MASS METROLOGICAL ARGUMENTS FOR DIFFERENTIAL WEIGHING IN THE EASTERN MEDITERRANEAN BRONZE AGE: AKROTIRI ON THERA, UGARIT, TARSOS, KATSAMBAS ON CRETE AND ATHENS*

with a digression on Aristotle's *Ath. Pol.* 10

Ruud de Zwarte

Abstract

This paper amplifies the evidence of the differential method of mass measurement as outlined in my earlier paper in *TALANTA* 26/27. It also makes plausible that more than one standard of mass was in use in the Mediterranean Bronze Age. Although the standards are reconstructed upon an analysis of individual sets of weights, again the Roman pound makes sense as a comparative metrological tool to set the local standard of the earlier period more precisely.[1] Apart from other evidence for foreign trade, metrology is in itself apt to demonstrate trade relations, especially when the same standard of mass turns up in different parts of the Mediterranean in about the same period; we present evidence of this for the Aegean and the Near East. The 'international' standard - a sheqel of 9.3312 g and a mina of 60 sheqels (559.872 g) - was certainly used in Ur, on Cyprus and on board of the merchantman that wrecked

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* In defence of the use of metric values like 9.3312 g (a), 10.8864 g (b) and 4.35456 g (c) and the exclusion of practical values (9.33, 10.89 and 4.35 g) it should be pointed out that in comparative studies only the theoretical values will show the exact relations of a, b and c. I would like to express my thanks to Dr. M.D. de Weerd (Alkmaar) for his good advice and kind assistance while I prepared this article.

[1] De Zwarte 1994/95a. Pure differential weighing: In one pan weights only, in the other pan weights and commodities. Mixed methods, that is, combinations of normal weighing and differential weighing, existed too. Adjustment of weights: single or in groups. If the differential method is used, only a set of weights will yield conclusive evidence of the standard of mass. My 1994/95a article contains the evidence of the Roman pound of 326.592 grams. An extremely accurate Old Babylonian weight-set from Ur in the same article allows us to prove that some of the early metrological evidence can be interpreted in terms of a known historical magnitude.

at Cape Gelidonya in Turkey.[2] For Ugarit, an important centre of trade in the Phoenician coastal area, the use of the sheqel of 9.3312 g may be defended, as already did Parise and Ben-David.[3] In this paper we broaden the argument for the 9.3312 g sheqel with a reexamination of the pertinent texts from Ugarit and substantial evidence from Thera.

Procedures of differential weighing

We see two methods of handling weight-sets:
(1) in class 1 only the difference in mass between individual elements or groups of elements in a weight-set produces a whole number of standard units of mass, e.g. minas, sheqels, half-sheqels etc., whereas the masses of the individual elements or groups in such a set do not equal such weight-units (e.g. A = 0.83; B = 1.83; CD = 2.33; CD - B = 0.5, B - A = 1, CD - A = 1.5).
(2) in class 2 procedures the masses of the individual elements or groups of elements equal whole numbers of standard units of mass (e.g. A = 2; BC = 3; BC - A = 1).
In some sets the range of steps shows a differential pattern with additive weighing only in the top of the range. When from such a set all class 1 elements have disappeared, our usual (additive) system (weights in only one pan) is near to existence.
The weight-sets we discuss here show predominantly class 2 procedures, the easiest system to handle. In our opinion class 1 differential weighing procedures predate those of class 2, which in turn might predate 'pure' additive weighing, which we call 'usual'.
Evidently, in some cases a fixed weight-group A - B was used as a permanent load (Table 3: 4.75 - 3.25 minas and Table 16: 2.5 - 2 minas). This load was meant to lessen the swing of the balance and make it come to rest quickly, a device at the expense of the range (compare Tables 3 and 4 and also 15 and 16).

[2] De Zwarte 1994/95a, 114-121. November 1996, Prof. G.F. Bass informed me that, in his dissertation, Cemal Pulak had very recently dealt with the Bronze Age weights from both the Uluburun and Cape Gelidonya shipwrecks. Prof. Bass is planning to write an updated version of the Cape Gelidonya excavation report as in recent visits to the site more weights have been found.

[3] Parise 1970/71, 22: 9.40 g; Ben-David 1979, 30: 9.25 g.

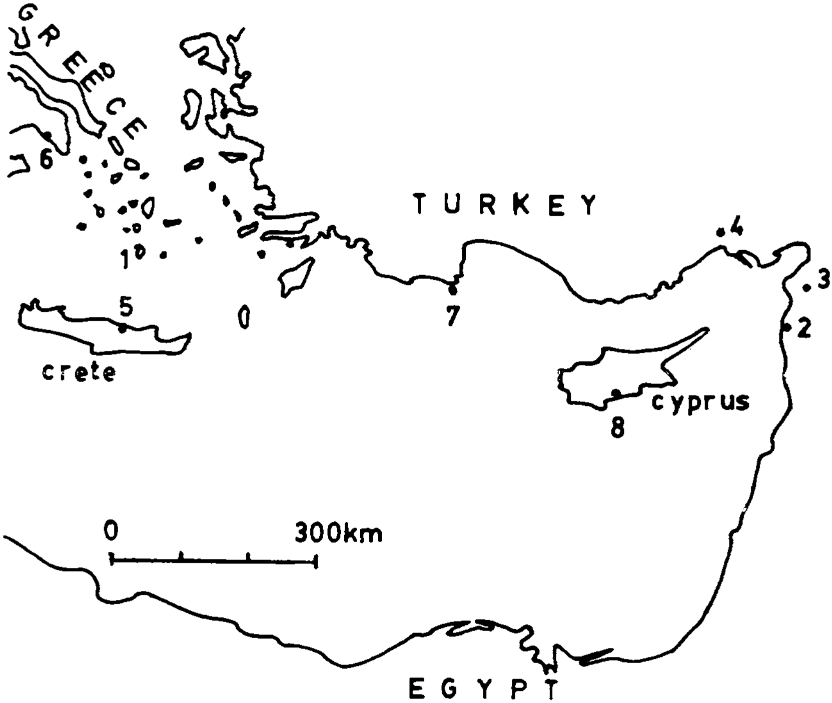

Fig. 1. Map showing location of sites. Thera (1), Ugarit (2), Alalah (3), Tarsos (4), Katsambas (5), Athens (6), Cape Gelidonya ship (7) and Ayios Dhimitrios (8).

Thera (1500 B.C. or earlier)[4]

Already twenty years ago Buchholz (1980) concluded that Thera could not have grown wealthy on its own resources, but only as a trading centre. Tripod stone mortars, ivory, ostrich eggs, wood, pigments (used for wall paintings) and lead link the island's economy up with sources abroad. We here present the evidence that even the standards of mass are of foreign origin.

[4] All evidence points to dating the volcanic eruption on Thera to around 1500 B.C. After the island was smothered under a thick layer of volcanic ash, life apparently ceased. See Doumas 1983.

In 1870, Gorceix and Mamet excavated a set of 11 stone weights near Akrotiri on the island of Thera (Santorini). The quotation here below, which I have copied from Viedebantt, is from Mamet's dissertation. It is also found in other publications on metrology.[5]

> "... lapides basaltae plerique rudes informesque, quales fiunt, quum diu fluctibus attriti sunt, neque ulli usui apti videbantur - his ponderatis constitit ita congruere pondera, ut eos librae fuisse adhibitos non dubium sit; ea enim sunt grammatibus expressa: 105. 139. 175. 212. 320. 425. 535. 840. 956. 1167. 1288, quae ad hos numeros redigi possunt 1. 4/3. 5/3. 2. 3. 4. 5. 8. 9. 11. 12."

In short and in English, they had found eleven basalt pebbles which seemed to conform to some standard of mass. According to Mamet, the standard was 105 g, according to Hiller and Lehmann it was a rather heavy Babylonian goldmina of 840 g (8 x 105 g) and according to Viedebantt it was a rather light Attic mina of 425 g. Then, Petruso took 1/3 of Mamets unit (= 35 g) to be the standard, not suggesting any provenance. Actually, the standard is the 16-multiple of Petruso's unit, that is the Cypriot mina of 559.872 g. Unfortunately, Petruso's attempt to recover the weights from the collection of the French School in Athens failed. Apparently any marking was absent, but the former presence of identification marks in ink or paint is possible. Applying the 559.872 g standard, the set allows of good use. Tables 1 and 2 show that some single weights (B, F and H) are fit for use. Table 2 shows an extension of this series of weights upon assembling groups of 2 or 3 individual weights.

Weights	Mass grams	Mina 559.872 g
A	105	0.187
B	139	0.248
C	175	0.312
D	212	0.378
E	320	0.571
F	425	0.759
G	535	0.955
H	840	1.500
I	956	1.707
J	1167	2.084
K	1288	2.300
Total	6162	11.006

Table 1. Stone weight-set from Akrotiri.

[5] Mamet 1874 was not available to me; Hiller von Gaertringen/Lehmann 1901, 114; Viedebantt 1917, 54; Petruso 1978, 109.

Groups	Mass grams	Corrected grams	Minas
B	139	139.968	0.25
AC	280	279.936	0.5
F	425	419.904	0.75
H	840	839.808	1.5
DEK	1820	1819.584	3.25
GIJ	2658	2659.392	4.75
Total	6162	6158.592	11

Table 2. Grouping of weights.

At first sight, weight F seems to be inaccurate. In my opinion, however, this weight is just as accurate as the others. The user of the set should have noticed that the balance beam was not level when it should and have concluded that weight F must be too heavy:

FGIJ	= 3083	grams and	ABCHDEK	= 3079	grams; 5.5	minas
FABC	= 844	grams and	H	= 840	grams; 1.5	minas
F	= 425	grams and	ABC	= 419	grams; 0.75	minas

Here, it is possible for a misprint - 425 instead of 420 grams - to have entered Mamet's work. The handling of the weight-groups could be based on the permanent load method, which implies differential weighing throughout. If so, the handling shows the same pattern as a late Roman weight-set from Málaga in Spain (De Zwarte 1994/95a, 134). The groups of 3.25 and 4.75 minas were in permanent use to control the swing of the balance (Table 3).

As the results were accurate, I was satisfied. However, Maarten de Weerd worked out that *the same weight-groups* can be used to extend the range to the total mass of the set, which means that the weighings are equally accurate. Table 4 shows the outcome of his study.

It could not be ascertained whether the weight-set was owned by an inhabitant of Thera or by a visiting Cypriot merchant. Mamet and Gorceix excavated an incomplete Cypriot White Slip I bowl on Thera (Buchholz 1980, 228).

Left pan					Right pan		
Weights minas					Weights minas		Commodities minas
				4.75	3.25	1.5	0
0.25				4.75	3.25	1.5	0.25
	0.5			4.75	3.25	1.5	0.5
		0.75		4.75	3.25	1.5	0.75
0.25		0.75		4.75	3.25	1.5	1
	0.5	0.75		4.75	3.25	1.5	1.25
				4.75	3.25		1.5
0.25				4.75	3.25		1.75
	0.5			4.75	3.25		2
		0.75		4.75	3.25		2.25
0.25		0.75		4.75	3.25		2.5
	0.5	0.75		4.75	3.25		2.75
			1.5	4.75	3.25		3
0.25			1.5	4.75	3.25		3.25
	0.5		1.5	4.75	3.25		3.5
		0.75	1.5	4.75	3.25		3.75
0.25		0.75	1.5	4.75	3.25		4
	0.5	0.75	1.5	4.75	3.25		4.25
0.25	0.5	0.75	1.5	4.75	3.25		4.5

Table 3. Step 0.25 mina, range 0.25-4.5 minas; the combination of groups GIJ (4.75 minas) and DEK (3.25 minas) is handled as the permanent load in a differential weighing method.

Left pan						Right pan
Weights minas						Commodities minas
					4.75	4.75
0.25					4.75	5
	0.5				4.75	5.25
		0.75			4.75	5.5
0.25		0.75			4.75	5.75
	0.5	0.75			4.75	6
			1.5		4.75	6.25
0.25			1.5		4.75	6.5
	0.5		1.5		4.75	6.75
		0.75	1.5		4.75	7
0.25		0.75	1.5		4.75	7.25
	0.5	0.75	1.5		4.75	7.5
0.25	0.5	0.75	1.5		4.75	7.75
				3.25	4.75	8
0.25				3.25	4.75	8.25
	0.5			3.25	4.75	8.5
		0.75		3.25	4.75	8.75
0.25		0.75		3.25	4.75	9
	0.5	0.75		3.25	4.75	9.25
			1.5	3.25	4.75	9.5
0.25			1.5	3.25	4.75	9.75
	0.5		1.5	3.25	4.75	10
		0.75	1.5	3.25	4.75	10.25
0.25		0.75	1.5	3.25	4.75	10.5
	0.5	0.75	1.5	3.25	4.75	10.75
0.25	0.5	0.75	1.5	3.25	4.75	11

Table 4. Range extended to 4.75-11 minas; usual weighing method.

The excavations at Akrotiri (starting 1967) and Ugarit (starting 1927) confront the metrologist with a serious problem: the many weights, including groups and sets, that were found have been inadequately published, or not at all.
As the question which mina standard was used in Ugarit haunted me, I gathered small bits of information on the weights from Akrotiri. To my surprise, I found a weight-set that works accurately if the mina is divided into a 100 sheqels instead of 60 (Cypriot system).
Let us first look at Ugarit. In 1933, Schaeffer bought a tablet, which had almost certainly been stolen from his own excavations in Ras-Shamra (Ugarit). Thureau-Dangin (1934) published this tablet with a list of 29 diverse items of purple-dyed wool. These items total 6600 units.[6] The tablet states the total as 2 talents + 600 units. From this it is easy to find that the talent of Ugarit consists of 3000 units, presumably called sheqels. The individual items state amounts of 100, 200, 300 or 400 units. The names on the tablet show no uniformity concerning the origin of the men.[7] The talent of 3000 sheqels has widely found acceptance with later writers on Ugaritic metrology. As far as I know, however, nobody has ever argued for a mina of 100 sheqels, which, I think, is the most convincing interpretation of the figures. Parise (Parise 1970/71, 21) suggested a mina of 50 sheqels. Pointing out texts on tablets found in the Ugarit archives that reveal a mina of 60 sheqels, Heltzer and Lipiński rejected the 50-sheqel mina.[8] Zaccagnini (Zaccagnini 1979, 472, note 2) perceives the difficulty:

> "Of course, the problem is to establish whether the Syrian talent consisted of 60 minas of 50 sheqels, or of 50 minas of 60 sheqels (....). The analysis of two bronze weights from Ugarit, weighing 468.5 gr. correctly led Parise (....) to suggest a mina of 50 sheqels (....). Some texts from the archives of Ugarit show that a mina of 60 sheqels was also in use."

Thureau-Dangin (1934, 141) already drew attention to a passage in the Old Testament (Exodus 38: 25-27) describing a parallel for a talent of 3000 sheqels. He proposed nothing, however, with respect to the mina. Unfortunately, the passage is of no use at all in evidence of Bronze Age Ugarit: the Hebrew talent of 3000 sheqels (40824 g; 50 minas of 60 she-

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6 The name of the unit is not given.

7 Thureau-Dangin 1934, 144: "Si les noms sémitiques se classent dans le groupe occidental, les noms non sémitiques paraissent appartenir à une langue ayant des attaches avec le hurrite."

8 Heltzer 1977, 204, note 10; Lipiński 1979, 576, note 51: "En effet, (....), la mine ugaritique comptait 60 sicles, comme il résulte d'une comparaison de RS 17.158 et de RS 17.42 (PRU IV, 169-172) avec RS 17.146 (PRU IV, 154-157)." See Schaeffer/Nougayrol 1956.

qels) dates from the Roman period or slightly earlier and the Judean talent of the Iron Age (40824 g) consists of 3600 sheqels (90 minas of 40 sheqels).[9]

Looking at Parise's (1970/71, 18 and figs. 2 and 4) evidence for a mina of 50 sheqels, we will find an unmarked weight (cow, lying down) and a weight (bull, lying down) marked in the Egyptian manner with two arcs, meaning "20". These weights tell us next to nothing about the Ugarit mina. We may surmise that the inscribed weight is part of a set based on the differential weighing system.[10] The unit is almost certainly a sheqel of 23.328 g, which is 2 1/2 times as heavy as the Ugarit sheqel and twice as heavy as the Hittite sheqel.[11] I dismiss the 50-sheqel mina and accept, in accordance with Thureau-Dangin's text, an Ugaritic mina of 100 sheqels = 933.12 g. A mina of 100 sheqels was not unusual in this region. At Alalah (level VII, Old Babylonian period), lying about 100 km northeast of Ugarit, metals were commonly settled in sheqels and rarely in minas. Two texts (a contract and a debt; Zaccagnini 1979, 473-474) state an amount of 33 1/3 sheqels of silver, which is best explained as 1/3 of a mina of 100 sheqels.

But what about the mina of 60 sheqels, which can also be inferred from written evidence?[12] In the texts concerned, the fine for killing a foreign merchant is described differently. Clearly, any modern interpretation of these texts should produce whole numbers of victims. Provided a mina of 40 or 50 sheqels is involved, Vargyas (1986, 104-105) suggestion that in one passage a heavier sheqel may have been meant actually solves the problem. I have applied this suggestion as follows: the Ugarit mina of 933.12 g was not only divided into 100 sheqels but also into 60 sheqels. The suggestion is that in the same passage a lighter sheqel may have been meant. Well then, the fine for killing a person was 3 minas of silver (300 x 9.3312 = 2799.36 g) or 180 sheqels (180 x 15.552 = 2799.36 g; 3 minas of 60 sheqels). It says in the problem text that 1200 sheqels were to be paid. The question now arises of how many merchants were killed. The answer will be: (1200 : 300 =) 4 merchants as 1200 : 180 does not produce a whole number of victims.

Let us now sail for Thera, well aware of an Ugaritic mina of 933.12 g. From 61 weights, excavated there by Marinatos, one complete set was singled out as follows. First, Buchholz (1980, 231-232 and 237, note 37) mentioned that on Thera sets of weights had been found (Fig. 2),

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9 De Zwarte 1994/95a, 127-131.

10 De Zwarte 1994/95a, 114 for a parallel in Quft.

11 Zaccagnini 1979, 472, note 2 (texts); 50 x 9.3312 (1/2 mina of Ugarit) = 40 x 11.664 g = 1 Hittite mina of 466.56 g; Otten 1956: 1 mina of Hatti = 40 sheqels.

12 For the relevant texts, see note 8.

which he illustrated in his fig. 4. He based his drawings on photographs from Marinatos' series "Excavations at Thera". On one of these photographs (Marinatos 1971, plate 88a), the inventory numbers are clearly visible (1298-1303). Then, in his dissertation, Petruso (1978, 191-199) mentioned these inventory numbers and the masses of all weights from Thera known to him in 1976. Although four of these weights already suffice to proof the standard of 933.12 g, I was not satisfied inasmuch as the total mass of the six weights was meaningless. Finally, I rearranged Petruso's list into a list of Marinatos' inventory numbers in numerical order, which runs as follows: 426, 648, 1298-1303, 1383, ...
I added no. 648 to the set on the assumption that it had been found in the same house, perhaps even in the same room - the 'Lilies room' - in an earlier stage of the excavations (Table 5).

	Marinatos Inv.no.	Petruso Cat.no.	Mass grams	Mina 933.12 g	Mark	Condition (B - G cleaned)
A	648	191	65.0	0.069		not stated
B	1298	196	88.1	0.094		cracking, sound
C	1299	206	216.0	0.231		cracking, complete
D	1300	219	704.6	0.755	4 circles	complete
E	1301	225	1021.2	1.094	2 triangles	complete
F	1302	227	1162.2	1.245		complete
G	1303	229	1408.6	1.509		complete, sound
Total			4665.7	4.999		

Table 5. Weight-set from Akrotiri (lead discs).

The capacity of the set can be seen at a glance. The differential combination E - B (933.1 g) yields one Ugaritic mina, the additive combination D + F (1866.8 g) yields two. Three minas are the outcome of both the differential combination D + E + F - B and the additive combination A + B + C + E + G.
This was extremely useful in trading with foreign merchants. When in doubt, the outcome of the first weighing could be checked with the other combination. The reason why this crosschecking was tied to these particular combinations will also be clear: 3 Ugaritic minas equal 5 minas of the Cypriot standard of mass (3 x 933.12 = 5 x 559.872 g).
Nevertheless, it cannot be ruled out that weight no. 648 does not belong to the set because the original set also allows of more accurate combinations yielding three minas: weight D can be replaced by group G - D (Table 6).

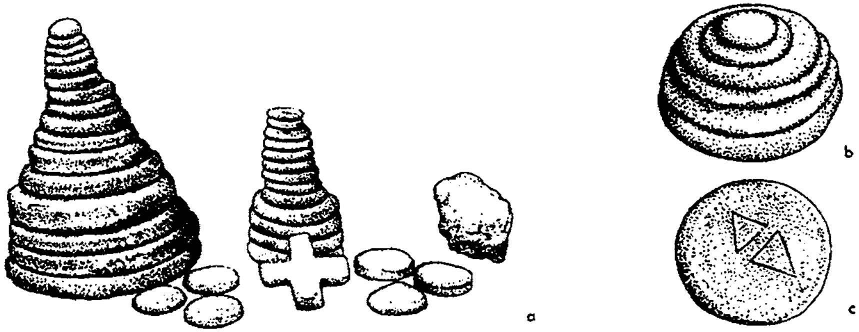

Fig. 2. Lead weights from Akrotiri (after Buchholz 1980).
Weight-group right is discussed.

Combination			Commodities minas	Mass grams	Target grams
E	-	B	1	933.1	933.12
B + D + F	-	E	1	933.7	933.12
B + F + G	-	D + E	1	933.1	933.12
D + F			2	1866.8	1866.24
F + G	-	D	2	1866.2	1866.24
D + E + F	-	B	3	2799.9	2799.36
E + F + G	-	B + D	3	2799.3	2799.36

Table 6. Step 1 mina, range 1-3 minas.

The standard of 933.12 g is clearly demonstrated, but the handling of the set is still unclear. Firstly, weight C (no. 1299) is not used in Table 6, which is an odd thing if indeed nos. 1298-1303 represent a complete set of weights. Secondly, the presence of the markings on weights D and E cannot be explained yet.

The weights were found in a Theran house, in a room with wall paintings. These wall paintings showing no Semitic elements, the owner of the house must have been a member of the Theran thalassocracy, not a merchant from Ugarit (Buchholz 1980, 234). This leads me to conclude that Thera had adopted a foreign mass system in which the sheqel of 9.3312 g was the basic unit.

It remains to be solved whether or not the Ugaritic mina of 100 sheqels was preferred to the Cypriote mina of 60 sheqels. Marinatos excavated a 'Canaanite' jar in Akrotiri (Buchholz 1980, 228). Thus, the pottery finds from Thera might lead one to infer contacts with both Cyprus and the coastal area.

Weight-set from Tarsos (c. 2400-2000 B.C.)

At Tarsos in Cilicia (modern Guzzle Kula in Turkey), eleven weights lying together on a floor were found in an Early Bronze III level.[13] The weights, all made of hematite, bare no marks. Among them Petruso distinguishes two shapes: ovoid (A, E and K) and spindle-shaped. I have not been able to involve these two shapes in an explanation of the working of the set (Table 7).

	A	B	C	D	E	F	G	H	I	J	K	Total
Mass (g)	4.4	5.2	6.5	8.0	16.6	18.5	20.5	22.5	32.5	48.5	100.0	283.2

Tabel 7. Weight-set from Tarsos

As demonstrated above, it is very useful to find out whether two weights or groups of weights balance when placed in opposite pans of an equal-armed balance.[14] In this case, the metric values of the weights being accurate to only one decimal, a perfect result is out of the question. Then, it is worth to investigate whether the value can be given as a fraction of the Roman pound, using the same denominator:

ABCE	(32.7 g)	and	I	(32.5 g)	equal	3/30 of 326.592= 32.6592 g
ACFGIJ	(130.9 g)	and	DHK	(130.5 g)	equal	12/30 of 326.592=130.6368 g
ACDHK	(141.4 g)	and	BEFGIJ	(141.8 g)	equal	13/30 of 326.592=141.5232 g.

We conclude that the standard is 1/30 Roman pound (10.8864 g). This standard divides the groups into useful smaller groups to produce a satisfying step and range (Table 8).

[13] Petruso 1978, 61-64 and 177-178. Petruso refers to H. Goldman, Excavations at Gözlü Kule, Tarsus. Volume II, 1956, 266-268, 275 and plate 420.

[14] See also the weight-set from Ur in De Zwarte 1994/95a, 116.

Groups	Mass grams	Corrected grams	Sheqels 10.8864 g
AC	10.9	10.8864	1
BE	21.8	21.7728	2
I	32.5	32.6592	3
FGJ	87.5	87.0912	8
DHK	130.5	130.6368	12

Table 8. Weight-groups.

The structure of the implied handling of the weight-system is completely differential (Table 9).

Left pan			Right pan					Error
Weights Sheqels			Weights sheqels			Bullion sheqels	= grams	grams
3			1	2		0	0	- 0.2
3				2		1	10.8864	- 0.1864
3			1			2	21.7728	- 0.1728
	8			2	3	3	32.6592	+ 0.5408
	8		1		3	4	43.5456	+ 0.5544
	8				3	5	54.432	+ 0.568
	8			2		6	65.3184	+ 0.3816
	8		1			7	76.2048	+ 0.3952
		12	1		3	8	87.0912	+ 0.0088
		12			3	9	97.9776	+ 0.0224
		12		2		10	108.864	- 0.164
		12	1			11	119.7504	- 0.1504
3		12	1	2		12	130.6368	- 0.3368
3		12		2		13	141.5232	- 0.3232
3		12	1			14	152.4096	- 0.3096
	8	12		2	3	15	163.296	+ 0.404
	8	12	1		3	16	174.1824	+ 0.4176
	8	12			3	17	185.0688	+ 0.4312
	8	12		2		18	195.9552	+ 0.2448
	8	12	1			19	206.8416	+ 0.2584
3	8	12	1	2		20	217.728	+ 0.072

Table 9. Step 1 sheqel, range 1-20 sheqels.

The mina[15] of Tarsos presumably consists of 60 sheqels, equalling 60 x 10.8864 g = 653.184 g or two Roman pounds. The standard of 10.8864 g was later known as the heavy gold standard of Kroisos of Lydia (561-546 B.C.; Kraay 1978, 31). The discrepancy between theory (standard of 10.8864 g) and practice (36 specimens known, mass mean 10.70 g; Naster 1983, 71) has been ardently discussed by numismaticians for roughly the last hundred years. Lydian electrum coins of 168 English grains (10.8864 g) have been found too (Head 1911, 643). Unfortunately, their alloy is not known. A gold-silver alloy with a gold content of 54.1 % has a specific mass of 14 (Oddy/Hughes 1972, 81); in the present instance, the capacity of the Lydian electrum mina is: (653.184 g : 14 =) 46.656 cm^3 = 3.6 x 3.6 x 3.6 cm. This can be conceived as a cube with an edge of two digits of 1.8 cm, resulting in a cubit of 24 digits = 43.2 cm.[16]

Katsambas on Crete (c. 1400 B.C.)

In Katsambas, once a seaport for Knossos, a group of 5 spindle-shaped ('sphendonoid') stone weights was found in a tomb (Petruso 1978, 124-127 and 202-203). Pottery of Late Minoan III A2 style dates the tomb to about 1400 B.C. I agree with Petruso (1978, 126) that the standard of mass of Katsambas seems to correspond to that of Tarsos. If it does, if its dating is correct and if the set from Tarsos is actually from 2400-2000 B.C., then this standard may either have been used for at least 600 years running or been introduced again after a period of disuse. Not constituting an unbroken range, the set may not be complete. The mate-

[15] In fact, there is no evidence of the value of the mina. The useful top of the range of the weight-set being 20 primary units, minas of 40 or 60 units would seam reasonable (21 and 22 are not impossible, but were almost certainly not used; over 20 I would expect two weighings for a standard practice, e.g. 20 and 2, 20 and 7, etc.). If the mina consisted of 40 units, then it had the same mass as the later Attic mina (below: Athens, LH IIIC period). I found no additional evidence of a mina of 435.456 g at Tarsos in the periods after EB III. In this light, I would surmise that Mesopotamian influence on early standards of mass may have lead to a 60-sheqel mina. Moreover, as in the LM IIIA2 period (see below: Katsambas) the half-sheqel of 5.4432 g was used on Crete and as a mixture of facts and assumptions brought to light the Minoan system of mass with a double mina of 1306.368 g (= 2 x 653.184 g), it would seem justifiable to infer a Tarsian mina of 60 sheqels = 653.184 g.

[16] De Zwarte 1994/95a, 110-111 (silver cube based on the same idea and confirmation of the cubic cubit in Tell al Rimah, Assyria). Nevertheless, the hypothetical character of this line of thought is to be emphasized. Finding a cube is not always a decisive argument for accepting a theory. See my commentary (de Zwarte 1994/95a, 110, note 69) which discusses the English Troy pound (373.248 g) in terms of a cube filled with water.

rial and colour of the weights might provide clues for useful groups (Table 10). The figures suggest that the half-sheqel (5.4432 g) was the unit of mass.

	Materials	Mass grams	Groups	Mass grams	Corrected grams	Sheqels 10.8864 g	Half-sheqels 5.4432 g
A	Green stone	5.7	AC	16.2	16.3296	1 1/2	3
B	White stone	10.2	BD	38.2	38.1024	3 1/2	7
C	Jasper	10.5	E	48.9	48.9888	4 1/2	9
D	White stone	28.0	Total	103.3	103.4208	9 1/2	19
E	Diorite	48.9					

Table 10. Weights from Katsambas on Crete.

Here, the two classes of differential weighing[17] are mixed. Both the class 2 groups (and the element E) and their differences in mass produce whole numbers of half-sheqels: AC = 3, BD = 7 and BD - AC = 4 half-sheqels.

The Katsambas set contains one class 1 combination: CE - AB = 43.5 g = 8 units of 5.4432 g (error 0.0456 g). Adding this combination to the above-mentioned weightings and accepting the half-sheqel as the step, the range will be 1-10 and 12 half-sheqels (Table 11).

Left pan: Weight-groups				Right pan: Weight-groups				Right pan: Bullion Half-sheqels
AC	BD					E		1
		E			BD			2
AC								3
	BD			AC				4
AC		E			BD			5
		E		AC				6
	BD							7
			CE				AB	8
		E						9
AC	BD							10
AC		E						12

Table 11. Step 1 half-sheqel, range 1-10 and 12 half-sheqels.

[17] See above: procedures of differential weighing.

Here is an opportunity to unravel the Linear B mass system. Bennett's 1950 article is still pertinent to this subject, but his numeration of Linear B signs - viz. 27, 28, 29 and 30 - is now obsolete. At present weights and measures are represented by single capitals. In Bennett's article (1950, 217), I found two facts and an assumption. The facts (of metals) are: M (28) is 1/30 of L (27) and N (29) is 1/4 of M (28). The assumption (concerning 30, nowadays P) is: "Therefore at least 7 of the measure 30, *and more probably 12*, equal one of the larger measure 29" (N). Unfortunately, Bennett did not explain his preference for P = 1/12 of N. Later on, Q, an even smaller unit, was discovered.
In Chadwick's *Documents in Mycenaean Greek* (1973, 55), P is described as "4th unit, probably 1/12" and Q as "5th unit, 1/6 or less". On p. 359 Chadwick mentions tablets giving amounts of P 7 and P 9. Thus, at least 10 of the measure P equal N. At this point, I am in need of factual evidence. I don't know of any other recent literature discussing new discoveries of or on tablets. If there is and P 10 or more or Q 6 or more have been found on Linear B tablets, then my 'Mycenaean mass system' can immediately be rejected, its assumptions being that P is 1/10 of N and Q is 1/6 of P.[18]
I shall proceed to illuminate the Mycenaean system of mass, realizing I might be building a house of cards. Apart from the assumptions already made, I have to mention one more: the man buried in Katsambas was an inhabitant of Crete, not a foreign merchant. I will deal, therefore, with a Cretan standard, not with a combination of a foreign standard and assumed relationships of Linear B measures.
Table 12 gives facts, assumptions and metrical values of the measures, that follow from Q equalling half a sheqel of 10.8864 g.

L	M	N	P	Q	grams
1	30	120	1200	7200	39191.0
	1	4	40	240	1306.368
		1	10	60	326.592
			1	6	32.6592
				1	5.4432

Table 12. Mycenaean system of mass.

[18] In his letter of March 12 1998 Dr. J.-P. Olivier kindly informed me that the situation had not materially changed from Documents². For Q, the maximum is always 1 in Knossos and it does not appear in Pylos. However, on tablet KN Og 7432 (Chadwick/Killen/Olivier 1971, 265) the maxima for P are 12 and 20. I quote the relevant part of the authors' comment: "Probably palimpsest, except for the small P20 at the end, perhaps not erased by omission; (....). 12 consists of 10 and 2 written underneath." In my opinion, the tablet determines my argument. Firstly, quantities have occasionally not been reduced to the higher unit. See Chadwick 1973, 55 (M63 instead of L2M3) and 360 (M30 instead of L1). Secondly, the way in which 12 was written supports the interpretation P1Q2.

The talent of 39191.04 g is the metrical equivalent of the trade talent of Athens at the time of Solon (see below).

It is a steady challenge to make some sense of archaeological discoveries. Let us consider the 'talent weight or anchor' problem. Evans (1935, 650-651) regarded the object of purple gypsum - with two octopods in relief and a hole for suspension - found in the palace of Minos at Knossos on Crete as the talent weight against which copper oxhide ingots were weighed. Generations of metrologists have accepted his view, although the exact mass is still a mystery.[19] Davaras, however, considered the possibility that the object was not a weight, but rather a sacred anchor.[20] So nothing was left for metrological speculations. I am, however, now inclined to accept the idea that a group of 'stone anchors' could be a complete set of weights. This is supported by the evidence given in Pulak's (1988, 33) description of the Ulu Burun shipwreck finds:

> "Seven of the eight anchors uncovered to date are grouped between the two uppermost rows of copper ingots. Although some of the anchors are still partly buried, they seem to come in three sizes: three large, two intermediate and one very small. The last, probable of marble or other light-coloured limestone, is too small to be an effective ship's anchor."

The storage of weights together with the commodities to be weighed is an obvious thing, but how to account for the storage of anchors together with ingots?

Athens (1200-1100 B.C.)

On the north slope of the Acropolis, many objects, LH IIIC pottery and fourteen weights were found in the fill of a forty metres deep subterranean well.[21] Petruso[22] determined the mass of the weights and provided a full description of each specimen. As the weights were deposited under humid conditions and free of air, I had to exclude the weight

[19] Bass 1967, 139: mass recorded as to be 28600 and 29000 g.

[20] Davaras 1980. The anchor theory was first defended by H. Frost, Under the Mediterranean, London 1963, 46. This publication was not available to me.

[21] In his publication, the excavator does not mention the weights. One specimen (Table 13: H) is depicted and described as a pestle. See Broneer 1939, 411, fig. 96e.

[22] Petruso 1978, 148-150, 211-213. Although I disagree with his results, my study of this weight-set clearly leans on Petruso's work on ancient weights, in particular on his conclusion that some of the objects (wrongly identified or not at all) must be weights.

showing conflicting depositional conditions from the analysis.[23] The total mass of the remaining 13 weights (2612.38 g, i.e. 6 minas) quite nearly coinciding with 1/10 Attic talent (2612.736 g), one is inclined to ascertain whether these weights would function as a set if the Attic mina of 435.456 g were the standard (Table 13).[24]

Weights	Description	Mass grams	Attic mina 435.456 g
A	Lead disc	12.95	0.0297
B	Lead disc	18.64	0.0428
C	Lead disc	21.41	0.0491
D	Steatite rectangle	21.65	0.0497
E	Lead disc	23.05	0.0529
F	Lead disc	28.32	0.0650
G	Lead disc	29.79	0.0684
H	Black stone sphendonoid	44.27	0.1016
I	Grey stone bulging cylinder	88.9	0.2041
J	Marble rough sphendonoid	138.3	0.3175
K	Marble egg	271.1	0.6225
L	Brown stone disc	853	1.9588
M	Grey amorphous worked stone	1061	2.4365
Total		2612.38	5.9991

Table 13. Weight-set from Athens.

None of the weights bears a value mark. Balance will result from splitting the set up into two parts: ACFHJM (1306.25 g) and BDEGIKL (1306.13 g), each nearly the equivalent of 3 Attic minas. Table 13 clearly shows that single weights do not fit this supposed standard. We have, therefore, to find out whether groups of weights were used for weighing. Moreover, in this case, we are left to solve an interesting problem: can we stick to the proposed standard? Our source of the Attic standard - a passage in Livy (see note 24) - refers to a point in history (189/8 B.C.), which is about a 1000 years later than the date of the weight-set. The passage relates the Attic mina to the Roman pound. If actually this set is the first proof of the Attic standard in so early a period, I cannot well reject the Roman pound as the underlying standard simply by

[23] I surmise that, prior to the registration of the finds, this weight was erroneously added to the other weights. Its condition, as described by Petruso (Cat. no. 360: "lead disc, poorly preserved, bubbly surface, uncleaned, probably overweight, 24.00 g.") points to original position in soil containing organic acids or permanently accessible to rain-water.

[24] The Attic mina = 1/60 x 80 Roman pounds (Livy 38.38.13: "Attica talenta (....); talenta ne minus pondo LXXX Romanis ponderibus pendat").

claiming it did not exist in the late second millennium B.C. In complication, the standard of Tarsos (see above) is equal to two Roman pounds and, therefore, also related to the Attic mina. Fortunately, the findspot of the weights being Athens, it is plausible for the step of weighing to be Attic, viz. a half mina. In order for the reader to assess the validity of the conclusion drawn in this study, two columns with the results for the related standards have been added to Table 14.

Groups	Mass grams	Mina of Athens 435.456 g	Mina of Tarsos 653.184 g	Pound of Rome 326.592 g	Error grams
ACHJ	216.93	1/2	1/3	2/3	- 0.798
DEGIK	434.49	1	2/3	1 1/3	- 0.966
BL	871.64	2	1 1/3	2 2/3	+ 0.728
FM	1089.32	2 1/2	1 2/3	3 1/3	+ 0.68

Table 14. Grouping of weights.

If the weight-set was used as in modern practice, that is, weights in one pan and commodities in the other, then its range was 1/2-6 minas. If only the differential method was in use, then the top of the range was 4 minas. Many weightings could be crosschecked where two combinations with the same outcome were at hand (Table 15).

Weights	-	Weights	= Commodities	Weights		-	Weights	= Commodities
2.5	-	0.5 + 2	= 0	2.5		-	0.5	= 2
1	-	0.5	= 0.5	0.5	+ 2.5	-	1	= 2
2.5	-	2	= 0.5	1	+ 2	-	0.5	= 2.5
2	-	1	= 1	2	+ 2.5	-	0.5 + 1	= 3
2.5	-	0.5 + 1	= 1	2	+ 2.5	-	1	= 3.5
2	-	0.5	= 1.5	2	+ 2.5	-	0.5	= 4
2.5	-	1	= 1.5					

Table 15. Differential weighing: step 0.5 mina and range 0.5-4 minas.

Finally, if permanent load on the pans was intended (2 1/2 minas and 2 minas in different pans), the top of the range was 2 minas (Table 16).

Left pan			Right pan		
Weights			Weights		Commodities
		2.5	2	0.5	0
		2.5	2		0.5
0.5		2.5	2		1
	1	2.5	2		1.5
0.5	1	2.5	2		2

Table 16. Differential weighing and permanent load: range 0.5-2 minas.

Metrology and trade

The above arguments allow us to extend an equation first mentioned by Evans:[25]

1008 English grains = 65.3184 grams = 5 x 13.06368 g (= 5 gold units of Egypt). Extension: = 7 x 9.3312 g = 6 x 10.8864 g = 15 x 4.35456 g.

The extended equation may shed fresh light on the *possible* economic contacts of regions that used these standards. However, where any considerable span of time is involved, the results of comparative metrology alone cannot be accepted in conclusive proof, which they have often been in the past. But then, if archaeologists would consistently publish full reports of the weights excavated, 'site metrology' would prove a very useful tool to uncover ancient trade relations pertaining to relatively short periods and to confirm evidence of relations during longer periods.

A DIGRESSION ON ARISTOTLE'S *ATH. POL.* 10

If actually the Attic standard of mass dates back to the Bronze Age - which I find no reason to deny - then I cannot leave out a discussion of

25 Evans 1935, 654. De Zwarte 1994/95a, 132, note 135.

the metrological implications of Aristotle's description of the reforms of Solon (archon of Athens in 594/3 B.C.) in *Ath. Pol.* 10:[26]

> "As far as his legislation is concerned, these appear to be its democratic features; but, even before his legislation, he had effected the abolition of debts and afterwards the augmentation of the measures, the weights, and the coin. For it was under his administration that the measures became larger than those of Pheidon, and the mina, which formerly had had a weight of seventy drachmae, was increased to a full hundred. The original type of coin was that of the double drachma. He also introduced (trade) weights corresponding to the coinage at the rate of sixty-three minae to the weight of a talent, and proportional parts of the three additional minae were apportioned to the stater and the other units of weight."

The information on the trade weights looks rather complex, but it simply says that 63 coin minas equal one trade talent = 60 minas = 30 staters = 6000 weight drachms. Unfortunately, Aristotle's[27] account lacks the crucial information: it does not tell us whether Solon's reform of measures had persisted until within Aristotle's time, nor whether it had been partially or wholly withdrawn by later authorities. Furthermore, Aristotle's statement on coins, implying the use of coins in Athens already before Solon's time, is controversial. Only few modern scholars subscribe to this view.[28] I know of no conclusive evidence to decide which dates are to be preferred as the beginnings of Aeginetan and Athenian silver coinages. I would, therefore, defend that fourth-century tradition may have wrongly attributed the reforms to Solon, but has given the correct details of the measures.

Let us first have a look at King Pheidon of Argos (7th century B.C.?). Herodotus (VI, 127) says that Pheidon introduced standard measures for the Peloponnesians. On the Parian marble it says that Pheidon the

[26] Translation into English by Von Fritz /Kapp 1966, 77. I have bracketed 'trade' as the word doesn't occur in the Greek text. I subscribe to the interpretation that the commercial talent should be meant here. As to the disagreement between the two principal sources, Plutarch's Solon 15 (which is based on Androtion, who lived slightly earlier than Aristotle) and Aristotle (384-322 B.C.), concerning the number of drachms in a mina (73 versus 70), Reinach appears to be correct in restoring the number 70 in Plutarch. See Reinach 1928. Most scholars have argued that Androtion's view is economically indefensible. Presumably, Androtion distorted history to suit political purposes. See Harding 1974. The two sources, both in Greek and translated into English, are also found in Kroll/Waggoner 1984.

[27] Aristotle's authorship of the Constitution of Athens is not beyond doubt. See Von Fritz/Kapp 1966, 4-7.

[28] Kagan 1982: yes, Kroll/Waggoner 1984: no. For the date of the electrum coins found in the Artemission of Ephesos see now Bammer 1990, 137 and 150.

Argive struck silver money in Aegina.[29] Another source mentions the same, adding "and as he had adopted money, he took the spits and dedicated them to Argive Hera".[30] Clearly, weighed iron was the monetary forerunner of (coined?) silver. This very dedication of iron spits (obols) indeed was attested by an excavation on the site of the Argive Heraeum on Aegina. The average mass of the six best preserved specimens (which constitute a drachm) was 403 g (Seltman 1924, 117-118). As all spits were corroded and incomplete, they are, in commercial transactions, likely to have been the basic unit of the Mycenaean standard of 435.456 g we found in Bronze Age Athens.

For unknown reasons, Solon raised the standard of silver to 100/70 x 435.456 = 622.08 g. If the Aeginetans struck coins already, Solon introduced these (didrachms of 12.4416 g) in Athens, paying Aegina for converting bullion into coins.[31] If, around 600 B.C., the Aeginetans still stuck to uncoined weighed silver, then the Athenians will have done so too.

The trade talent of Solon is very interesting: it is 63 x 622.08 g = 39191.04 g = one third of a cubic cubit of water based on the Attic foot of nearly 32.66 cm.[32] A talent of 120 Roman pounds (39191.04 g) can be derived from a passage in Vitruvius (X 15, 7). The trade mina is also striking: it is 1/60 of 39191.04 g = 653.184 g = the surmised standard of Tarsos in the Early Bronze Age (see above). The time may have come for us to stop investigating Bronze Age buildings using foot measures sprung from imagination[33] and to examine whether the Attic foot or cubit is a proper means to an understanding of Mycenaean/Minoan architecture.

As Solon's silver mina of 622.08 g was unpractical in international trade, the question of whether it has lasted for a long time should be

[29] Seltman 1924, 117. Regling in: Von Schrötter 1930, *s.v.* Pheidonisches Mass, Gewichts- und Münzsystem.

[30] Seltman 1924, 117: *Etym. Magn., s.v.* obeliskos.

[31] Dependently on the several conjectures as to the missing pot in which the hoard of Matala on Crete was buried, didrachms of type II are dated to 550 B.C. (Holloway 1971, 3), to 520 B.C. (Kraay 1964, 79) and, upon reconsideration, to 500 B.C. (Kraay 1978, 50). All coins in the Matala hoard show abrasion. The earliest Aeginetan coins, which were not among the Matala hoard, display a phenomenon reminiscent of some early Ionian electrum coins: Kroll/Waggoner 1984, 336.

[32] De Zwarte 1994, 127-128. The theoretical length of the foot is 32,6592 cm.

[33] Cherry 1983. Hypothetical measures of length are often based on the assumption that ancient architects built applying round numbers of feet whenever they could. So far, however, in my research on the designs of archaic and classical Greek temples, I haven't found a scrap of evidence in support of this assumption. See De Zwarte 1994/95b and 1996.

answered in the negative. Seltman (1924, 119) says that, in 664 B.C., Psammetichus I, who had become Pharaoh of all Egypt with the help of Greek forces, built the fortress of Daphnae and that Egypt was opened up to Greek trade. Pharaonic Egypt knew no coinage. It used metal by mass for a standard of value. In Daphnae, Petrie excavated a set of weights. Their standard was the contemporary qedet (9.072 g; De Zwarte 1994/95a, 122-125). The Solonian standard would be awkward here, 622.08 g equalling 68 4/7 qedets. The Pheidonian standard, however, which also was the Attic standard later in the sixth century, equalled 48 Egyptian qedets, 35 Aeginetan didrachms and 25 Attic tetradrachms.[34] The Aeginetans never abandoned the Pheidonian standard of 435.456 g. The hoard of Matala on Crete, whatever its date may be, contained 70 Aeginetan didrachms and one Theran coin.[35] The total mass (c. 860 g) is very near to two minas of silver of the Pheidonian standard. The drachm of Delphi was of Aeginetan standard. In 336 B.C., the mina contained 70 drachms (Kraay 1968, 5).

Bibliography

Bammer, A. 1990, A Peripteros of the Geometric Period in the Artemission of Ephesus, *Anatolian Studies* 40, 137-160.

Bass, G.F. *et alii* 1967, *Cape Gelidonya: A Bronze Age Shipwreck* (Transactions of the American Philosophical Society 57/8), Philadelphia.

Ben David, A. 1979, The Philistine talent from Ashdod, the Ugarit talent from Ras Shamra, the 'PYM' and the 'NSP', *Ugarit Forschungen* 11, 29-45.

Bennett, E.L. 1950, Fractional Quantities in Minoan Bookkkeeping, *American Journal of Archaeology* 54, 204-222.

Broneer, O. 1939, A Mycenaean Fountain on the Athenian Acropolis, *Hesperia* 8, 317-433.

Buchholz, H.-G. 1980, Some observations concerning Thera's contacts overseas during the Bronze Age, in: C. Doumas (ed.), *Thera and the Aegean World* II, London, 227-240.

Chadwick, J./J.T. Killen/J.-P. Olivier 1971[4], The Knossos Tablets, Cambridge.

Chadwick, J. 1973[2], *Documents in Mycenaean Greek*, Cambridge.

Cherry, J. 1983, Putting the best foot forward, *Antiquity* 57/219, 52-56.

Davaras, C. 1980, Une ancre minoenne sacrée?, *Bulletin de Correspondence Hellénique* 104, 47-71.

Doumas, C.G. 1983, *Thera, Pompeii of the ancient Aegean. Excavations at Akrotiri 1967-79*, London.

Evans, A. 1935, *The Palace of Minos at Knossos*. Vol. IV: Part II, London.

Fritz, K. von/E. Kapp 1966, *Aristotle's Constitution of Athens and related texts*, New York/London.

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[34] The immediately preceding 'Wappenmünzen' - didrachms on the Attic standard - were hardly used for long distance trade. Kraay 1978, 57: "if we exclude coins which had obviously drifted far afield to such places as Egypt, all finds are concentrated within Attica and Euboa".

[35] Holloway 1971, 1. See also note 31.

Harding, P. 1974, Androtion's view of Solon's seisachtheia, *Phoenix* 28, 282-289.
Head, B.V. 1911, *Historia numorum*, Oxford.
Heltzer, M. 1977, The metal trade of Ugarit and the problem of transportation of commercial goods, *Iraq* 39, 203-211.
Hiller von Gaertringen, F./C.F. Lehmann 1901, Gewichte aus Thera, *Hermes* 36, 113-133.
Holloway, R.R. 1971, An archaic hoard from Crete and the early Aeginetan coinage, *American Numismatic Society Museum Notes* 17, 1-21.
Kagan, D. 1982, The dates of the earliest coins, *American Journal of Archaeology* 86, 343-360.
Kraay, C.M. 1964, Hoards, small change and the origin of coinage, *Journal of Hellenic Studies* 84, 76-91.
Kraay, C.M. 1968, An interpretation of *Ath. Pol.* ch. 10, in: C.M. Kraay/G.K. Jenkins (eds.), *Essays in Greek coinage presented to Stanley Robinson*, Oxford, 1-9.
Kraay, C.M. 1978, *Archaic and classical Greek coins*, London.
Kroll, J.H./N.M. Waggoner 1984, Dating the earliest coins of Athens, Corinth and Aegina, *American Journal of Archaeology* 88, 325-340.
Lipiński, E. 1979, Les temples néo-assyriens et les origines du monnayage, *Orientalia Lovaniensia Analecta* 6, 565-588.
Mamet, H. 1874, *De insula Thera* (thesis), Paris.
Marinatos, S. 1971, *Excavations at Thera* IV, Athens.
Naster, P. 1983, The weight-system of the coinage of Croesus, *Numismatica Lovaniensia* 6, 68-77.
Oddy, W.A./M.J. Hughes 1972, The specific gravity method for the analysis of gold coins, in: E.T. Hall/D.M. Metcalf (eds.), *Methods of chemical and metallurgical investigation of ancient coinage*, London, 75-87.
Otten, H. 1956, Zum hethitischen Gewichtssystem, *Archiv für Orientforschung* 17, 128-131.
Parise, N.F. 1970/71, Per uno studio del sistema ponderale ugaritico, *Dialoghi di Archeologia* 4, 3-36.
Petruso, K.M. 1978, *System of Weight in the Bronze Age Aegean* (Thesis Indiana University).
Pulak, C. 1988, The Bronze Age Shipwreck at Ulu Burun, Turkey: 1985 Campaign, *American Journal of Archaeology* 92, 1-37.
Regling, K. 1930, Pheidonisches Mass-, Gewichts- und Münzsystem, in: F. von Schrötter: *Wörterbuch der Münzkunde*, 508-509 (Reprint Berlin 1970).
Reinach, T. 1928, Zu Androtion fr. 40 Müller, *Hermes* 63, 238-240.
Schaeffer, C.F.A./J. Nougayrol 1956, *Le palais royal d'Ugarit.* Vol. IV, Paris.
Seltman, C.T. 1924, *Athens, its history and coinage before the Persian invasion*, Cambridge.
Thureau-Dangin, F. 1934, Un comptoir de laine pourpre à Ugarit d'après une tablette de Ras-Shamra, *Syria* 15, 137-146.
Vargyas, P. 1986, Trade and prices in Ugarit, *Oikumene* 5, 103-116.
Viedebantt, O. 1917, *Forschungen zur Metrologie des Altertums*, Leipzig.
Zaccagnini, C. 1979, Notes on the weight system at Alalah VII, *Orientalia* 48, 472-475.
Zwarte, R. de 1994, Der ionische Fuss und das Verhältnis der römischen, ionischen und attischen Fussmasse zueinander, *Bulletin Antieke Beschaving* 69, 115-143.
Zwarte, R. de 1994/95a, On the use of the balance as a device for measuring commodities and the accuracy of ancient weighing, *Talanta* 26/27, 89-139.
Zwarte, R. de 1994/95b, Der Vorentwurf und die Dimensionierung des spätarchaischen Aphaiatempels auf Ägina, *Talanta* 26/27, 141-149.
Zwarte, R. de 1996, Der ursprüngliche Entwurf für das Hephaisteion in Athen –Eine modulare architektonische Komposition des 5. Jhs. v. Chr., *Bulletin Antieke Beschaving* 71, 95-102.

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