taxila bent bar coinage, as discussed above. However, I can see no reasons to view this as other than a coincidence, without additional evidence. It contradicts the testimony of Alburuni, accounted below. The heavy ratti which Thomas was so familiar with is not clearly attested before the Ghorid invasions of the early 13th century. Thus an anachronistic and misguided mid-19th century interpretation of the weight of the Hindu ratti has continued to bedevil Indian numismatics for the last 150 years. It ought to have been rejected when Marshall published his findings about 70 years ago. It should be rejected now. We must fundamentally revise all these 19th and 20th century numismatic ideas in the light of the findings at Mohenjo Daro and Sirkap, and the subsequent rediscovery of the Arthashastra text. Interestingly, '80 rattis' in the (later) Islamic systems does correspond to '96 rattis' in the (old) Hindu system, we shall return to the significance of that coincidence.

The Shahi 'jital'

After the fall of the Guptas, Indo-Sasanian coin types, apparently struck to Persian weight standards, came to dominate Medieval Indian circulation. These were imported by the Huns and others, as will be accounted below. The Ancient Hindu metrology seemed to become extinct in India, at least regarding coinage matters. But in Afghanistan around (very roughly) 750 AD, the ancient metrology was apparently resurrected.

This is apparently how it happened. Lagarturman, the last of a line of kings ruling in Kabul, claiming descent from the Great Kushans, was overthrown. His Brahmin minister Kallar took control and founded the Hindu Shahi dynasty. Away to the West, Moslem Caliphs had very successfully launched their distinctive iconoclastic silver dirhem around 700. In 750 AD Moslem armies stood at the gates of both the Hindu Shahis in the East and Christendom in the West. It was at just about this time that Charlemagne put a Christian Cross at the centre of a brand new European coin, a kind of European version of the dirhem, the silver penny. It is surely not a complete coincidence that simultaneously, in the East, another brand new coin appeared, the 'jital', centrally featuring a Hindu religious icon, the Bull.

(809) *Shahi jital*

The very first of the Bull and Horseman jitals weighed about 4.2 grams and thus seem to be struck to the standard of the Persian mithcal. These are very rare. I know of no metallurgical analysis of these very early issues, but subsequent Shahi jitals seem to be about 70% fine silver. If the first issues are struck from the same metal, their silver content would be c. $^{7}/_{10}$ x c. 4.2g = c. 2.94g, that is to say, about seven-tenths of a Persian mithcal, thus a very good approximation of the actual weight of the pure silver early Islamic reformed dirhem of 'Abd al Malik. (Metallurgical analysis of these very early jitals would quickly determine whether they were good silver and likely intended as versions of the obsolete Persian drachm, or debased silver and perhaps intended to equate to the reformed Islamic dirhem. It is a pity that, to the best of my knowledge, such analysis has never been carried out).

Very soon the weight of the Shahi jital was lowered to about 3.4g.[121] A vast number of coins were struck at around this weight. This is clearly neither an Islamic dirhem nor a Persian mithcal. The only standard it does seem to resemble is the old Mauryan dharana, used in the same area, but abandoned almost a thousand years earlier. If calculated according to the ancient ratti in use until Mauryan times, four masha would also weigh c. 3.4 grams. The actual Shahi standard apparently dropped over time, but that is to be expected over two centuries or more. Thus we have a prima facie case that the Shahis resurrected the very ancient dharana denomination.

However, the crucial evidence that the Shahi jital standard was fixed to a still extant traditional Hindu 4-masha standard comes from the Moslem commentator Alberuni. Alberuni travelled in India during the early decades of the 11th century AD. He was a leading mathematician and scientist of his day, with an objective and open minded outlook, and an outspoken manner. The Ghaznavid Sultan Mahmud disliked to him and sent him into internal exile in the new Ghaznavid territories of India, where Alberuni usefully spent his time exploring and recording the Hindu science and philosophy of those times. Amongst his writings is a priceless account of Hindu metrology in the early post Shahi period.

Alberuni tells us that in their fundamental system of weights, Hindus used a very old standard exclusively for weighing gold called a suvarna which was reckoned as 16 mashas, and that the suvarna approximately equalled 3 Arab mithcals. Alberuni makes it clear he is talking about a mithcal which is $^{10}/_{7}$ of the dirhem, which is surely the canonical Arab mithcal of 4.25 grams. Thus the suvarna he was talking about was roughly 12.75 grams. He also makes it clear that they more frequently used a tola, a weight of 12 mashas, as their standard unit of account, (and that they counted not weighed their dirhems for payment. Further he adds rather cautiously that, according to what he had been able to learn, their tola weighs 3 of our (i.e. Islamic) dirhems.[122]

It is obvious that Alberuni was explaining the same general weight system, a suvarna of 16 mashas, that we found recorded in the Arthashastra about 1300 years earlier, and that we saw exhibited in the weights of the Indus Valley 1,500 years earlier still. Our puzzle is working out what (if any) exact standards in grams these weight denominations were calibrated to by his time. It is clear from Alberuni's testimony that Hindus themselves were very confused about this matter, and he was only able to give a very rough account of their rather hazy beliefs and practices, on the basis of the informants he met. As mentioned, one of those suggested that a tola was 3 dirhems, that is to say, on the basis of his defined dirhem of 2.97g it would be roughly 8.91g.

(459) *Ghaznavid silver dirhem*

This would also be a quite good approximation of the weight of three Ghaznavid dirhems, current coin in Alberuni's day, which were apparently being produced at the old Shahi mint, on similar flans to the earlier Shahi jitals.[123] Thus we might make the assumption that this is a bazaar weight, calculated according to the coins in circulation, and that just before the conquest, about 20 years earlier, such a tola would have represented three Shahi dirhems, which were, as mentioned, just a little heavier, and so would have weighed around 9.6g to 9.9g. If we make this assumption, then we have a tola that roughly tallies with the information Alberuni got from his second informant, that the suvarna was around 3 mithcals, or c. 12.7g. (That of course yields a tola of around 9.5g). Thus we are roughly dealing with a tola and suvarna figured at close to the old Greek-ratti standard (c. 9.6g & 12.8g). The fit is not exact, but given Alberuni's own reservations about the reliability of his information, they are surely accurate enough to strongly suggest that the traditional Hindu system was still in place in late Shahi times, and that that was the system that the Shahis had adopted when they first issued their jital a couple of centuries or so earlier.

Alberuni further tells us that the weight of 6 mashas was called a 'drankshana'. Written in Arabic *dr-ksh-m* looks very like the Greek word 'drachm'. If the word was borrowed from the Greek, then that would strengthen our earlier argument that the masha had been associated by Greeks with the obol, since a drachm was 6 obols just a the drankshana was 6 mashas. Which in turn gives extra weight to the suggestion that the so called Indo-Greek 'tetradrachm' is more realistically equated to a stater of two drachms, that is to say, 12 mashas. So this etymological evidence further supports the hypothesis lodged earlier, that the introduction of the tola into the Hindu weight system, with its move from binary to duodecimal reckoning, was due to Greek influence.

Throughout his account Alberuni stresses that there were many varying weight systems and terminologies in use in India, and many mistakes were being made concerning their usage. He classified them into one universal and correct system (corresponding well to the binary system of the ancient stone weights) and many local, confused, and incorrect ones (which do not). Among the confused ideas he mentions is the 'false' idea that the suvarna was equivalent in weight to 3 of 'our dirhems' (i.e. c. 9 grams). This perhaps points to the confusion inherent in associating the weight of the Gupta gold coin of c. 9.5g (sometimes called a 'suvarna') with the canonical suvarna weight, which both he and I prefer to use in conjunction with much older and much heavier c. 12.7g - 13.2g standard.[124]

The Vijayanagar Pagoda

Thus, on the evidence of both the coins and Alberuni's testimony, the Shahis of Medieval North West India seem to have been out of step with the rest of the subcontinent, in resurrecting the traditional Magadhan metrology. Most of the medieval silver and gold coins of Central and South India

seem to derive their metrology from the Persian mithcal, theoretically about 4.17 grams, in ways which will be accounted below. However from about 1200 onwards the various gold pagodas of the South fall away from that standard. At the time of the rise of the Vijayanagar empire, in the late 14th century, a 'new' standard seems to emerge. If we consider the very earliest of the Lion obverse silver Vijayanagar coins issued around Bhatkal, they weigh around 1.9 grams, but much commoner later issues of the same type average rather closer to 1.7 grams in weight.[125]

(834) *Vijayanagar lion type* & **(837)** *'tara'*

The tiny silver taras of a similar period seem to fit into the same pattern, thirty two of them in mint state put on a scale weighed 3.19 grams. So these two coin types look as if they might have been adjusted to the ancient 2 masha and 1 ratti standards respectively.

(839) *Vijayanagar gold pagoda*

The evidence of a reversion to the ancient standards got from the early Vijayanagar silver is admittedly slender, but thence forward we get a long series of gold pagodas issued by Vijayanagar kings weighing 3.4g, along with half pagodas of 1.7g. That standard then persists for another 4 centuries, right into colonial times, with for example the British 'three swami' pagoda at Madras (1740-1807) being carefully regulated to 3.43g.

We saw above that the Shahis seem to have reverted to ancient Hindu metrology when directly confronted by a warlike Moslem culture around the 8th century AD in the far North of India. It looks as if that Vijayanagar did exactly the same in South Central India in the 14th century AD. The standard of the pagoda is astonishingly close to that of the very ancient standard of the 4 masha dharana, the standard at Mohenjo Daro, and of the Mauryans. As with the Mauryans, it seems very unlikely that the Shahis or Vijayanagar had ancient Mauryan stone weights to rely upon, more likely they relied upon traditional account of the system and took their standards from ratti seeds themselves, or ancient punchmarked coins, or a combination of the two. Writing in the mid 19th century Thomas[126] noted a series of monies of account that were still then in use in South India which made 4 rattis equal to a fanam and 8 fanams equal to a pagoda. Likewise writing in 1924 Codrington[127] notes that in Telegu money reckoning at that time the pagoda was divided in a binary fashion into 32 bedas, where a beda is a ratti seed. The physical weights and the mathematical structures of these systems are exactly those of the Arthashastra, Indo-Scythian Sirkap, and the Indus Valley.

Hindu Weight System: Summary

A fundamental Hindu weight system exists and is characterised by an absolute theoretical standard of c. 13.7g, a suvarna, divided in a strictly binary fashion down to a single ratti seed. Strong evidence suggest the system was in place by about 2,600 BC and that it was still in place when the Indo-Greeks entered India in c. 180 BC. It seems very probable that the Indo-Greeks created an adjusted version of that metrology. The same metrology was very probably resurrected by the Shahis around 750 AD. The same metrology was very probably resurrected again by Vijayanagar as the basis of the South Indian pagoda system.

The key insight in this chapter, and in the study as a whole is this: ***A weight system comprises two things: an absolute standard, and a mathematical system of dividing it up. There can be almost no doubt that weight systems can persist little changed for millennia, regarding both their mathematical structure, and, at least in some cases, their absolute weight standard.***

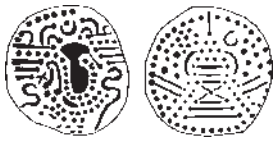
Indo-Sasanid coinage

The discussion of Sasanid weight standards above noted the adoption of the c. 4.17g standard drachm by Peroz, and the termination of this standard in Persia a little after the Islamic conquest in the 7th century. However, that was not the end of the story, as this c. 4.17g standard, abandoned in Persia, apparently lived on and dominated Indian coin standards in the medieval period. We will explore that matter now.

In the later Sasanid period a huge ransom was paid to the Huns for the return of Peroz, 459-84, and the vast number of Peroz drachms contained in this payment became the staple currency of the Huns, used and later copied in the lands they occupied.

(105) *Sasanid Peroz drachm*

Close copies of Peroz drachms are found in early medieval Afghanistan, North West India, and Gujarat, in all cases probably due to the influence of the Huns. On some accounts Gujarat takes its name from the Gujaras, an offshoot of the Hunnic invaders. However, it should be borne in mind that when the Arabs conquered Persia (around 651 AD) it is believed that many Persian refugees fled to Gujarat, who laid the foundation of the modern Parsee population in India. Thus it is possible that an influx of Persians about that time also had a bearing upon the adoption of Sasanid coin types in India, especially in the Gujarat area. Which cultural influence was strongest, the Huns or the Parsees, we do not know, but between them they brought a new Sasanid style of coin, struck to the Persian weight standard, into Gujarat and Rajasthan.



(787) *Gadhaiya Paisa*

Early, realistic copies of Peroz 'drachms' are scarce in India, but a chain of increasingly stylized copies eventually leads us to a very common coin type indeed, the so called 'Gadhaiya Paisa'. These exist in vast numbers and seem to have been struck in and around Gujarat for about 400 years, down to the Moslem conquest of Gujarat around 1300 AD. Their silver is variously debased, but they weigh quite often just a little over 4 grams.[128] Within India there were many

varieties of Indo-Sasanian base silver coinage, most of which seem to follow the Persian mithcal weight standard.

(780) *Bhoja base silver Adivaraha dramma*

Other coins developed alongside them which bore only slight traces of Indo-Sasanid influence, but still respected the Persian weight, such as the 'Adivaraha dramma' of King Bhoja 836-85.[129] As a memento of their Sasanid origins these coins have a diminutive stylized fire altar below the inscription on the reverse.

(796) *Govinda Chandra gold 'Lakshmi stater'*

The base silver Adivaraha drachms of the Pratiharas were replaced as the staple currency of Northern India around 1000 AD by gold coins which bear no resemblance in design to Sasanid coins at all. However the new 'Lakshmi staters', such as the issue of Govinda Chandra pictured above, still weigh close to a theoretical Persian mithcal, at c. 4.13g.[130] Govinda's gold coin directly succeeded the billon type initiated by Bhoja at the same place and the same weight standard, and thus very likely also followed the Persian mithcal tradition. In design however the Lakshmi gold coins are apparently stylised versions of the gold Laksmi issues of the Guptas. As we have already seen, the Guptas seem to have struck some of their issues to an 80 ratti standard, probably taking their tradition from the ancient text such as the Arthashastra. Ultimately it seems that standard is best explained as deriving from Attic practice, and thus c. 8.6g. But transformations to the ratti since that time much complicated matters, and it is no surprise that by the time of Peroz, around 500 AD, a kind of Persian half shekel coin became understood as the same 40 ratti in India, but now at 4.15g. So these 'lakshmi stater' coins might seem to be either Persian mithcals or half staters, as you choose, of circa 4.17g. Further yet, textual evidence shows that Govinda Chandra levied a tax called the kumara-gadianaka which presumably was collected in gadyana weight coins, and which more or less have to be these 'laksmi staters', which dominated his coin issue. And the gadyana is of course the name of the South Indian 'bean', the 'kalanda', whose weight is traditionally taken to be 40 rattis. Thus throughout the medieval period Hindu officials seem to have been fixed on a formula that a Persian mithcal, or half gold-suvarna, equated to 40 Hindu rattis, just 3.5% astray from the original Attic standard. In both Central and Southern India from around 1000 AD onwards we get other coins which also seem to be called gadyanas, and which also weigh c. 4.15g.

(831) *Chola silver*

For instance, from South India we get gold and silver coins of the Cholas, such as this silver inscribed with the name Uttama Chola, probably issued around 1012-44 AD, which weighed very close to a Persian mithcal at c. 4.18g.[131] Texts indicate these coins were associated with the same gadyana tax under the Cholas in the South that we saw levied under Govinda in the North. More than that, we get evidence that at least some versions of these coins were figured in the Indian tradition at 40 rattis.[132] Thus again linked to the Persian mithcal as above. Medieval Canarese accounting tables routinely describe the gadyana as weighing 40 mashas.[133]

Thus it seems very probable that an imported Persian standard of c. 4.17g regulated the weight of a very large proportion of India medieval coinage systems.

Simple mathematics show us that 4.10g x $^{5}/_{2}$ = 10.25g Thus 5 typical gadhaiya paisa, taken out of circulation, could be used to make a good approximation of the weight of two canonical Hindu tolas, that is to say, the tola of c. 10.26g, the very ancient Magadha standard that probably best represents what 96 ratti seeds actually weigh. In itself this coincidence might seem just that, a chance fact, of no importance. However, when we come to study Indo-Moslem weight standards we will see that the relationship between various later standards seems to be governed by a presumption of a such a fixed $^{5}/_{2}$ relationship. In due course we shall examine how this notion seems to have influenced the (Persian) Sefavid mithcal, Akbar's Moghul rupee, the larin, and the Gujarat kori.

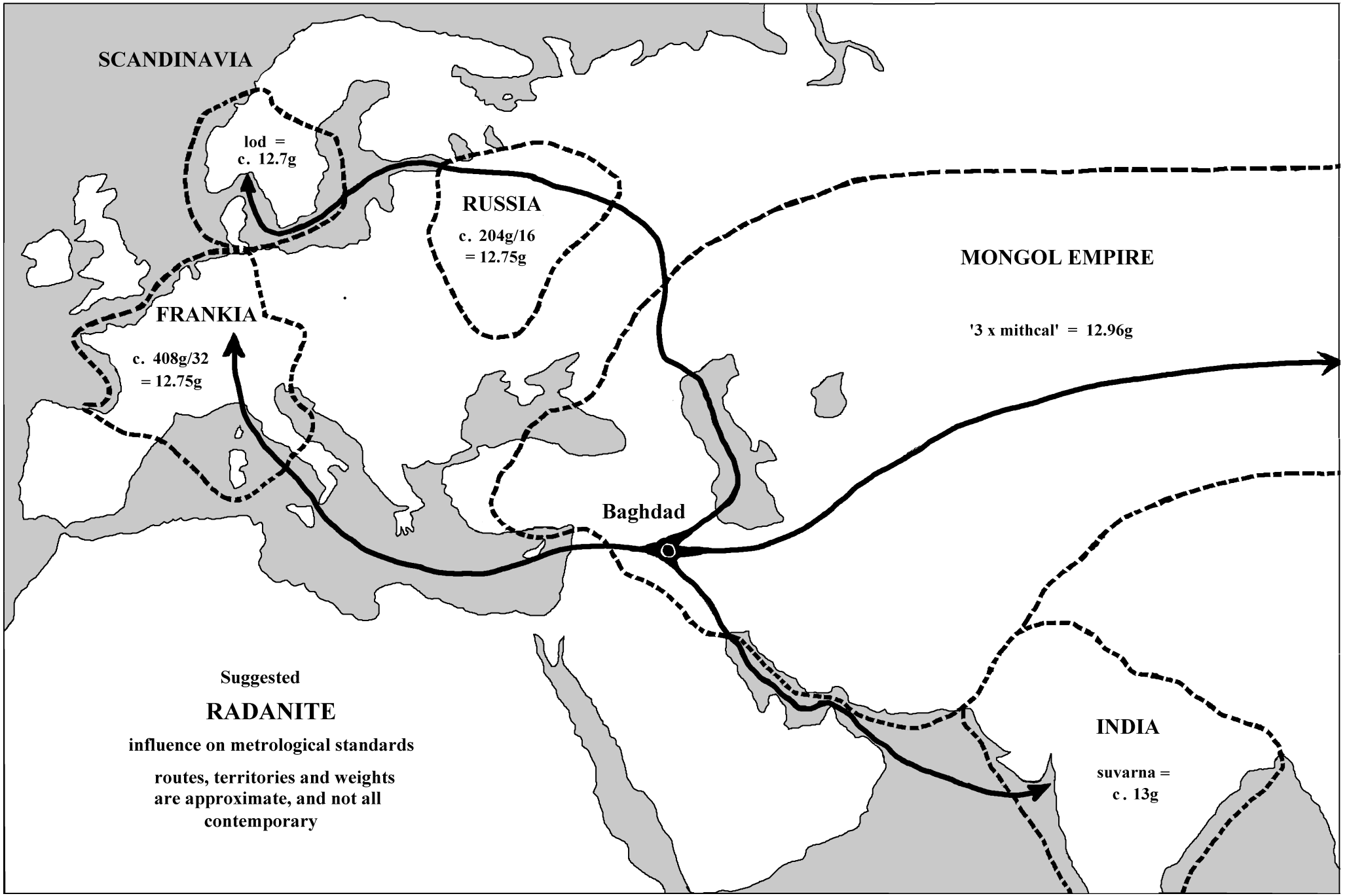
We noted above a suggestion by Alberuni which associated the Hindu suvarna with three Arab mithcals. Again when we come to study Indo-Moslem standards we will see how this convention also perhaps became deeply entrenched. This seems to create a permanent tension within Indo-Moslem metrology, since if we try simultaneously to make a tola equal to $^{3}/_{4}$ of a suvarna, but also to equal $^{5}/_{2}$ gadyanas, and yet make a suvarna equal to 3 gadyanas, then, obviously, we are going to run into difficulties.....

Mongol, Later Persian and Russian standards

In the early 13th century Mongol armies conquered Central Asia and Persia, along with much of China. Inevitably this impacted upon existing metrological systems, though as usual, we are left to guess the nature of the changes they wrought, in large part on the basis of the surviving coins.

(490) *Khwarezm Shah jital*

Immediately prior to the Mongol invasion, the Khwarezmian Emperor, Ala-ud-din Muhammad, 1200-20 AD, struck an extensive billon coinage in the area of modern Afghanistan. Most of the coins seem to ultimately derive, in general fabric, from the 32 ratti jital of NW India. Idiosyncrasies in these issues include coins in the North and West of the Empire, around Taliqan, Kurzuwan and Herat, which seem to consistently weigh closer to c. 2.8g, thus perhaps representing the 'dirhem of two thirds' i.e. 4.24g x $^{2}/_{3}$. They also include coins from the North East of the empire, Qunduz, which weigh about 4.2g, thus full mithcals by weight.[134]


SCANDINAVIA
lod =
c. 12.7g
RUSSIA
c. 204g/16
= 12.75g
MONGOL EMPIRE
'3 x mithcal' = 12.96g
FRANKIA
c. 408g/32
= 12.75g
Baghdad
Suggested
RADANITE
influence on metrological standards
routes, territories and weights
are approximate, and not all
contemporary
INDIA
suvarna =
c. 13g

(503) *Ghengis Khan billon jital*

Ghengis Khan struck few coins himself, the only reasonably common issue ascribed to him is a species of billon jital apparently struck at Ghazni. It seems to copy a c. 3.1g issue of the Khwarezm Shah, but clearly itself aims at c. 4.2g. This suggests that the Mongols had an early preference for the Islamic mithcal standard.

(513) *Early Ilkhanid silver dirhem*

This impression is reinforced by the early Mongol silver issues in Persia, of the Ilkhanids, which initially often seems to weigh close to the 2.8g 'dirhem of $^{2}/_{3}$rds' standard, although later issues drop away from this weight.

(516) *Ghazan silver double dirhem*

However, the rather ad hoc post conquest Ilkhanid coinage standards were all swept away by a major reform of the coinage brought about by Ghazan around 1298 AD. It is associated with a large c. 12.96g silver 'dinar', which comprised 6 'dirhems' each of c. 2.16g.

Drawing upon literary sources Album tells us that this silver dinar, figured as equivalent to three mithcals in weight, became the Mongol unit of account as early as the 1240's.[135] Thus the 1298 monetary reforms of Ghazan seem to bring the coinage into line with a pre-existing Mongol weight system. During subsequent decades of the early 14th century, Ilkhanid silver coinage underwent a series of hefty weight reductions, such that 50 years later the physical silver dinar coin weighed even less than the dirhem of account; a more than 6-fold reduction in the silver content. Thus the fundamental metrology and the physical weight of the coins rapidly parted company. These rapid centrally directed devaluations coming at a rate of about one every 5 years, seem to be a kind of tax on money, a fiscal process deliberately set in train by the state.

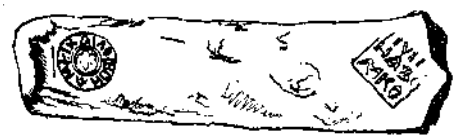
Since our interest here concerns only the most fundamental relationships between coinage and metrology, our key problem is: why did the Ilkhans adopted three mithcals, each of c. 4.32g, as their weight standard for silver? But this is really not one question but two. Firstly, why a unit of three mithcals, not one of a single mithcal? Secondly, why a mithcal based on a standard of 4.32g, when the canonical Islamic dinar had long since been established at c. 4.24g? This 12.96g standard, called the 'currency dinar' continued to represent the fixed weight underlying Persian currency, to which subsequent calculations referred, long after the weights of the coin themselves had fallen very substantially.

So firstly, recall that this is not the first time we have met a weight standard of 3 mithcals. The earlier instance was the standard weight found in Scandinavia around the 10th century AD, the lod, accounted above. In it we saw a useful way in which Islamic mithcal weight could be readily converted to Carolingian coining ounces. A lod of 3 mithcals was about half a Swedish ounce or 'ora', which in turn was rather close to the ounce of Charlemagne's coining pound.

((3 x 4.24g = **12.72g**) x 2 = 25.44g) x 16 = 407g = 240 x 1.7g

This was explained in part by the Vikings wishing to simplify exchanges with both eastern (Islamic) and southern (Frankish) trading partners, and in part by the possible influence of international Radanite Jewish traders. But in connection with this matter we should note another geographical fact: the Mongols were also bounded in much the same way. Their 'south-western neighbour', Islam, was entirely conversant with a weight of 3 mithcals. And their 'western neighbour', Russia, seems to have been using something very like a Carolingian mark as the basis of its currency in the 11th to 13th centuries. For, after a brief flirtation with coinage in the 10th century, Russia returned to the use of rather heavy ingots, called 'grivna' or later, 'roubles'. These are somewhat variable in weight, but a consensus seems to exist suggesting that in both cases the full unit was intended to weigh c. 204g,[136]

Medieval Russian Grivna silver ingot



Medieval Russian Rouble ingot

Thus they would equal the 8 ounce mark of Charlemagne's coining pound. In sum, as the Mongols were geographically placed somewhat similarly to the Vikings, in metrological terms, it is no great surprise when they also to adopt a standard weight of 3 mithcals. Even more striking is the further fact that 'southern' neighbours of the Mongols, Hindus, traditionally used a dharana or jital in practice of about 3.3g, four to a suvarna of around 13g.

All of this could still be dismissed as a set of surprising coincidences, were it not for the likely influence, in all these areas, of Radanite Jewish traders. Let me now quote in full a short piece which Ibn Khurdadhbah wrote in his 'Book of Roads' in 836.[137]

"*The Radanites speak Arabic, Persian, Greek, Frankish, Spanish, and Slavonic. They travel backwards and forwards from the farthest west to the farthest east . From a starting point in Spain or France they cross the Mediterranean to Egypt, transfer their merchandise to camels across the isthmus of Suez to the Red Sea, from where by ship they can reach India and China. They return bringing musk, aloewood,*

camphor, cinnamon, and other products of the oriental countries. Likewise from the west they bring eunuchs, slave girls and boys, brocade, beaver and marten skins, and swords. They sell their goods in Constantinople and at the palace of the Franks. Sometimes, instead of using the Red Sea route to the East, they disembark at Antioch and cross Syria to the Euphrates and Baghdad. From there they go down the Tigris to the Persian Gulf, and so on to India and China.

They also travel by land. Thus these Jewish merchants proceed from the far West via Tangier, Kairouan, and the other North African towns, reaching Cairo, Damascus, Kufa, Basra, Ahwaz, Persia, and then on to India, before again, this time by land, reaching China..

Another of their routes lies across Europe, behind Rome, and through the country of the Slavs to Khamlij (Atil), the capital of the Khazars. From there they cross the Caspian Sea, thence to Balkh and Transoxiana, and so to China."

It is inevitable that networks of merchants travelling and intercommunicating along these routes would be intimately acquainted with all the metrological standards accounted above. In fact, it seems most likely on the basis of what has already been said, that there are at root only two basic coincidences here. The first is the very rough correspondence of three mithcals, canonically 12.72g, with the Hindu suvarna, which equated to something between 13.2g and 12.8g during the life of the Shahi dynasty, c. 750-1000 AD. The tweaking of three mithcals upwards, to a weight of 12.96g could serve to regularize trade between Mongolia, Islam and India around this new unit. The second coincidence, noted previously, is that if we create a standard of three canonical Islamic mithcals, we get the 'lod' a unit of c. 12.72g. 16 of these are a good approximation to 15 Roman ounces, which was Charlemagne's coining standard. Thus eight of them is obviously a good approximation to a Russian rouble ingot too.

We identify a single unit of 3 mithcals here, but it is a reasonable fit for two different standards, one of c. 12.72g (Sweden), the other of c. 12.96g (Ilkhan). There is no great problem in associating the two standards however, because two different periods are involved. We can distinguish an early Western phase which seems likely to have evolved in the ninth and tenth centuries, at a standard of about 12.72g. The later Eastern phase appeared sometime before the mid-13th century, and was about 2% heavier. It is easy to believe that a three mithcal weight might have been adjusted by about a quarter of a gram over a period of three centuries, perhaps by the Mongols themselves, to bring it into line with other Eastern standards. The possibility that this later 'lod' was correlated with a Hindu suvarna of around 13g was mentioned above. Correlation with Chinese affairs is also an important consideration here, regarding the vast Mongol Empire. Some authorities suggest that the Chinese liang was fixed at 37.3g from the Tang through to the Qin dynasties, but Iwata[138] estimates the liang higher in earlier dynasties, 41.69g under Tang, falling to 38.33g under the Yuan Mongols. 12.96g x 3 = 38.88g, thus the dinar of the Ilkhanids is tantalisingly close to one third of the Chinese liang under the Yuan Mongols, on this estimate.

It seems likely to me that most of these weights, the Scandinavian lod of 3 mithcals, c. 12.7g, the Carolingian coining pound of c. 408g, the Russian grivna of c. 204g, and the Mongol 3 mithcals of c. 12.96g stem from a system created by the Radanite Jewish traders, with just very minor local variations showing up in the standards when we encounter them, often centuries after they were probably created.

Critics might still wonder whether this whole system of correspondences is not just a kind of gigantic mirage, that these weights and practices perhaps fell into alignment by accident. This is of course possible. However, that would leave us with three important problems completely unexplained

i) Why did the Ilkhans adopt a 3 mithcal standard?

ii) Why was this standards adjusted upwards to 12.96g?

iii) Why did Russia alone in Europe, (outside France) adopt a standard corresponding to a Carolingian mark?

There will be more to say later regarding the post-Mongol metrology of Persian and Central Asia, but largely to do with its relations with the Indian rupee standard. So we postpone that discussion and return now for a final time to India.

Indo-Moslem standards

The Caliphate made initial inroads into Western India in the early eighth century AD. The Moslem province of Sind seems to have used imported Islamic coins from Persia at first, no doubt side by side with contemporary Hindu coins from territories to their North and West. Thus these first Islamic Indians would be faced with the problem of operating two incompatible metrologies. Let us reprise what we have conjectured about these two standards.

The Islamic monetary system of the 8th/early 9th centuries AD largely comprised of dirhems to a 2.92g standard, which would likely be treated as circulating bullion in the later 9th century. The Arabs allowed all sorts of rather arbitrary local divisions into grains, but it seems likely that the 2.92g dirhem was regularly divided into 60 grains of c. 0.0486g. These are the familiar troy wheat grains, which might also be called 'real' wheat grains, in so far as that phrase has a meaning.

Meanwhile, Hindus primarily figured their weights in mashas of 8 rattis, with the basic coin weight being a dharana of 4 mashas, accompanied by a tola equalling three of these coins, (96 rattis) and a suvarna four of these coins (128 rattis). According to the earliest stone standards this was all based on a ratti of 0.107g, a masha of 0.855g and a 32 ratti coin weight of 3.42g. By the 9th century AD this system was still in place, the shahis having resurrected the original standard, although their coins fell away from that full standard over the following two centuries, to about 3.2g.

It is obvious from the above that, in a rough and ready way the rattis was equal to two grains (of about 0.05g). Around 1000 AD we find Alberuni defines the suvarna not as 128 rattis but 256 grains ('yava'). Likewise it is obvious that the ordinary Arab 10th century traveller, meeting with a late period Shahi 'drachm' of c. 3.2g, is going to view it as a species of dirhem (2.97g).

(802) *Anonymous silver masha, c. 9th century AD*

The coin that seems to have most influenced early Islamic practice in Sind was an anonymous silver piece of about 0.8g, which very probably represented a Hindu masha. Sometime around 900 Moslem rulers of Multan created their own version of this coin, initially at a similar weight. Over subsequent decades its weight fell, eventually to about 0.5g. To the South, in the area of modern Karachi, the Habbarids struck a similar series of coins, but with purely inscriptional types.

(866) *Multan Islamic silver 'masha'*

These all seem to weigh approximately 0.5g. The very final phase, posthumous issues of Ahmed, seem to be calibrated even more exactly, to a 0.49g standard

(879) *Ahmed silver danik*

A Moslem coin of about 1000 AD weighing 0.49g must very likely represent a danik, $^{1}/_{6}^{th}$ of a legal dirhem of 2.97g. It is surprising to find such an issue in 11th century Islam, since away from the Hindu marches coinage was issued on random weight flans, and circulated by weight. Contrary to this, the Moslems of Sind apparently struck their later coins to strict (Islamic) weight standards, so as to pay them by count in the Hindu manner. Tracking the steps by which this change took place over the course of the 10th century is more problematical. The earliest issues seem to be 0.8g mashas, thus 'farthings' to the Shahi 'jital'. And the last phase coins seem to be Islamic daniks. But there seems to be an intermediate phase, at a standard of perhaps 0.6g. This mysterious standard might represent a Persian danik, the $^{1}/_{6}^{th}$ to the c. 4.15g Persian drachm, or gadyana, as we have dubbed it in its Indian incarnation.

In the reign of Mahmud of Ghazni, 998-1030 AD, Islamic rule pushed further into India, roughly to the Eastern borders of modern Pakistan. As mentioned, Islamic practice had abandoned the issue of coin at fixed weight standards but as Alberuni informs us, Hindu practice was not to weigh their coins, but to count them. Worse still, for Hindus, coins probably served as weights for many bazaar transactions. This mismatch in the approach to maintaining metrological standards seems to have created near anarchy in the metrological system as understood by the population of early Moslem India, if we judge the matter by Alberuni's account.

It is against this backdrop that we must try to understand the weight standard of the unique 'gold dinar' of Mahmud of Ghazni, struck in India in 1005, and weighing 11.62g. [139] At about this time, the circulating Shahi 'bull and horseman' coins weighed about 3.2g. Thus a tola in the bazaar should weigh c. 9.6g, and a suvarna c. 12.8g. This dinar seems a poor fit for either. However, at this date a Hindu gold coin ought to weigh a suvarna, according to Alberuni, and in some understandings at least, the weight of the suvarna was notionally shifted to make it equal 4 dirhems. Now, 'gold dinar' of 11.6g is a reasonably good fit for 4 Islamic legal dirhems (11.88g). So the indications seem to be, if anything is indicated at all, that this 'dinar' was a new 'Islamic' species of suvarna. But it is unwise to hypothesise too much on the basis of just one specimen, which might after all be just a presentation piece, struck to no intentional standard at all.

The Silver 11g Tanka, and the Rupee

Ghorid armies pushed much further into India at the end of the 12th century, rapidly taking both Delhi and Bengal. Within a couple of decades 'tankas' of around 10.5g were being struck in both gold and silver. The surviving accounts and coins produced by Thakkura Pheru, mint master at Delhi around 1320, show that an 11g coin was, by that time, viewed as a tola. This 'tanka' contained 12 mashas, each masha being 16 grains. Pheru's tola was figured unambiguously as 192 grains (java), but in two different sorts of rattis, for it equalled either 96 'banker's rattis', or 72 'jeweller's rattis'.[140] The 96 ratti version seems to have been the most widely used. This new set of equivalencies established a completely new heavy Islamic 'delhi-ratti' of about 0.115g.

(904) *Delhi silver tanka*

There can be no doubt that this coin was intended to represent a continuation of the ancient tola of 96 rattis, since versions of the bull and horsemen jitals[141] continue to be struck as its subsidiary coinage, but now raised in weight to around $^{1}/_{3}^{rd}$ of the new tanka coin, thus to c. 3.6g.

(895) *Delhi billon jital*

Although the weights of the billon coins vary somewhat, they very clearly evolve into the later 'dugani' and kindred issues of the early 14th century sultans, struck to the same weight standard. We can see from Pheru's accounts that such coins were intended to be 32 ratti pieces, thus three to the tola by weight, (but, being debased, not by intrinsic value).

There can be no doubt that the weight of the tola was changed at around the time of the introduction of the Ghorid/ Delhi tanka, since according to traditional Hindu precedent it should have weighed much less, towards the bottom of a range of weights between 9.6g and 10.3g. It can hardly be a coincidence that a 3,000 year old Hindu standard underwent a quantum shift in magnitude at the very moment of the Moslem conquest. In order to explain this shift we must surely look for an attempt to accommodate traditional Hindu measures to the Islamic standards of the new rulers.

Despite much thought, I have not found any really clear cut explanation of the raising of the tola weight from c. 9.6g to c. 11g. The matter is the most perplexing I have come across in this entire study. The standard cannot have sprung out of thin air, and the preceding Hindu and Moslem traditions seem clear enough, yet no very obvious mathematical relationship leaps from the page. All that can be done is to present the most likely looking of the possible solutions, unsatisfactory though the move is. Bearing in mind this caveat, what I propose is that the Ghorid tola was initially not a Hindu tola revised upwards, but a suvarna revised downwards. The logic of the suggestion runs as follows. A suvarna was traditionally the weight of four coins (four 'dharana', which in this context are 'jitals'). These jitals weighed c. 3.2g, thus very approximately an Islamic dirhem, at the time of the conquest. Thus we can imagine a new bullion suvarna being created, and being standardised at four Islamic legal dirhems for the convenience of the new Moslem rulers: 4 x 2.97g = 11.88g. Having created such a new bullion standard, the Ghorids might then have taken a seigniorage of $^{1}/_{12}^{th}$, creating a new coin, a tanka, weighing around 11.88g x $^{11}/_{12}$ = 10.98g. The obvious

problem with this suggestion is that in the early fourteenth century, Pheru clearly calls this piece a tola, not a suvarna. Perhaps this arose because, in the traditional system, c. 11g is closer to a 'real tola' of c. 10.3g than it is to a 'real suvarna' of 13.7g. Perhaps the Hindu population began to call it a "tola" pejoratively, despite its pedigree, and that nomenclature had become entrenched by the 14th century.

This hypothesis is not particularly well supported by facts, but I know of nothing better. There are further lines of reasoning which tend to support the suggestion, albeit indirectly. The c. 11g tanka was well maintained up to the reign of Muhammad III bin Tughluq, 1325-51. Soon after that the Delhi empire fragmented and the 11g tanka more or less disappeared at the capital. However, most of the successor states continue to strike it. Bengal had access to silver from Burma and South West China, and was the most prolific issuer of silver tankas. Its tankas start at about 10.8g but drift down to about 10.5g over the next couple of centuries.[142] We see a similar picture in the Bahmanid state. However, if we turn to Gujarat, rather perplexingly we see what seems to be a species of tanka that is struck to a higher standard, in the range 11.2 to 11.5g. This is contrary to the normal turn of events where coin weight is likely, if anything, to decline over time, as new coin tracks the weight of circulated worn coin downwards. It is unusual to see a contrary drift upwards.

One possible explanation of the rise in weight of the tanka in Gujarat is that, being one hub of international commerce for the Indian Ocean as a whole, Gujarat was seeking to trim seigniorage rates in order to draw Persian bullion to its mints. If that were the case, it supports at least part of the explanation adopted above.

Similar things seem to have happened at the Venice mint when it was at the hub of the medieval Mediterranean commercial world. We must tread with caution, as Gujarat metrology is itself perplexingly complex, but this explanation might also help us understand what happened later at Delhi, under Sher Shah.

(965) *Sher Shah silver rupee*

Sher Shah became emperor of much of North India in 1538. He issued the first rupee, a denomination which has dominated Indian currency from that day forward. Its weight was above the old c. 11g Sultanate tanka standard: it fairly quickly standardised at c. 11.5g.[143]

We have no direct record of Sher Shah's logic in creating this new heavier 'rupee', but we have detailed records associated with its mechanism of issue under the succeeding Moghul Emperor, Akbar, 1556-1605 AD. It seems very likely that practices under Akbar closely resemble those initiated by Sher Shah. From Akbar's official histories we discover that the silver tola was actually a bullion weight of very close to 12 grams, figured at 96 rattis. The rupee coin was officially issued at a weight of 92 rattis, approximately equal to 11.5g, after the mint took 0.5g, (half a masha), as seigniorage. According to the new standard, old Sultanate tankas would be under weight, and thus would only be accepted at the mint as bullion, to be recoined at a profit to the state.[144]

Sher Shah was a far sighted economist, seeking to boost production and trade by opening up markets, and judiciously lessening the burden of taxation. Thus it seems possible that he deliberately acted to cut seigniorage on the coinage in half, from 1 gram per tanka to half a gram per tanka. If this was actually the case, then it seems to vindicate our original contention. For it is possible that, just as in the later Moghul period, so too under the Delhi Sultans there were two tola weights, but at that time they were a bullion tola of 12 bullion mashas (96 Delhi-rattis or c. 12g) and the coin tola of 11 bullion mashas (88 Delhi-rattis or c. 11g). This may sound complicated, but such developments are commonly seen in metrology, as with the English Troy and Tower pennyweights, and all the other dual systems detailed earlier.

(913) *Billon 'adli Tanka*

In seeking to understand the Delhi c. 11 gram tola standard our account skipped forward in time somewhat. It will now return to a more proper sequence of events, in order to examine other metrological developments under the medieval Indian Sultanates.

A major reform of Indo-Moslem metrology took place under Muhammad bin Tughluq, 1325-51. This briefly brought into being a gold coin weighing c. 12.8g, and for a more substantial period reduced the silver coin of Delhi to a billon 'adli , which weighed c. 9.0g.[145] Muhammed was a strange individual, prone to all sorts of schemes, most of them none too sensible. We can only guess at his aims in creating these two denominations. The billon 'adli could be understood as an attempt to return closer to strict Islamic standards, if it is interpreted as a 3 dirhem piece. Since a substantial seigniorage could be got from the debasement of its metal, there would be no fiscal problem in arranging to strike such a piece at full weight standard. The c. 12.8g piece could be any of three standards. It could be aiming at three canonical dinars (theoretically c. 12.72g), it could be matching the contemporary Mongol version of the same (theoretically c. 12.96g), and of course it could represent a traditional Hindu suvarna, figured at 128 of the old Hindu 'Greek-rattis'. For myself, I would have no problem believing it was trying to be all of these three things simultaneously, but given the paucity of evidence we have to back the hypotheses, any particular line of speculation has to be treated with caution.

About 130 years ago Thomas[146] dubbed the 'adli an '80 ratti' piece, and linked it to the tradition of 80 ratti coins mentioned in the ancient texts of Manu. It does weigh around 80 rattis using a heavier sort of Islamic ratti standard. It is possible that propaganda surrounding the issue of this novel tanka may have sought a precedent in the ancient tradition of the Arthashastra etc, in order to put a positive spin on its reduced weight and debased metal. However, discoveries made since Thomas' day show that that ancient 80 ratti piece was 80 Mauryan rattis and thus 8.6g or less, not the c. 9gm, or 80 delhi-rattis, which Thomas' hypothesis requires.

A further possibility exists regarding a c. 9g 'adli tanka. We know from the texts of Thakkura Pheru that the 11 gram silver tanka was valued at 60 gani or jitals, so a 50 jital coin should appropriately weigh c. 9.16g, and some of the early 'adli issue are closer to 9.2g than 9 grams. Striking a 'high

value' base coin, with a fiduciary value fixed against the existing jital sized coins in some kind of decimal system would have worked much to Muhammad's financial advantage. His well known extravagant and abortive experiment with brass forced tankas seems perhaps to lend credence to such an explanation.

What does seem clear is that, one way or another, Muhammed was pushing a bigger slice of the cash economy into the sphere of fiduciary base billon transactions, so as to extract silver to use elsewhere in his grandiose and ill-founded plans for world domination.

The Multiple Silver Standards of Gujarat

(948) *Gujarat silver tanka*

Gujarat broke away from Delhi to become an independent Sultanate around 1396 AD. The subsequent Gujarat coinage had a very complex metrology. Over the next couple of centuries, amongst its gold, silver and billon coins, Gujarat struck a bewildering set of binary fractions and multiples to the following five weight standards:

7.2g, 8.4g, 9.6g, 11.4g, and 12.7g

Worse yet, in some reigns we seem to find more than one standard in use simultaneously. Since the 19th century scholars have treated these as

64, 72, 80, 96 and 112 ratti pieces

This interprets the physical weights according to 19th century thinking, in what here we have called 'delhi-rattis'. We have now established however that lower weight 'greek-rattis' and 'mauryan-rattis' existed in India long before this delhi-ratti. We have also seen that these Hindu standards apparently persisted, or were reintroduced, in South India in the later medieval period, for example at Vijayanagar. Gujarat was under (northern) Delhi rule for a relatively limited period of time, and it seems very likely that an understanding of more traditional (southern) Hindu measures was retained there. If we re-calibrate the Gujarat standards in terms of "greek-rattis", of c. 0.1g, we get something very like the following:

72, 80, 96, 112 and 128 rattis

This is a more satisfactory set of figures: 96 and 128 are the well known and very ancient Indian tola and suvarna standards. The 80 ratti standard is known from ancient times, and represents a trivial extension of the 40 ratti gadyana standard associated with the gadhaiya paisa which dominated coin use in Gujarat just a century earlier. The 112 ratti has no Hindu precedent, but appears to be the 11 gram tankas of Delhi expressed in these Hindu rattis, raised a little in Gujarat in connection with seigniorage matters already discussed. Thus the only new coining standard seems to be a 72 ratti piece of about 7.2g. Long tradition has it that the mithcal of Mecca should contain 72 grains. That was probably a distant remembrance of Roman standards. Nero's denarius was 72 grains if we figure the grain as 1/4 of the siliqua (ie a 'wheat' grain). The solidus is 72 grains if we figure the grain as 1/3 of the siliqua (ie a 'barley' grain). We saw above that Pheru also figured the Delhi tanka at 72 rather oddball "jeweller's rattis". Perhaps some kind of religious orthodoxy might have been used as a pretext to create this new, low weight, tanka? Whether or not this is the case, the rest of the denominations fit so well to traditional Hindu standards, figured in traditional "greek-rattis", that it seems very likely that a full decoding of metrological events in Gujarat should best rely upon the application of a light weight Hindu ratti standard of a c. 0.1g ratti, and we should now abandon the 19th century convention of reckoning in heavy 'Delhi-rattis'.

Jaunpur billon tankas

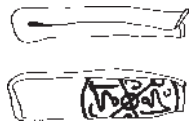
(924) *Jaunpur billon tanka*

Amongst the Gujarat standards listed above was a species of tanka weighing c. 9.6 grams, which was equated to a traditional Hindu tola of 96 rattis. Issue of coin to this standard was not restricted to Gujarat. Jaunpur broke away from Delhi in 1393, and the tankas produced there much resembled the sort of billon 'adli tankas seen at Delhi, excepting that the weight was raised to c. 9.6g.[147] This lead was eventually followed in Delhi too, since in the course of time the weight of the 'adli also rose there.

It is interesting to note that the later billon tanka standards of Delhi and Jaunpur brought a rather pleasing harmony to Indian metrology. According to the northern, Islamic, Delhi-ratti a 9.6g coin represented 80 rattis, the old gold-suvarna of Attic origin, whilst the same 9.6g coin represented a 96 ratti tola according to the southern, Hindu, "greek-ratti" standard. Both interpretations of the standard respect traditions already more than 1,000 years old, even then.

India & Persia: Decoding the Larin

In this, the final section on India, we shall address the complex and perplexing matters concerning the links between the weight standards of later medieval India and later medieval Persia. This subject seems to me a kind of maze, parts of which I have not yet penetrated. Physical weights of the Persian coins involved are all as determined in Stephen Album's slim but indispensable '*A Checklist of Islamic Coins*' (Santa Rosa 1998). Our task here is to try make sense of the way some of those weights seem to be have been co-ordinated in connection with international exchanges.



(572) *Persian silver larin*

The larin is a peculiar coin, a bent bit of silver wire, crudely stamped to show parts of inappropriately shaped dies. The larin apparently take its name from the city of Lar on the Persian Gulf. Its use apparently oiled a significant proportion of the international trade at ports all the way from the Persian Gulf down the west coast of India to Sri Lanka, during much of the 16th and 17th centuries.

The shape of the larin indicates it was specifically designed to be made at a minimum cost. A drawn wire could be made to an exact diameter, thus the length and therefore weight could be regulated with speed and ease. Both the 'flan fabrication' and the striking were of the most rudimentary kind imaginable. Everything about the larin suggests it was an attempt to get silver into circulation, in units of certified weight and purity, at the lowest possible cost.

Let us consider the people who used these larins. They were issued and used along the seaboards, somewhat regardless of national boundaries. We find in texts that foreign merchants were on occasions banned from using anything but larins in their trade in India. Likewise, away from the coasts, we find other people avoiding them, using regular sorts of coins. Given the fact that many sea traders in the period would be operating beyond the sway of their own government control, and that such international traders might feel little allegiance to any foreign government, it seems likely that the larin arose as an appropriate form of currency for their exclusive use, a currency embodying a minimal element of seigniorage, circulating at something very close to an internationally recognised bullion value.

The earliest known larins were issued by the Sefavid, Isma'il I, 1501-24 AD. A well preserved group of these normally rare coins recently came to light, thus it is possible to accurately fix an average weight for them[148] which is very close to 5.08g. In connection with this weight I put the following six facts up for consideration.

i) We noted above that the ratio between the weight of the very ancient Persian half shekel (c. 4.17g) and the very ancient Indian tola (c. 10.26g) was quite close to two to five.

ii) If we take the weight of the earliest larin: 5.08g, and multiply it by $^5/_2$ we get 12.7g. This closely approximates our proposed 128 ratti suvarna of the Gujarat Sultans, of Muhammad bin Tughluq, and of the Shahis. It also reasonably approximates the proposed core Radanite bullion weight, the Mongol '3 mithcals' and the Scandinavian lod.

iii) In 1150H (1737 AD) Nadir Shah of Persian briefly conquered North India and he fixed the metrology of his Indian style silver 10 shahi 'rupi' at 11.52g and his Persian silver shahi at 1.15g, so that the Persian 4-shahi abbasi weighed 4.61g. At the core of this unification we see a 5 **:** 2 ratio between his Persian abbasi and his Indian rupi.

iv) The last prolific silver issue of Gujarat was an innovative silver 'half tanka' or 'mahmudi' of Muzaffar III, 1560-73 AD. It was turned out in very large quantities and must have been enormously popular, as versions of it were struck locally long after the demise of the Gujarat Sultans. Dubbed 'koris'; versions continued to be the denomination of choice around Saurashtra down to the early 20th century. Being a carefully produced and common coin, we can get a fix on its intended initial weight, which was very close to 4.8g.[149] The coin appeared just as Akbar was spreading the use of his rupee throughout North India. As we saw above, Akbar's bullion tola weighed 12 grams. And 4.8 x $^5/_2$ = 12 grams

v) Codrington cites records made by Valentyn in 1726 which figure the rupee at half the Spanish dollar (piece of eight), and the larin at five to the Spanish dollar.[150] That the larin may well have been a money of account by that stage seems to reinforce its pre-eminence as a tool of international exchange. The ratios seem to reveal another 5 : 2 ratio in force, at that date, between the larin and the rupee

vi) At the time of its demonetisation in the mid 20th century, the kori weighed 4.7g, the rupee weighed 11.77g, thus the ratio was just 1% away from 5 **:** 2.

One or two of these correspondences alone could probably be dismissed as coincidence, but all six taken together suggest a need for further investigation.

(549) *Timurid silver shahrukhi*

Let us start with the earliest 5.08g larin of Isma'il I, 1501-24 AD. Album plausibly links this standard with the Timurid 5.15g 'shahrukhi' brought out in 1425 AD. The Persian tanka around this period ran through a whole series of apparently fiscally driven weight reductions. Its origin seems to be the Indian 11 gram tanka, a standard adopted by the Karts of Herat around 1350 AD. However, Album suggests it subsequently fell in weight according to the following steps:

11g- 8.5g - 7g - 6.2g - 5.6g- 5.15g - 4.78g - 4.61g.

Prior to 1500 it is possible that the 'shahrukhi' of 5.15g gained some recognition outside Persia because they usefully represented $^2/_5$ of the old Mongol 3-mithcal weight standard ($^5/_2$ x 5.15 = 12.88g). They would represent a handy form of circulating bullion along the old 'Radanite' trade route in the Indian Ocean, easily accountable against a c. 12.8g suvarna. Allowing for wear on the coins and a small making charge the larin might well have been created to supplement the stock of old Timurid shahrukhi's after 1500. This seems plausible, but it would be good to get additional supporting evidence.

(951) *Silver mahmudi of Gujarat*

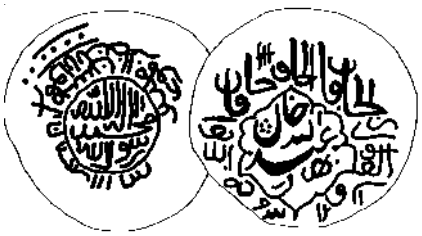
Now let us turn to the Indian 'mahmudi', primarily represented by the issue of Muzaffar III, 1560-73. This was a hugely influential coin, spawning later copies by Nawanagar, Kutch, and Porbanda. Versions of it, in later centuries called a 'kori', were continuously produced in Kutch until 1947. The initial issue in 1562 weighed close to 4.8g. The final issue almost 400 years later weighed 4.7g. As mentioned above, prior to the issue of this coin, Gujarat silver existed in a range of denominations struck to about 5 different weight standards, so we are faced with the question, why did this particular coin, fixed at a 48 Greek-ratti standard, get so popular, and became so influential? The answer seems to lie in its weight. Around 1540 Sher Shah apparently fixed his bullion tola at 12 g, and his rupee at 11.5g, in a system which Akbar adopted, and which remained little changed right down to the 20th century. The weight of the mahmudi 4.8g x $^5/_2$ = 12g. Thus the mahmudi could easily be used to complete payments figured in 12 gram Moghul tolas. To put it another way, the mahmudi could be used to make tax free payments, in bullion, free of all seigniorage. It seems likely that this was the fundamental reason why, in the West Coast trade, the mahmudi came to twin the rupee of the interior over several centuries.

(552) *Timurid silver husayni*

Nor should it escape our attention that the Gujarat mahmudi is a more or less an exact match for the weight of the Husayni Timurid tanka, a standard of c. 4.78g,[151] created in 1490, fifty years earlier. Thus we seem to see two state imposed coinage systems, of Persia and Gujarat, being co-ordinated one with the other, and both with the value of bullion in the interior of the Indian Moghul empire.

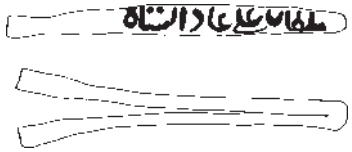
(587) *Persian abbasi of 4.61g*

After something of a hiatus in early Sefavid metrology, Muhammed Khudabanda 1578-88 created a new mithcal of 4.61g, and both his gold dinar and his silver 2 shahi piece were struck to that standard. This seems to bring the Persian coinage into line with Moghul coinage (the rupee), since $^{5}/_{2}$ x 4.61 = 11.53g, a good estimate of the rupee weight at that time. A century and a half later a silver 4.61g coin in Persia had lost half its value for internal use, as it now represented an abbasi of 4 shahi, but for external, international purposes it replicated the earlier 2-shahi piece, still two-fifths of the carefully maintained Moghul rupee.



(606) *Shaybanid silver tanka*

The influence of the c. 4.61g standard stretched far beyond Persia into Shaybanid, and subsequently Janid Central Asia. In the later Janid period the weight of the tanka slipped below 4g, but apparently for fiscal reasons.



(964) *Bijapur silver larin*

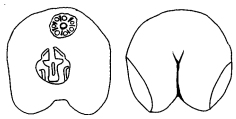
About 150 years after the first Persian larins appeared, we find large numbers of another version of the larin being struck at Bijapur in Western India, by 'Ali Adil Shah, 1656-72. These weigh about[152] 4.7g. Since 4.7g x $^{5}/_{2}$ = 11.75g these coins could be used to approximately yield the value of the rupee of the later 17th century, which was very similar to that of Akbar, but had drifted up just a little to about 11.65g. Their purpose is less clear than the earlier Persian larin, since they appear to offer little more in intrinsic value than the rupees they were issued alongside. Soon after this time the larin disappeared as a coin, but continued to exist as a money of account, apparently to the formula 2 rupees = 5 larins = 1 Spanish dollar.

It is surely clear that some sort of co-ordination of coin metrology existed which encompassed the territories of most of Persia, Central Asia and India. This co-ordination of values lasted, all told, for more than 400 years, at the behest of scores of rulers, representing more than a dozen dynasties. It perhaps arose because an early 15th century Persian coin, the shahrukhi, fortuitously represented $^{2}/_{5}$ of what may have been a bullion weight associated with international trade, the c. 12.8 gram suvarna or lod, that is to say, 128 ratti suvarna of Hindu India. For many years thereafter we see Persian and Gujarat coin issues tracking Indian rupee bullion values, with the physical Indian rupee weighing just a little less, being tariffed at $^{1}/_{24}$th above its metal value. Ultimately Persian and Gujarat coins were reduced in weight, so as to end the 2 : 5 ratio of Persian coin to Indian bullion, but creating a new 2 : 5 fixed relationship between the coin of Persia and Central Asia (the abbasi and tanka), and the coin of India (the rupee). Thus the weights of the coins give us a window into a secret world of tacit international agreements, a world that to the best of my knowledge has scant acknowledgement in official documents of the times.

Sometime in the 17th century the method of dividing the rupee changed, and even the theoretical link to the ancient binary system, in which 128 ratti seeds equalled a suvarna, was lost. Amusingly, the rupee was viewed as the fixed weight, a tola, which was divided anew in a binary fashion, into 16 annas. This anna, for monetary purposes, was divided into 4 pice. Things change, but stay the same.

Burma

I lack the sources to comment on Burmese weight standards in general, but think it worth adding a short note on the system that survived into modern times. This was based upon a weight called a "baht", or "tical". We can determine the smaller denominations of the baht from the divisions of the silver bullet coins issued to that standard in the 18th and 19th centuries. These run: $^{1}/_{32}$, $^{1}/_{16}$, $^{1}/_{8}$, $^{1}/_{4}$, $^{1}/_{2}$, 1 baht.



(1063) *Bangkok AR baht*

The higher denominations of weight we can get from the animal weights manufactured during the same period.

'To' 'Opium weight'

These were issued in the denominations $^{1}/_{8}$, $^{1}/_{4}$, $^{1}/_{2}$, 1, 2, 5, 10, 20, 50, 100 baht. The structure of the weight denominations looks identical to that of the very ancient Hindu system, of the Indus Valley. Turning now to the absolute weight of the baht, this is still in use today, and is fixed at 15.244g. This of course is higher than the traditional Hindu suvarna of the Indus Valley et al, of 13.7g. However, if we interpret the Moghul silver rupee as a tola of 96 rattis,then the correponding suvarna (the 'rupee' suvarna) of the 17th century would be $^{128}/_{96}$ x 11.5g = 15.33g. Thus the system as a whole looks like a very traditional Hindu one, adapted in its absolute standard to the notion that the Mogul rupee represents a canonical tola.

Sources suggest[153] that the baht was figured as a binary multiple of the ratti seed and in earlier times it varied locally between 12.5g and 15.7g. Thus all the evidence at my disposal points to this same conclusion.

CHINA

For the sake of completeness I will give a short account of what I have discovered about Chinese metrology and Chinese coin weight. The information published in English on this matter is scanty, nor is it clear that Chinese historical metrology itself has yet received careful attention within China.

Chinese coins were by long tradition made of cast copper, a technology that does not allow for very accurate weight control. It seems likely that specific weights of metal were used to create specific numbers of coins. But the batch sizes could have been large, and the variation coin to coin within the batch considerable. If we could identify a single very specific issue of coins, and we have a large sample of well preserved coins from that issue, we probably could confidently take the average weight of the coins as indicating the intended weight of the coins. However, confidently identifying such a sample is often not an easy task. Coins like ban liangs and wu zhus were struck for long periods, at varying standards. So in general coin weight is not, in the case of China, a very useful guide to metrological standards. Much more than elsewhere, we are dependant upon the surviving physical weights themselves, and texts associated with them.

However, when we begin to examine the published weights we get a second disappointment. There seem to be few early weights to base any study on. An account published in 1989 by Iwata[154] identified no weights before the 'Spring Autumn' period, traditionally 770-480 BC. It identified only two weights from that period, which were taken to indicate a 'liang' of just under 13 grams. A few more weights were noted for the Warring States period 480-221 BC, which seem to indicate a diversity of standards from state to state at that time. The liang in the State of Qin for instance seems to approximate to 11.6g, whilst that in East Chu was more like 14.9g. and that in Zhao and Qi nearer to 15.6g. These estimates are based upon a very limited number of physical weights and should be treated as possibly rather poor approximations.

Iwata noted many weights from the Qin and Han Empires, and they yield an average close to 15.8g, which is likely a fairly reliable estimate of the standardized universal liang created by the Qin Emperor Qin Shih Huang. There are contradictions as to fact with other modern authors writing on this subject however, so all these figures should be used with caution. One source of possible confusion is recorded in texts which suggest that in some states during the Warring States period, two sets of weights sometimes existed side by side. A 'long' set purportedly used for making loans, and a 'short' set purportedly used for collecting taxes[155].

Another puzzle appears when we look at the divisions of this liang as described in the literature. In the Han period the liang was multiplied by 16 to make a 'catty', in much the way 16 ounces make a standard pound in the west. However the liang divided into 24 zhu, each of which made 10 lei. Thus a puzzlingly complex situation, at least for what is apparently taken to be China's earliest metrological system. It seems likely that there was an earlier, less complicated set of units.

It is interesting to note that the preferred catty after the unification of the various states would represent 16 x 15.8g, thus 252.8g. This is a good approximation to half the very earliest c. 500g mina of Persian and Egypt. That 500g mina was explained as perhaps representing two units of the heaped grain that could be held in the cup of two hands. Thus this catty could be explained as having the same early origin, representing one unit of the heaped grain that could be held in the cup of two hands.

Likewise, the early liang seems to range from 11.6 to 15.6 grams, which is a bigger range than the Egyptian beqa, and the Indian suvarna, but is of much the same sort of size. Thus the liang too may well represent an early gold trading standard, possibly even originally derived from the same binary multiple of 256 grains. But such a suggestion takes speculation rather far beyond the narrow evidential base currently available.

We do have a clue as to how the system of division of the liang found in Han documents might have come into being, and that is in connection with a very strange idiosyncrasy in the Chinese metrological system, which sought to unify weight standard with musical tone.

The ancient Chinese sought to organise number, musical tone, length, area, volume and weight into a single unified hierarchical system. The date of this innovation is not known, but details of it were recorded in the Han Shu in the first century AD (chapter 21A). Unfortunately only parts of this text seem to have been translated into English[156] Sets of bells with very sophisticated tuning systems are known from several centuries earlier, so it seems possible that the system of unification it describes was put in place significantly before the earliest known texts describing it.

The 'Han Shu' explains how a tubular measure could be made to a very specific height, and cross section. A tube constructed according to standard measures that would hold exactly 1200 millet grains. That is to say, half the liang described above. This tube will also, if used as a simple flute and blown across its top, produce the Chinese musical note 'kung', the Chinese equivalent to the western middle 'C'.

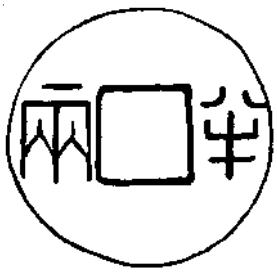
Thus the basic standard weight in that Chinese system is 1200 millet grains, which equates to 12 zhu or half a liang. If we examine the etymology of the word 'liang' we find it means 'two', thus the basic unit in the historical period is really two of the basic units derived from this curious musical standardization.

Again, we can only speculate as to why in Ancient China pitch and weight were associated in this way. The calculations involved in mathematically determining pitch are rather complicated, and involve a lot of binary fractions. It is possible that at some early stage, the usefulness of binary fractions in connection with weights generated by 2-pan scales became associated with the usefulness of binary calculations in connection with determining musical pitch. Perhaps, somewhat like Pythagoreans in the west, the ancient Chinese thought such mathematical co-incidences were a kind of gateway to a more fundamental, transcendental, reality.

The complex division of the liang into 2,400 millet grains may have something to do with facilitating the very complex calculations concerning musical pitch however, and this might explain why the Chinese developed such an odd way of dividing up its 'ounce'.

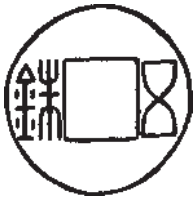
The commonest of the early round coins is the 'ban liang' or half-liang. These coins, in theory, should weigh one of the standard units derived from the 'musical system', 12 zhu or 1200 millet grainss. Early specimens however, which perhaps belong to the 4th century BC, often weigh 12 grams or even more, which is close to a full liang, and far more than a half

liang ought to weigh. This is very hard to explain. It is possible that in some areas coin circulated by weight, and the 'half liang' inscription became merely a formula, indicating a coin, of no relevance to the actual weight. I know of no other simple answer to this puzzle.



(1084) Ban Liang

In a process that rather resembles the changes to the early copper asses at Rome, the ban liang lost weight in a step wise fashion, before being stabilised at 4 zhu in 175 BC. The great majority of the ban liangs we see today seem to approximate this 4 zhu standard, and weigh between 2 and 3 grams.

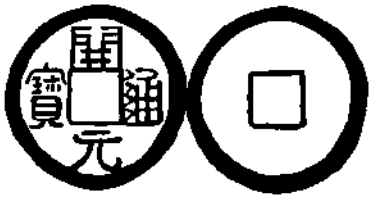


(1095) wu zhu

In 118 BC the ban liang was replaced by a new coin, the wu zhu, or 'five grainer' . This coin was cast, on and off, for the next 600 years, and as there were inevitable variations over such a time, again we have difficulties in deciding exactly what the 5-zhu was supposed to weigh. Nice looking pieces seem to vary between 3.55g and 3.65g, which puts them closer to 6 zhu than 5 zhu, according to excellent weight sets, apparently of the contemporary Han period.[157] Peng claims the first 5-shu issues were even heavier, at c. 4g.[158] Since Peng does not seem to have seen the excellent sets of weight similar to that just cited - this makes the situation even worse than he judged - with the original issues apparently above 6 zhu. One starts to wonder what is going on altogether. Contemporary issues of Khotan seem to equate the liang to a reduced version of the Attic tetradrachm. This so called "grain" does not resemble the weight of any grain from the traditional Chinese canon, but it does closely resemble a Western danik or obol. Likewise, there are of course 24 such obols in the attic tetradrachm, and 6 in the standard coin, the drachm.

If the wu szu really is, in a metrological sense, a kind of copper six obol drachm, why on earth call it a five grainer? One line of reasoning might be that the Chinese phrase "five grains" in some contexts translates merely as "sustenance", in which case the five grainer might be viewed as the thing that bought sustenance. Others will surely see this line of reasoning as going way out on a limb - perhaps correctly. But if nothing else I hope it will motivate others to try to deal with the problems metrology thows at us - rather than duck them, as I am afraid we see too frequently in recent decades.

In 621 AD the Tang dynasty simultaneously created a new decimal metrology, and a new coin type. The coin was used to demonstrate and distribute the metrology. A new 'ounce', or liang was created, its weight being equal to that of ten kai yuan coins. Since the coins tend to weigh around 4g to 4.2g, this substantially increased the weight of the liang, to about 41 grams. Surviving Tang weights suggest a theoretical standard of 41.69g grams.



(1114) Tang 'kai yuan'

Over following centuries the weight of the liang dropped a little away from this standard, thus by the time of the Yuan Mongol emperors, the liang seems to have fallen, on some reports, to c. 38.3g. This might be to do with some kind of slippage, perhaps arising from matters like coin wear. Equally it could be a deliberate recalibration by the Mongols, to tweak the weight into line with other standards, far away at the other end of their empire, perhaps attempting to make the liang equal to 9 Ilkhanid 'mithcals' as mentioned above.

In the late 19th century the Qing liang had changed only slightly from the standard of Yuan times, at around 37.6 grams (customs liang was 37.68 grams, 'Canton' liang was 37.57 grams).

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Comments on alternative viewpoints

To be revised soonish.....

In the course of studying coin weight, I have had many interesting debates and discussions, and I thank all for their comments and criticisms. The most common criticisms tended to bear on general philosophical and methodological matters. Any defence of philosophical or methodological positions tends to be long winded and convoluted; a serious distraction from the job of actually explaining past metrological systems. Further, such discussion is not to everyone's taste. Thus discussion of such matters has been moved to this appendix, where those who have no interest in it may easily pass it by. Lines of criticism are divided into three broad areas and taken in turn:

Accuracy of the quoted weights

Broadly speaking, I take the weight of a particular coin type to be the average weight of an adequate, randomly constituted sample, of uncirculated and undamaged specimens of that type.

What actually constitutes 'a coin type', 'an adequate number' and 'a random sample' are matters that are open to endless debate. In addition this definition has to be amended when coin weight is not, in a statistical sense, normally distributed, as will be explained below. However, it is reasonable to assume that, generally speaking, ancient and medieval minters checked the weight of the metal they used, on what are by modern standards rather rudimentary scales, to create a specific number of coins. Weighing a good number of the surviving coins, the products of this method, and then taking the average (mean) ought to lead us to a reasonable estimate of the ideal standard aimed at, in most cases.

Regarding the weights of many oriental issues, over the years I have had access to groups of good coins myself from time to time, and have taken the averages myself. In many cases my results could be compared with those got independently by Deyell[159] for coins of Medieval India and by Album[160] for the well regulated Islamic issues, and in both cases the match was very good.

In the case of the coins of Ancient and Medieval Europe, I have often had to rely upon the results published by earlier generations of scholars, and these weights should be treated with more caution. In particular, some 19th and early 20th century writers, most prominently Ridgeway[161] argued that no mint master would ever issue a coin that was overweight, thus the theoretical weight of a coin type must be equal to, or slightly heavier than, the heaviest known specimen. This is a mistake. At a practical level, stray overweight coins are regularly found, as well as stray underweight coins. A mint-master was normally tasked to turn given weights of silver into so many coins per mark, or per pound. To place sole reliance upon the weight of stray overweight pieces makes a nonsense of the sort of trivial accidents which will very likely occur in any workplace. Thus I have done my best to avoid quoting any weights derived in accordance with that misguided theory.

Critics of my procedures, outlined above might make the following points.

a) I have often taken it for granted that the weights of the coins would form a normal distribution. It would be better practice to graph the weights of a good sample of coins, and confirm that the distribution is in fact normal. I accept this criticism, and will gladly yield to anyone who challenges my conclusions on the basis of better data, more thoroughly analysed. However:

b) Some academic authorities, in order to create a large data set for statistical analysis, have taken coin weights from museum catalogues without physically examining the coins themselves (in order to weed out those which are worn or damaged).[162] Grierson[163] particularly warned against this, and I would second his opinion. The fraudulent practice of clipping small amounts of metal from the edge of coins was rife at certain periods. The inclusion of any such clipped coins in the data set skews the result. Thus weight analysis should be based only upon undamaged coins which competent researchers have checked for themselves.

c) If a set of coins when weighed and graphed produces a skewed, rather than a normal distribution curve, there is often no unambiguous way of interpreting why the deviation from normal occurred. For instance, it has been argued that if the curve drops steeply at the leading (heavy) end, then this indicates that the mint master was producing flans rather randomly, but then carefully checking them for overweight specimens, which he withdrew and remelted. If we know this had taken place, it would be an argument for making the theoretical weight equal to the weight of the heaviest specimens in such cases. However such a distribution could also be created if hoarders or exporters were routinely skimming off the heavier coins after they left the mint. And in that case the theoretical weight would probably better be judged by the modal value, assuming the curve had an unambiguous mode.

Likewise a long tail at the back (light) end of the curve could be evidence that the mint master was deliberately and dishonestly producing occasional batches of underweight coin. Again, in such a case the mode should perhaps be preferred.

All we can say in the general case is that metrological arguments are best advanced upon the evidence of coin types which show statistically a close to normal weight distribution, since evidence from other sources is always going to be fraught with difficulties of interpretation.

d) Certain scholars have routinely assumed that coins are almost always significantly worn, or inevitably leach away metal during their centuries buried in the ground, and thus that the theoretical weight of a coinage was originally always higher than that observed in the surviving specimens. For instance Miskimin[164] determined that undamaged later period Carolingian pennies mostly weighed around 1.7g, or less, but assumed an addition "wear factor" of around 10% to justify his own pet theory which predicted a theoretical weight of about 1.86g.

It is true that bronze, lead or iron coins or weights will often be adversely affected by burial. Hard stone, like gold, will likely be unaffected by burial. Silver will vary. If buried in salty soil it will likely corrode and become useless for metrological purposes. However, if silver is buried along with copper, the copper will often preferentially corrode, and protect the silver in the ground. It is not uncommon to remove encrusted copper salts from silver coins, and reveal that the underlying coins still preserve the mirror finish got from the polished die that struck them, and that they still 'ring' when

spun. Such uncirculated, perfect coins, if unclipped, weigh exactly what they did the day they were struck. Experience weighing such coins, alongside specimens showing moderate wear, will usually show little difference in weight between the two. Thus whilst clipped, heavily worn or corroded silver coins are useless for metrological work, and perfect coins are to be preferred, reasonably well preserved coins in silver generally give a good indication of the original, theoretical weight.

e) In recent years some academic scholars (especially in France) have preferred to get all their metrological data from hoard coins, arguing that coins owned by collectors have been subjected to a selection procedure that unacceptably skews the data they present. This seems unnecessary in general to me. Collectors will select well struck pieces, from fresh dies, over badly struck ones from worn dies, but there is no obvious reason to suppose the flans of well struck pieces will weigh differently from other coins. Thus this procedure seems to place an uncalled for difficulty in the path of the metrologist . However, it does not introduce any error into the procedure, so I have no objection to it. When I had the opportunity to examine the results of such a study, it was consistent with alternative results got from 'collector' coins.[165]

In my opinion the main problem we face in fixing on a theoretical weight for a coin type is largely in dealing with our own misguided psychological demand for an exact answer. Trivially, nothing has an exact weight, except the arbitrarily created standard weight itself. The relative weight of any other object, according to this standard, is presumably an infinite real number, which science can only approximate. More importantly, there is endless scope for prevarication concerning matters such as possible bias in the sample upon which any conclusion is based. With skill and determination a critic can defer agreement till doomsday. The question, 'what is the exact theoretical weight standard of such and such a coin type' normally does not have an exact answer. But this does not matter, since we only need an approximation good enough to solve the problem before us. If a critic offers a different theory about the origin of a particular coin weight standard to my own, and supports it with a different and better determination of what that standard is, then I must and will defer to this superior theory.

The situation is somewhat similar to that of defining the meaning of words, criticised as 'essentialist', by Popper

Never let yourself be goaded into taking seriously problems about words and their meanings. What must be taken seriously are questions of fact, and assertions about facts: theories and hypotheses, the problems they solve and the problems they raise.[166]

We can never have an ultimate definition of any word we use, but if we define it well enough to solve the problem in hand, then that is all we need. The same applies to the weights of coin types.

The problem of the multiplicity of standards

The central idea of this study is that metrological standards can be passed from generation to generation more or less unchanged for millennia. This finding runs quite contrary to the widespread expectations of many, perhaps the majority, of educated people who have views on pre-modern weight standards. Probably most informed commentators think of pre-modern weight regulation as both arbitrary and chaotic. The study itself represents my argument as to why this preconception must be rejected. But that leaves us with a separate question: how did this erroneous idea become so prevalent?

The answer to this question seems to have two parts, the first part is simply that yes, there frequently were a large number of different, rather arbitrary weight standards in use side by side in the past, but that these were local standards, often associated with specific trades. Amongst an educated elite, more stable and universal standards were preferred and retained. Thus when Alberuni discusses Hindu weight standards around 1020 AD, he says of the *pala* that it was different for different wares and in different provinces, Yet he says of the suvarna, used for weighing gold: *people in general agree that.....1 suvarna is equal to 3 of our mithcals.*[122] Thus side by side we have a fixed universal standard for gold, and varying standards for other merchandise. This seems to be commonly the way at other times and places.

In addition to this consideration, there is a second one. When a new weight system is proposed by a state, scholars associating themselves with the state and the utility of its new standard will tend to bend the truth a little, in order to stress the convenience of the new system. This importantly seems to have happened in connection with the imposition of imperial standards on the British empire in the 19th century, and imposition of metric standards worldwide during the 19th and 20th centuries. In their enthusiastic proselytizing in favour of the new system, the defects of the old order tended to be exaggerated. Thus we find Prinsep writing in 1858 *in upholding one common system for the whole of British India....there is some hope that, eventually, the incongruous mass now prevalent will gradually give place to the convenience of a universal and single species of weight.*[167] Similar claims were by republicans in France in 1790, that there were 700 or 800 different measures in use; that the variety of measures exposed people daily to swindlers, and that the nobles' measure waxed larger year by year. Such claims stoked the revolutionary zeal behind calls for metrication, part of whose legacy was, and remains, a rather exaggerated notion of the chaotic nature of earlier metrological systems.

The problem of full weight payment

It is widely believed that in England during early Anglo-Saxon times, payment of a pound (value) in silver meant payment of a pound (weight) of silver. But the truth of the matter is that we do not know with any certainty how payments were weighed out in early Anglo-Saxon England. The weights and scales we find from that period seem to indicate two parallel weight systems in use, simultaneously. We do not know how either of these related to modes of payment.

The idea of payment in pure metal at an exact agreed weight between free independent individuals who are then 'paid and quit' is a very satisfying one to many. It seems such a delightfully clear and simple transaction, when contrasted with the contorted forms of money, payment and indebtedness that we often encounter in the modern world. This idealised notion of payment by full weight of metal was politically very popular amongst classical liberals of 18th and 19th centuries, and remains popular today amongst many 'right-libertarian' leaning individuals. The ideal of payment by full weight of metal is one I find attractive myself, and I do not doubt there have been situations in the past when it has been the norm. However there seems to be a desire by some to create a kind of monetary golden age in the past, exaggerating the prevalence of such very straightforward monetary transactions: making

the past a much simpler and more straightforward place than the present, out of some kind of romantic and perhaps politically biased sentiment. This sentiment can lead some to distort historical fact, sometimes even in academic circles.

Money takes many forms, but here we concern ourselves merely with physical cash, used for immediate payment. At various times and places this has taken the form of pure metal by weight, sometimes in the form of coin. However, in most instances, the nominal value of coin has been fixed above its intrinsic value by government edict, using a reduction in weight or purity of coin, or both. The amount of overvaluation is sometimes fairly small and can usefully be thought of as a reasonable seigniorage, as a small charge made over and above the making charge to cover the costs of policing the circulation of coinage, and perhaps policing the markets and trade routes that facilitate money use. Since around the mid 20th century however man has become accustomed to dealing with base metal tokens and paper cash exclusively. The value of a coin bears no relationship to its intrinsic metal value. It is more in the nature of a credit note, held by the citizen, and valid for the payment of his future tax demands from the state. This sort of money, often called chartal money, contrasts quite markedly with the gold currencies of the 19th century which circulated at close to their metal value.

Due to matters which include the specialization of modern academic life, a false paradigm has gained wide acceptance, that such chartal money is an exclusively modern phenomenon, to be explained by changes in the nature of economic and political thought in modern times. This is clearly false. China began to adopt fiduciary chartalist coinages at the very start of the Christian era (Wang Mang from 9 AD). The policy was not consistent over time, rather we find Chinese regimes oscillated between relatively metallist approaches to their coinage, and chartalist approaches. We also find chartalist currencies being used successfully at Bokhara from about 775 AD onwards, apparently for several centuries. Whilst the elites of Ancient Greece and Rome primarily used gold and silver coin, the great mass of the poorer sort of citizens would mostly handle copper, and this appears to have had a mostly fiduciary character, especially the huge copper issues of the Roman empire of the 4th century. Even amongst populations who routinely strike their coin in gold and silver at near to full intrinsic value, it is sometimes the case that old coin stays in circulation that is both worn and clipped, and continues to be accepted in payment merely by force of tradition, long after it has fallen short of representing full metal value.

Thus the idea that, prior to modern times, coin circulated 'by weight' is largely a myth, underpinning a false understanding of past economies, and bolstering a particular set of somewhat libertarian, anti-state, political ideologies. The truth is that coin sometimes circulated by weight, but most often circulated by count. That sometimes coin contained its full metal value, but at other times it contained none. That there is no special point at which a precious metal coin bearing seigniorage charge suddenly changes into something different, a fiduciary 'token'. That some people in the past favoured metallist currency, others favoured fiduciary or chartalist currencies, and a great many were probably just plain confused by it all. From time to time people in the past argued over the correct way of forming a currency, and sometimes fought over it too. Taken all in all, people in the past were much like us.

The subtleties of a pure silver or gold coinage that is nevertheless intrinsically still worth less than the bullion it contains are perhaps nowadays somewhat difficult to grasp. However, if we do not grasp this point, then we cannot understand many of the complexities of pre-modern metrological systems.

In 1977 two prominent scholars attended the same conference but posited directly opposing views upon the question at hand. Miskimin held that in Medieval Europe *coins are weighed and circulate as bullion; the market rate for bullion then dominates over all official rates.*[168] on the other hand, Munro asserted that *silver coins in particular normally circulated by 'tale,' at decreed face values, and not by weight.*[169] It appears that Miskimin was wrong. We have a mass of documents which specify the seigniorage applied to various coin issue. But Miskimin bolstered his position by going on to say *since weighing coin and defying the king's will were illegal practices, it is especially unlikely that adequate records would be kept.* This claim seems a little unfair, since it represents an apparently rather unjustified refusal on Miskimin's part to put his theory to the test against the documentary evidence. This however, is exactly where the archaeological evidence of weights can be brought to bear, in undermining Miskimin's metallist position, as we shall see below.

Firstly however I will fix my own position, which is very similar to that spelled out by Munro, but more exactly that specified by Jervons: *few people have scales and weights suitable for weighing a coin.....people in general accept coin simply on the ground of its familiar appearance.....the public do not generally discriminate between coin and coins.....*(but)*... a small class of money- changers, bullion dealers, bankers or goldsmiths make it their business to be acquainted with such differences, and know how to derive a profit from them.*[170] What Jervons is saying here is that the nature of money is different for different classes of people, that the great mass of people took their payment by count, and accepted valuation by decree or by custom, but simultaneously, a small elite took payment by weight, and attribute value by intrinsic metal content. Jervon's contention is corroborated by a comment from the banker Barbon, who near two centuries earlier wrote *not one in a thousand can tell how many grains there are in a crown.*[171]

It is a short step from this analysis of money to Grierson's analysis of weight in the Carolingian Empire. As explained, Grierson postulated two versions of the Carolingian pound, a heavy weight one of 16 ounces, for use by a narrow elite, at the state mint and by international merchants operating beyond state frontiers, and a light weight one of 15 ounces for the great mass of the population. These groups would appear to replicate fairly exactly the two opposing groups mentioned by Jervons. And the situation also seems to parallel aspects of the use of 16 and 15 ounce troy pounds in early Islam and, via the sterling system, of later Medieval Europe, as indicated in this study. It should become clear now that anyone favouring a metallist or commodity theory of money, be they students of modern economic theory, 19th century liberals, or medieval merchants, they are liable to be intellectually hostile to many of the theses proposed in this study, and this in turn should explain to some extent both the paucity of the historical sources at our disposal, and the neglect of these theses in recent times.

Let us turn now to a very specific matter in the history of Islamic metrology. Amongst the early medieval Egyptian glass weights mentioned heretofore there were a large number that were adjusted to a weight of approximately 2.82g, some of which are inscribed "dirhem of $^{2}/_{3}{}^{rds}$". Clearly they represent

the weight of $^{2}/_{3}$ rds of a dinar (of c. 4.24g). It seems anyone adopting a metallist approach to monetary usage must assume that at the time of manufacture of these pieces, payments were made by weight according to a dirhem of around 2.82g. This assumption runs into a practical difficulty however. Large payments, for convenience, would require the use of large denomination weights, such as ten dirhem weights (c. 28.2g) and 100 dirhem weights (c. 282g). However, such weights have not been found. The obvious solution to this problem is that the metallist solution is wrong, that coins around the 8th century were in fact counted, and that the one dirhem weights were used merely to check the weights of individual coins, so that stray clipped or damaged pieces could be rejected from the count. This solution also explains the anomalous 2.82g standard. The theoretical weight of the dirhem of the 8th century was close to 2.92g. Thus these weights were carefully adjusted to a lower standard, which was not the weight of the dirhem, but likely was the legal weight below which dirhems could be rejected. This situation would be in line with say the recorded situation in later times at Venice, where coin was considered legal tender so long as it retained at least 90% of its theoretical weight.

Bates, working in the metallist tradition, sought to solve these problems by suggesting that *the fact that no multiple weights glass weights have survived .....does not mean they did not exis*t.[172] But concerning what appears to be exactly the same series of official weights Morton writes *if multiples existed in any material it is extraordinary that none of them have yet been recorded.*[173] In a further attempt to save the hypothesis Bates suggested that bulk weighing of dirhems was done, but by counting out and using large numbers of single dirhem glass weights. This suggestion seems far fetched, and was dismissed by Morton. A further problem for any metallist lies in the idea that these glass weights set a dirhem weight at 2.82g. Since the metallist recognises only one weight standard, the one used for transactions based upon intrinsic value, this would imply that dirhems actually weighed 2.82g. But careful examination of 8th century Islamic issues shows that the issues of the main mints average very close to 2.92g and very rarely fall below 2.90g. It is only by including clipped coins in the sample, or disproportionately representing the issues of obscure provincial mints, that one can derive the 2.82g answer that the metallist theory demands.

In summary, the 2.82g weights were almost certainly used for checking the weight of suspect coins, in accordance with payments made by count. Much confusion has been thrown about this matter by false assumptions deriving from the dogmatic metallist position. This situation is by no means unique to 8th century Islam, and the reader is advised to think carefully about this potential problem, in connection with all treatments of weight and payment in modern studies, and in early sources. Errors deriving from misguided metallist theories are almost endemic in metrological studies.

A new generation of metallist thought, arising out of the faulty position laid out by Miskimin, is represented by the work of Velde and his co-authors. Velde writes *'On the empirical level.....* (circulation by tale)..... *is inconsistent with the fact that many coins circulated by weight.....On the theoretical level, circulation by tale is an unsatisfactory argument because it merely replaces the debasement puzzle with another puzzle. No existing model of commodity money delivers circulation by tale as an equilibrium outcome.*[174] This argument apparently suggests that, if historical evidence contradicts the expectations of modern economic theorists, we should reject the historical evidence! Not a very happy state of affairs.

Concerning evidence that coins circulated by count, Velde, an economist, shows a limited knowledge of the proper treatment of historical sources. Mode of payment is a matter that rarely appears in historical sources, but when it does, it tends to indicate that coin circulated by count. Consider Babur's personal account of the looting of the treasury at Qandahar: *'Such masses of white money had never been seen in those countries; no-one indeed was to be heard of who had seen so much.....to count the coins being difficult, they were apportioned by weighing them on scales.*[175] Thus mention was made of weighing the coin, not because it is normal, but because it was extraordinary. Concerning the problems with his theory, Velde is correct to say that if one assumes that payment was made universally by 'commodity money', then one has great trouble making sense of many historical events concerning money use. But the obvious solution to this problem is simple; free oneself from the illusion that the use of commodity money (i.e. payment by weight according to intrinsic value) was the norm.

In conjunction with Sargent, Velde seems to have come closer to this conclusion himself. In a later attempt to address the same problem, Sargent and Velde acknowledge that a growing understanding of the use of fiat money, in accordance with principles deriving from the quantity theory of money, must be assumed in order to account for the facts of money use during the later medieval and early modern period. However, they stick by their notions of the commodity theory of money (payment by weight) under Charlemagne, and indeed right down to the end of the 12th century,

European monetary authorities did not think of money as something whose value emerges from its role as a medium of exchange. Instead they shared a conception that ignored its moneyness and focused solely on the substance it contained, namely silver.[176]

This runs completely contrary to the findings of this study, that Charlemagne and his successors carefully constructed their metrology in order to build a seigniorage element into their coinage. We know that Pepin charged a seigniorage on coinage even before Charlemagne. It seems very likely the very first coins, struck about 1400 years earlier still, contained a substantial seigniorage element. As things stand, it is not at all clear that modern orthodox economic theory, as it is often presented, has come to terms with what coinage actually is, nor with the real metrological and political ideologies which lie behind its creation and use.

One might go even further and suggest that the rather cynical attitude towards metrological studies taken by some scholars derives from the fact that such studies inevitably lead to evidence for the existence of economic systems employed in the past which differ from their own preferred understanding.

I am by no means the first to make such points. Alexander Del Mar, writing in the late 19th century, published many studies of coins and texts in an effort to show that orthodox economic positions of his day, bearing directly upon seigniorage, money supply and taxation policies, were misguided. In his theoretical work he anticipated positions later adopted by such as Keynes. Del Mar got an enthusiastic response to his work from some outside mainstream economics, (most notably in the person of the poet, and critic of government policy, Ezra Pound). Del Mar's work however was almost completely ignored by orthodox scholars. The

details of this case have been examined in two papers by Tavlas and Aschheim,[177] the second of which (2004) suggested that Del Mar's contribution was perhaps disregarded because his position was at variance with that held by the established but less competent authorities of his day.

Endnotes

1. Barry J Kemp, *Ancient Egypt Anatomy of a Civilisation*, 2nd ed. Routledge, 2006, p 178 estimates an Egyptian XIIth dynasty soldier's daily grain ration at c. 600g. Thus a rough average ration of 500g/day to meet the needs of a mixed group of men, women and children seems acceptable

2. F G Skinner, *Weights and Measures,* HMSO, 1967, Plate I

3. W M Flinders Petrie, *Ancient Weights and Measures,* 1926 Note that the Petrie weights are now in the Petrie Museum, at UCL. Photos of the entire collection has been put to the web. Unfortunately, the actual weight of each weight is not given. Further, all the reference numbers were changed, and not cross referenced back to Petrie. Thus it is near impossible to use. A very expensive and badly misguided example of modern museum practice.

4. Lorenz Rahmstorf *In Search of the Earliest Balance Weights, Scales and Weighing Systems from the East Mediterranean, the Near and Middle East* 2006, available at: www.academia.edu/1864503

5 Robert Tye, *Yorkshire Shield Shaped Lys or Lys & Crown Lead Weights,* https://www.academia.edu/4645906

6 Scull C, *Scales and weights in Anglo-Saxon England,* in *The Archaeological Journal*, London 1990, p183-215

7 Ibid, Rahmstorf, www.academia.edu/1864503

8 ibid, Skinner, *Weights and Measures,* p. 7

9 ibid, Skinner, *Weights and Measures,* p. 31

10 *The Origins of Metrology: Collected Papers of Dr. Daniel McLean McDonald*, 1992

11 I use the term 'Persian' to denote all the empires roughly centred upon Mesopotamia - encompassing Sumerians, Akkadians, Assyrians, Babylonians etc - merely to distinguish them generically from (say) Europeans, Indians, or Chinese.....

12 Ibid, Rahmstorf, www.academia.edu/1864503

13 ibid, Skinner, *Weights and Measures*

14 Source: Powell M A, *Sumerian numeration and metrology* (University Microfilms 72-14 445), Minneapolis, 1971

15 Ibid, Rahmstorf, www.academia.edu/1864503

16 Cemel Pulak, *Analysis of the weight assemblages from the late Bronze Age shipwrecks at Uluburun and Cape Gelidonya, Turkey* (unpublished PhD - but findings much quoted)

17 Ephraim Stern, *The silver hoard from Tel Dor,* in *Hacksilber to Coinage: New Insights into the Monetary History of the Near East and Greece* ed. Miriam Balmuth, ANS 2001 (p 24: Tel Dor)

18 as last - page 24: Arad

19 Lorenz Rahmstorf *The concept of weighing during the Bronze Age in the Aegean, the Near East and Europe* in Morley & Renfrew 2010: https://www.academia.edu/1495241

20 N. F. Parise, *Per uno studio del sistema ponderale ugaritico,* Dialoghi di Archeologia 4, 1970-71, p. 3-36
also
Mina di Ugarit, mina di Karkemish, mina di Khatti, Dialoghi di Archeologia, n.s. 3: 1981 p. 155-160

21 Raz Kletter, *Economic Keystones: The Weight System of the Kingdom of Judah*, 1998, p. 124, (and elsewhere!)

22 Lorenz Rahmstorf, *Zur Ausbreitung vorderasiatischer Innovationen in die frühbronzezeitliche Ägäis* 2006

23. Kletter seems to take an idiosyncratic view of mathemetics itself when he suggests in his *Economic Keystones* (above) p. 127 that there is no "direct correlation" between Mesopotamian and Judean standards. The well known 3:4 correlation (silver:gold) found in the coinage of Darius more or less fits here too - and seems to be just as good a fit as the correlation Kletter actually adopts for Egypt (4:5). But then, Kletter is an archaeologist, with idiosyncratic views on pre-coinage money too.

24. K M Petruso, *Ayia Irini: The Balance Weights*, Mainz, 1992

25. Christopher F. E. Pare, *Weights and Weighing in Bronze Age Central Europe*, 1999

26. Stuart Needham et al, *Claimed by the sea : Salcombe, Langdon Bay, and other marine finds of the Bronze Age*, 2013, p. 89

27. J Mark Kenoyer, *Measuring the Harappan World* 2010 (at https://www.harappa.com)

28. I hold that coins were from the start tied to markets and retailing, and their introduction represents a somewhat popularist political move to a more egalitarian kind of society. Others who publish similar views include:

P N Ure, *The Origin of Tyranny*, Cambridge, CUP, 1922,

Leslie Kurke: *Coins, Bodies, Games and Gold. The Politics of Meaning in Archaic Greece*, P U P, 1999

29. Gerald Finkielsztejn: *The Weight Standards of the Hellenistic Levant, Part Two: The Evidence of the Phoenician Scale Weights* INR 10/2015 (https://www.academia.edu/35065895)

30. J. Pakkanen, Aegean Bronze Age Weights etc, 2011 for background data on this (https://www.academia.edu/20324382)

31. Christopher Howgego, *Ancient History from Coins*, 1995, p. 53

32. Michael Mitchiner, *Ancient Trade and Early Coinage*, p.287. There is little exact agreement about exactly when coinage appeared at different cities, thus we will follow Mitchiner's plausible guesswork here.

33. Oguz Tekin, *Balance Weights in the Aegean World. Classical and Hellenistic Periods*. 2016

34. Finkielsztejn: (https://www.academia.edu/35065895) p. 73

35. Finkielsztejn: (https://www.academia.edu/35065895) p. 77

36. Aside from F. G. Skinner (Science Museum), we might mention

Jon Bosak: https://en.wikipedia.org/wiki/Jon_Bosak

A E Berriman:
https://www.gracesguide.co.uk/Algernon_Edward_Berriman

D M McDonald
https://www.gracesguide.co.uk/Birmingham_Sound_Reproducers

McDonald apparently donated 11 million pounds to Cambridge University, money used to found the eponymous institute, which in turn pubished *The Archaeology of Measurement* (2010). The co-editor of that volume, Lord Renfrew, had already deemed McDonald's work "unfashionable" which perhaps helps explain why no trace of it is found in the presentations in *'A of M'*. Kenoyer (p. 117) devotes just one sentence in that book that is reminiscent of the approach taken by those above, or indeed, in this account as a whole.

37. Rahmstorf, favoured in the McDonald Institute publication and heading up the ongoing European Research Council's investigation of metrological matters, nevertheless still holds that the c. 61.7g Minoan "2oz" unit was fixed at 5 Egyptian "beqa" - thus - apparently inadvertently - still points indirectly towards the sort of 40 beqa c. 500g mina McDonald and others championed.

38. J L Milne recommends such a reading: *The Economic Policy of Solon,* Hesperia, 1945

39. an alternative argument in the 19th century made much play of the fact that 60 x 8.16g = 489.6g, which is very close to a traditional French livre. As we will see below, the early modern French livre seems to be a fairly late medieval creation, perhaps of the 13th century AD, and if so any apparent similarity to that standard would be entirely coincidental. Here it is suggested the weight was an ephemeral product of just brassage applied to the Mesopotamian shekel of c. 8.33g

40. Barkley Head, *Historia Numorum* 1911, introduction, p. xlix http://snible.org/coins/hn/intro.html

41. http://snible.org/coins/hn/intro.html, Campania, p. 36

42. Lorenz Rahmstorf *The Concept of Weighing etc (ibid)* in Morley & Renfrew 2010: https://www.academia.edu/1495241

43. Alan M Stahl, *Zecca: The Mint of Venice in the Middle Ages*, New York. 2000

44. Darius had Palace weights, The Athenians reputedly kept their primary standards in a temple called the Tholos, close by the Agora. The Romans in the temple to Juno Moneta, etc

45. H. T. Pledge, *Science since 1500* (HMSO) 1966, p. 126

46. Actually, the sort of accuracy achieved after 1825, about 0.0005g in 5 grams, only required fairly obvious developments, like agate bearings, (see Pledge/Skinner above) so would have available to even the ancients with a little skill and ingenuity, if they happened to care about such things.

47. Kraay C M, *Archaic and Classical Greek Coins,* London, 1976

48. ibid, Skinner, *Weights and Measures,* p. 58

49. Philip Grierson, *Numismatics,* 1975, p. 198

50. M. M. Austin & P. Vidal-Naquet *Economic & Social History of Ancient Greece*. 1977, p. 331 gives the full text, which most probably imposes a state monopoly on the import of gold and silver, and specifies only coin of the city be used in trade. Note however that the authors reject that view, instead following the interpretation of Moses Finley, *The Ancient Economy* 1973, p. 168. Readers should be aware that Finley was for much of his life a professional propagandist, and, although doubtless an erudite man, it seems probably he never quit that trade entirely. On such matters as this, he seems rather to determined to undermine at root any inclination in the reader to make rational attempts at understanding the past. I say much more on Finley elsewhere, see https://www.academia.edu/356701

51. Annexe : Names and weights inscribed on some vessels from the silver hoard, Journal des savants, 2001, Harry Falk https://www.academia.edu/22335441/

52. Information got via Ross Glanfield, in Konrad Hitzl, *Die Gewichte griechischer Zeit aus Olympia,* ISSN 0474-1242, Pub. W. de Gruyter, 1996

53. Christopher Howgego, *Ancient History from Coins*, 1995, Pub. Routledge, ISBN 9780415089937, see page 55

54. The mathematical structure of this pound, preserved at Constantinople and bequeathed to the renaissance world by Ibn Sena, Dino, Agricola and others, gives us what appears to be tantalising further evidence that the Roman pound might have derived from the ancient circa 500g. According to the system of division specified above, and taking the imperial denarius of Nero (3.4g) and his successors as the drachm, the Roman pound would seem to have been figured as 12 ounces of 8 denarii of 6 obols each most plausibly of 12 grains. On this reckoning the Roman pound was 6,912 grains. Sixteen of the same ounces would give an Attic pound of $^{16}/_{12}$ x 6,912 = 9,216 grains. If we assume that the Attic pound, at least mathematically, was $^{7}/_{8}{}^{ths}$ of the Persian mina, i.e. a '14 oz pound' then the number of Roman grains in the 'full 16 oz' pound of c. 500g would be $^{8}/_{7}$ x 9,216 = c. 10,532.6 grains. Now recall that, as divided by the Egyptians, the 500g pound apparently consisted of 40 beqa which it was proposed above equated to 10,240 grains. A simple calculation confirms that the Roman grain would in fact be adjusted from the Egyptian grain in a very exact way - it is exactly $^{35}/_{36}$ Egyptian grains. And a little thought leads us to why this might be. Since the factorisation of the Egyptian pound is 2 x 5 x 2^{10} grains, then the Attic pound, $^{7}/_{8}{}^{ths}$ of it, would be 7 x 5 x 2^{8} grains. A rather awkward set of factors to work around. But if 7 x 5 is replaced by 3 x 12 a much more satisfactory set of factors is created. And if the Roman grain is such a simple ($^{35}/_{36}$) numerical variant of the Egyptian grain that would be evidence that, fossilized within the mathematical grain structure, the Attic and 'Egyptian' pounds are numerically related in a simple way, and that sometime in late prehistory Attic weight might have been born as a subsidiary 14oz version of a binary Egyptian 500g pound. This argument has a degree of circularity about it, as it very difficult to get any account of Roman grain weight. I mention it here in the hope it might prompt someone to contact me and mention any sources that might exist.

55. R D Connor, *The Weights and Measures of England.* HMSO, London: 1987, p. 132 (footnote). Petrie and Skinner make similar claims. However, the weights themselves seem to tell a different story. There seem to be a good number of Roman weights calibrated to a higher but different standard. Most notable of all is the Temple of Ops weight now in the British Museum. It is quite possibly part of the official set of weights of the Roman state itself, held at the Roman equivalent of Fort Knox, or the Bank of England, on the Capitoline Hill. It is marked II and weighs 713.6g. This implies a pound of 356.8g which in turn might be intepreted as 13 ounces of a 12oz pound weighing 329.3g. Note that Capiabanchi, in work cited below, working on official seeming weights of Charlemagne, fixed the true Roman pound at 329.1g. So, while in c. 620AD we find Isidore pointing up two Roman pounds of 12 oz and 12.5 oz respectively, weights from perhaps 600 years earlier seem also to indicate two Roman pounds, but rather of 12 oz and 13 oz. Just why historians of the Roman period have said so little on this matter is very puzzling.....

56. 4.15g is the weight suggested by Nikolaus Schindel (with S. Stanek, R. Linke and M. Schreiner), *Syllogue Nummorum Sasanidarum, Volume III: Shapur II - Kawad I,* Osterreichischen Akademie Der Wissenschaften, Wien (2004). Francois Gurnet in *Studica Iranica,* Cahier 21, Paris 1999 favoured a figure of 4.13g for thewell produced late style Khusru II drachms of the 'afid' type. This is very similar to results I have observed myself for mint state K II drachms. Elsewhere lower figures, such as 4.08g have been suggested - but it is possible that slight clipping of some specimens influenced this result.

57. Most reference works give 2.97g for the theoretical weight of the post reform dirhem (pre c. 220H). This is incorrect. Skinner determined the weight as 2.92g. As regards the majority of issues, from the main three mints, 2.92g is correct, according to my weighings, and weighings carried out independently by Lutz Ilisch, and others.

58. Arbuthnot, J. *Table of Ancient Coins, Weights and Measures* (1727) suggested that English Troy weight was brought from the Holy Land during the crusades by Edward I. He relied chiefly upon John Greaves findings on a journey to Egypt (primarily to measure the Pyramids) around 1640. Arbuthnot followed Dr Hooper, Bishop of Bath and Wells, who held similar views in the early 18th century. In the early 19th century Ruding makes no mention of these suggestions, but they were resurrected again by Alexander Del Mar *History of Monetary Systems,* London 1895 (and no doubt by others I have overlooked)

59. Morton, A. H. *Early Islamic Glass Stamps in the British Museum,* London 1985

60. Hinz W, *Measures And Weights In The Islamic World*, is widely used as a standard reference and incorrectly assumes that 2.82g is the canonical dirhem weight

61. Lane E W, *Manners and Customs of the Modern Egyptians*, first published in 1836, I quote the 1860 edition. p. 579

62. Adel Allouche, *Mameluke Economics: Study and Translation of al-Maqrizi's Ighathah,* Salt lake City, 1994, p. 59

63. Sauvaire *Journal Asiatique* 8, IV, (1884) p. 308 gives the general 12 ounce of 10 dirhem structure, as does J. A. Decourdemanche, *Note sur les poids medicaux arabes*, in: JA 10. ser., Tome 16, 1910, p. 510. Both make errors concerning the dirhem involved

64. see for instance Frank McLynn *Crime and Punishment in Eighteenth Century England*, London 1989 for insights into the sociology of clipping in a better documented context

65. Album *Checklist of Islamic Coins* 3rd Edition, 2011 p. 49 gives us a date for the abandonment of weight standards for silver dirhems, during roughly the period c. 867-92 AD. Puzzlingly, Album still sticks by the misleading *'2.97g or slightly lighter'* weight for the earlier dirhems.

66. Stephen Album, *Marsden's Numismata Orientalia Illustrata* New York, 1977, p. 24 makes the same point.

67. Henri Pottier recently studied these weights in considerable depth and concluded they were intended to weigh dirhems of 2.98g, a negligible difference from the expected - see his paper in: *Revue Belge de Numismatique*, CL, 2004, esp pp. 86-88

68. Sauvaire M H, *La Numismatique et la Metrologie Musulmanes* (a series of articles published in the Journal Asiatique, 8th series, vols., 3, 4, 5, 7 and 8). A large but rather miscellaneous collection of references to Islamic metrology

69. I have omitted a further point from the main text, as it would over complicate the narrative. However, it should be noticed that if we fix a dirhem at 2.97g, its traditional fraction, the sixth part or danik becomes 0.495g, and thus 1,000 daniks equals 495g which is a very good approximation of the ratl kayl. Thus, apparently by default, a new decimal system of measurement came into being, which is spookily like the modern metric system. More than this, it seems we have evidence that this system was recognised and used in some contexts. Balog (*Umayyad, Abbasid and Tulunid Glass Weights and Vessel Stamps*, ANS, New York, 1976) records the existence of six official early Islamic measuring cups, which fall into two series: 50, 24 & 9.75 cc and 60, 5.9 & 3 cc. It seems these cups were very likely to contain the water weights of 100, 50 and 20 daniks, and 120, 12 and 6 daniks. The second series are of course 20, 2 and 1 dirhems, but the first series looks a lot like part of a decimal, indeed, proto-metric system (50, 20 and 10 ccs).

70. Philip Grierson, *Numismatics,* Oxford: OUP, 1975, p. 24

71. Reginald A Smith, *Early Anglo-Saxon Weights*, in *Antiquaries Journal*, 1923, pp 122-9

72. Scull C, *Scales and weights in Anglo-Saxon England,* in *The Archaeological Journal*, London 1990, p183-215

73. Mark Blackburn, *Finds for the Anglo-Scandinavian site of Torksey,* in *Moneta Mediaevalis*, edit Paszkiewicz, Warsaw, 2002

74. I am relying here upon details of coins in the Tonegawa Collection, kindly provided by Tawfiq Ibrahim.

75. Published by Tawfiq Ibrahim, *Ponderales andalusies*, in *Numisma Separata*, num 233, June-December 1993, p. 44

76. This puzzling matter of an 84 grain dinar was first brought to my attention on the Yahoo Islamic Coin Group by Tawfiq Ibrahim, it was, I think, solved there with the kind assistance of Ed Hohertz and Michael Powell. That solution seems to be found already in 2015 when Rafael Frochoso Sánchez pointed to a grain of 0.054 to 0.056 in a footnote here: https://dialnet.unirioja.es/servlet/articulo?codigo=4764209

77. Philip Grierson, *Money and Coinage under Charlemagne*, 1965, reprinted in *Dark Age Numismatics*, paper XVIII, 1979

Harry Miskimin, *Two Reforms of Charlemagne, Weights & Measures in the Middle Ages, Economic History Review*, 1967, p 35+

Morrison, K.F. & Grunthal, H.: *Carolingian Coinage*. New York, 1967 (ANS NNM No.158)

78. See for instance the later medieval town weight of such as Toulouse, which retain this old Carolingian standard.

79. Miles, George C. *Early Arabic glass weights and stamps* American Numismatic Society Numismatic Notes and Monographs, no. 111. New York, 1948

80. Sperber E, *Balances, Weights and Weighing in Ancient and Medieval Sweden*. Theses and Papers, Scientific Arch. 2. Stockholm, 1996

81. see:

http://domongol.org/gallery/image_page.php?image_id=8001 (5 ertogs)
http://domongol.org/gallery/image_page.php?image_id=7903 (4 ertogs)
http://domongol.org/gallery/image_page.php?image_id=7905 (3 ertogs)
http://domongol.org/gallery/image_page.php?image_id=7908 (2 ertogs)
http://domongol.org/gallery/image_page.php?image_id=7948 (1.5 ertogs)
http://domongol.org/gallery/image_page.php?image_id=7952 (1 ertog)
http://domongol.org/gallery/image_page.php?image_id=7968 (0.5 ertog)

82. https://www.academia.edu/1872071

83. I corresponded with Sperber as he approached his 100th year, and found hin lucid, and with the generosity of spirit that once was the norm in such scholarly exchanges. Much as I found with Grierson, (who died soon after I met him, in his nineties) The same could be said of John Munro, who sadly died younger, and indeed Mark Blackburn, and Nick Rhodes, both taken from us much too young. I regret to have to write this - but their attitude contrasts sharply with the sort of stance taken by many of the the younger sort of archaeologist one too often meets these days, and this seems quite notably so in connection with the Viking matters.

84 . For these Ottoman/Byzantine standards see Halil Inalcik *An Economic and Social History of the Ottoman Empire*, Vol. 1

85. Saigey, J.F., *Traite de metrologie ancienne et moderne*, 1834, Paris

86. Witthöft, H., 1985, *Spuren islamischen Einflusses in der Entwicklung des fränkischen Münzwesens des 8. Jahrhunderts*, in: Albert Zimmermann A., Craemer-Ruegengerg I., Orientalische Kultur und Europäisches Mittelalter, Berlin).

87. Naismith, R., 2012, *Money and Power in Anglo-Saxon England: The Southern English Kingdoms*, 757–865, Cambridge) I corresponded at some length with Naismith on this matter, without getting any clear response.

88. IV.10.23 in the Museum catalogue

89. Blancard, L. *La Livre de Charlemagne d'après le Caroli Pondus du musée Kircher.* Paris, S.n., 1889.

90. M. V. Capobianchi, *Les Caroli Pondus conservés en Italie*, Mélanges de l'école française de Rome, Année 1900 20 pp. 43-77

91. Thanks to Prof. Metcalf for pointing out the likely date of the re-adoption of sterling weight (in correspondence). *The Oxford English Dictionary,* apparently taking as its source a paper by Grierson, associates the earliest use of the word sterling (in the form 'esterlin') with documents written in Normandy around the late eleventh century. see P. Grierson, *Sterling*, in *Anglo-Saxon Coins*, ed. Dolley, 1961, pp. 266-83

92. Stewart Lyon, *Silver weight and minted weight in England c. 1000-1320, with a discussion of Domesday Terminology, Edwardian Farthings and the Origin of English Troy* in *The British Numismatic Journal*, vol 76, 2006, pp. 227-241

93. see F G Skinner, *Weights and Measures,* HMSO, 1967, p. 99

94. In 1987 R D Connor wrote "the statement that an English silver penny weighs 32 wheat grains is simply not true" *Weights and Measures of England,* HMSO publications, p. 124-5. Connor revised his opinion after criticism from Biggs, see page 117 of *Weights and Measures in Scotland*, Connor and Simpson, National Museums of Scotland, 2004. In doing so Connor fell into line with a body of opinion running through English metrology for more than a century (defended in recent times by Lyon and Biggs) which assumes that Tower weight long pre-dates Troy weight, and that the 13th century sterling penny consisted of 32 now forgotten tower wheat grains, which weighed less than (exactly $^{15}/_{16}{}^{ths}$ of) the troy wheat grain.

I will mention two problems with this idea. Firstly, as shown earlier, the fully fledged Troy/Tower system, as we know it, existed long prior to the 13th century, within late 7th century Islam. It derives from a Babylonian practice that is more than 2000 years older still. The Tower weight is a subsidiary derivative of Troy weight, which appears to have come into existence as such, at least as early as 700 AD, as our examination of Islamic practice has shown. Secondly, whilst it is easy to see how Tower weight could develop as an adjunct to Troy (essentially a 15 troy ounce pound created by the deduction of $^{1}/_{16}{}^{th}$ as seigniorage from the troy pound), it is very hard indeed to see how the reverse process could ever occur. If Tower began as a 12 tower ounce pound, comprising 240 sterling pennies each of 32 tower grains, what could possibly cause it then to be down sized to a $11^{1}/_{4}$ ounce pound and a thirty grain penny in order to create a new heavier troy pound, penny and grain?

Much simpler, is to return to Connor's initial position, and simply assume the Bread assize document of around 1266 misleads, most probably deliberately. It should be noted that the document stipulates the statutory weight of the farthing loaf in £:s:d. If we assume that the theoretical standard was originally Troy weight, but, as seems quite possible, provincial standard weights were customarily got from physical piles of English pennies, 'called a sterling round, and without any clipping', then any seigniorage deduction levied upon silver metal in order to turn it into coin would automatically be reflected in a reduction in the weight of the loaf of bread also. In effect the merchant body as a whole, although apparently losing out through seigniorage applied to bullion presented at the mint, were remunerated by being enabled to sell bread, and other goods, at equivalently short weight, merely by using coins as their weights.

Magna Carta (1215) stipulated that one weight should govern trade in England, without specifying what that weight should be. The assize of Bread and Ale seems to indicate an official policy of paying lip service to this agreement by suppressing the existence of Troy, and promoting Tower as the sole weight, and by obfuscating troy and tower penny weights, henceforward misrepresenting the sterling penny as the sole 32 grain penny. Such a move may well have been politically expedient in the troubled 13th century. At a practical level, the misrepresentation was rectified by the move back to the Troy standard by Henry VII in 1497. But the apparent misrepresentation has never been espunged from the historical record, and a failure to see it for what it was has thrown the study English metrology into a confusion that persists after eight centuries.

95. John H Munro, *The Maze of Medieval Mint Metrology*, in *The Journal of European Economic History*, 29:1 (Spring 2000), p. 173-99

96. see *The Complete Oxford English Dictionary*, entry for 'sterling', and note 48 above

97. Norman Golb. *The Jews in Medieval Normandy: A Social and Intellectual History* New York: CUP. 1998

98. Arthur Engel, Raymond Serrure, *Traité de numismatique du Moyen Âge.* p. 605, footnote (A rather dated reference, but I have located none better)

100. Alan M Stahl, *Zecca: The Mint of Venice in the Middle Ages*, New York. 2000

101. This point is one of several valuable observations made in: Harry A Miskimin, *Two Reforms of Charlemagne, Weights and Measure in the Middle Ages, EHR*, 1967, p 35+. However, Miskimin's paper as a whole is something of an object lesson in how not to approach metrological studies.

102. This point was correctly made by Pamela Nightingale in: *The Evolution of Weight Standards,* in *Economic History Review,* 1985, pp 192-209. Unfortunately Nightingale followed Miskimin's lead and gave a different interpretation

103 Peter Spufford, *'Money and its use in Medieval Europe*', CUP 1988, pp. 160-161.

104. John D Brand, *The English Coinage 1180-1247: Money, Mints and Exchanges*, British Numismatic Society Special Publication No 1, London, 1994, appendix 2, pp 73-5

105. I owe this point, and many others to web debate, and criticism, from Ross Glanfield of Sydney, Australia

106. R D Connor, *The Weights and Measures of England.* HMSO, London: 1987, p. 132 (footnote)

107. Stephen Album, '*A Checklist of Islamic coins'* Santa Rosa, 1998, p 51

108. R D Connor, *The Weights and Measures of England,* HMSO, London: 1987, pp. 131-3

109. F G Skinner, *Weights and Measures,* HMSO, 1967, p. 10

110. John H Marshall, *Taxila,* Cambridge, CUP, 1951, pp. 508-12

111. ten such coins in mint state (all GH 566, perhaps 200 BC) average 3.39 grams:
3.10, 3.45, 3.28, 3.46, 3.52, 3.67, 3.31, 3.26, 3.61, 3.16
ten earlier coins (GH period I, various types, circa 400 BC) in excellent condition average 3.43 grams:
3.36, 3.48, 3.35, 3.50, 3.51, 3.50, 3.38, 3.37, 3.43, 3.41

112. *The Laws of Manu*, trans. by G Bühler, *Sacred Books of the East, Volume 25,* 1886, Chapter VIII, verses 134-136

113. Two days after I wrote this, and completely unexpectedly, a small packet of ratti seeds arrived through the post, a gift from (the late) Dr K G Atkins, collected in India in 1989. I took 32 randomly from the bag and was amused to find they weighed 3.39g

114. *The Arthashastra,* trans R. P. Kangle, Delhi, 1972, 2.19.5-8 Note that since I wrote in 2009, a new translation of the Arthashatra has appeared, by Olivelle. This apparently seeks to associate the contents of the book with a period at least 200 years after the reputed author, Kautilya. Whilst it may well be true that the version we have was ultimately composed as late as the 3rd century AD, that does not in itself contradict the position taken by Kangle, that it incorporates material from very much earlier times (much as similar ancient Chinese and indeed Greek political documents seem to do). The passage referring to "hardner" (2.12.24) seems highly pertinent to the 'score-and-snap' technique of Mauryan flan manufacture. It seems unlikely anyone would be much aware of the details of this long after the fall of the Mauryas. When I put this point to Olivelle, he replied that he 'knew nothing about numismatics'. In "*Reimagining Ashoka*" (Olivelle, 2012) Shailendra Bhandare attempts to treat with the matter directly, but does so unsatisfactorily. I will stick by the Kangle interpretation here.

115. H W Codrington, *Ceylon Coins and Currency*, Colombo, 1924, Appendix C, pp 188-90 has a useful collection of passages from Ancient and Medieval Indian texts bearing upon metrology, including extracts from the cited authors.

116. This significance point was brought to my attention by Meeta Rajivlochan. He made a second thoughtful comment which I will mention here - that the failure of India to adopt a mina similar to those found in Persia and Europe was primarily to do with rice being a staple crop in much of India, and having a significantly lower calorific content, leading to a higher weight (seer) standard

117. Prashant P. Kulkarni, *Earliest gold coins of India and Baktria*, Numismatic Digest 40, 2016 One coin of this type has long been in the BM - John Allan, *Catalogue of the Coins of Ancient India*, British Museum, London, 1967, p. 236 # 169, Pl XXXV 11

118. Robert Tye, *The Cast Copper Coinage of Ancient Northern India*, ONS Newsletter #69, February 1981

119. Some authorities put the Early Indo-Greek (so called) 'tetradrachm standard' a little lower at 9.6g. Most agree that during a later debasement, by the Indo Parthian Gondophares, it was raised again to around 10g

120 Some may feel that the Taxila bent bars (615 above) might qualify as the first tolas, and at c. 11.5g they do nearn exactly replicate the rupee standard tolas issued by Akbar almost 2 millennia later. This seems to me to be just a coincidence however. The weight of the Taxila Bars was explained above in terms of the so called "Hittite standard". The tola of 11.5g+ emerges during 16th century, and we have no evidence at all to support a narrative carrying the standard back to the very early times of the Taxila Bars.

121. Personal communication from Robert Bracey

122 *Alberuni's India. An account of the religion, philosophy, literature, geography, chronology, astronomy, customs, laws and astrology of India about A.D. 1030*", (published in English) London, K. Paul, Trench, Trübner & Co., 1910.

121 Astonishingly, when I tracked down 29 selected early Shahi Spalapati silver coins for a talk I gave in 2010, I found they gave an average weight of 3.41g, or 3.43 when outliers were rejected. Near exactly the Same as Hemmy's result for both Indus Valley and Mauryan coins. An average for 10 somewhat later Samanta Deva (type Tye 14) in VF condition is 3.26g viz: 3.22, 3.26, 3.19, 3.17, 3.23, 3.28, 3.25, 3.26, 3.35, 3.25 Since the coins were struck with little change of type for over two centuries it is hard to get a satisfactory, chronologically homogenous sample, or to tell how, or even if, the weight changed over time.

123. Ten random Yamini dirhems of Mahmud, Tub. 107+ in good condition: 2.87, 3.14, 2.86, 2.91, 2.80, 3.46, 3.29, 2.82, 2.79, 2.94

124. Oddly Alberuni does not mention the ratti, nor make room for a weight equal to 128th of the suvarna. In its place he mentions a 'yava', which is a grain, and four of which make an 'andi'. The yava was 256 to the suvarna, and thus on the Indus scale would weigh 0.0535, a little heavier than the wheat grain of Roman and Arab metrological systems, but exactly half the ratti. Whether the change from a ratti to a yava basis was due to borrowing from Islamic, Greek, or Persian sources I cannot say, but some such seems likely.

125. Ten good coins weigh: 1.78, 1.84, 1.49, 1.50, 1.55, 1.50, 1.80, 1.87, 1.50, 1.89. The weights seem to point to two standards here, but the coins look identical, and several different random mixes all came out as an average close to 1.7 grams.

126. Thomas E, '*The Chronicles of the Pathan kings of Delhi*' p. 224

127. H W Codrington, *Ceylon Coins and Currency*, p. 6

128. John Deyell, *Living Without Silver* OUP, Delhi, 1990. 655 specimens of variety Deyell 159 averaged 4.04g (Deyell's bulk weighing). Ten excellent specimens here average 4.08g: 4.17, 4.00, 4.04, 4.10, 4.09, 4.17, 4.09, 3.95, 4.07, 4.11

129. Typically these weigh about 3.9 to 4.25g, but I once came across a group of exceptionally well made pieces, probably part of a hoard, which weighed: 4.15, 4.17, 4.14, 4.14, 4.17. This suggests that there was perhaps an initial issue that adhered very closely to the Persian mithcal, unless an unlikely fluke was involved.

130. John Deyell, *Living Without Silver*, item 145, average of 33 pcs

131. ten specimens : 3.99, 4.25, 4.17, 4.24, 4.20, 4.14, 3.97, 4.16, 4.10, 4.21g

132. H W Codrington, *Ceylon Coins and Currency,* page 7, note 23.

133. H W Codrington, *Ceylon Coins and Currency,* page 7, note 20.

134. See Tye, *Jitals*, South Uist 1995 for further details.

135. Stephen Album, *A Checklist of Islamic Coins* Santa Rosa 1998, p. 103, footnote

136. I G Spassky, *The Russian Monetary System*, 1967, Amsterdam, p. 74

137. Joseph Jacobs, *Jewish Contributions to Civilization,* Philadelphia 1919, pp 194-6

138. Iwata Shigeo: *Changes of the Chinese Standard Mass Unit*, in: *Acta Metrologiae Historicae*: Travaux du II 3rd-5th Oct, 1986, Linz, pp. 117-129.

139. Goron & Goenka, *The Coinage of the Indian Sultanates,* New Delhi, 2001 item GZ 1

140. Thakkura Pheru, *Dravya Pariksha*, composed around 1318 AD. Translation in *Indian Numismatic Chronical*, Vol VII, parts I-II, (1969), pp 100-114. Discussed in Deyell, *Living without silver*, OUP, Delhi, 1990, Appendix B, also in Marie H Martin '*Reforms of the sixteenth century'* in *The Imperial Monetary System of Mughal India*, ed J F Richards OUP Delhi 1987

141. 'Jital' seems to be the name given in common parlance to the 4 masha coins of the Hindus by Moslems, to distinguish them from species of the dirhem. The name of the 4 masha weight in Islamic text however is 'tanki' which translates as 'coin'. The practice of using 4 masha coins as standards of weight in Shahi, as in Mauryan times is likely the basis of this etymology.

142. Goron & Goenka, *The Coinage of the Indian Sultanates,* New Delhi, 2001, gives the best comprehensive survey of Indian Sultanate coins and their weight standards.

143. In succeeding centuries it drifted up a little, to 11.6g or 11.7g

144. This account closely follows the very accessible commentary on Abu-l Fazi's original text by Marie Martin in *The Imperial Monetary System of Moghul India*, in J F Richards, Delhi, 1987

145. ten well preserved tankas, type as Goron D. 448 weigh: 8.9, 9.0, 9.0, 8.8, 8.9, 9.0, 9.0, 8.9, 9.0, 8.9g

146. Edward Thomas, *The Chronicles of the Pathan Kings of Delhi*, London, 1871, p 223

147. ten well preserved tankas of Mahmud, Goron J 12 weigh: 9.7, 9.8, 9.4, 9.4, 9.8, 9.6, 9.8, 9.8, 9.7, 9.7g

148. ten well preserved specimens weigh 5.06, 5.07, 5.07, 5.06, 5.07, 5.08, 5.07, 5.08, 5.06, 5.10g

149. ten well preserved specimens weigh: 4.78, 4.81, 4.79, 4.80, 4.78, 4.79, 4.80, 4.76, 4.81, 4.80g

150. Codrington, *Ceylon Coins and Currency*, Colombo 1924, p 115

151. Stephen Album, *A Checklist of Islamic Coins,* Santa Rosa 1998, p. 120, type 2432.3

152. 7 pieces weigh: 4.77g, 4.70g, 4.69g, 4.67g, 4.63g, 4.69g, 4.84g

153. Braun R & I, *Opium Gewichte*, Ladau, 1983, p. 40 ff, and Wicks R S *Money Markets & Trade,* SEAP, 1992

154. Iwata, Shigeo. *Changes in the Chinese Standard Mass Unit* in *Acta Metrologiae Historicae II* Ed. Harald Witthöft and Cornelius Neutsch. Linz: Rudolf Trauner Verlag, 1989

155. Endymion P. Wilkinson, *Chinese History*, HUP, 2000, p. 234

156. Fragments of this are translated by Homer Dubs in: '*The History of the Former Han Dynasty*' by Pan Ku, Baltimore,1938, page 276 ff

157. see this link for an excellent set, with a liang of 15.5g a catty of 251.3g and a double catty tequaling the mina of Darius..... http://www.kepu.net.cn/gb/civilization/zhou/tolerance/200204110135.html

158. Peng makes the initial Wu Shu issues 4 grams, and (albeit rather casually) directly compares them with the Athenian drachm *A Monetary History of China,* Volumes One and Two by Peng Xinwei, translated by Edward H. Kaplan. p. 107

159. John Deyell, *Living without silver*, OUP, Delhi, 1990

160. Stephen Album, *A Checklist of Islamic Coins* Santa Rosa 1998

161. Sir William Ridgeway, *The Origin of Metallic Currency and Weight Standards*, Cambridge, 1892

162. Marie H. Martin, *The Reforms Of the Sixteenth Century and Akbar's Administration: Metrology and Monetary considerations*, in Richards, J.F., Ed. *The Imperial Monetary System of Mughal India* OUP Delhi, 1987

163. Phillip Grierson, *Numismatics*, Oxford 1975, p. 148, Grierson suggests damaged and badly worn pieces should be excluded. Where possible also significantly worn coins.

164. Harry Miskimin, *Two Reforms of Charlemagne? Weights and Measures in the Middle Ages*, in *Economic History Review*, 20 (1967), pp. 35-52,

165. Gurnet, Francois. *Quelques considerations sur le monnayage Sassanide de Xusro II avec "afid"* in *Materiaux pour l'histoire Economique du Monde Iranien,* Paris, 1999.

166. Karl Popper, *Unended Quest*, London, 1976, p. 9

167. James Prinsep, *Essays on Indian Antiquities, Historic, Numismatic, and Palæographic: To which are added his useful tables, illustrative of Indian history, chronology, ... coinages, weights, measures, etc.*. 1858, (edited by Edward Thomas)

168. Harry Miskimin, *Money and money movements in France and England at the end of the Middle Ages*. In *Precious metals in the later medieval and early modern worlds,* ed. J. F. Richards, Durham, 983, p. 84

169. John Munro, 1983. *Bullion flows and monetary contraction in late Medieval England and the Low Countries*. (also in J. F. Richards, Durham, 1983, above), p. 109

170. W Stanley Jervons, *Money and the Mechanism of Exchange*, London, 1896, quoted in *Money and Banking in Medieval and Renaissance Venice,* Lane & Mueller, Baltimore and London 1985, p. 59

171. Nicholas Barbon, *A Discourse of Trade*, London 1690, p. 29, Quoted in *Studies in the Theory of Money*, Douglas Vickers, New York, 1959. Barbon was a Chartalist 200 years before Knapp invented the term.

172. Michael L Bates, *Coins and Money in the Arabic Papyri*, in *Documents de l'Islam médiéval: Nouvelles perspectives de recherche Actes de la Table Ronde,* Paris, 1988 ed. Yusuf Ragib; Cairo, 199, pp. 43-64.

173. Morton A H, *A Catalogue of the Early Islamic Glass Stamps in the British Museum,* London 1985 p. 14

174. Arthur J Rolnick, Francois R Velde, Warren E Weber *The Debasement Puzzle: An Essay on Medieval Monetary History* in *The Journal of Economic History*, Vol. 56, No. 4 (Dec., 1996), pp. 789-808

175. *The Babur-nama*, trans. Beveridge, London, 1921, p. 338-9

176. Thomas J Sargent and Francois R Velde, *The Big Problem of Small Change.* Princeton' 2002. pp 4-5

177. Aschheim J and G S Tavlas (1985), *Alexander Del Mar, Irving Fisher, and the quantity theory of money*, Canadian Journal of Economics, vol. 18, no. 1, pp. 293-313. &
Aschheim J and G S Tavlas (2004), *Academic Exclusion: the case of Del Mar,* European Journal of Political Economy, vol. 20, no. 1, pp. 31-60

6. Bibliography of Coin Reference Catalogues

There is a huge literature cataloguing known coin types, far greater than any one individual could master. The works already cited are repeated here - they are reasonably easy to locate, reasonably comprehensive and reasonably easy to use. In addition is a list of further useful books which offer yet more comprehensive coverage. Finally there are some suggestions about where to look to find further, more detailed bibliographies, which will catalogue even more obscure issues.

MODERN WORLD COINS

Chester L Krause and Clifford Mishler: *Standard Catalogue of World Coins,* Iola, (many editions)
This is the most complete all world catalogue for recent times, the most comprehensive editions of which attempt to cover all issues world wide from around 1701 to the present day

ANCIENT GREEK COINS

SG = David R. Sear, *Greek Coins and their values, Volumes 1 & 2,* Seaby, London (1978-9)

Richard Plant, *Greek Coin Types and Their Identification.* London, 1979
This arranges more than 2000 commoner types according to their design, allowing fast attribution by the novice

SNG Cop. = *Sylloge Nummorum Graecorum: Royal Collection of Coins and Medals, Danish National Museum* 1942-77
The Sear books include only a selection of known Greek coin types. However, there is no attempted complete catalogue of the whole series, more detailed coverage is largely offered by reference to catalogues of large collections. SNG Cop., originally published in 43 volumes is perhaps the most complete and widely used, but there are many other collections published in the Sylloge series, and many others published independently. The British Museum Catalogue of Greek coins for instance runs to 29 volumes.

Dennis Kroh, Ancient Coin Reference Review, 1993
Gives a detailed bibliography of all the standard references for Greek, Roman and Byzantine coins, including the attempted complete catalogues of many individual series within Greek coinage as a whole.

CELTIC COINS

R. D. Van Arsdell , *Celtic coinage of Britain*, Spink, London 1989
Celtic coins are sometimes incorporated into catalogues of Greek coins, or rather imprecisely into catalogues of the coins of individual modern European countries. The above is the currently most widely used catalogue of British Celtic issues

JEWISH

Ya'akov Meshorer, *Ancient Jewish Coinage*, 2 vols New York, 1982

ANCIENT ROMAN COINS

SR = David R. Sear, *Roman Coins and their values,* Seaby, London (1988)
This is merely the most widely used single volume catalogue of Roman coins. Sear himself has produced a more comprehensive 4-volume catalogue of the series. More comprehensive still are:

Michael H. Crawford, *Roman Republican Coinage*, 2 vols, Cambridge 1974

Mattingley, Sutherland and others, Roman Imperial Coinage, 10 volumes, Spink, London 1923-1994, (many revisions)

Roman provincial issues of the East are often catalogued with Greek coins, the most widely used specific catalogue is

SGI = David R. Sear, *Greek Imperial Coins and their values,* Seaby, London (1982)

More detailed is: **A Burnett, *Roman Provincial Coinage,* 2 vols, British Museum, London, 1992-9**

BYZANTINE COINS

SB = David R. Sear, *Byzantine Coins and their values,* Seaby, London (1987), More detailed is:

Bellinger, Grierson & Hendy, *Dumbarton Oaks Byzantine Coin*, 5 Volumes 1-5 1966-99

MEDIEVAL EUROPE

E&S = Arthur Engel & Raymond Serrure. ***Traite de numismatique du Moyen Age*****, 3 vols, Paris (1891-1905)**
A largely textual account of the medieval coins of Europe, with almost 2,000 types are illustrated by line drawings. Recent inexpensive reprints make it the best available catalogue of the whole series - but a long way from what could be desired.

Kristian Erslev, Medieval Coins in the Christian J Thomsen Collection, Attic Books, New York 1992
The most widely available single volume catalogue of the coins of (large parts of) Medieval Europe. The illustrations are mostly of rather rare and expensive pieces, the descriptions of unillustrated coins rather terse

Philip Grierson & Mark Blackburn, Medieval European Coinage Volume 1: ***The Early Middle Ages (5th-10th Centuries)*****,** ***with a Catalogue of the Coins in the Fitzwilliam Museum, Cambridge.*** **Cambridge, 1986**
This is the first of a projected 17 volume set: MEC, to cover the entire coinage of medieval Europe. Two volumes have been completed, 8 more are in preparation

As should be clear from the above, there is no satisfactory single reference to medieval European coinage, and cataloguing requires access to and knowledge of a rather large library. I list here just a selection of books which I have found useful in covering fairly large amounts of material in full, or reasonable detail:

MEDIEVAL LOW COUNTRIES

F. Den Duyts, ***Les Anciennes Monnaies des Comtes de Flandre, Ducs de Brabant, Comtes de Hainaut, Comtes de Namur, et Ducs de Luxembourg*** **Published by Alfred Szego, 1972 (Reprint of the 1847 original)**

MEDIEVAL REGAL FRANCE

Jean Duplessy, ***Les Monnaies Francaises de Hugh Capet a Louis XVI*****, volume I and II, 2nd edition, Platt, Paris, 1999**
which is more up to date than:

Ciani, L.: ***Les monnaies royales Françaises de Huges Capet a Louis XVI*****, Barcelona, 1965** reprint of the 1926 original,

MEDIEVAL FEUDAL FRANCE

Jean Duplessy, , ***Les Monnaies Francaies Feodales,*** **Tome 1, Platt, Paris, 2004** which partially replaces
F. Poey D'Avant. ***Monnaies Feodales de France*****. Three volumes. Paris, 1858 – 1862,** a useful summary of this is
Boudeau, E., ***Monnaies Francaises Provinciales*****, Florange, Paris, 1996** (reprint)

MEDIEVAL SPAIN

Juan R. Cayon & Carlos Castan, ***Monedas Espanolas*****, Madrid 1991,** also

Alois Heiss, ***Descripción general de las monedas hispano-cristianas*****, 3 vols, Madrid, 1865-1869**

MEDIEVAL ITALY

Elio Biaggi, ***Monete e Zecche Medievali Italiane*** **Turin 1992,**

since minor coins of Sicily turn up quite frequently, the following is also useful
Rodolfo Spahr, ***Le Monete Siciliane Dai Bizantini A Carlo I d'Angio 582 - 1282*****, Zurich/Garz, 1976**

MEDIEVAL GERMANY

Hugo von Saurma-Jeltsch, ***Die Saurmasche Münzsammlung*****, Berlin, 1892, reprinted 1977**
Coins of Germany and surrounding areas (from around 1280 to 1620). It focuses specifically upon the common everyday denominations that collectors are most likely to come across, thus is one of the most useful catalogues on medieval European coins there is. Further it is available on line at **http://someoldcoins.org/saur/**

D M Metcalf. ***The Coinage of South Germany in the Thirteenth Century*****, Spink, London, 1961.**

MEDIEVAL AUSTRIA

Luschin: ***Friesacher Pfennige*** **in** ***Numismatische Zeitschrift*****, vol. 55, pp. 89-118, 1922; & vol 56, pp. 33-144, 1923.**

MEDIEVAL POLAND

Marian Gumowski, ***Handbuch der Polnischen Numismatik*****, Graz, 1960**

MEDIEVAL HUNGARY

Huszar, Lajos: Münzkatalog Ungarn von 1000 bis heute. München 1969, also

L. Rethy, ***Corpus Numorum Hungariae*****, Akademische Druck, Graz, 1958**

MEDIEVAL S. E. EUROPE
D M Metcalf, *Coinage in South-Eastern Europe, 820-1396* RNS, London, 1979

MEDIEVAL RUSSIA
I G Spassky, *The Russian Monetary System, A Historico-Numismatic Survey*, Amsterdam, 1967
More an account than a catalogue, but well illustrated, and it is hard to find anything more comprehensive and accessible.

MEDIEVAL CRUSADER STATES
D M Metcalf, *Coinage of the Crusades and Latin East in The Ashmolean Museum* Oxford, 1995, RNS, London, 1995

Malloy, Preston and Seltman, *Coins of the Crusader States*, Attic Books, New York, 1994, 2nd revised edition 2004

MEDIEVAL ARMENIA
Paul Z. Bedoukian, *'The Coinage of Cilician Armenia,'* American Numismatic Society NNM 147, New York, 1962

ANCIENT PERSIA

The coinages of the Achaemenids, the Parthians, and the lesser Ancient States are included in the Seaby publications **SG** & **SGI** referenced above. They also appear in the Mitchiner catalogue **MA** referenced below - which also covers Sasanid issues. Stand alone catalogues for the series include:

PARTHIAN
David Sellwood, *An Introduction To The Coinage Of Parthia,* Spink, London, 1980

SASANIAN
David Sellwood, Philip Whitting and Richard Williams, *An Introduction to Sasanian Coins,* Spink, London, 1985

MEDIEVAL ISLAM

A = Stephen Album, *A Checklist of Popular Islamic Coins*, Santa Rosa, second edition, 1998
A very comprehensive catalogue of all Islamic coin types, it unfortunately has no illustrations at all. An illustrated version is promised, and the sensible move for anyone on a budget wanting just one illustrated standard reference for the Islamic series is to wait for it to appear.. It also includes a very full bibliography.

MI = Michael Mitchiner, *Oriental Coins and their Values: The World of Islam*. Hawkins, London, 1977 Reprinted 1998
The most widely used reference to Islamic coins at present available

Stanley Lane-Poole, *Catalog of Oriental Coins in the British Museum*. Ten Vols. British Museum, London, 1875-1890
This is rapidly being replaced by publications of more complete collections of the 20th century:

***Sylloge Numorum Arabicorum Tuebingen.* Tübingen: Ernst Wasmuth Verlag, 1993 onwards**
Five volumes have so far appeared, but the projected total is more than 20 volumes, a much more complete collection of the whole series than any so far published. Arrangement of type is geographical rather than dynastic, which makes it difficult to use to catalogue a coin, (unless you already know what it is!)

***Sylloge of Islamic Coins In the Ashmolean,* Ashmolean Museum, Oxford, 1999** ongoing
Three of the proposed 10 volumes have so far appeared, in a more traditional and accessible layout

Useful studies of the coins of individual dynasties include:

ISLAM UMAYYAD
Klat, Michel G. *Catalogue of the Post-Reform Dirhams of the Umayyad Dynasty*. Spink & Sons Ltd., London, 2002.

ISLAM AYYUBID
Balog, Paul. *The Coinage of the Ayyubids*. Royal Numismatic Society Special Publication Number 12, London, 1980.

ISLAMIC MAMLUQ
Balog, Paul. *The Coinage of the Mamluk Sultans of Egypt and Syria*. ANS Numismatic Studies No. 12, New York, 1964.

ISLAMIC ILKHANID
Omer Diler, Ilkhans, Coinage of the Persian Mongols, Istanbul 2006

ISLAMIC OTTOMAN
Slobodan Sreckovic, Akches, 5 vols, Belgrade 1999-2007 covers the minor issues in siver from 1299 to 1622

ISLAMIC LATE MEDIEVAL IRAN
Farahbakhsh, H. *Iranian Hammered Coinage, 1500-1879,* Berlin, 1975

ANCIENT INDIA

MA = Michael Mitchiner, *Oriental Coins, the Ancient and Classical World,* London, 1978
The most complete coverage of ancient Indian coins in a single volume, also covers Ancient Persia and Ancient China

R = Dilip Rajgor. *Punchmarked Coins of Early Historic India*, California, 2001
The most complete coverage of the punchmarked silver coins of the early independent states

P. L Gupta & T R Hardaker, *Ancient Indian silver punchmarked coins of the Magadha-Maurya Karshapana series*, IIRNS, Anjaneri, 1985 The most complete catalogue of the Imperial punchmarked issues. Terry Hardaker is planning to replace the current edition with a revised and updated version

O. Bopearachchi, *Monnaies Greco-Bactriennes et Indo-Grecques,* Paris, 1991
The most up to date catalogue of Bactrian and Indo-Greek coins

Robert C. Senior, *Indo-Scythian Coins and History,* (3 volumes), Classical Numismatic Group, Lancaster, 2001
The most compete and up to date catalogue of Bactrian and Indo-Greek coins

John Allan, *Catalogue of the Indian Coins in the British Museum*. London. 1936
Though long out of date this remains the best corpus of post imperial civic and 'tribal' copper issues. Wilfried Pieper is working on a more up to date corpus, which will contain a great many more types

A S Altekar, *Coinage of the Gupta Empire*, Varanasi, 1957
Most up to date catalogue, but photo quality not very good

MEDIEVAL INDIA

D = John Deyell, *Living Without Silver,* OUP, Delhi 1990
The most complete single reference on North India (primarily Hindu) Medieval coinages 750-1250

MN = Michael Mitchiner, *Oriental Coins, Non-Islamic States and Western Colonies,* London, 1979
Contains many medieval Indian (Hindu) Issues, alongside Medieval issues of Burma, China and other Eastern states

MSI = Michael Mitchiner, *The Coinage & History of South India*, 2 vols, London, 1998
The most complete listing of the Hindu issues of both Ancient and Medieval South India

T = Robert & Monica Tye, *Jitals*, South Uist, 1995
Integrates the Medieval jital issues of Hindu and Islamic North India with the contemporary issues of Islamic Afghanistan

Rhodes, Gabrisch, & Valdettaro *The Coinage of Nepal* 576AD - 1911
Very complete listing of all Nepalese coinages

G = Stan Goron & J P Goenka, J.P. *The Coins of the Indian Sultanates*, New Dehli, 2001
Very complete listing of all the Sultanate coinages

SAC = Colin R Bruce et al, *South Asian Coins and Paper Money*, Krause Publications, 1981
This is the most up to date corpus of Moghul coins. Unfortunately it is OOP and subsequent Krause catalogues have reprinted only parts of it. The Krause world coin catalogues remain the first port of call in referencing post Moghul issues

FURTHER EASTERN

Jiang Qixiang (ed) Xinjiang Numismatics, Hong Kong, 1991
A fairly comprehensive and well illustrated listing of ancient and medieval issues of Central Asia

Allan R Barker, *The Historical Cash Coins of Vietnam,* Singapore, 2005
The most complete single reference on Vietnamese coins

H = David Hartill, *Cast Chinese Coins*, Victoria BC, 2005
The most complete single volume reference on Chinese coins

There are a number of more complete works in Chinese, including:

Zhong Guo Li Dai Hou Xi, or Shanghai Encyclopedia ("Daxi")
twelve-volume work in progress by the Shanghai Museum and Shanghai Numismatic Society

***Zhong Guo Qian Bi Da Ci Dian* (Great Dictionary of China Numismatics)**
10 volume work in progress from Henan Numismatic Society, edited by Zhao Hue Yuen,

Francois Thierry, Monnaies Chinoises, Bibliotheque Nationale
Projected to be the most complete catalogue in a European language, 2 volumes produced so far

Ting Fu Pao *Li Dai Gu Qian Tu Shuo*
A single volume illustrated catalogue in Chinese widely used but superseded by Hartill

F. Schjöth, Chinese Currency, Oslo, 1929
A single volume illustrated catalogue in English widely used but superseded by Hartill

Suggested Pound structures, Expressed in their own Grains, and in Grams calibrated to a 497.66g Troy standard, by Families

Babylonian Mina pre-2000 BC 180 x 60 = 10,600 @ 497.66g yields 0.0469g (sixty shekels x 180 grains, factors 60^2 x 3)
Beqa/Troy family (c. 497.66g)
Egyptian Beqa pre-2000 BC: 256 x 40 = 10,240 @ 497.66g yields 0.0486g (forty beqa, factors 2^10 x 10)
Early Islamic Bullion (& Troy) c. 698 AD (12/16 x 497.66g = 373.24g) = 12 x 10 x 64 = 7680 @ 373.24g yields 0.0486g (12 wuqiyah x 10 dirhems x 64 grains: 2^9 x 3 x 5)
Sterling standard (15/16: thus c. 466.5g)
Early Islamic Coin (& Tower) c. 698 AD (15/16 x 373.24 = 349.9g) = 12 x 10 x 60 = 7,200 @ 349.9 yields 0.0486g (12 wuqiyah x 10 dirhems x 60 grains: 2^5 x 3^2 x 5^2)
Venice (bullion) c. 1200 AD 16 x 24 x 24 = 9216 @ 477.00g yields 0.0517g (16 oncie x 24 denari x 24 grani)
Venice (coin) c. 1200 AD 16 oz Venice = 164 matapans x 41/40 = 160 matapans = 465.4g = approx. 240 sterlings = approx.12oz Tower = approx 12 oz Islamic coin
Cologne (1720 AD) (15/16 x 497.66 = 466.56g) 16 x 8 x 76 = 9,728 @ 466.46 yields 0.0480g (16 ounce x 8 drachms x 76 grains: factors 2^9 x 19)
Cologne (1805) 9,216 grains @ 467.6g yields 0.0507g **Spain** (?) 460g = 16 x 576 = 9216 yields 0.0499g [460g = 130 florins]
Deben/Avoirdupois family (c. 9/10: thus c. 450g)
Egyptian 5-Denen post 1500 BC 192/256 x 50/40 x 497.66g = 466.55g ? but falling to about 455g: 5 deben of 10 kadet of c. 9.1g (thus falling from 7,200 to 7,000 Egyptian grains)
Lydia, Phoenicia, Ptolemaic Egypt (The reduced pound now finds a binary expression) 32 tetradrachms @ 14.2g = 454.4g
Rome post Constantine 100 solidi @ 4.54g = 454g (100 x 12/16 x 7/8 x 1/72 x 497.66 = 453.6g) (note, in practice, 100 solidi at 4.48g yields the Islamic goods pound below)
Early Islamic (goods) 12 x 12 x 64 = 9216 @ 0.0486g = 447.9g (12 wuqiyah x 12 dirhems x 64 grains: factors 2^10 x 3^2)
Florence (yields avoirdupois & US customary) 128 florins @ 3.54g = 453.12 = 16 oz = 9216 grains yields 0.0493g, (florin = 72 grains - Roman Imp. denarius = 72 (Rome) grains)
Attic/Roman coining family (c. 7/8: thus c. 435g)
Attic (coin) c. 600 BC (7/8 x 497.66g = 435.45g) = 100 x 6 x 8 x 2 = 9,600 @ 435.45g yields 0.0456g (100 drachms x 6 obols x 8 chalkous x 2 grains: factors 5^2 x 2^7 x 3)
Roman (coin) c. 50 AD (12/16 x 435.45g = 326.6g) = 12 x 8 x 6 x 12 = 6912 @ 326.6g yields 0.0473g (12 ounces x 8 denarii x 6 obols x 12 grains: factors 2^8 x 3^3)
Roman/Attic (goods) 435.45g = 16 x 8 x 6 x 12 = 9216 @ 435.45g yields 0.0473g (16 ounces x 8 denarii x 6 obols x 12 grains: factors 2^8 x 3^3)
Charlemagne (bullion) c. 790 AD (7/8 x 497.66g = 435.45g) = 16 x 16 x 32 = 8,192 @ 435.45 yields 0.0532g (16 ounces x 16 pennies x 32 grains: factors 2^13)
Charlemagne (coin) c. 790 AD (15/16 x 435.45 = 408.23g) = 20 x 12 x 32 = 7680 @ 408.23 yields 0.0532g (20 shillings x 12 pennies x 32 grains: factors 2^9 x 3 x 5)
France (tournois?) c. 12th century 16 x 8 x 3 x 24 = 9216 @ 0.0532 yields 489.5 (16 once x 8 gros x 3 denier x 24 grains: factors 2^10 x 3^2) [489.5g = 18 Roman ounces]
France (medieval bullion) 12oz France x 20/21 = 349.6g = approx 12oz Tower = approx 12 oz Islamic coin = approx 12 oz Cologne

7. Thanks

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Abbreviations

AD = date after 1 AD

AE = copper, brass etc

AR = silver

AU = gold

B = black billon

BC = date before 1 AD

BOR = Board of Revenue

BOW = Board of Works

c. = circa

cit. = citing

g. = grams

L = value less than £20

M = value less than £100

H = value more than £100

rev. = reverse

T. B. = Tong Bao

W = white or silvery billon

Y. B. = Yuan Bao

Z. B. = Zhong Bao

OLD INDEX (Now up to 4 pages out of true)