ON THE USE OF THE BALANCE AS A DEVICE FOR MEASURING COMMODITIES AND THE ACCURACY OF ANCIENT WEIGHING*

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Abstract

The evidence handed down to us in both literary and archaeological sources is amply sufficient to hold that weights were much more accurately made than earlier investigators tried to make us believe. To arrive at this conclusion, it is necessary to reconstruct how weighing and the adjusting of weights were actually executed. The principal results of this study point to methods no longer in use in our days. In the first place, the system of weighing appears to be in part differential, that is, the system often requires weights to be placed in both pans of an equal-armed balance. Secondly, within a set of weights, individual adjustment, adjustment in groups of weights or both can be observed. Consequently, statistical treatment of mass data of uninscribed single weights is of no use in mass metrology. Thirdly, inscribed weights are not always adjusted according to their inscriptions, which is, however, no problem if they are used in a differential system. For example: a pair of weights marked 4 and 3 is capable of weighing 1 unit exactly, whether they are adjusted to 4 and 3 or 3.8341 and 2.8341 units. Thus, finding weights bearing identical marks of value, but of slightly varying masses in a single excavation level is not conclusive proof for badly adjusted weights.

* In vindication of metric values like (a) 0.05315625 grams (x 9216 = 489.888 grams = 1 theoretical pound of Paris) or (b) 318.1090909r grams (r = recurring decimals) it should be pointed out that any rounding off is unsuited in a comparative study as (a) the resulting value for the pound must be compared with the legal value of the pound (divided into 9216 grains of Paris) and (b) the ratio of different pounds must be established exactly (489.888 : 318.1090909r = 1.54 = 77 : 50).

The excursion on medieval standards constitutes the vital introduction to the standards and method of weighing used in older periods of human history.

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As to the origins of standards of mass a complete new picture emerges which enhances our knowledge on the main stream of the spread of culture. The Cyprian system of mass is sexagesimal in structure and the basic unit is the same as used in Ur half a millennium earlier. Thus, contrary to the prevailing opinion, the Cyprian primary unit of about 1200 BC is a Mesopotamian *sheqel* and not an Egyptian *qedet*.

Introduction

The origins of standards are just as important as motives, style and mass in any study of the birth of coinage, and at present there is little consensus on this matter. The problem of the origins of standards of mass—strongly related to the introduction of coinage—has been discussed as an aside by Seidenberg and Casey.[1] Their article is of considerable importance as it raises topics which bear upon the practical use of the balance.

Seidenberg and Casey have written about the ritual use of the balance. Let me summarize their conclusions. In the beginning was the see-saw, and a rite in which two human participants placed themselves on the see-saw. They seesawed standing up and the first to fall off was the loser. To expedite the ritual, images were used instead of people, and the rites were reduced to symbols. The equal-arm balance was the result of this symbolization. Then the standard weight came into existence: it corresponds to the Aga Khan in the Aga Khan rite.[2] This rite is an example of the practical use of the balance in the way that we know it, that is to put weights in one pan and commodities in the other one. However, what is familiar in our times does not necessarily reflect ancient practice. It cannot yet be decided for certain whether the ritual use anticipates the practical use. Conclusive evidence has still not been found. I am inclined to accept a ritual origin because their thesis "balance, not weight, is the fundamental aspect of the balance" does, indeed, appeal to me more.

A note on the Egyptian balance in particular may be useful before entering into the practical use of the balance in general. Seidenberg and Casey found a similarity to the Aga Khan rite, and hence to our system of mass measurement, in the Judgement Scene (Fig. 1) which is described in the ancient Egyptian Book of the Dead.

The heart of the deceased is weighed in a balance against a standard, the feather of *Maât*.[3] The method of finding a level position for the balance beam is very simple. The god Anubis points to, or raises, a device

[1] Seidenberg & Casey 1980.

[2] In 1952, the Aga Khan, who was head of the sect of Ismailis, had himself weighed against gold and precious stones.

[3] Stern 1877.

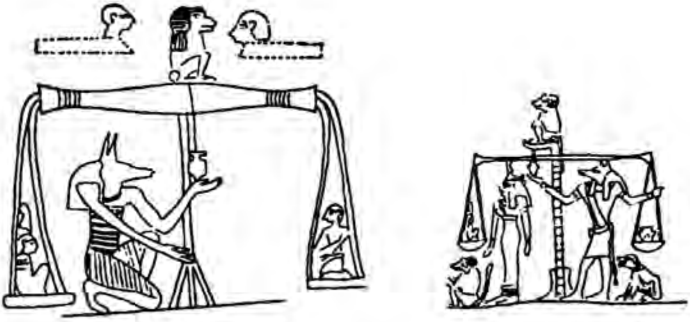

Fig. 1. The Judgement (from Kisch 1975).

which is hanging from the stand of the balance as a demonstration that the beam is horizontal. This object is usually considered to be a plummet,[4] but we do not have a clear view of how the plummet was used. More plausibly the object is a beaker[5] (filled with water) made of transparent stone, e.g. alabaster. So it is obvious that Anubis checks whether or not the balance beam is parallel to water-level.

How was the equal-armed balance used?

The actual handling of the balance cannot be considered in isolation, but rather along with either extant weights of a known ancient standard or with related units known from documentary evidence. Both approaches will be executed to answer the question heading this section.

The quest for ancient standards of mass started three centuries ago. The mass standard attracting generations of scholars is undoubtedly the Roman pound. Early research was mainly devoted to Roman coins as plenty of them in perfect condition were available. Letronne (1817) calculated the mass of the Roman pound from the average mass of a large quantity of Roman gold coins whose relationship to the pound was known: 6154 grains of Paris = 326.868 grams. However, it seems to be possible to find the average mass in different ways and Böckh[6] accepted the higher average mass calculated by Paucker, rounded off to the nearest

[4] Ducros 1908: 36 and plates I-II; Kisch 1975: 34, 36.

[5] This suggestion is based on philological explanations given by Dümichen (1872: 38-40).

[6] Böckh 1838: 165 "Paucker nimmt die Durchschnitte anders, und findet aus den Letronne'schen Münzgewichten ein Pfund von 6165.0288 Par. Gran." In 1799, the standard of the kilogram in Paris was found to be equal to 18827.15 grains of Paris, which gives the grain the legal value of 0.053114783 grams.

grain: 6165 grains of Paris = 327.45 grams. As a mere convention Böckh's value finds almost general acceptance today. However, Letronne was far nearer the truth.

The quantity of actual weights was less plentiful and specimens both inscribed with value of mass and in excellent state of preservation were a rare exception. In the course of the nineteenth century a rapid increase in finds intensified the study of weights. The recovery of inscribed Roman weight-sets revealed a problem, namely, that the Romans[7] "apparently" were unable to make correct weights. A lamentation of Regling[8] outlines the moribund state of research in 1930: "Die monumentalen Quellen ferner sind, was die Gewichtsstücke (....) angeht, oft so haarsträubend ungenau, daß sie meist nur sehr unsichere Zeugen sind."

The opinion that ancient weights have been badly adjusted is based on our system of mass measurement. Using an equal-arm balance, we place the antique specimen in one pan, and precision weights in the other pan until a level position for the beam has been achieved. This is, of course, the correct way of doing it. However, the usual conclusion drawn from the result, concerning the mass of the ancient standard, turns out to be incorrect. Two late Roman weights from Malaga in Spain,[9] inscribed 2 pounds, mass 661 grams (: 2 = 330.5 grams) and 3 pounds, mass 987.4 grams (: 3 = 329.133 grams) will demonstrate what I mean. According to the student's opinion—either the Roman standard has been maintained over the centuries or was a few grams lower in the late Roman period[10]—his conclusion would be that the weights are slightly or badly inaccurate. But the previous owner of the set was not primarily interested in the mass of his weights. His aim was the correct mass of the commodities he was measuring. When placing the 3-pound weight in one pan of the balance and the 2-pound weight and commodities in the other pan, the quantity of commodities was correct if the balance beam was level: 3 - 2 = 1 pound of commodities or 987.4 - 661 = 326.4 grams. Of course, the result of any study is totally dependent on the available facts. The metric values of weights have to be determined as accurately as possible, using suitable equipment. Thus, stressing the need for more precise gram values, a better result should be obtained, e.g. with 987.49 - 660.90 = 326.59 grams.

This method, most suitably defined as the differential system of mass measurement, was used from ancient Antiquity up to modern times. In

[7] Kubitschek 1907: 137-139.

[8] Regling in von Schrötter 1930: 388-389 (= s.v. *Metrologie*).

[9] De Palol 1949: 134 and plate I. Set of seven bronze weights with marks of value. An unmarked weight of 4.7156 grams most probably does not belong to the set. The method of weighing with this set is described in the appendix.

[10] Detailed later on.

most cases a weight-set designed for differential weighing also had additive elements (2 or more weights in a pan) and/or weights were occasionally placed in only one pan instead of in both pans.

The rediscovery of the differential method needs a total reconsideration of the ideas pertinent to mass measurement, as can easily be seen by quoting Petruso:[11]

> "In his study of Near Eastern data available to him in the 1920s, Petrie concluded that, as a rule, we ought not to expect awkward multiples to be represented in metrical artifacts. Denominations of, e.g., 11, 23 or 47 units would be of limited utility in a set of weights, and, moreover, would introduce unnecessary complications in mental tallying."

On the contrary, admitting that the system is differential in structure, a nice series of 12 (23 - 11), 24 (47 - 23) and 36 (47 - 11) units is obtained.

It is not possible to present abundant direct evidence for the differential system of mass measurement. I have found only one ancient source, from Egypt, which points to this method. Petrie,[12] though missing its significance, saved a precious piece of evidence: "There is a weight (....) of about 10 normal deben on which is clearly written "The 12 deben contained in the 2 weights of alabaster of Neferrenpet"." The weight to match has never been recovered.

In perusing the available metrological literature, and especially those works containing ethnographical details, I came across the account of an eye-witness regarding weighing on Madagascar. To clarify the type of argument, I give a new interpretation of the reported evidence of this late 18th-century procedure.

Weighing on Madagascar about 1800 AD

The differential method is still traceable to modern times. Ridgeway,[13] quoting Ellis in his vivid picture of the commercial dealings of the inhabitants of Madagascar, has made a conclusive piece of evidence accessible to scholars who are more familiar with the older periods of human history:

> "The Malagasy have no circulating medium of their own. (....) The Spanish dollar, stamped with the two pillars, bears the highest value. For sums below a dollar the inconvenient method is resorted to the interior, of weighing the money in every

[11] Petruso 1984: 299.

[12] Petrie 1926: 3 and pl. XXVII. Mass 13870 English grains (*c.* 898.8 g).

[13] Ridgeway 1892: 187. Ridgeway referred to Ellis, *History of Madagascar* I, p. 335. The mass of the Mexican silver pillar dollar (1732-1821) is *c.* 27.0635 grams and 8 1/2 dollars were struck to the Spanish mark of 230.04 grams. This Spanish mark and the earlier ones will be discussed later.

case. Dollars are cut up into small pieces, and four iron weights are used for the half, quarter, eighth, and twelfth of a dollar. Below that amount, divisions are effected by combinations of the four weights, and also by means of grains of rice, even down as low as one single grain (....), valued at the seven hundred and twentieth part of a dollar."

Ridgeway did not recognize the importance of its contents. He quoted this passage with the sole intention of showing that on Madagascar, as in other parts of the world, the lowest unit of mass was a natural seed or grain. Clearly Ellis also failed to understand the details of the system of weighing he observed. It is obvious that the differential method was used. However, Ellis' conclusion that combinations of weights only were used to weigh out different amounts of silver below 1/12 of a dollar must be rejected. Below that amount only 1/24 of a dollar is possible.[14] Any other combination will effect a higher result.

If we accept the suggestion that the merchant possessed at least one dollar in excellent condition, then a better explanation can be given: dollars were not accepted at face value. The economy on Madagascar was entirely based on the bullion value of silver. The pillar dollar was the unit of mass of the Malagasy. In fact, leaving aside the grains of rice, with those four iron weights and a dollar serving as a weight which represents the unit, a range of 1/24 - 1 dollar, with steps of 1/24 dollar, can be realized. To minimize the complexity of the interpretation, the dollar has been fixed at 24 parts and the four iron weights—1/2, 1/4, 1/8, 1/12 dollar —have been denoted reciprocally with 12, 6, 3 and 2 parts.

Many weighings can be realized using various combinations of weights. It follows that the weights must be accurate because, in case of doubt, a comparison of the results can be obtained by using another combination. It is clear that the system of mass measurement of the Malagasy precludes fraud. Of course, weighing in practice has to be simple and clear to both buyer and seller. It is easy to satisfy these conditions, as illustrated in table 1.

[14] Viz. 1/8 - 1/12, 1/4 - (1/8 + 1/12) and 1/2 - (1/4 + 1/8 + 1/12) = 1/24.

Left pan	Right pan		Left pan	Right pan	
Weights 1/24 $	Weights 1/24 $	Silver 1/24 $	Weights 1/24 $	Weights 1/24 $	Silver 1/24 $
3	2	1	12 3	2	13
2		2	12 2		14
3		3	12 3		15
6	2	4	12 6	2	16
3 2		5	12 3 2		17
6		6	12 6		18
6 3	2	7	12 6 3	2	19
6 2		8	12 6 2		20
6 3		9	12 6 3		21
12	2	10	24	2	22
6 3 2		11	12 6 3 2		23
12		12	24		24

Table 1. System of weighing on Madagascar. Step 1/24 dollar, range 1/24-1 dollar.

The combinations used for weighing from 1 to 12 parts are repeated for 13 up to and including 24 parts with addition of the 12-parts weight. The dollar is used in the second series as a substitute for the 12-parts weight in the first series. The dollar, which embodies 24 parts, is rarely used, which explains—he was not there at the moment—why Ellis did not mention the dollar serving as a weight. To achieve the intermediate amounts and amounts below 1/24 of a dollar, at most 29 grains of rice have to be added to one pan as 30 grains equal 1/24 of a dollar.

The principal standards of mass of Europe as revealed by Pegolotti (c. 1340 AD) and the standard of Peru

E.M. von Hornbostel suggested a direct derivation of the Peruvian standard of mass from a Mesopotamian standard. As we shall see, the differential system and the adjustment of weights in groups—both practised in Ur in the second millennium BC (see below)—were also known in Peru. But when? Before Columbus' arrival in the New World? The key question is: which standard of mass was in use in Peru in those days? We have an option between a Spanish or a native standard.

The argumentation for a ritual origin of the balance by Seidenberg and Casey[15] is greatly hampered by the problem that some Peruvian weights have been dated to the pre-Spanish period:

> "(....) the question of whether the New and Old Worlds are culturally disparate worlds, or not; for if the balance was independently invented in the two Worlds

[15] Seidenberg & Casey 1980: 183.

(or if one regarded this as the plausible view to hold of the evidence), then the proposal to prove its ritual origin would be an implausible line of thought to follow: one would hardly suppose that the same general ritual set-up, followed by the same mental associations, and by the same application, could occur independently twice."

Their conjecture was that the balance was brought in from Asia over the Pacific, which is possible but unprovable. A definitive solution to the problem would be to disprove the pre-Columbian date of the Peruvian weights. We are inclined to conclude that the art of weighing was introduced by the Spaniards if the weights, though made by the Incas, fit in with a Spanish standard.

Peruvian weight-sets are known. Unfortunately, the sets do not come from controlled excavations, but are the result of grave robbery around the end of the last century. Nowadays it is not clear whether these weights are from the Spanish period or earlier. I agree with Nordenskiöld[16] that the weight-sets have been used for weighing gold, as one can refer to none less than Pizarro as an eye-witness.[17] Weighing of gold presupposes the existence of accurate weights in Peru. Of course, a study of the accuracy of weights has to rest on reliable evidence pertaining to once existing standards in the territory where the weights have been discovered. Nordenskiöld calculated his figures starting from a Spanish onza of 28.716 grams. He gave no reference for this value and I presume that he noted it incorrectly because the more accurate value is approximately 28.756 grams. The difference of 0.04 grams is too much to sustain the pertinent conclusions reached by him. However, Nordenskiöld[18] must be given the credit of being the first scholar to point to the advantages of the system of differential weighing.

Doursther[19] gives some useful information on standards used in Peru in the nineteenth century: in Peru the Spanish mark was used, its mass being 230 grams or 3550 English grains. The mark is subdivided (for silver) into 8 onzas = 64 ochavas = 384 tomines = 4608 granos and (for gold) into 50 castellanos = 400 tomines = 4800 granos. The subdivision for gold was prohibited in Spain in 1731 but maintained in the South American colonies. The mark of Castile is the legal mark of Spain. As is

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[16] Nordenskiöld 1930: 221.

[17] Guerra 1960: 343 "A controversy arose over the statement of Francisco Pizarro, that in Tumbez, Perú, he had observed a Roman scale being used by the Inca to weigh gold: this record is now understood to refer to a European contrivance imported by the Spanish since no other example of such a scale has been discovered."

[18] Nordenskiöld 1930: 216 "in order to balance 2 U, 1 U would have to be placed in the same pan as the goods and 3 U in the opposite pan." See also Seidenberg & Casey 1980: 189.

[19] Doursther 1840: 250 (s.v. *Pérou*), 249 (s.v. *Espagne*).

well known to scholars specialized in modern and medieval metrology, the articles written by Guilhiermoz in the first quarter of this century contain a wealth of reliable information and an astonishing variety of references pertaining to the European systems of mass: in 1799, Ciscar,[20] one of the Spanish delegates to the international commission of weights and measures, compared a legal copy of the double-mark of Castile with the standard of the kilogram in Paris, resulting in the ratio 1 : 2.173474 or 460.093 grams for the double-mark, hence 230.0465 grams for the mark. As we shall see, the theoretical value of the Peruvian mark has to be 3550 Troy grains = 230.04 grams. The smallest Peruvian weight which needs to be discussed has a mass of 1.09 grams. Thus, the more important lower units of the mark are in descending order (silver) 28.755, 3.594375, 0.5990625 and (gold) 4.6008, and 0.5751 grams.

The first difficulty arises here. Mass measurement of precious metals requires a result with a reasonable degree of accuracy, say 0.05 grams each way for all steps within the intended range. Ample research proved that these conditions could not be met, supposing that one of the above mentioned units had to be considered as the step. Moreover, efforts to draw up a range, using our method of weighing and additive, differential and mixed systems, were unsuccessful. Taking the starting-point—these small weights were destined for accurate weighing of gold—for granted, only one conclusion can be drawn, namely, that another unit of mass underlies the Peruvian weights. Nordenskiöld and von Hornbostel[21] argued that some Peruvian weights followed a pre-Columbian standard. Curiously enough, the underlying standard is indeed pre-Columbian, but also Spanish in origin. The earliest possible use in Peru may be linked to the expeditions to the coastal area (Balboa in 1515 or Pizarro, Almagro and Luque in 1525 and 1527) or to the expedition to Cuzco (Pizarro in 1532). However, weights are tools of trade in that they facilitate the evaluation of traded commodities. Among different cultures the standard of the dominant culture will be used. These conditions are met at a slightly later date, viz. after the installation of the first viceroy in 1544.

As stated previously, the mark of Castile was the legal mark of Spain in the nineteenth century. In 1348, in a decree by King Alphonso XI of Castile, it was ordered that the mark of Cologne, which was divided into 8 ounces, had to be used for weighing money and precious metals and the mark of Troyes for other commodities.[22] Pegolotti's merchant manual, written in *c.* 1340, but only surviving as a copy from a copy dated the

[20] Guilhiermoz 1906: 440-441.

[21] Nordenskiöld 1930: 219; Von Hornbostel 1931. Seidenberg & Casey (1980: 187-189) discuss the opinions and conclusions of Nordenskiöld and von Hornbostel.

[22] Guilhiermoz 1906: 440, note 1 "Oro e plata e todo byllon de moneda, que se pese

nineteenth of March 1472, includes abundant information on weights and measures.[23] Pegolotti was a Florentine and active in the famous banking house of the Bardi in Florence from *c.* 1311 till 1347. He worked in Antwerp, London, Cyprus, Florence and Bruges. Pegolotti did not draw up his tables of comparison in Florentine units of mass but in units—tarì and grani—current in Sicily, Naples and Apulia. The ounce (for silver) of 33 tarì was widely used, e.g. in Cologne, London (Tower), Avignon and Messina.[24] In 1348 this ounce became the ounce of Spain for gold and silver.

The second difficulty arises here. Actual standard weights from about the fourteenth century have not survived and, as was shown recently by Ghyssens,[25] the metric values of standards known from the late eighteenth and early nineteenth century do not match Pegolotti's statements. The only possibility is to find an accurate arithmetical link between the figures of the nineteenth century and those mentioned by Pegolotti. Fortunately, I have found five links and one of these is supported by documentary evidence.

Naples. Doursther[26] informs us that the pound of Naples (gold, silver and commodities) was subdivided into 12 ounces and 7200 acini. Its mass is 320.76 grams. Guilhiermoz[27] states that, in 1811, an official commission evaluated the pound of Naples at 320.759 grams. The theoretical value is 320.76 grams and with the factor 120/121 we arrive at the pound[28] as it was in Pegolotti's days: 318.1090909r grams. The pound was divided into 12 ounces = 360 tarì (or terì) = 7200 grani. The grano of Sicily, Naples and Apulia is 318.1090909r : 7200 = 0.044181818r grams. The tarì = 20 grani = 0.88363636r grams. The "international" ounce of 33 tarì (for silver) is equal to 29.16 grams. These values are still hypothetical, thus must be proved.

England. In England, in the fourteenth century, at least 3 pounds existed, called Tower, Troy and Mercatoria. In 1526, the abolishment of the Tower pound was announced in a letter by King Henry VIII.[29] In 1527, in another letter by Henry VIII, it was stated that the Tower pound contained 11 1/4 ounces of the Troy pound. The Tower pound of 12 ounces of 29.16 grams equals 349.92 grams. The Troy pound = 349.92

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por el marco de Colonna e que aya en el ocho onzas; et cobre e fierro e (....) que se pesen por el marco de Tria."

[23] Evans 1936.

[24] Evans 1936: 114; 168.

[25] Ghyssens 1986.

[26] Doursther 1840: 227.

[27] Guilhiermoz 1906: 174-175.

[28] Evans 1936: 168: for gold and silver.

[29] Guilhiermoz 1906: 427-428.

: 11.25 x 12 = 373.248 grams = 16/15 x 349.92 grams. The Troy pound is subdivided into 5760 grains. Hence the theoretical value of the English Troy grain is 373.248 : 5760 = 0.0648 grams. The legal value of the Troy pound is *c.* 373.242 grams.[30]

Rome. Pegolotti[31] evaluated the ounce of Rome at "tarì 31 e grani 7", which makes a pound (12 ounces) of 7524 grani = 332.424 grams x 51/50 resulting in the nineteenth century value of 339.07248 grams. In 1811 the commission of weights and measures arrived at 339.07185 grams.[32]

Genoa. In linking Pegolotti's figures to those known from nineteenth century sources a series of natural factors was discovered: 121/120 (Naples), 16/15 (London) and 51/50 (Rome). Finding, e.g., 239/236 does not necessarily mean that one is on the wrong track, but more probably that the new standard was derived in a different way. The values of the Genoese standards prove this statement conclusively. Thus Pegolotti[33] valued the ounce of Genoa at "tarì 29 e grani 10". The pound (12 ounces) = 354 tarì = 312.80727272r grams x 239/236 = 316.78363636r grams. Guilhiermoz[34] informs us that in 1800 two pounds were known, a subtle pound of 316.778 grams and a gross pound of 317.664 grams. The Genoese pound was 354 tarì in 1340. The 18th century pounds are a few medieval Sicilian tarì heavier. The subtle pound became 358 1/2 tarì = 316.78363636r grams and the gross pound 359 1/2 tarì = 317.66727272r grams. Clearly, for the economic historian, these kinds of facts are more informative than arithmetical factors can ever be.

Spain. Since 1348 the mark of Spain was equal to the mark of Cologne, that is, as I have proved conclusively, 8 ounces of 29.16 grams or 233.28 grams. At a certain moment, which is as yet unknown, the mark was reduced by 1/72 resulting in a new mark of 233.28 x 71/72 = 230.04 grams or 3550 Troy grains. This standard was still in use in the nineteenth century.

The relationships of mass standards of the 19th century to earlier standards have been summarized in table 2.

[30] Guilhiermoz 1906: 186: 373.2419541 grams, which gives the grain a legal value of 0.06479895 grams.

[31] Evans 1936: 114, 168.

[32] Guilhiermoz 1906: 413.

[33] Evans 1936: 114, 168.

[34] Guilhiermoz 1906: 195.

Mass of Pound or Mark (faktual) grams	(theoretical) grams	Ratio &	Date	Pound/Mark grams	Ounce grams	Ounce (*c.* 1340) Tari&Grani
Naples (1811) 320.759	320.76	121:120	(?)	318.109r	26.509r	30 (gold)
Naples, Cologne (*c.* 1340)				233.28	29.16	33 (silver)
England (19th century) 373.242	373.248	16:15	(1526)	349.92	29.16	33
Rome (1811) 339.07185	339.07248	51:50	(?)	332.424	27.702	31 & 7
Genoa (1800) 316.778	316.7836r	358.5:354	(?)	312.80727r	26.06727r	29 & 10
Genoa (1800) 317.664	317.66727r	359.5:354	(?)	312.80727r	26.06727r	29 & 10
Spain (1799) 230.0465	230.04	71:72	(>1544)	233.28	29.16	
Spain (Sevilla, 1348-?; cf. note 37)	233.28	50:49	(1348)	228.6144	28.5768	32 & 6 4/5

Table 2.

Peru. Finally, let us return to our Peruvian problem. Two weight-sets have been found in Peru. The underlying standard is a mark of 233.28 grams = 8 onzas of 29.16 grams. The subdivisions are not known from documentary evidence but appear to be a half ounce of 14.58 grams and a quarter ounce of 7.29 grams.

I have not succeeded in finding any reports on recent discoveries of weight-sets in Peru. The following facts were taken from Nordenskiöld's article of 1930: small balances have been recovered in large numbers from ancient Peruvian graves. The beams were made of bone. Instead of copper pans cloth nets were used. Two times a small piece of lead (0.2806 and 0.0296 grams) has been attached to a net. These weights were presumably added to achieve a level position for the beam preparatory to weighing. The balances are sufficiently sensitive for weighing precious metals. One specimen reacted distinctly down to 0.05 grams. Only one beam has a mechanical device for determining when the beam is horizontal. The two weight-sets were stored in cloth bags.

In 1930, a set of weights together with a balance were part of the Dr. E. Gaffron collection in Berlin. He discovered these objects at Hacienda de Sagrario, near Huacho. The set consists of 13 weights:[35] "The stones (....), which Dr. Gaffron always looked upon as weights, are, with the exception of one which he supposed to be a piece of meteoric iron,

[35] Nordenskiöld 1930: 215-216.

common water-polished pebbles picked up, may be, on some river bank or sea beach, all then probably still further polished." The masses have been stated in table 3, together with a column, expressed in quarter onzas. I have succeeded in a regrouping of the recorded masses of these pebbles which makes plausible the system of differential weighing.

Weights	Mass grams	1/4 *onza* (7.29 g)
A	1.53	0.209
B	4.45	0.610
C	4.49	0.615
D	7.80	1.069
E	8.10	1.111
F	14.60	2.002
G	15.71	2.155
H	16.04	2.200
I	18.44	2.529
J	23.43	3.213
K	27.44	3.764
L	27.50	3.772
M	29.17	4.001
Total	198.70	27.256
ABDFGHJKLM	167.67	23

Table 3. Weight-set from Hacienda de Sagrario, Huacho.

Ten weights, with a total mass of exactly 5 3/4 onzas, are all we need for a useful range. Consequently, the weights C, E and I do not belong to the original set. F (1/2 onza) and M (1 onza) are suitable for use in practice. The other weights can be joined to useful groups (table 4).

Weights	Mass grams	1/4 onza (7.29 g)	Error grams
F	14.60	2.002	+ 0.02
M	29.17	4.001	+ 0.01
DGL	51.01	6.997	− 0.02
ABHJK	72.89	9.998	− 0.01

Table 4. Weight-groups of 2, 4, 7 and 10 units.

Groups of 2, 4, 7 and 10 units are now available for weighing, using a mixed system of normal and differential mass measurement. If necessary, only the single weights (F = 2 units and/or M = 4 units) are added to commodities, presumably gold. The error does not exceed 0.05 grams, which is in accordance with the sensitivity of balances of the kind used by the Peruvians. The results are specified in table 5.

Left net Weights units	Right net Weights units	Right net Gold units	Error grams
7	2 4	1	−0.05
2		2	+0.02
7	4	3	−0.03
4		4	+0.01
7	2	5	−0.04
2 4		6	+0.03
7		7	−0.02
10	2	8	−0.03
2 7		9	0
10		10	−0.01
4 7		11	−0.01
2 10		12	+0.01
2 4 7		13	+0.01
4 10		14	0
7 10	2	15	−0.05
2 4 10		16	+0.02

Table 5. Step 1/32 marca, range 1/32-1/2 marca.

The second set, coming from Pachacamac,[36] consists of 9 stones. This set was to be found in the Gothenburg Museum in 1930 (inv. nr. G.M. 30.2.14). The masses are 1.09 (A), 1.64 (B), 2.13 (C), 2.74 (D), 3.72 (E), 3.86 (F), 11.20 (G), 69.41 (H) and 95.23 grams (I). Total mass 191.02 grams. The mass of five of these stones (DEFHI) is 174.96 grams or exactly 6 *onzas* of 29.16 grams. Either A, B, C and G do not belong to the set or some weights are missing. I have a slight preference for the latter suggestion as the total mass of 8 weights, leaving G aside, is exactly 6 1/6 onzas.

The Incas were able to make accurate weights. Is there any reason to believe that the Mesopotamians were less advanced? No, there is not, if we accept that the Peruvian system of weighing, and of adjustment of weights in groups, has a long history.

Comparative evidence—spanning an interval of about four and a half centuries—from Naples, London (supported by documentary evidence of 1527), Rome, Genoa and Spain (supported by an extremely accurate Peruvian weight-set dating from about the middle of the time span) yielded the metric value of the medieval Sicilian grano of 0.044181818r grams. I see no difficulty in considering this metric value as an established fact. We can employ it without reserve—apart from copyist's errors[37]—for the conversion of Pegolotti's statements into metric values.

[36] Nordenskiöld 1930: 219.

[37] Apart from copyist's errors, compare p. 114 and 168 the values of the ounces of Acre, Venice (silver) and Bologna, some approximations can be expected because Pegolotti used only the *grano* fractions 1/2, 1/3 and 2/3. E.g., the mark of Seville (Sobilia, Sibilia di Spagna)—calculated from Pegolotti's statement: 228.5673 grams—

Some of his statements may be of interest in discussing the mass of the Roman pound:

Paris. Pegolotti[38] fixed the ounce of Paris (for silver) at "tarì 34 e grani 13" or 693 x 0.044181818r = 30.618 grams, which makes the mark (8 ounces) 244.944 grams. The pound for commodities is equal to two marks or 489.888 grams but divided into 15[39] ounces of 32.6592 grams. The theoretical value of the grain of Paris is 244.944 : 4608 = 0.05315625 grams.[40]

Venice. The real Roman pound (my thesis) was in Pegolotti's days only in use in Venice for weighing spun gold:[41] "tarì 30 e grani 16 = once 1 in Vinegia d'oro filato", which gives 27.216 grams in metric value and a pound (12 ounces) of 326.592 grams.

Paris. The English Troy ounce was used in Paris for weighing spun gold and silver:[42] "Libbra 1 d'oro e d'argento filato di Vinegia fae in Parigi once 10 1/2", thus 326.592 : 10 1/2 = 31.104 grams.

On comparative metrology and the mass of the Roman pound

In 1838 a new method of research, comparative metrology, was introduced by Böckh. His method was based on the assumption that all standards of mass, from ancient Antiquity up to the present, are historically/genetically interrelated because of a relationship in whole numbers. The discovery of such a rational relationship should create the possibility to deduce a standard, working from the known to the unknown. Recent research has revealed that the method rests on a solid foundation, but also that it is very dangerous to draw any far-reaching conclusion on the basis of the established relationship alone. Even if both standards—inferred from local data—are known, and a simple relationship is observed, there is no basis for extreme inferences. For the sake of clearness I will give an example which can be proved. There is a simple arithmetical relation-

can be valued at 228.6144 grams = 49/50 mark of Cologne and London = 14/15 mark of Paris, resulting in an ounce of 646 4/5 grani instead of 646 2/3 grani. Seville was taken from the Moslems by Castile in 1248. Thus the standard of Seville in *c.* 1340 is the standard of Castile before the reform of 1348.

[38] Evans 1936: 114, 168.

[39] Evans: 236 "e la libbra si è once 15 di Parigi"; Guilhiermoz 1919: 7-8. In 1307 was valid: "Que nul marcheant d'avoir de pois ne puisse vendre à autre livre que à la nostre, qui est de .xv. onces", that is 15 x 32.6592 = 489.888 grams. However, after Pegolotti's time (1416, standard of Rouen) "pois au marc de Traye, qui est et doit estre de .xvi. onces pour livre comme celui de Paris", that is 16 x 30.618 = 489.888 grams.

[40] For the legal value see note 6. Doursther 1840: 250 (s.v. *Marc*): 1 mark = 4608 grains of Paris.

[41] Evans 1936: 114, 168.

[42] Evans 136: 148.

ship between the mina of Ur from the second millennium BC and the mark of Peru from the sixteenth century AD: five minas of Ur are equal to 12 marks of Peru (5 x 559.872 = 12 x 233.28). This only means that the basic assumption—all standards are interrelated—seems to be correct.[43] However, in the thirties scholars went a step further. In discussing two Peruvian weight-sets it was assumed that some of the weights did not fit in with the Spanish standard known from documentary evidence of the nineteenth century. Nordenskiöld came to the conclusion that these weights follow a pre-Columbian, i.e. Indian standard. Von Hornbostel went a step further arguing that the Spanish as well as the Indian standard derived from two, slightly different, Babylonian gold standards. As we have already seen, Nordenskiöld's conclusion was the result of incomplete knowledge of Spanish standards of mass. Von Hornbostel's solution to the problem was, to say the least, far-fetched.

Comparative metrology during the second part of the nineteenth century can be characterized as the reign supreme of the hypothetical approach, resulting in a house of cards. The outcome of the controversy between Lehmann-Haupt and Weissbach (1907-1916) did not bring an end to the application of comparative metrology but stimulated younger scholars to adopt the statistical approach to the problem of standards of mass. Unfortunately, both cluster analysis and probability analysis (when used to reveal any pattern in matrices of single numbers) obscure the facts—notably of differential weighing—and neither helps to form the student's notion of standards: we are still in the dark.

The controversy started with an article by Weissbach.[44] The main point was that documentary evidence revealed that the Babylonian mina was subdivided into 60 sheqels and never into 50 sheqels. Minas of 50 sheqels (gold and silver, different standards) alongside a mina of 60 sheqels (commodities) were a hypothesis of Brandis.[45] In 1866, the relevant cuneiform texts were not yet available for study. Lehmann (later Lehmann-Haupt) extended Brandis' hypothesis, ignoring the texts which had been

[43] Another example, this time remaining in the same territory and spanning an interval of about 1500 years: in 1811, 56 pounds of Naples should be equal to 55 Roman pounds (56 x 320.76 = 55 x 326.592). This is an interesting but useless fact as we have already seen that the medieval pound was slightly lower, namely 318.1090909r grams. Of course it is possible, but not very likely, that the medieval pound was derived directly from the Roman pound: 77 x 318.1090909r = 75 x 326.592 grams. The case is no better for the medieval pounds of Rome and Genoa: 56 pounds of Rome = 57 Roman pounds and 308 pounds of Genoa = 295 Roman pounds. The factors 77/75, 56/57 and 308/295 do not support direct derivation from the Roman pound.

[44] Weissbach 1907.

[45] Brandis 1866: 100: 60-sheqel minas (commodities) of 505 grams and 1010 grams, 50-sheqel minas for gold (5/6 x 505 g) and silver (10/9 x 505 g).

published in the meantime.[46] Regling and Lehmann-Haupt defended Brandis' doctrine furiously.[47] Of course, Weissbach could not accept that the 50-sheqel minas were not abandoned immediately and repeated his objections supporting them with fresh evidence. Moreover, he attacked several other topics, such as the surmised standard of the Neo-Assyrian mina (see below), the Persian daric, the Egyptian deben (see below) and the ratio of gold to silver in the Persian period. Weissbach could prove that much supposed facts were in reality mere hypotheses. Thus, Lehmann-Haupt's and Regling's persistency in maintaining a mina of 50 sheqels caused the downfall of comparative metrology as a whole which did not survive the confrontation with archaeological reality as interpreted near 1916.[48]

However, Weissbach made several serious mistakes. Firstly, a Persian silver mina of 90 sheqels and a talent of 5400 sheqels were in direct contradiction to the documentary evidence revealing a mina of 60 sheqels and a talent of 60 x 60 sheqels. Secondly, the erroneous idea that the ratio of gold to silver could be deduced from the mass of two Persian weights of Darius I which were recovered by chance and, thirdly, that one of those weights (without any indication of mass) incorporated a mass of 400 sheqels which does not fit in with a mina of 60 sheqels.[49]

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[46] Anonymous 1889 (account of a lecture held by Lehmann in 1888): Böckh supposed that all later standards of mass came from Babylonia. Mommsen, Nissen and Brandis did not agree because no apparent ratio was visible between the *mina* of 505 grams and Böckh's pound of 327.45 grams. Lehmann referred to some recently discovered weights from the third millennium BC whose masses point to minas of 982.4 grams and 491.2 grams, i.e. equal to 3 and 1 1/2 Roman pounds. In subsequent years Lehmann expanded his theories to fit in with Brandis' conclusions. At least two minas should have existed at the same time, a *mina* of the country (491.2 grams and its double) and a royal standard which was heavier, for example 1/36 heavier and equal to Brandis' standards of about 505 and 1010 grams. Lehmann accepted Brandis' idea of the 50-sheqel minas but connected them with the mina of the country (gold, 5/6 x 491.2 = 15 Roman unciae and silver, 10/9 x 491.2 = 20 Roman unciae). A mina of 1 1/2 Roman pounds (489.888 grams) may be of interest (below).

[47] Regling & Lehmann-Haupt 1909.

[48] Lehmann-Haupt died in 1938. In Memoriam by E.F. Weidner in *Archiv für Orientforschung* 12 (1937-39): 310. It contains no word about his metrological research. Nevertheless, his article "Talent", ready in 1936, was published in Pauly-Wissowa's *Real-Encyclopädie* 20 years later! Unfortunately, he never abandoned the 50-sheqel standards. But different standards have existed, even at the same time: Weissbach 1938. In fact, many problems can be solved with the evidence available in 1909 or earlier (below: Egypt and Neo-Assyria).

[49] Weissbach 1911: 688 and 674-675. Weissbach apparently forgot for a moment that his (hypothetical) mint instructions, that 60 gold sheqels and 90 silver half-sheqels were struck to the same mina, have nothing to do with book-keeping. If different sheqel standards existed, the same must be true for mina and talent. Herodotus (*Historia* III. 95) tells us that gold was valued at 13 times the value of silver, but Mommsen (1863) corrected Herodotus' statement into 13 1/3 : 1. Weissbach

In these times comparative metrology is clearly an unscientific method of research.[50] In fact, several ideas of the older metrologists come out to be not as bad as they appear when we read the critical articles of Weissbach. The actual problem is that a combination of hypotheses and mere statements is never trustworthy. The statements, at least, need to be proved at some time or another.

Let us consider what was known about the Roman pound. Ridgeway wrote "no weight-unit is more accurately known than the Roman pound",[51] and "the Roman lb. = 5040 grains".[52] However, to my surprise I found "The solidus (itself weighing 72 grains Troy or 1/72 of the Roman pound)",[53] which leads us to a late Roman pound of 5184 Troy grains or 1/35 heavier than the earlier pound. The following quotation enlightens us that Ridgeway's Roman pound was not based on a fact, but built on a hypothesis: "If we take an ordinary engineer's table of materials we shall find that a copper rod a Roman foot long, and half a Roman inch in diameter, weighs 5040 grs. Now, as the Roman pound weighs 5184 grs. this approximation seems almost too close to be a mere coincidence."[54] As we shall see, there are some indications for a *lower* early Byzantinian gold pound (*c.* 445-470 AD) but the standard Roman pound (commodities) is indeed equal to 5040 Troy grains (see below).

German scholars applying comparative metrology (Brandis, Mommsen, Nissen, Hultsch, Regling, Lehmann-Haupt) invariably stuck to Böckh's Roman pound of 327.45 grams as an established fact and, therefore, could not come any nearer to the truth. Another reason might be that before the transition to the metric system, the German states had no common unit of mass, discouraging, perhaps, any attempt to connect a particular local German standard to the Roman pound.[55]

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found this ratio confirmed in dividing the heaviest mass by the lightest, 2222.425 : 166.724 = 13.3299 or almost exactly 13 1/3. We can infer that these weights are very accurately adjusted but nothing more (see below).

[50] Powell 1979: 74-79. Powell bases his opinion on two points, i.e. the (supposed) inaccuracy of ancient weights which should make it impossible to deduce the standard accurately and insufficient reserve in practising comparative metrology in the past. I only agree with the second point.

[51] Ridgeway 1892: 234.

[52] Ridgeway 1892: 135.

[53] Ridgeway 1892: 181.

[54] Ridgeway 1892: 359.

[55] Only the medieval mark of Cologne (*c.* 1340), as far as I know, bears a constant ratio to the Roman pound. But this mark twice underwent minor changes, around 1500 and in the first half of the sixteenth century. Its mass early in the nineteenth century was 233.7741 grams but has been augmented to 233.855 grams by a Prussian law passed on 30.7.1838. Perhaps the factor 7/5, which is correct for 1340, was not very attractive to German scholars as its use casts doubt on Böckh's value of the Roman pound (327.45 x 5/7 = 233.89; *c.* 1340: 233.28 x 7/5 = 326.592).

Cocheteux[56] wrote in 1884 that "cette livre devrait être représentée par le nombre 6,180 7/8 et non par 6,144 grains comme on le fait généralement aujourd'hui." Le Blanc,[57] writing in 1692, was the first scholar to suggest a Roman pound of 6144 grains of Paris. Though Böckh is supposed to be the inventor of comparative metrology, it was Le Blanc who made a modest start in evaluating the Carolingian pound at 9/8 x 6144 = 6912 grains. I hold with Le Blanc that 6144 is indeed the correct number of grains of Paris for the Roman pound.

Finally Berriman, the last major representative of old style metrologists, discovered the relationships of the English and French pounds to the Roman pound in 1953.[58] Indeed, Roman pound : English Troy pound : French pound as 14 : 16 : 21. Berriman unfolded curious ideas and was very good in arithmetic, but his solutions are hardly ever supported by documentary evidence. Nevertheless, he was on the right track.[59]

Following Le Blanc and Ridgeway we come to: 1 Roman libra = 2/3 pound of Paris = 6144 grains of Paris (326.337 grams) = 7/8 English Troy pound = 5040 Troy grains (326.586 grams). As we see, using legal metric values of the grains, the results do not match. However, Pegolotti's statements produced the theoretical values of the grains, 0.05315625 grams for the grain of Paris and 0.0648 grams for the English Troy grain, resulting in 326.592 grams for the Roman pound in both calculations.

The reader may object that so far I only have proved that 2/3 pound of Paris is equal in mass to 7/8 English Troy pound. I cannot deny it. Thus, I defend the position that the Roman pound equals 326.592 grams. A strong argument in favour of this value is, of course, its neat relationship to the medieval marks of France (244.944 grams) and Cologne and England (233.28 grams) as revealed by Pegolotti's manual. Moreover, all standards proposed so far for Charlemagne's reformed pound are both related to these medieval marks and to a Roman pound of 326.592 grams.[60]

[56] Cocheteux 1884: 131.

[57] Le Blanc 1692: 3, 70, 83. Le Blanc's opinions were based on actual weighing of Carolingian and Roman coins and deducing simple relationships between the mark of Paris and the earlier standards: 4/3 mark of Paris = 326.592 grams = 1 Roman pound (I agree) and 3/2 mark of Paris = 367.416 grams = Carolingian pound = 9/8 Roman pound.

[58] Berriman 1953: 22.

[59] Anonymous 1742: 187 "The Paris Two Marc, or 16 Ounce Weight, weighs English Troy Grains 7560. Whence it appears, that the English Troy Pound of Twelve Ounces or 5760 Grains, is to the Paris Two Marc or 16 Ounce Weight, as 16 to 21."

[60] Proposed pounds (smoothed by me arithmetically) 367.416 g, 408.24 g, 419.904 g, 428.652 g, 435.456 g and 489.888 g. The available evidence (written source of the 13th century, Carolingian weights and coins) points to a pound of 419.904 g = 12 ounces of 34.992 g = 96 gold coins (Louis the Pious) of 4.374 g = 240 silver pennies of 1.7496 g.

Among numismaticians another Roman pound found some support. Grierson[61] gives a useful summary. After tabulating the masses of many hundreds of solidi—this gold coin was first struck in 312 AD—Luschin von Ebengreuth (1910) and Naville (1922) came to the conclusion that the mass of the solidus was standardized at 4.48 grams. From literary evidence, and by the existence of solidi marked LXXII, it is known that 72 solidi were struck to the pound. Naville calculated the pound at 72 x 4.48 = 322.56 grams. Luschin von Ebengreuth accepted the traditional mass of the pound and explained the difference by seignoriage, a deduction made by the issuing authority to cover the mint expenses. Abundant documentary evidence exists for seignoriage in the medieval period but there is not a shred of evidence to support it in Roman times. Grierson argued for an allowance for wear, 1 or 1 1/2 per cent, to arrive at a higher value for the pound, but the problem is complicated by the existence of solidi of much higher mass, resulting in a pound of over 330 grams, even with an allowance of only 1 per cent.[62]

Comparative evidence for a lower pound of 322.56 grams exists, but might be misleading: pound of 326.592 grams x 80/81 = 322.56 grams. However, if the gold pound was temporarily lower, the solution of the possible standard has to be sought within the Roman carat system in which the mass of a full weight solidus is 24 carats. For instance, one can argue for a solidus of 23 3/4 carats = 4.48875 grams and a pound of 72 x 4.48875 = 323.19 grams = 95/96 x 326.592 grams. One problem remains: these lower pounds cannot be linked to the major medieval marks from which follows that the full weight standard must have been restored at a later date.

As the specialized numismatic literature on this subject was not available to me (and most probably would not have settled the question) I have restricted myself to some general remarks on the established value of 4.48 grams. Naville and Luschin von Ebengreuth studied late Roman and early Byzantine solidi, that is, say, a period of about a century and a half. Grierson[63] mentioned a hoard of 397 coins found at Rome in 1899: "Nearly 350 of these were solidi of Anthemius (467-72) fresh from the mint, and these averaged exactly 4.48 gm., the highest weight attained

[61] Grierson 1964 (1979).

[62] Grierson 1979, in addendum to article XX, concerning solidi of Magnentius (350-353) in the Emona hoard: "The average weights of the single, double and triple solidi, which were in perfect condition, imply figures for the solidus of 4.50, 4.55 and 4.49 g. respectively, all above Naville's figure of 4.48 grams." Calculated with the average of averages and 1 per cent allowance, the result is still above Böckh's Roman pound, namely, 328.2096 grams. However, a 1/2 % allowance gives a pound of 326.5848 grams.

[63] Grierson 1964 (1979): xiii. As the coins were fresh from the mint any allowance for wear is out of the question.

being only 4.515 gm." I found some new evidence in an article by Martin.[64] In Szikáncs in Hungary a hoard of 1439 solidi (1440 solidi = 20 librae by tale) dated to the fifth century (after 443) was found. Its total mass was 6446 grams and the average mass 4.479 grams. However, Martin also remarks that the average mass of some larger series lies between 4.493 and 4.501 grams; e.g. 902 specimens of the same issue averaged 4.497 grams and of these 902 coins 855 (94.8 %) were between 4.48 and 4.52 grams. No information is given on the remaining 47 coins. My conclusion is that Grierson's argument for a standard of 4.48 grams (without allowance) is comparable with Martin's figures 4.493, or 4.497 or 4.501 and consequently has to be rejected. It is not certain whether the Szikáncs hoard has been completely recovered. It is tempting to suppose that only one coin is missing, but the Rome 1899 hoard contained 397 coins, that is 5 1/2 librae plus 1 coin. At a guess these hoards are equal to a number of librae by mass, not by tale. In support of this suggestion I quote a fragment of an anecdote, set in medieval Cairo, which can be found in an Arabic book entitled *Requital*:[65]

> "I was referred to a man from Syria who dealt in pledges. While I was at the Treasury a well-bred, old man of agreeable appearance approached me and said "How much do you need." "Two hundred dinars." He took money from his room, weighed it, and asked his assistant for a few more dinars to make up the two hundred."

I conclude that the evidence may point to a temporarily lower gold pound but that only the total mass of a hoard is a basic figure for a discussion on the intended standard. The total mass has to be ascertained by weighing all coins together, that is, including obsolete denominations (aurei) and pierced solidi. Unfortunately, the total mass is hardly ever published. The only available figure, the Szikáncs hoard, can easily be taken as evidence for the existence of the usual pound: 19 3/4 x 326.592 = 6450.192 grams, which makes it plausible that only one coin is missing.

A perusal of the metrological literature produced some statements which may be useful for further comparative research. Lehmann-Haupt[66] stated that the primeval Old Babylonian mina was equal to 1 1/2 Roman pounds. Büsing[67] wrote recently: "Das 'Urgewicht' stelle ich mir in der Tat als einen Silberwürfel vor, der jederzeit reproduzierbar war, solange der geeichte Mass-stab verfügbar war." A combination of these statements creates very interesting possibilities: 1 1/2 Roman pounds = 1 1/2

[64] Martin 1987: 236-237.

[65] Frantz-Murphy 1981: 284.

[66] Lehmann-Haupt 1918: 609. His statement was based on Böckh's Roman pound of 327.45 g.

[67] Büsing 1982: 41.

x 326.592 g = 489.888 g. If the Babylonians used the silver cube as their standard (with a specific mass of 10.5), we can easily calculate the length of the cube's edge: 489.888 g : 10.5 = 46.656 cm^3 = 3.6 cm x 3.6 cm x 3.6 cm, i.e. an edge of 2 digits of 1.8 cm (see infra). It follows, that the surmised Babylonian table of specific masses would be identical with ours.[68] However, an expatiation by Büsing on the specific mass of silver poses something of a problem that could not be solved before new, or preferably, old and forgotten evidence came out. A question arose, and an answer was found. The question was: what habit do Mesopotamian and English weight-makers have in common? The answer: they never used a hammer when making solid metal (cubical?) weights.[69] So far as I know, Büsing stands alone in his argument for an original standard weight made of silver. On the basis of scanty evidence many scholars supposed the existence of a standard of mass based on a cube of water or barley grains, the cube being a measure of capacity and a fraction of a cubic cubit. In the Babylonian *Talmud* (tractate Erubin 83a) it is said that a measure of capacity, the desert seah, was equal in size to the volume of 144 eggs.[70] Recent research produced the evidence that the cubit and measures of capacity and mass were connected in ancient Athens.[71]

The silver cube can be explained as a cube with an edge of two finger-widths (digits) of 1.8 cm. Vitruvius (III 1, 7-8) tells us that cubits were

[68] Powell 1989-90: 508-509: The Old Babylonian (*c.* 2000-1600 BC) mathematical texts reveal that "brick weight was calculated as being 20 percent heavier than water weight: water weight of a given volume and brick weight of the same volume always stand in the ratio 5 : 6", which is about correct for soft baked Dutch bricks if dry.

[69] Büsing 1982: 34 "Noch um die Jahrhundertwende hielt man es für richtig, das 'specifische Gewicht' des Silbers mit 'ungefähr 10,5' anzugeben mit dem Hinweis: 'durch Hämmern kann es bis auf 10,62 erhöht werden'." Hauschild (1836: 117) reports on a comparison of a Russian pound with an English Troy pound (373.248 g) in St. Petersburg in 1835: "ein von Bate in London 1824 verfertigtes messingnes englishes Troypfund. (....) In Theilen dieses Commissions-Pfundes wiegt das englische Troypfund im leeren Raum (wobei das specifische Gewicht des Troypfundes = 8,00 angenommen wurde) (....)"; 373.248 = 8 x 3.6^3; Hauschild did not state the shape of the Troy pound. However, in those days, at the height of experimental research, a cubical weight manufactured in accordance with the new metric decimal system is possible. As $8 = 2^3$, the Troy pound is also a cube of water with an edge of 7.2 cm. Using metric dimensions, the Troy pound appears to be a cube of water, but a rational relation between the metre and the English foot does not exist. The Troy pound was already known in the fourteenth century. We can conclude that the discovery of a cube is not always conclusive evidence for the existence of a connection between measure of length and measure of capacity and/or mass. Thus, the Troy pound of 373.248 g was independent of the English foot of 30.48 cm because the cube's edge of 7.2 cm cannot be expressed as a legal fraction of the foot.

[70] Lewy 1944: 67.

[71] De Zwarte 1994: 128.

usually reckoned equal to 24 digits. According to this line of thought some hopeful preliminary results—based on a cubit of 24 x 1.8 = 43.2 cm—could already be obtained.[72] For the moment it may suffice to point out that it supports the thesis for a Roman pound of 326.592 grams.

A Roman pound of 326.592 grams and the uncia of 27.216 grams bear clearly a fixed proportion to the major medieval marks. If Böckh's basic assumption—all standards are interrelated—is correct, these Roman standards are also connected with the earlier standards of mass. As I have said before, statistical methods are of no use in mass metrology. Thus, a new thesis has to be proved, that namely, like the Peruvians, the ancients could make accurate weights. The first question is, then, which grade of accuracy can be expected. A few examples may throw some light on this, even if the meaning of the result is not clear, the only purpose being to gather some useful figures for future research. Let us bring together five weights in excellent condition:[73]

(1) Dudu (the priest), Lagash, *c.* 2500-2450 BC, inscribed 1 mina of wages in wool, mass 680.485 grams; 25 Roman unciae = 680.4 grams.
(2) Ur-Ningirsu, Lagash, *c.* 2125 BC, inscribed 2 talents, mass 60555 grams; 2225 Roman unciae = 60555.6 grams = 89 minas of Dudu.
(3) Darius I, Persia, 521-486 BC, uninscribed, mass 2222.425 grams; 81 2/3 Roman unciae = 2222.64 grams.
(4) Ditto, inscribed 2 karsha, mass 166.724 grams; 6 1/8 Roman unciae = 166.698 grams x 13 1/3 = 2222.64 grams.
(5) The heaviest weight known from the Indus Valley culture (*c.* 2200-1700 BC), found at Harappa, has a mass of 26535.60 grams which is exactly 975 Roman unciae = 39 minas of Dudu.

In my opinion the comparative method has its dangers but it can sometimes provide the unexpected bonus. If the weights are in perfect condition and the metric values are known with a sufficient degree of accuracy, clear numerical relationships can be observed. Nevertheless, the time span is considerable and far-reaching conclusions should be delayed until more evidence is available.

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[72] Unger (1927: 58-59 and plate 14) published the Nippur cubit, found in a temple at Nippur. Calculated length 51.8 cm, theoretical length 51.84 cm x 5/6 = short Nippur cubit of 43.2 cm, resulting in a cubic cubit of 80.621568 litres = 1 homer (imeru). Confirmation for this value (Postgate 1978) was found in Tell al Rimah (Assyria, *c.* 1800 BC). See also Powell 1989-90: 462 (Nippur cubit), 502 (jar from Tell al Rimah). The mass of water contained in the short Nippur cubic cubit can also be explained as 144 minas of 559.872 grams, that is the mina of Ur in about the same period (below). Independent proof for a cubit of 43.2 cm divided into 24 fingers for this period is still lacking (Powell 1989-90: 470).

[73] Langdon 1921 (Dudu); Powell 1989-90: 509 (Ur-Ningirsu); Regling 1915: 98 (Darius I); Hendrickx-Baudot 1972: 25 (Harappa).

As a further support to my position—the mass of the Roman pound is equal to 326.592 grams—I shall now deal with the standard of Uronarti, which is 1/25 of that pound, and the standard of Ur, the Cape Gelidonya (Turkey) shipwreck and Cyprus being 1/35 Roman pound.

Mass standards used at Uronarti and Ur in the early second millennium BC

Uronarti in Nubia (1991-1786 BC). The unmistakable fact that the standard of mass of Uronarti, an island near the second cataract of the Nile in modern Sudan, is exactly three times the mass of the about fourteen centuries younger Attic weight-drachm is rather surprising.[74] The gold standard of Uronarti—3 x 4.35456 = 13.06368 grams—can be deduced from the handling of a set (?) of weights which has been described and depicted by Petruso.[75] The weights were discovered in 1924 by a joint expedition from Harvard University and the Museum of Fine Arts in the ruins of an Egyptian fort and dated to the twelfth dynasty (1991-1786 BC). The six well-preserved rectangular stone weights were excavated in a single archaeological deposit. Three specimens are now in the Museum of Fine Arts in Boston and three in Khartoum. According to the inscriptions the weights were destined for weighing gold. Petruso related the findspot on the Nubian frontier to the presumable origin of the gold from Kush in the territory south of the second cataract of the Nile. The details of these weights are indicated in table 6, together with a suggestion for the correction of the individual masses if related to the Attic drachm. Whether these corrections really reflect the intention of the Egyptian weight-maker remains open for future study. Preliminary research on a Roman weight-set of the first century AD from Pompeii (CIL X, 8067-14) reveals individual adjustment but the weights from Ur (see below) point to the contrary. As we have seen, the set from Huacho in Peru is an example of adjustment both of individual weights and groups of weights.

[74] In 189/8 BC (Livy 38.38.13) was valid: *Argenti probi Attica talenta (....) : talentum ne minus pondo LXXX Romanis ponderibus pendat.* The Attic talent was divided into 60 minas of 100 drachms, hence 1 Attic weight-drachm = 80 x 326.592 : 6000 = 4.35456 grams. See Regling in von Schrötter 1930: 46-48 (s.v. *Attischer Münzfuß*).

[75] Petruso 1981: 44-47.

	Inscription	Mass grams	Units (13.06368 g)	Corrected grams	Units
A	"Gold, 5"	61.0	4.6694	60.96384	4 2/3
B	"Gold, 5"	66.3	5.0751	66.28608	5 2/27
C	"Gold, 6"	74.5	5.7028	74.51136	5 19/27
D	"Gold, 6"	86.5	6.6214	86.60736	6 17/27
E	"Gold, 7"	92.0	7.0424	91.9296	7 1/27
F	"Gold, 9"	116.0	8.8795	116.1216	8 8/9
Total	38	496.3	37.9908	496.41984	38

Table 6. Weights from Uronarti in Nubia.

Nothing definitive can be said on the accuracy of the weights as the metric values are insufficiently determined for this purpose. None of the weights is in accordance with the inscribed value of mass. Used in combination 7 hits, comprising 3 additive and 4 differential weighings (table 7), can be observed. The real mass of the 6 misses is exactly one unit below or above the value indicated by the inscriptions. Perhaps to avoid mistakes three types of stone have been used: serpentine (A and C), granite (B) and alabaster (D, E and F). Clearly, the set is far from complete as no range can be drawn up.

Units	Combination			Units according to inscriptions			Mass grams	Corrected grams
0	A+E	-	B+D	1= 5+7	-	5+6	0.2	0
3	C+E	-	A+B	3= 6+7	-	5+5	39.2	39.19104
4	B+E+F	-	A+C+D	4= 5+7+9	-	5+6+6	52.3	52.25472
6	B+D	-	C	5= 5+6	-	6	78.3	78.38208
6	A+E	-	C	6= 5+7	-	6	78.5	78.38208
6	B+C+F	-	D+E	7= 5+6+9	-	6+7	78.3	78.38208
9	D+E	-	A	8= 6+7	-	5	117.5	117.57312
12	A+B+F	-	D	13= 5+5+9	-	6	156.8	156.76416
15	B+C+F	-	A	15= 5+6+9	-	5	195.8	195.9552
15	C+E+F	-	D	16= 6+7+9	-	6	196.0	195.9552
17	A+C+D			17= 5+6+6			222.0	222.08256
21	B+E+F			21= 5+7+9			274.3	274.33728
38	A+B+C+D+E+F			38= 5+5+6+6+7+9			496.3	496.41984

Table 7. System of weighing in Uronarti.

I would like to emphasize that it is a fortunate situation that all six weights have been recovered. If only 4 or 5 were found the problem could not be solved convincingly, as the total mass would point to a slightly different standard making the arithmetical link to the Attic drachm inadmissible. However, if only group ACD or BEF had been excavated, no problem of that kind would have arisen. This observation gives rise to the suggestion that for some reason exactly half the set, comprising weights inscribed 7, 8, 8, 9, 10 and 10 units, were stored or hidden elsewhere.

The method of weighing and the surmised metric value of this Egyptian gold standard (13.06368 grams = 201.6 English grains) is supported by 2 inscribed weights which were bought or excavated by Petrie and published by Weigall:[76]

> "The Gold Standard. 7029. Red veined limestone, oblong, rounded corners, inscribed "50". It comes from Quft, and weighs 10,453 grains, which divided by 50 gives 209.06 as the unit.
> 7030. Red veined limestone, oblong, rounded corners, inscribed "30". It comes from Quft, and probably belonged to the same set as No. 7029. It weighs 6,431 grains, thus giving a unit of 214.3."

Placing these weights in different pans reveals the unit:
(10453 - 6431) : (50 - 30) = 201.1 English grains.

Ur (*c*. 2000-1600 BC). Several sources of the 4th century BC inform us that 100 Attic drachms are equal in mass to 70 Aeginetan drachms.[77] Thus, the mass of the Aeginetan weight-drachm can easily be calculated as we know the mass of the Attic weight-drachm: 4.35456 x 10/7 = 6.2208 grams. As I have shown, the unit of Uronarti was equal in mass to three Attic weight-drachms. It appears that a simple relationship also exists between the Aeginetan weight-drachm and the sheqel of Ur: 6.2208 x 3/2 = 9.3312 grams. The interval is one millennium or a few centuries more. Presumably, the Uronarti weight-set was not complete. Of course, it is much easier to deal with a weight-set. The results can be astonishing if accurate gram values are also reported. The set, coming from grave LG/45 at Ur, was described in an article by Roaf.[78] Extremely accurate weighings can be obtained leaving no room for any doubt as to the standard involved.

It is taken for granted that weights used for weighing precious metals are very accurate. A set consisting of small carefully made weights falls into that category without further proof. The first step is typical for a devoted supporter of comparative metrology. I start with the assumption that at least some, and perhaps almost all, standards of mass are interrelated in one way or another. It remains to be solved whether such relationships or patterns of continuity can be interpreted as being an outcome of long-distance trade or spread of a standard from one point of origin or whether another explanation is required. Without additional evidence or a plausible hypothesis at hand, the safest conclusion is that

[76] Weigall 1901: 383-384.
[77] Regling in von Schrötter 1930: 11 (s.v. *Äginäischer Münzfuß*).
[78] Roaf 1982: 139.

such an arithmetical relationship adds nothing to our understanding of the above. If the weights bear no inscribed value of mass, I proceed empirically, dividing the total mass of the set by the mass of known standards or fractions of the Roman pound. In this case the best result was obtained with a unit of 9.3312 grams, which is 1/35 of a Roman pound of 326.592 grams. A unit of 1/70 Roman pound will do equally well but is otherwise not known and, of course, can easily be explained as half the unit. A unit of about 9 1/2 grams is generally understood to be the Egyptian *kite* or *qedet*. With the Aeginetan drachm (2/105 Roman pound) as supposed standard no useful range could be drawn up. The total mass of the set, 121.316 grams, divided by 9.3312 results in 13.0011. As the Mesopotamian mina is divided into 60 sheqels, most probably the top of the range lies at 1/5 mina or 12 sheqels. The smallest Mesopotamian unit is the grain, being 1/180 sheqel. The set consists of 12 weights. The masses are stated in table 8 together with the corresponding values in grains of the supposed sheqel. The result has been corrected to the nearest whole grain.

Weights	Mass grams	Grains (0.05184 g)	Corrected grains
A	1.152	22.222	22
B	2.94	56.712	57
C	4.03	77.739	78
D	5.31	102.430	102
E	5.76	111.111	111
F	8.192	158.024	158
G	8.512	164.197	164
H	8.62	166.280	166
I	16.64	320.987	321
J	16.64	320.987	321
K	17.92	345.679	346
L	25.6	493.827	494
Total	121.316	2340.200	2340

Table 8. Weight-set from grave LG/45 at Ur.

On the face of it the results seem worthless as none of the grain values is in accordance with the unit, a fraction, or the unit and a fraction, known from any written sources. But a closer look reveals additive possibilities, e.g. 22 + 158 = 180 grains or 1 sheqel. This observation enlightens us that the individual weights have not been adjusted to an intended mass and points the way for further advancement: the weights have to be combined into useful groups (table 9).

Weights	Mass grams	Mass sheqels	Error grams
AF	9.344	1	+ 0.0128
CD	9.34	1	+ 0.0088
BEIJ	41.98	4.5	– 0.0104
ABCDEFIJ	60.664	6.5	+ 0.0112
GHKL	60.652	6.5	– 0.0008
BDE	14.01	1.5	+ 0.0132
CIJ	37.31	4	– 0.0148

Table 9. Weight-groups of 1, 1, 4.5 and 6.5 units or 1, 1.5, 4 and 6.5 units.

Since the weights are not labelled as to denomination, the intended standard has to be derived from the internal evidence. The figures, I think, speak for themselves. The evidence points clearly to a standard of 9.3312 grams from which follows that both the method used to arrive at this result is correct and the starting point, a Roman pound valued at 326.592 grams, has been proved. Weight-group AF is as heavy as group CD and the total mass of groups AF, CD and BEIJ equals that of group GHKL. These features were probably designed to check the balance on its performance with light and heavy loads. Here we encounter the visualization of Seidenberg's and Casey's thesis "balance, not weight, is the fundamental aspect of the balance".

The capability of the set is already recognizable: 1, 2, 2 1/2, 3 1/2, 4 1/2, 5 1/2, 6 1/2, 7 1/2, 8 1/2, 11, 12 and 13 sheqels can be weighed. In all probability the step is a half-sheqel. In this case the presence of 2 groups incorporating 1 sheqel seems not very useful. However, this problem is easily solved in changing over a few weights from groups CD and BEIJ: (B + E) - C or (5.76 + 2.94) - 4.03 = 4.67, corrected 9.3312 : 2 = 4.6656 grams. The new groups BDE and CIJ, as is illustrated in the lower part of table 8, are also extremely accurate.

The groups of 1, 1 1/2, 4 and 6 1/2 sheqels are suited to a range of 1/2 up to and including 12 sheqels in steps of a half-sheqel. A small imperfection necessitates the restoration of group CD if a weighing of 8 1/2 sheqels has to be performed (table 10). Most probably this was also the standard practice for weighing 2 sheqels.

Left pan	Right pan		Left pan	Right pan	
Weights sheqels	Weights sheqels	Bullion sheqels	Weights sheqels	Weights shequels	Bullion sheqels
			6.5 1	1.5	6
			6.5		6.5
1.5	1	0.5	6.5 1.5	1	7
1		1	6.5 1		7.5
1.5		1.5	6.5 1.5		8
6.5 1	1.5 4	2	6.5 1 1		8.5
1.5 1		2.5	6.5 1.5 1		9
4	1	3	6.5 4	1	9.5
4 1	1.5	3.5	6.5 4 1	1.5	10
4		4	6.5 4		10.5
4 1.5	1	4.5	6.5 4 1.5	1	11
4 1		5	6.5 4 1		11.5
4 1.5		5.5	6.5 4 1.5		12

Table 10. Step 1/2 sheqel, range 1/2-12 sheqels.

The weight-set from grave LG/45 at Ur has been dated to the Old Babylonian period (*c.* 2000-1600 BC). Thus, at a certain moment within that period, Ur used a mina of 60 x 9.3312 = 559.872 grams. Roaf[79] deduced from a written source (tablet UET 5.796, from Ur) that 1/8 mina of Dilmun equals 1/3 mina of Ur. The Ur mina of 559.872 grams does not support that equation when using the masses of 7 known weights found at Bahrain (ancient Dilmun) as a starting point in a calculation of the Ur mina. It follows that either Ur used two different minas at the same time or that the documentary evidence points to a moment in history that Ur did not use a standard of 559.872 grams. Due to lack of evidence no good hypothesis can be put forward at present. The written source has been dated very differently.[80] It may be relevant to recall that about 1800 the ratio of gold to silver altered drastically.[81] The standard of 559.872 grams is best understood if dated to the end of the OB period.

The standard of 9.3312 grams seems to be of Mesopotamian origin. If this is true, then, contrary to the current opinion, the unit has to be called a sheqel and not an Egyptian qedet.

The Eastern Mediterranean Standard of Mass in the Late Second Millennium BC

The underwater exploration of the Cape Gelidonya shipwreck yielded no less than 60 objects classified as weights. Huge quantities of other objects

[79] Roaf 1982: 137, note 1.

[80] Some research in literature provided me with the following opinions: OB; OB, time of Rim-Sin; Rim-Sin (1735-1675 BC); *c.* 1800 BC; OB, 1870-1643 BC and even the foregoing UR III period.

[81] Leemans 1971: 512-513.

made it possible to pinpoint a close date for the loss of the ship. These weights furnish an ideal opportunity to determine the standard of mass in *c*. 1200 BC, but there might be a problem in that we cannot be certain that all weights, once existing on board the merchantman, have been found. Bass[82] already recognized a standard of about 9.32 or 9.33 grams but supposed also that 7 other standards could be derived from this material. It follows that at least 8 sets of weights have to be postulated. Only one specimen is marked, its mass being 9.30 grams.[83]

We are faced here with a mixture of objects, presumably for the greater part weights. The standard could be 9.3312 grams which can only be proved by restoring an original set. Thanks to the perfect description of the weights by Bass it was indeed possible to separate one set (table 11). All weights conform to the general description domed stone weight (DSW) and some of them have another feature, a flattened top (FT) or are polished (P).

Weights	Bass no.	Type	Mass grams
A	W 12	DSW, FT	26.20
B	W 20	DSW	43.80
C	W 23	DSW, FT	47.70
D	W 26	DSW, FT	51.50
E	W 28	DSW, FT	55.50
F	W 43	DSW, FT	92.00
G	W 44	DSW	93.20
H	W 45	DSW, FT	99.60
I	W 47	DSW	146.40
J	W 49	DSW	185.50
K	W 50	DSW, FT	188.00
L	W 51	DSW	194.00
M	W 55	DSW, P	279.50
N	W 57	DSW	457.00
Total			1959.90
3.5 minas = 3.5 x 60 x 9.3312 =			1959.552

Table 11. Weights from Cape Gelidonya shipwreck.

Then the weights have to be grouped according to their characteristics (table 12).

[82] Bass 1967: 137. Cape Gelidonya is the southernmost point of the Anatolian peninsula in Turkey.

[83] Bass 167: 136, cat. no. W 2: "Spendonoid stone weight. Straight scratch across top at right angle to long axis. 9.30 grams." A little bit alarming are the many weights stated with grade of accuracy .00 (20 weights). It gives the impression that the weights have been adjusted in grams.

Weights	Type	Mass grams	Error grams
M	DSW, P	279.50	− 0.436
ACDEFHK	DSW, FT	560.50	+ 0.628
BGIJLN	DSW	1119.90	+ 0.156

Table 12. Weight-groups of 0.5, 1 and 2 minas.

The system of weighing is as we know it or it is differential (table 13). I defend the position that the 2 minas group BGIJLN was permanently placed in one pan and never combined with commodities, presumably bronze in the shape of slab ingots of about 0.5, 1 or 1.5 kg. These ingots all came from the area of the captain's cabin and are the most likely ones to have served as currency.[84]

Left pan	Right pan		Mass	Error
Weights minas	Weights minas	Bronze minas	corrected grams	grams
2	0.5 1	0.5	279.936	− 0.036
2	1	1	559.872	− 0.472
2	0.5	1.5	839.808	+ 0.592
2		2	1119.744	+ 0.156
2 0.5		2.5	1399.68	− 0.28
2 1		3	1679.616	+ 0.784
2 1 0.5		3.5	1959.552	+ 0.348

Table 13. Step 0.5 mina, range 0.5-3.5 minas.

Bass[85] concluded that the ship sailed from a Syro-Palestinian port on the evidence of the personal possessions of the crew, admitting that the cargo was certainly Cypriot. However, weights were necessary for any merchant who might be trading in Mediterranean ports. In fact, the standard of 9.3312 grams, which was the standard of Ur in origin, might also be Syrian[86] but was certainly Cypriot.

Kalavassos-Ayios Dhimitrios in Cyprus (c. 1300-1200 BC)

South[87] reported the discovery of a closed deposit of weights during the 1982 season at the Late Bronze Age site of Ayios Dhimitrios. The stone and metal weights were found tightly packed into a small hole cut through

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[84] Bass 1967: 82.

[85] Bass 1967: 164-165.

[86] The corpus of weights from Ugarit still awaits publication, as far as I know. At least one set was excavated in ancient Ugarit, see Chavane 1987: 369, note 93.

[87] South 1983: 103.

the floor of a building in the central area. A cylinder seal was found together with them. The weights were cleaned and conserved in the laboratory of the Cyprus Museum. Courtois[88] undertook the metrological study of the weights. Unfortunately, I disagree with his results.

Three spindle-shaped weights are made of hematite (mass: 4.2, 6.6 and 10.8 grams). Since 4.2 + 6.6 = 10.8, these weights might have been used to level the balance prior to weighing. Table 14 presents the metal weights.

	Description	Mass (grams)	Sheqels (9.3312 g)
A	Calf's head	28.4	3.043
B	Boar, lying down	63.7	6.827
C	Bull's head	66.6	7.135
D	Human negroid head	94	10.073
E	Bull's head	94.8	10.159
F	Bull, lying down	139.8	14.982
G	Lioness, lying down	159.2	17.061
H	Duck	202	21.648
I	Cylinder, marked "+"	230.1	24.659
J	Cylinder, marked "v"	487.5	52.244
K	Cylinder, marked "'v"	580.9	62.254
Total set		2147.0	230.088

Table 14. Metal weights from Kalavassos.

The marks on weights I, J and K have been engraved. Courtois (p. 119) gives the following description of these marks: Inv. nr. K-AD 447 (I), "une marque cruciforme"; K-AD 448 (J), "un signe en forme de V"; K-AD 449 (K), "un signe en forme de V dont la branche de gauche est surmontée d'un point ou petit cercle".

Weight E is of solid bronze. Weight B is also of bronze, with a cavity, which is empty. The remaining nine weights are of bronze filled with lead. Courtois makes a remark on the condition of some weights: signs of wear (C), in some places still oxyde adhering (D, H and I) and lead filling slightly damaged (G). The mass of weight J is 487.5 g.[89]

The unit cannot be situated in the sheqel range as the weights are too heavy for that aim. The weight-groups point to a unit of five sheqels (table 15).

[88] Courtois 1983.

[89] Courtois 1983: 127 (119: printing error 478.5).

Description	Group	Sheqels (9.3312 g)	Error grams
Cylinders, marked "v"and "˚v"	K - J	10	+ 0.088
Human head and bull	DF	25	+ 0.52
Animal heads and cylinder marked "+"	ACEI	45	– 0.004
Cylinder marked "v" and wild animals	HJ - BG	50	+ 0.04
Cylinder marked "˚v" and wild animals	HK - BG	60	+ 0.128

Table 15. Grouping of weights.[90]

The types in a group were clearly not chosen at random. However, group DF seems to me a remaining group, but it may well be that the reader has a dissenting view. The Cyprian basic unit of 9.3312 g is indeed a sheqel and not a qedet as the higher unit is a mina of sixty primary units (table 16).

Weights - Weights =	Commodities (sheqels)	Mass corrected grams	Error grams
HJ - BG ACEI	5	46.656	+ 0.044
K - J	10	93.312	+ 0.088
HK - BG ACEI	15	139.968	+ 0.132
ACEI - DF	20	186.624	– 0.524
DF	25	233.28	+ 0.52
ACEI K - J DF	30	279.936	– 0.436
ACEI J - K	35	326.592	– 0.092
DF HK - BG ACEI	40	373.248	+ 0.652
ACEI	45	419.904	– 0.004
HJ - BG	50	466.56	+ 0.04
ACEI K - J	55	513.216	+ 0.084
HK - BG	60	559.872	+ 0.128

Table 16. Range 5-60 sheqels, step 5 sheqels.

It should be noticed that the set is capable of weighing 1 1/2 minas if the full set is used: BGHJK - ACDEFI = 839.6 g; 1 1/2 minas = 839.808 g. In all probability this feature was only known to the manufacturer of the set as BGHJK is not the sum of the separate groups.

The Mesopotamian source for the Cypriot system of mass measurement as well as the presence of a *negroid* human head in the weight-set bring up difficult questions.[91] The answers are best left to the ancient historians.

[90] A minus sign indicates that weights are placed in both pans.
[91] Best 1992-3.

Long distance comparative metrology, e.g. modern Britain versus ancient Judea (see below), gives the correct result for the mass of the Judean sheqel but the method has the disadvantage that it does not prove the claim. A comparative study which is coherent in time and space, is methodologically only correct if fact and hypothesis are presented separately. I offer comparative research on the basis of extant weights and a written source. Let us first consider the Egyptian weight-system.

Daphnae in Egypt (New Kingdom, *c.* 650-550 BC). Gardiner informs us that from the time of the 18th dynasty (*c.* 1580-1350 BC) onwards the mass-standard employed for metals of all sorts was the deben. Subdivisions are the qedet (1/10 deben) and the scty ("seal", 1/12 deben). For masses less than the qedet the ordinary fractions were used.[92] According to Gardiner the mass of the deben is about 91 grams or a little more than 1400 English grains. Consequently, the mass of the qedet should be *c.* 140 grains.

The dates of the kings from the 18th dynasty onwards are known with very fair accuracy. Amenophis I (1546-1526 BC) and his successor Tuthmosis I (1526-1512 BC) still used the gold standard of 201.6 grains (13.06368 g).[93] Extant qedet or deben weights inscribed with personal names and royal cartouches are all of the 26th dynasty or later.[94]

Weissbach[95] brought together what was known about the deben and the qedet as factual material and the prevailing opinions. This information is still very useful. It became clear to me that the standard of the qedet was known since 1861. However, the metrologists of the second decade of this century were unable to cope with the factual evidence available then, which seems to disprove the results of earlier research. The trouble with the weights is that the Egyptians, like the Judeans (see below) used two classes of weights, namely weights designed for normal weighing and weights designed for differential weighing. Only the first class of weights is accurate in the strict sence of our time. The earliest finds were weights of the first class, e.g. an inscribed five-qedet weight in the former Harris collection (mass 698 English grains). Chabas (1861) made an allowance for loss through damage of two grains and set the standard of the qedet at 140 grains (9.072 grams). Another inscribed weight is in better condition and slightly heavier (45.48 g = 701.85 gr), which makes

[92] Gardiner 1957: 200.
[93] Griffith 1892: 442; above: Uronarti.
[94] Griffith 1892: 443-444; Griffith 1893: 313.
[95] Weissbach 1916: 370-374.

the qedet 140.37 grains. Weissbach reported several weights of—as we now know—the second class, which brought about insurmountable problems among metrologists as the differential system had disappeared and been forgotten long since. Weissbach concluded that the Egyptian standard was not constant in mass, other metrologists held that the Egyptians, like other ancient peoples, were unable to manufacture accurate weights. This belief resulted in the statistical treatment of mass data, which gives always a result but no understanding or consensus. Gardiner probably did not read Weissbach's paper, so he kept the standard of *c.* 140 grains alive. Rightly, as we shall see. Weissbach demonstrated that in 1871 Lepsius avoided to explain that his "more accurate" norm in essence was derived from the Roman pound, namely as 1/36 of Böckh's pound of 327.45 g. Nevertheless, Lepsius was on the right track. I accept his hypothesis but use the mass of the Roman pound already settled above: one qedet = 326.592 : 36 = 9.072 g (= 140 grains). Thus, the standard of Chabas is regained. Conclusive evidence for the standard of 140 grains became already available in 1888. Unfortunately, Petrie was fascinated by statistics and later metrologists overlooked the set of weights.

During the investigation of the frontier fortress of Daphnae (Defenneh), lying east of the cultivated Delta region, Petrie discovered a deposit of weights in 1886. Daphnae was an advanced post to guard the highway into Palestine and Syria. Petrie dated the founding of the fort and camp at about 664 BC. In Petrie's opinion the importance of Daphnae declined about 560 BC as a consequence of the total cessation of Greek trade before the Persian period.

In one spot in the camp a large find of 17 weights was obtained.[96] In my opinion the heaviest weight (cat. no. 1170, made of limestone, mass 15200 English grains) does not belong to the set. The remaining 16 weights are made of basalt.[97] Only one weight, cat. no. 1057, is slightly damaged. Petrie corrected its mass of 1466.2 grains to 1471 grains.[98] I fix the original mass at 1470.1 grains assuming that all weights were made to uniform degree of accuracy. The weights are all domed but show distinct differences.[99] The mass data are shown in table 17.

[96] Petrie 1888: 92-93.

[97] Petrie 1888: 93. Cat. no. 1046 is a printing error, compare no. 1045 and 1046 on p. 86.

[98] Petrie 1888: 86.

[99] Petrie 1888: pl. XLVI.

	Petrie cat. no.	Mass grains	qedets (140 gr.)
A	1086	24.8	0.177
B	1121	25.2	0.180
C	956	35.3	0.252
D	900	45.2	0.323
E	1014	48.2	0.344
F	1015	48.2	0.344
G	1217	66.6	0.476
H	936	69.9	0.499
I	1042	73.1	0.522
J	1102	74.7	0.534
K	1226	134.6	0.961
L	989	143.3	1.024
M	995	143.4	1.024
N	1039	145.8	1.041
O	1045	146.6	1.074
P	1057	1470.1	10.501
Total		2695	19.25

Table 17. Weight-set from Daphnae.

The approach to the problem is more or less the same all the time. In most cases the standard is no invention of my own but the fruit of earlier research comprising a fair proposal or tentative results. Of course, the set must properly and accurately work on the basis of the supposed value of the unit. The total mass (table 17) is both indicative of the accuracy of the weights and a useful step—a quarter of a qedet—in just one case, that is an underlying unit of 140 English grains. Then, the decisive proof is to compose succesfully accurate weight-groups which permit mass measurement within a range consistent with Egyptian custom (table 18).

Weights	Mass			Error
	grains	grams	qedets	grams
AD	70	4.536	0.5	0
GM	210	13.608	1.5	0
BIO	244.9	15.86952	1.7493	− 0.00648
CEFJKLN	630.1	40.83048	4.5007	+ 0.00648
P - H	1400.2	90.73296	10.0014	+ 0.01296

Table 18. Weight-groups of 0.5, 1.5, 1.75, 4.5 and 10 units.

Four weight-groups are fit for a range of 1/4-5 qedets. Group P - H gives an extension of the range to 15 qedets which is illustrated with examples in table 19.

Left pan					Right pan					
Weights qedets					Weights qedets					Bullion qedets
		1.75				1.5				0.25
				0.5						0.5
		1.75		0.5		1.5				0.75
			1.5		0.5					1
		1.75			0.5					1.25
			1.5							1.5
		1.75								1.75
			1.5	0.5						2
		1.75		0.5						2.25
	4.5				0.5	1.5				2.5
	4.5						1.75			2.75
	4.5					1.5				3
	4.5			0.5			1.75			3.25
	4.5			0.5		1.5				3.5
	4.5		1.5		0.5		1.75			3.75
	4.5				0.5					4
	4.5		1.5				1.75			4.25
	4.5									4.5
	4.5	1.75				1.5				4.75
	4.5			0.5						5
P			1.5				1.75	4.5	H	5.25
P			1.5				1.75		H	9.75
P									H	10
P		1.75				1.5			H	10.25
P	4.5	1.75				1.5			H	14.75

Table 19. Step 1/4 qedet, range 1/4-15 qedets.

The weight-set was found in Egypt, so it seems obvious to understand the unit as an Egyptian qedet and the range as 1 1/2 deben. However, Daphnae was a frontier fortress. If the qedet was identical with the sheqel of a neighbouring country or town, as was the situation about eight centuries before, the range may also be interpreted as a quarter of a mina.

In a letter of Amenophis III (1417-1379 BC) of Egypt to Milkilu of Gezer 40 female cupbearers of 40 (sheqels) each are valued at 160 deben.[100] Thus, a sheqel of Gezer is equivalent to an Egyptian qedet. Unfortunately, we can only hypothesize that the qedet of that period is equal in mass to the qedet of Daphnae, eight centuries later.

Neo-Assyria. There must have existed strict state control of the manufacture of weights in Assyria. Weight-sets must be identical in mass and shape to ensure that government offices were using uniform weights. On these conditions we may include the weights kept by invading Assyrian armies. If so, we are entitled to use the data from different places

[100] Rainey 1970: 36-37.

for the reconstruction of the weight-system of the period. As we shall see, the weight-systems of Assyria and Judea are interrelated in 701 BC. Nothing prevents the assumption of an analogous relationship between the systems of Egypt and Assyria. Thus, in an attempt to elucidate the Assyrian standards, it seems correct to use the known metric value of the Egyptian qedet or its tenfold, the deben of 90.72 g, as expedient for the correction of the metric value of Assyrian weights. In order to achieve verification of these hypotheses, it is of utmost importance that the real metric value of the weights hardly differs from the theoretical value. The decisive argument in favor of the hypotheses is that the same result can be achieved by starting the procedure from the mass of the Judean sheqel.

The bronze lion weights from Khorsabad (60303 g) and Susa (121543 g) are both uninscribed. Weissbach[101] supposed that both weights were manufactured in the reign of Sargon II (722-705 BC) on the evidence of the findspot of the smaller lion, the ruins of the town Dur-Sarrukin. Dur-Sarrukin was founded by Sargon II and deserted after his death. Weissbach put the lion of Susa without reliable evidence in the same period. As I see it, the date of this lion weight is a matter of opinion: 5-4th century (W. Andrae), 5th century (E. Porada), 6-5th century (C.K. Wilkinson) and 3rd quarter of the 6th century (L.H. Jeffery).[102] But the possibility of an earlier date cannot be excluded since it was not found in a clearly dateable context. For the sake of my argument the weight must have been made under Assyrian state supervision, that is before 610 BC. Susa was ravaged and destroyed by the Assyrians in about 640 BC, which gives the most likely date for the weight.

The mass of both weights has been ascertained with greatest precision.[103] As to the original mass I cannot agree with Weissbach: "Beide Stücke sind von ausgezeichneter Erhaltung, aber mit Patina bedeckt, also schwerer, als sie ursprünglich gewesen waren."[104] Weissbachs opinion relies on Petrie.[105]

Thureau-Dangin derived the mina from the sum of the masses and division by 360.[106] Powell took 1/240 of the mass of the Susa lion as a hypothetical mean mina in his research of uninscribed weights.[107] In the light of the foregoing, it will be no surprise that the standard is found by ascertaining the difference of the metric values of the weights: 121543 - 60303 = 61240 (double talent) : 2 = 30620 (talent) : 60 = 510.33r (mina)

[101] Weissbach 1916: 74.
[102] Mitchell 1973: 174, note 13.
[103] Thureau-Dangin 1909: 95-96.
[104] Weissbach 1916: 74.
[105] Petrie 1886, 70-72.
[106] Thureau-Dangin 1909: 96.
[107] Powell 1979: 82.

: 60 = 8.5055r grams (sheqel). These are the raw data, which can be corrected by converting to Egyptian deben: 121542.12 (= 1339 3/4 x 90.72) - 60306.12 (= 664 3/4 x 90.72) = 61236 (675 x 90.72) : 2 = 30618 : 60 = 510.3 : 60 = 8.505 grams. Fifteen Egyptian qedets are equal in mass to sixteen Neo-Assyrian sheqels.

Judea. The treaty of 701 BC between Judea and Assyria deals with Hezekiah's tribute to Sennacherib. According to the *Old Testament* (2 Kings 18: 14) the treaty stipulates the payment of 30 talents of gold and 300 talents of silver. In the annals of Sennacherib the amount of gold is the same, but for silver 800 talents are demanded.[108] The difference in numbers of talents of silver reflects different standards. In the transcription of Sennacherib's annals by Oppert the figure 400 was stated. Oppert informed Brandis that 400 was a misprint and must be 800.[109] For no apparent reasons Hultsch was unwilling to accept the higher figure and kept 400 in the text.[110] Nowadays common opinion holds that 800 Neo-Assyrian single silver talents are equal to 300 Judean double silver talents. Arithmetical proportion is also obtained by putting 800 Assyrian double talents equal to 300 Judean quadruple talents.[111] Of course, this solution would at least double the amount of nearly 25000 kg of silver that the treaty involved; 800 x 30618 : 300 = 81648 (double talent) : 2 = Judean talent of 40824 grams. In order to tackle this problem it seems relevant to note the following three possible interrelations:
(1) 40824 g = 3600 sheqels = 60 minas of 60 sheqels?
(2) 40824 g = 3000 sheqels = 50 minas of 60 sheqels?
(3) 40824 g = 3600 sheqels = 90 minas of 40 sheqels?

1. *40824 : 60 = 680.4 (mina) : 60 = 11.34 g (sheqel)*
If a talent is divided up to 60 minas and the mina up to 60 units (gin), the system can be termed Mesopotamian.[112] I already mentioned (see p. 111 above) the mina weight for wool of Dudu, priest of Lagash (*c*. 2500-2450 BC), which pertains to a talent of 40824 g and a sheqel of 11.34 g. The system of mass measurement is not differential because balance pans were not used. The top of the weight is pierced by a round hole by which the weight was suspended.[113] No doubt the fleece was also suspended. Up

[108] Scott 1970: 355, note 12 (referring to ANET, p. 288).
[109] Brandis 1866: 74, note 4.
[110] Hultsch 1882: 465, note 7.
[111] Powell 1979: 84, note 43.
[112] Powell 1990: 508. Powell remarks that the term sheqel is Semitic and of later origin.
[113] Langdon 1921: 575.

till now I found no evidence that this talent was used continuously over a period of 18 centuries.

2. *40824 : 50 = 816.48 (mina) : 60 = 13.608 g (sheqel)*
The talent of 125 Roman pounds, 125 x 326.592 = 40824 g, is well known. It is mentioned by Dionysius of Halicarnassus,[114] who lived in Rome from 30 BC onwards, and by bishop Epiphanius in his "Weights and Measures", composed in 392 AD.[115] Hultsch noted a stone weight, of which presumably both the mass and the provenance were unknown, inscribed *pondo. CXXV. talentum siclorum III.*[116] Flavius Josephus (37-105 AD; *Ant. Iud.* XIV, 106) fixed the mass of the Hebrew mina at 2 1/2 litrai (2 1/2 Roman pounds = 816.48 g). The same author (*Ant. Iud.* III, 144) also mentions a talent of 100 minas, which is the same talent of 40824 g, but split into 100 light minas of 408.24 g. Solid evidence for the lighter mina was brought up by Meshorer, who published an inscribed stone three-mina weight bearing the name of king Herodes and the year 32, which probably refers to 9 BC.[117] Its mass is 1233 grams, i.e. slightly heavier than the theoretical mass (3 x 408.24 = 1224.72 g), which in my opinion points to the use of the differential system instead of an incorrect adjustment or even an altogether different standard.

In times that the Jews did not struck sheqels, the Temple tax must have been paid in foreign coins made of almost pure silver, like the Tyrian sheqels and half-sheqels.[118] Ben-David weighed 940 Tyrian sheqels struck between 126 BC and 56 AD, and calculated the average mass to be 14.1 g.[119] Thus, the Temple authorities were better off with Tyrian coins. The Capitoline tax after 70 AD (Flavius Josephus, *Bell. Iud.* VII, 218) was certainly paid in Roman currency as the reformed denarius of Nero and the denarius of his immediate successors were struck 96 to the pound, that is exactly the mass (3.402 g) of a quarter Hebrew sheqel.[120] The existence of two minas in Roman times has been established. It follows, then, that sheqels of 13.608 and 6.804 g were known, which explains why the denarius in the Talmud is identified with the half-sheqel ("zuz").[121]

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[114] Hultsch 1882: 151.
[115] Dean 1935: 56-57.
[116] Hultsch 1882: 469.
[117] Meshorer 1970: 97-98.
[118] Ben-David 1966: 168; Wirgin 1969: 53.
[119] Ben-David 1968: 146.
[120] Ben-David 1966: 169, note 3 (parenthetical note by the editor).
[121] Powell 1979: 99 (referring to J.A. Montgomery, *Journal of the American Oriental Society* 29 (1908) 204-209.

3. *40824 : 90 = 453.6 (mina) : 40 = 11.34 g (sheqel)*
In 1959, Scott arrived at the standard of the Judean sheqel by application of long distance (in time and space) comparative metrology. Scott supposed the existence of a pre-exilic (*ante* 586 BC) Judean mina of 50 sheqels and concluded that the half-mina was equal in mass to 5/8 lb. avoirdupois: 5/8 x 453.6 : 25 = 11.34 g.[122] Unfortunately, even if correct, one cannot derive evidential value from this calculation. The standard has to be deduced from the Judean weights themselves. Some years later a four-sheqel weight of 45.36 g in "mint" condition was found in an archaeological context in Jerusalem, and Scott wrote: "The single stone in new condition yields a shekel of 11.34 gm. which can be taken as the standard at Jerusalem early in the sixth century B.C., in the reign of Zedekiah."[123] In his study of the inscribed weights from Khirbet El-Kom, Dever accepts, on paleographic grounds, an earliest *terminus post quem* for the Judean weights of 722 BC.[124] The above mentioned four-sheqel weight, which exactly equals four sheqels of 11.34 g, is a rare exception. The bulk of the known weights vary in mass between 44 and 47 grams and can only be used in a differential system of mass measurement.[125] This system is implied by a weight which is inscribed "one quarter of a nesef, one quarter of a sheqel"[126] and an inscribed beqa-weight with symbols for 8 and 4 on the bottom which points to uselessness if used single.[127] The heavier weights are interstandard weights combining in one piece (according to their mass) 4, 8, 16, 24 or 40 Judean sheqels, but are inscribed with the hieratic numerals for 5, 10, 20, 30 or 50 Egyptian qedets.[128] In sum, then, our proposal for the Judean standards of mass in 701 BC is correct if the sheqel standard is indeed 11.34 grams.

Only a set of weights can establish conclusive evidence of the standard when a differential system was used. A set of eleven stone weights was presumably found in the Idna-Tarqumieh area in the Judean foothills, about 10 km north-west of Hebron. The weights have been described and depicted by Spaer.[129] Experimental research revealed that neither the subdivision of the sheqel in 20 gerahs (Ezekiel 45: 12) nor the assumed

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[122] Scott 1959: 34-35. The legal value of the imperial British avoirdupois pound is 453.59 g and equal to 7000 Troy grains. The theoretical value of the Troy grain (above) of 0.0648 g x 7000 yields 453.6 g. In 1496, the English avoirdupois pound was equal to 7680 Troy grains or 497.664 grams.

[123] Scott 1965: 133.

[124] Dever 1969-70: 187.

[125] Dever 1969-70: 177.

[126] Shany 1967: 54, note 4.

[127] Dever 1969-70: 183.

[128] Aharoni 1966 and 1971.

[129] Spaer 1982.

original subdivision in 24 gerahs make something clear about the underlying structure.[130] I assume that the Judean sheqel contained 180 grains, as was usual in Mesopotamian weight-systems of the period.[131] Table 20 contains the relevant details for a metrological discussion.

	Inscription	Mass (grams)	Sheqels (11.34 g)	Grains (0.063 g)
A	4 sheqels ("5")	45.99	4.055	730
B	2 sheqels	23.40	2.063	371.428
C	1 sheqel	11.41	1.006	181.11r
D	Nesef	10.05	0.886	159.523
E	Unmarked	8.63	0.761	136.984
F	Pym	7.98	0.703	126.66r
G	M	7.42	0.654	117.77r
H	Unmarked	5.48	0.483	86.984
I	2 strokes	4.29	0.378	68.095
J	1 hooked stroke	3.22	0.283	51.11r
K	4 strokes	2.30	0.202	36.507
Total set		130.17	11.478	2066.190

Table 20. Judean weight-set.

The sheqel column offers in no way support for the assumed standard of 11.34 grams, but the grain column reveals that weights C and J differ 130 grains and weights E and H 50 grains. In other words, the presence of weights C and E in one balance pan and weights H and J in the other pan results in a difference of one sheqel of the supposed standard: CE - HJ = 11.34 g.

When the user puts only two weights in both pans or four weights in one pan, he has the next combinations for exact weighing of sheqels and sheqels and half-sheqel at his disposal:

CE - HJ = 1	AD - BI = 2 1/2
BF - CE = 1	AG - CF = 3
BF - HJ = 2	ACGJ = 6

Starting from BF - CE = 1 sheqel, it is possible to obtain the combination for two sheqels by putting group HJ in place of group CE. This method is also practicable if only one weight of a group is in use. For example, starting from AG - CF = 3 sheqels (first column), one adds—in one's mind—the missing weight of a group to *both* pans (line 2: E) and substitutes the completed group (line 3: CE) for another group (HJ).

1.	AG - CF = 3	AG - CF = 3	ACGJ = 6	ACGJ = 6
2.	E - E	B - B	E - E	H - H
3.	AEG - CEF	ABG - BCF	ACEGJ - E	ACGHJ - H
4.	AEG - FHJ = 4	ABG - CHJ = 5	ABFGJ - E = 7	ABCFG - H

130 Scott 1959: 34.

131 Powell 1979: 93.

Actually it is a simple operation: put weight E in left pan and substitute group HJ for weight C in right pan. Starting from AD - BI = 2 1/2 sheqels, one obtains a difference of 3 1/2 or 4 1/2 sheqels by putting F in left pan and replacing CE or HJ for B in the other pan.

For the sake of convenience one would wish to obtain the desired effect by using the inscriptions of the weights. However, I failed to discover a clear procedure because, firstly, two weights are unmarked. Perhaps, the marks were written with ink and now faded.[132] If so, there is no possibility to recover them. Secondly, three weights are marked with strokes, the lightest bearing the largest number. It is clearly impossible then to equate one stroke with a fraction of the sheqel. It seems necessary to have a good memory for a limited number of combinations and then to proceed as demonstrated. This is within the bounds of possibility if the half-sheqel is intended to be the smallest fraction. However, this is not very likely as simple combinations (giving exact results) for the fractions 1/3 (FJ - G) and 2/3 (EJ - I) are available. Accurate combinations (error 0.01 g) for 1/2 are F - K and BK - CE (K being replacement for F), for 1/6 G - KJ and for 5/6 EG - KI.

I refrain from adjusting the mass of the weights as it is possible that the set is incomplete. The missing weight could be a beqa-weight, which is mentioned in the Bible (*Exodus* 38: 26) and well-known from Judean Iron Age sites.[133] No doubt I did not write the final word about this set of weights, but I see no difficulty to consider the standard of 11.34 g as an established fact.

Perhaps, another set made by the same manufacturer was found at Bet Gubrin. Ben-David visited many private collectors of weights but published only the nesef- and pym-weights which he came across. A comparison of our weights D, F and G with the 3 inscribed weights from Bet Gubrin is most promising: two pym-weights (mass 7.98 and 7.42 g) and a nesef-weight (mass 10.04 g).[134]

In sum: local data of the 8th and 7 or 6th century BC reveal that 136.08 g (5 Roman unciae) of silver correspond to 16 Neo-Assyrian sheqels, 15 Egyptian qedets and 12 Judean sheqels.

All in all, this strongly enhances the validity of comparative metrology.

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[132] Diringer 1942: 93.
[133] Dever 1969-70: 183.
[134] Ben-David 1979: 37; 42.

Conclusion

The aim of this work has been to rectify the wide-spread misunderstanding regarding the adjustment of ancient weights and to demonstrate that a basic principle of mass measurement was already known in various parts of the ancient world millennia before our era. As a consequence of the supposed inaccuracy of weights, much still awaits publication or is inadequately published, which means that facts of paramount importance for a better insight into ancient trade relations and spread of culture have been neglected.

The balances and weights found in Peru have to be dated to the Spanish period. One might conclude that the origin of the balance has to be sought elsewhere, almost certainly in the Old World. Of course, any connection between Mesopotamia on the one hand and Cologne, England, Spain or Peru on the other, is out of the question, notwithstanding the fact that the medieval mark of 233.28 grams proves to be equal to 25 sheqels of Ur.

Whether relations, trade or otherwise, existed between Ur and Egypt, Nubia or Kush about 2000 BC is as yet unproven. The answer largely depends on the identification of Maluhha, mentioned in documentary evidence from Ur, with either Nubia and Ethiopia or western India. This problem is still subject to debate among Orientalists and not yet conclusively solved. Judging from the standards of mass, we can only conclude that potential trade was not seriously hampered by problems of exchangeability: e.g. 7 x 9.3312 = 5 x 13.06368 = 65.3184 grams.[135]

Using the differential method of mass measurement we can prove that the standard of mass used in the Indus Valley at about the same time (*c.* 2200-1700 BC) is also related to the Roman pound: 326.592 : 24 = 13.608 grams.[136]

Clearly all standards are connected with the Roman pound of 326.592

[135] Knossos on Crete: 65.3184 grams is exactly 1008 English grains. Evans 1935: 654 "a unit of almost exactly 65.5 grammes (c. 1,008 grains). The unit thus arrived at represents 5 Egyptian gold units of c. 13 grammes (= 65 grammes)." Evans' statement is arithmetically correct: 5 units of Uronarti and Quft (above: 201.6 grains) are equal to 1008 grains. However, a set of five ellipsoid hematite weights found at Katsambas on Crete (Petruso 1984: 303) does not seem to prove the basic standard. Preliminary research points to a unit of 5.4432 g (1/60 Roman pound and 1/12 of 65.3184 g), i.e. the later silver standard of Lydia and Persia.

[136] It is due to an important observation by Petruso (1981: 50) that the mass standard of the Harappa culture could be established more precisely. In discussing the cubical shaped stone weights from Chanhu-daro in the collection of the Boston Museum of Fine Arts, he remarks: "The largest (36.2328) appears to have been damaged at one of its corners, but close examination reveals that the fracture (accidental?) has been intentionally and carefully rubbed smooth." In fact, several weights of the kind, labelled in the excavation reports as "slightly chipped" or "badly chipped" or "unfinished", reflect accurately their intended mass. Lots of weights have been found, but no weight-set was recognized as such by the excavators of Mohenjo-

grams, providing a firm basis for transforming comparative metrology into a discipline founded on scientific method.

However, all these facts leave us in the dark about the real origin of the act of determining mass. Nevertheless, I can only partly agree with Seidenberg and Casey when they write:[137]

> "(....) but there is no reason, so far as we know, to think that the balance entered daily life as a device for measuring commodities as early as the second millenium B.C., except for some items whose links with ritual we can for the most part see. In Greece, in classical times, the balance was used in the market place in the way that we do, but the earlier use, except for the commercial weighing of gold, is pretty closely linked to ritual."

Firstly, it seems almost impossible that the Greeks did not know differential weighing because the Romans knew it.[138] Secondly, the differential system of mass measurement was called in Sumerian *ki-lá tag*.[139] The term is attested for Presargonic (*ante* 2350 BC) Girsu (modern Tello) in South Babylonia, where it is linked to the weighing of *silver.* Of course, the earlier ritual use of the balance remains possible.

Appendix

The set from Malaga (see note 9) cannot be put forward as conclusive proof for the theoretical mass of the Roman pound of 326.592 grams because the metric values of the pound weights were not determined with a sufficient degree of accuracy. The set is tolerably accurate if used with weights in both pans.

Indication of mass	Mass grams	Roman unciae (27.216 g)
1 (uncia)	27.2394	1.0008
3 "	82.5954	3.0348
4 "	109.6822	4.0300
6 "	164.0420	6.0274
I (libra)	328	12.0517
II "	661	24.2871
III "	987.4	36.2801

Table 21. Late Roman weight-set from Malaga.

daro, Chanhu-daro and Harappa. Some spherical stone weights found at Mohenjo-daro point to the mina of 1360.8 grams and the differential system of weighing: 2735.78 - 1375 = 1360.78 grams and 1375 + 1431.675 - 1445.85 = 1360.825 grams. Harappa: 26535.60 grams = exactly 19 1/2 minas of 1360.8 g and thus pointing to normal weighing. See Hendrickx-Baudot 1972: 25 for these weights and the excavation reports (*ibid.*, p. 5, note 1).

[137] Seidenberg & Casey 1980: 224.

[138] See appendix below.

[139] Powell 1977: 26.

The 2- and 3-pound weights were permanently in use to keep the swing of the balance within bounds. If necessary, the 1-pound weight and/or 1-ounce weight were added to commodities. Variations in handling the ounce weights were permissible, e.g., 3 or 4 - 1, 3 + 1 or 4, which hardly affects the accuracy of weighing.

Left pan Weights unc. & lib.		Right pan Weights lib. & unc.		Right pan Commodities lib. & unc.		Commodities grams	Error grams
	III	II I			0	– 1.6	– 1.6
1	III	II I			1	25.6394	– 1.5766
3	III	II I	1		2	53.756	– 0.676
3	III	II I			3	80.9954	– 0.6526
4	III	II I			4	108.0822	– 0.7818
1 4	III	II I			5	135.3216	– 0.7584
3 4	III	II I	1		6	163.4382	+ 0.1422
3 4	III	II I			7	190.6776	+ 0.1656
3 6	III	II I	1		8	217.798	+ 0.07
4 6	III	II I	1		9	244.8848	– 0.0592
4 6	III	II I			10	272.1242	– 0.0358
1 4 6	III	II I			11	299.3636	– 0.0124
	III	II		I		326.4	– 0.192
1	III	II		I	1	353.6394	– 0.1686
3	III	II	1	I	2	381.756	+ 0.732
3	III	II		I	3	408.9954	+ 0.7554
4	III	II		I	4	436.0822	+ 0.6262
1 4	III	II		I	5	463.3216	+ 0.6496
3 4	III	II	1	I	6	491.4382	+ 1.5502
3 4	III	II		I	7	518.6776	+ 1.5736
3 6	III	II	1	I	8	545.798	+ 1.478
4 6	III	II	1	I	9	572.8848	+ 1.3488
4 6	III	II		I	10	600.1242	+ 1.3722
1 4 6	III	II		I	11	627.3636	+ 1.3956
	I III	II		II		654.4	+ 1.216
1	I III	II		II	1	681.6394	+ 1.2394
3	I III	II	1	II	2	709.756	+ 2.14
3	I III	II		II	3	736.9954	+ 2.1634
4	I III	II		II	4	764.0822	+ 2.0342
1 4	I III	II		II	5	791.3216	+ 2.0576
3 4	I III	II	1	II	6	819.4382	+ 2.9582
3 4	I III	II		II	7	846.6776	+ 2.9816
3 6	I III	II	1	II	8	873.798	+ 2.886
4 6	I III	II	1	II	9	900.8848	+ 2.7568
4 6	I III	II		II	10	928.1242	+ 2.7802
1 4 6	I III	II		II	11	955.3636	+ 2.8036
3 4 6	I III	II	1	III		983.4802	+ 3.7042

Table 22. Step 1 ounce, range 1 ounce up to and including 3 pounds.

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