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The Lead Weights from Akrotiri: The Archaeological Record

ABSTRACT

In the previous congress on Thera and the Aegean World, K. Petruso presented a metrological analysis on fifty seven lead weights from Akrotiri. In this paper a closer look to the objects themselves is attempted and various aspects of the whole subject are considered; aspects like the state of preservation, the mode of manufacture (experiments proved that they were cast in moulds) or the spatial distribution of the lead weights within the settlement along with the coexistence of other artefacts in the same house or room.

The total number of the weights is today 102. In this paper a different approach to metrological analysis is attempted with the weights from the West House. It looks as if the collection of the discs of this house was a real set of balance weights and there are no grounds for suggesting two different systems.

Furthermore, it seems that weighing was an everyday practice for the inhabitants of Akrotiri since the distribution of the weights within the settlement indicates that specialized household industries were an essential part of the LC society of Akrotiri.

Introduction

Metal finds in Akrotiri are quite few in comparison with artefacts made of clay or even stone. It seems the inhabitants had time enough to gather their most precious belongings before leaving the settlement. In contrast to the small number of bronze items, a greater number of lead objects — mostly weights — were found in the ruins of the houses. One would gather that these were neither valuable nor of the utmost necessity to their possessors. So one would expect a quantity of lead weights from other contemporary settlements too, especially in flourishing Crete. Up to now, 102 lead weights have been found in one settlement in Thera (Akrotiri) and a total of approximately 36 has been reported from various settlements in Crete. Of course we have the thick layers of volcanic materials to thank for the better preservation of houses in Akrotiri, but still, the fact that the site of Ayia Irini in Kea comes second in producing great numbers of lead weights, probably gives a special hint for the Cyclades (cf. Caskey 1969, 95-106; Petruso 1979, 138, 140).

Fifty-seven lead weights from Akrotiri have been studied and presented by K.M. Petruso in the previous conference on Thera and the Aegean World (Petruso 1978b) and they have been incorporated in his Ph.D. on the Aegean systems of weight (Petruso 1978c). He assigned 37 of them to the Minoan system he is suggesting — a system based on a unit in the vicinity of 60 g — and 28 weights to a non-Minoan system, based on a unit of approximately 180 g (Petruso 1978c, 111-116; 1978b, 550-552). He convincingly linked the unit of 60 g with possible interpretations of most of the marks on lead and stone weights from Crete, Kea and Thera, and he associated the Minoan system of weight with denominations indicated in the Linear A and B Tablets (Petruso 1978a, 26-42; 1979, 135; cf. Chadwick 1976, 104). His efforts followed those of Evans (1935, 651-652; 1906, 336-367) and Caskey (1969, 95-106), both scholars having indicated a unit of 65.5 g for the weights from Crete and Kea.

But the lead weights of Akrotiri deserve something more than merely the study of their contribution to the metric systems of the period. The title of the present paper is: 'The lead weights from Akrotiri: The archaeological record'. By this I mean a closer look to the objects themselves, their context and their spatial distribution within the settlement. Questions like how they were manufactured, in what state they were found and whether there are only lead weights in the site, should be answered. The archaeological record, so vaguely known from other sites, may give us more information on their function within the economic system of Late Cycladic society.

To begin with, the weights from Akrotiri are — in reference to the weights from other sites — of special value for the following reasons: 1) They are securely dated. 2) They represent the largest collection yet found in a single settlement. 3) They show a greater span and variety in value. 4) Most of the weights are found in groups. 5) In some cases the exact find-spot is recorded.

1) The thick layers of pumice and volcanic ash that covered the ruins of the houses at about 1500 BC, did not permit any further disturbances by excavation for foundations of later buildings. There is a safe *terminus ante quem* for the chronology of the weights. The *terminus post quem* is the previous disaster, detected at the beginning of LC I and followed by vast rebuilding activities (Marthari 1984; Palyvou 1984). So it is most probable that all lead weights from the houses of Akrotiri are dated in LC I, belonging to one period of the settlement's life. (Only weights proved to have been found in the levelled debris of previous buildings could be earlier.) In contrast to other sites we have a clearer picture and the certain knowledge that all the weights were actually used at the same time.

2) It has been pointed out (Petruso 1979, 138) that Akrotiri and Ayia Irini have produced fully two thirds of the total number of lead weights known. The contribution of Akrotiri has now been enlarged: forty-five (45) more are added, due to the enormous task of sorting out, arranging and recording the older finds, undertaken after 1975 by the scientific team of the Akrotiri excavations. So the total number of the weights from Akrotiri today is 102, twice as many as those from Ayia Irini. Now, the biggest advantage of Akrotiri, in contrast to other excavated places is that, for obvious reasons, the quantity of objects found is very close to the quantity actually used at the time. Therefore the number of one hundred may represent the closest to the number expected to have been in use in an LC I or LM I (?) settlement of a size analogous to that excavated up to now.

3) The greater number preserved results in greater variety in values. What is more, there is a greater span in the whole, as the largest and heaviest of the lead weights so far reported are found in Akrotiri: lead weights of the approximate value of 3, $4^1/_2$, 6 and 15 kg. The smallest weight from Akrotiri has a value in the vicinity of 10 g (found elsewhere too).

4) It is a piece of good fortune to find the weights in groups. As a rule in Akrotiri more than one is reported from the same house and sometimes the number amounts to 26 pieces found almost together. This is the case with the West House, but there are other groups coming from Complex A and from Complex Δ. When dealing with a group it is possible to decide the values most needed for the scale and probably the commodities weighed (from this point of view I think groups coming from tombs are also valuable, e.g. the weights from Vapheio).

5) It is useful to know the archaeological context of the weights rather than, for example, the information that they come from various parts of the palace, as is the case with Knossos, or having no report at all, as is the case with the group from Mochlos. The above mentioned weights from the West House were not only found in the same room (room 6 in the upper floor) but at least some of them were put on a shelf along with hundreds of conical cups (S. Marinatos 1974, Pl. 34, where some

Fig. 1.

Fig. 2.

of the weights are discernible at the bottom left of the picture, among the cups fallen from the shelf). This room was a storeroom for food and vessels. In another instance (roóm 8 in complex Δ) the weights were found together with a fine clay bowl, a bronze dagger and a whetstone (S. Marinatos 1971, Pl. 18b). Of course the problem of making 'convenient and probably meaningful categories' of the various artefacts of a room (Whitelaw 1979, 21), always exists.

State of preservation

Almost all the lead weights are in the shape of a disc. There are only two exceptions up to now: a possible weight in the shape of a cross (S. Marinatos 1971, Pl. 87b; Petruso 1978c, No. 202) and another in the shape of a cube (length: 1.4 cm). The latter recalls a similar cube of later date coming from Cyprus (Masson 1963, 152).

The weights are concreted over the entire surface, hence their white appearance (Fig. 1, right). The layer of encrustation is thin (approx. 1 mm). As proved by mineralogical analysis by X-ray diffraction (performed by V. Perdikatsis and Y. Maniatis at the Institute of Geology and Mineral Exploration, Athens) the weights were made of metallic lead (Pb) and when buried in the pumice their surface was transformed to lead oxide, lead carbonate and lead hydrocarbonate. In some instances the body of the weight has been eroded: first small white circles appear (Fig. 2) and in a second stage the white substance is gradually converted to dust, leaving circular depressions on the surface of the object (Fig. 3). Thus most of the weights tend to be underweight. In addition, some are battered due to their soft material (cf. Petruso 1978c, 4, for the advantages and disadvantages of the lead). Some crackings are caused by the oxidation but their location, usually near the periphery, is due to the way the objects were manufactured (the oxidation reveals the irregularities of the manufacture: see immediately below).

Mode of manufacture

Pétruso (1978c, 7) noticed the slight difference between the two faces in the larger discs from Akrotiri (one slightly convex and rough, the other concave and quite smooth) and thought that these weights were cast in a shallow dish mould; on the other hand he accepted a different way of manufacture — proposed by Caskey — for weights like the big one from Mochlos. Caskey had noticed that some weights from Ayia Irini are slightly flanged at their rims, which rise a little higher than the central surfaces, and he decided that these were not cast in moulds. He suggested that a specific quantity of molten lead was poured onto a flat surface, giving an object of plano-convex profile and then its thin edge was crimped inward and hammered (Caskey 1969, 101).

The large discs from Akrotiri certainly look as though they were cast in moulds, as suggested by Petruso, but their profile has a light groove around, which seems against the idea of a mould (cf. drawing, Fig. 21). Other weights — usually small ones — look as though they were made of two circular sheets of lead, one above the other (Fig. 4) sometimes joined with the help of a third (Fig. 5).


Fig. 3.


Fig. 4.


Fig. 5.

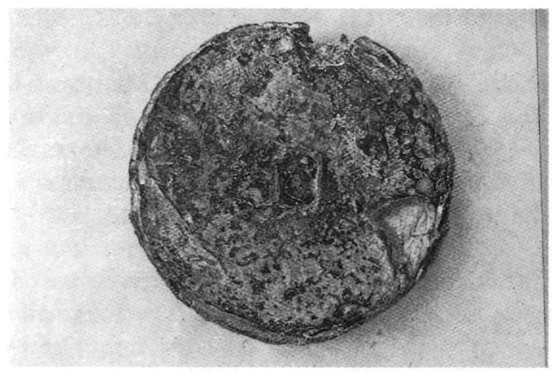
Fig. 6.

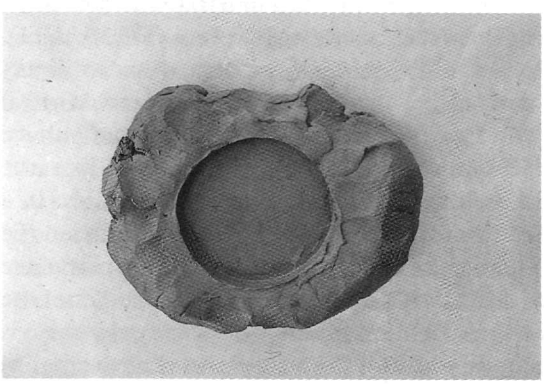
Fig. 7.

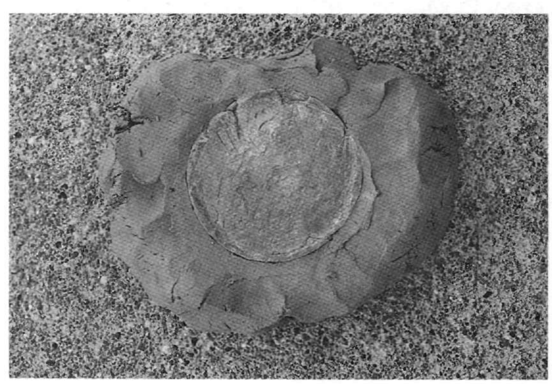
Fig. 8.


Fig. 9.


Fig. 10.

Fig. 11.

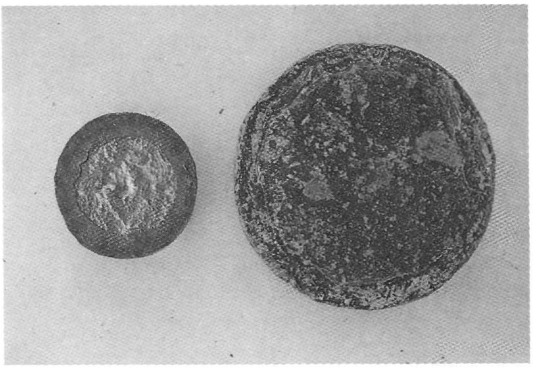

Fig. 12.

Some weights (Fig. 11 and 12, right) do have the higher rims or a 'folding' around the edge, as noticed by Caskey, while in others the rims are hammered to be lower than the central surfaces. Since cuttings for sampling revealed a solid mass in the body of the weight, I decided that experiments with casting should be done and if the products could explain all the peculiarities noticed in the ancient weights, then casting in moulds would be the answer.

Aris Gerondas, an experienced conservator of our excavation team, undertook the task. No appropriate stone or clay moulds have been found up to now. He used unfired clay that had been discovered kept in abundance in a specific place in complex Δ (*Ergon* 1985, 64). It was quite easy to press a specific weight (let's imagine it to be the standard) into clay and thus make a temporary mould (Fig. 7). Then molten lead was poured and the result was a weight with a concave top face (Fig. 8). In most of the cases, it was not possible to pour all the quantity needed at once, so two or three layers were discernible when the piece became cool (Fig. 9). Sometimes the result was even worse (Fig. 10, left), but by good chance it explained an ancient mis-product (Fig. 10, centre). To eliminate the joints of the layers, he hammered the periphery around, with the result that the edge around the face became higher than the central surface, just like some ancient weights (Fig. 11). When this projecting edge was hammered inwards, in order to produce a smooth top face without changing the diameter of the weight, then the 'folding' appeared (Fig. 12, left). So casting in a mould and hammering afterwards was the process for all weights, small or large. It must be added that when a large cast specimen was hammered around the edge on both faces, then the 'groove' in its periphery appeared. Caskey has mentioned that when a disc was found to be overweight, then a little of the metal was chiselled out (Caskey 1969, 101). The trouble was when it was found to be underweight, for an additional quantity of lead would easily detach. So a groove had to be made in order to pour the metal in the cavity (Fig. 13) or even better the body of the weight was pierced, the new metal poured on one surface and a little through the hole, then hammered on both faces (Fig. 5, 6, 9; Fig. 6 shows the reverse of the weight in Fig. 5). When hammered, the new metal made a cavity in the body of the weight, which was not apparent then but is now revealed by the flaking away of the thin piece of metal, due to oxidation (Fig. 14). In general, oxidation reveals all the irregularities of manufacture. So the central cavity on the weight (Fig. 5) was not made deliberately and this particular specimen was rather an unsuccessful product of the ancient mould (three layers of lead) found to be underweight, maybe when compared with the standard (?) with the central mark of a circle (Fig. 15 right), which is of the same size.

Marks on the lead weights

To the marks already mentioned (Petruso 1978c, Table 28; 1978b, Table II), few more instances may be added (1-5) and a comment:

1) The sign D incised on a weight of approximately 25 g but obviously underweight (cf. Petruso above, for the suggestion of a half-unit symbol).

2) A very elongated rectangle incised on a weight of approximately 53 g, maybe a mark.

3) A linear sign Y incised on a weight of approximately 86 g. Up to now it is unique among the signs on weights referred from the Aegean sites.

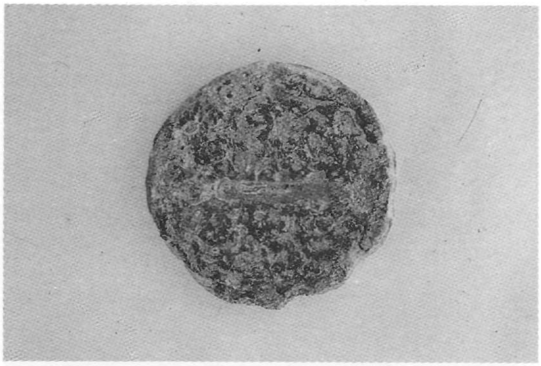
Fig. 13.

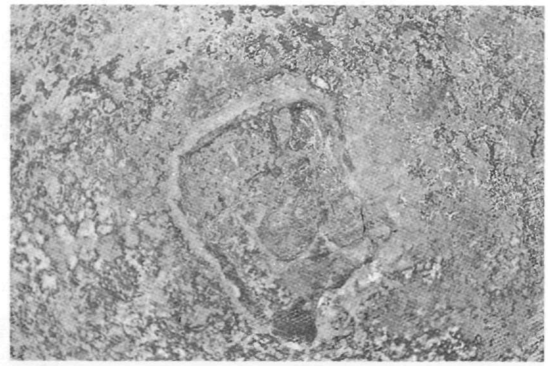
Fig. 14.

Fig. 15.


Fig. 16.

4) Two (or three?) dots were drilled on a very under-weight item of 142 (-) g. Maybe not a symbol but a way to take off some extra weight?

5) A triangle incised on a weight of approximately 980 g (Fig. 16). A triangular depression maybe was intended on a weight of approximately 104 (-) g, since it differs from the circular impressions caused by oxidation (Fig. 3).

6) The sign mentioned as one impressed dot (Petruso 1978b, Table II), is an incised circle (d = 1.9 cm) and this weight (Fig. 15, right) is of the same size as the weights with the four dots (Fig. 15, left) and the unsuccessful product mentioned above (Fig. 5). I deliberately speak of size because the size was the first obvious indication of differences or similarities in a collection of weights.

Even allowing for the possibility of some more signs to be found in future in the few yet uncleaned weights from Akrotiri, the number of the items marked is very small in comparison with that of the unmarked. So one thing is certain for the marks, whether symbols of value or not: their presence was not necessary.

Was lead the only material?

One should not expect an exclusive presence of lead weights, since from many contemporary sites, stone balance weights are reported along with or instead of lead ones. It is safer to speak of a preference for lead discs in some sites (e.g. Ayia Irini in Kea, Mochlos in Crete) or for stone discs in others (e.g. Zakros, though the total number of two is too small to reflect the reality). Places like Knossos, Tylissos and Ayia Triada have revealed both materials (cf. Petruso's catalogue in 1978c). The popularity of lead in Akrotiri is obvious enough, but there are some stone instances to be considered (in addition to the possible instances from the collection in the French School at Athens, referred by Petruso in 1978c).

Some of the stones thought of as tools could easily function as weights, e.g. the polisher of black volcanic stone from Complex A (Fig. 17, right) which easily stands on each of its flattened bases and

Fig. 17.

Fig. 18.

Fig. 19.

Fig. 20.

weighs 480 g (= 1 Mina, see Petruso 1978c, Table 27). Relics of a substance on its working surface prove that it was used as a polisher, but since similar stones are abundant on the site, it would have been quite easy for the inhabitants to weigh some of them against proper balance weights and after some rough preparation use them as weights themselves, at least for general everyday weighing. In the same sense the rough stone sphere with a flattened base (Fig. 17, left), found with two lead weights in Complex A, could function as a weight for the value of 1050 g (cf. S. Marinatos 1969, Pl. 41, 3; Petruso 1978c, No. 226).

One possible second use for some cores from stone vases — those which have one or two circular faces polished — could be for balance weights. One very thin section of a serpentine core (h = 1 cm) looks like a stone disc, it weighs 26 g (-) but unfortunately it is not intact. One section of a marble core (h = 2 cm) can stand and weighs 61 g (Petruso's unit). In a group of five selected cores (Fig. 18), the weight is respectively about 340 g, 170 g, 110 g and 58 g (the fifth is a fragment). That gives a scale of 6x, 3x, 2x, x, and x is very near to Petruso's unit again. But the items were selected because they had at least one flat base, and only the two heavier were found in the same room (Δ 16), so this second use remains to be proved.

Some elongated stones, possible weights, come from Akrotiri. One, of a value of 66.5 g, was found among lead weights in Complex A (S. Marinatos 1969, 49, Pl. 41; Petruso 1978c, No. 192). There is another which can also stand and is polished; its weight is about 720 g (Fig. 19, right). The third one is a regular weight of the sphendonoid type and of a value of 475 g (= 1 Mina?); pieces of the same stone were found in Akrotiri (Fig. 19, left).

Stone discs, interpreted as lids for jugs could prove to be weights (cf. also Petruso 1978c, 7). This is the case with a disc of white marble, found in a drawer among other stone lids, but weighing 62 g and bearing a small single circle incised in its centre (Fig. 20, right). The analogy with other stone weights from Crete, especially Knossos (Petruso 1978c, Table 20, No. 85, 86) is too strong to ignore. So this stone disc, with a weight value of Petruso's unit and the relevant incised symbol, is added to the other with the triangle (Fig. 20, centre), already known (S. Marinatos 1969, Pl. 41;

Petruso 1978c, No. 173), while the third lid in the same picture remains only a candidate for a balance weight (regular disc, 12 g of weight).

In conclusion, two stone discs and one sphendonoid are the certain stone instances against the hundred lead ones.

The lead weights from the West House

Of the 26 pieces found in this house, 15 are almost intact and 11 are damaged. Since even solid pieces are usually underweight due to the oxidation of their surfaces, I tried to make clusters by size: all weights — but one — preserve their two dimensions, the diameter (d) and the thickness or height (h). It was easy to make a catalogue (Table I) with the discs listed progressively by diameter,

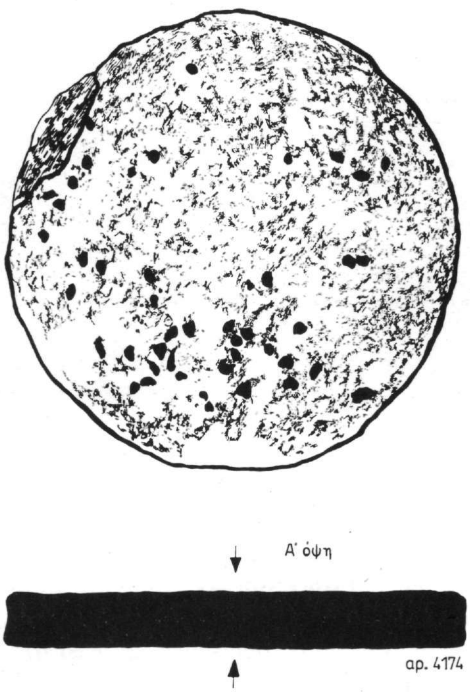

Fig. 21.

as this is the principle variable factor; differences in height are smaller and do not follow every change of the diameter. If we regard each lead disc as a thin section of a cylinder, then we may calculate its theoretical weight value using the formula for the mass: m = vρ, where m = the mass of the cylinder, v = its volume and = ρ the density of the material (in this case defined at 11,35 gr/cm³). Since $v = \pi r^2 h$, we have: $m = \pi r^2 h\rho = \pi (\frac{d}{2})^2 h\rho = \pi \frac{d^2}{4} h\rho = \frac{\pi}{4} d^2 h\rho$ and $\pi = 3{,}141$, $\rho = 11{,}35$ gr/cm^3 and the values of d and h are expressed in cms. All the weights of the catalogue have been cleaned, so their dimensions may be closer to the original ones, since the encrustation on the weights augments their volume. The values of mass, calculated as above, are written (in grams) in the fourth column of Table I.

If one takes the values of mass in column 4, to be closer to those originally intended, then one could apply to these values the simple statistical approach: $x = Mq \pm e$, proposed by Broadbent (1956) and already applied by Cherry to the values of the Minoan foot (Cherry 1983, 52-56) and to the values resulting from the actual weighing of the lead discs (Cherry 1980, unpublished paper which he kindly let me read, for which I am grateful to him). The idea is that each member of a set of measurements (x) is expected to be the product of a multiple (M) and the quantum (q) plus or minus some error (e), so one has to detect a quantum that fits the data best and with the least error, and then this could be the unit. Using the real weight values of today as data for the quantal analysis of

TABLE I

No	1 piec.	2 d	3 h	4 mass (m=vρ)	5 Mq (q=65,5)	6 e gr	 %	7 ratios	8
1	1	1,9	0,5	16,087	1/4q=16,375	−0,288	1,7	1/4	
2	1	2,3	0,7	33,002	1/2q=32,75	+0,25	0,76	1/2	
3	2	3	0,6	48,127	3/4q=49,125	−0,99	2	3/4	
4	2	3,1	0,5	42,824	2/3q=43,666	−0,84	1,92	2/3	1
5	1	3,5	0,6	65,507	1q=65,5			1	
6	2	4	0,6	85,56	4/3q=87,333	−1,77	2		2
7	2	4,4	0,7	120,78	2q=131	−10,2	7,78		
8	1	5,2	0,8	192,79	3q=196,5	−3,7	1,88	3	
9	1	5,4	0,8	207,91	3q=196,5	+11,41	5,8		
10	2	5,7	0,9	260,61	4q=262	−1,9	0,72	4	6
11	2	6,2	1	342,59	?5q=327	+15,5	4,5		
12	2	6,7	0,9	360,07	6q=393	−33	8,39		
13	1	9,2	1	754,35	12q=786	−31,6	4	12	
14	1	9,8	1,2	1027	16q=1048	−21	2	16	24
15	1	11,3	1,4	1593,2	24q=1572	+21	1,3	24	32
16	1	14	1,8	3144,3	48q=3144	+0,33	0,01	48	72
17	1	16,2	1,9	4444,1	64q=4192	+252	6		
18	1	18	2,2	6352,8	96q=6288	+64	1	96	144

TABLE II

AYIA IRINI Norm	AKROTIRI m=vρ
1/4 (16,375)	16,087
1/2 (32,75)	33,002
2/3 (43,667)	42,8245
Unit (65,5)	65,507
1 1/3 (87,333)	85,56
2 (131)	120,7822
4 (262)	260,610
16 (1048)	1027

TABLE III

No	Mq	Chadw.	Symbols in Lin. B	Mass/M	Mass/LANA
10	262	250	N1	1/4	1/12
11	327?		N1 P3 or P15	1/3?	
12	393		N1 P6 or P18		1/8
13	786		N3		1/4
14	1048	1000	M1	1	1/3
15	1572	1500	M1 N2	3/2	1/2
16	3144	3000	M3 or LANA 1	3	1
17	4192	4000	M4 or LANA 1 M1	4	4/3
18	6288	6000	M6 or LANA 2	6	2

the lead discs, Cherry's first results were that 30,32 g is the best quantal value for the weights from Ayia Irini, but that this seems not to be the case for Akrotiri, where neither a *c.* 30 or *c.* 60 g quantum is indicated strongly; and that there seems to be no statistical difference between those weights thought by Petruso to fit a Minoan 61 g system and those thought not to belong to this system (Cherry 1980). But the agreement between the systems of weight in Ayia Irini and Akrotiri is rather evident (cf. Parise 1986, 305) and no. 5 in our Table I corresponds to the value of 65.507 g; that is exactly the unit proposed by Caskey for the weights in Ayia Irini and, what is more, there is a strange coincidence between most of the original values proposed by him, based on this unit (Caskey 1969, 103-104), and the assumed values in Table I, column 4 (see now Table II).

I used the value of 65,5 g as a potential quantum and applied Broadbent's method to the new data for values of mass, as suggested in the fourth column of Table I. The results are shown in the fifth column of the same table: at first glance, the quantum of 65,5 g seems to minimize error (sixth column e%) for most of the weights. There are some explanations for those instances where error is above 5% (suggested by Skinner as the higher Normzone acceptable: cf. Petruso 1978b, 548), which are considered in the publication of the lead weights from the West House (forthcoming, in a volume on the West House material), and these show that more work has to be done on the stages of collecting the data and deciding on the factors influencing values of error (see also Cherry 1983, 53). And of course the sample of 25 pieces must and will be enlarged with the rest from Akrotiri.

The above results do not mean that Petruso's unit of *c.* 61 g should be replaced by 65,5 g; it may be only because the values of mass taken as data in our Table I are higher than the values produced by weighing by Petruso. What is really important is that the ratios in the seventh column of Table I are not different from those suggested by Petruso (1978b, Table III; Parise 1986, 305). The reasons I propose the theoretical calculation of values of mass (m = vρ) instead of just weighing the discs are: 1) This method enables us to use all specimens available, even fragments. 2) It aims at the normalization of all members of the set under study. 3) It helps us to establish safer patterns of frequency. 4) In general, it enlarges the sample. 'The most damaging criticism of much previous work in historical metrology is that consideration has been given to only a very limited number of possible values, chosen subjectively.' (Cherry 1983, 53.) On the other hand there are some disadvantages too, e.g. the theoretical values of weight may be proved higher than the original ones.

If we return to Table I, we must notice the possibility that nos. 3 and 4 of the catalogue may represent the same intended value and this is certainly the case with nos. 8 and 9. So the value of 2/3 unit or 3/4 unit is represented in this close set of weights by the greater number of pieces (four), while the potential unit is represented only by one piece, and this must be taken into account along with the ratios in the eighth column.

It looks as if the collection of lead discs from the West House was a real set of balance weights. It was found as such (all pieces together) and almost all fractions (except 1/3) and multiples of the potential unit were available, either by the presence of the balance-weight specimens themselves, or by the combination of their values. So they could be used for any kind of weighing, though of course lead is not so good for accurate weighing. In addition, this particular set seems specially meant for big quantities of commodities, since the heavier discs (but one) were found in this house. If we take it that foodstuffs were measured by volume, as indicated in the Linear B tablets, that leaves raw materials or finished products. In Table III the intended mass (Mq) of each of the heavier discs of these is associated with absolute values by Chadwick and symbols in the Linear B tablets (as Chadwick 1976, 104; 1973, 57; Petruso 1978a, 41; cf. Parise 1986, 308).

In the tablets, the quantities of bronze issued to the smiths were usually M3 to M4 and sometimes as little as M1 N2 and once as much as M12 (Chadwick 1976, 104). Lead is probably mentioned three times in only one tablet up to now (Ventris and Chadwick 1973, 359), each time in amounts of M3. So the lead discs of the West House could have been used for the weighing of metals. But attention should be drawn to the fact that along with the greater number of lead discs, this house has also yielded the greater number of loom weights, again concentrated in one room only (room 3 on the upper floor, for that reason thought to have been a workshop for textiles, cf. Tzachili in this volume). Wool was evaluated by weight, as both tablets and later representations on Greek vases indicate and even Homeric similes confirm (*Iliad* XII, 431-435). Is it just a coincidence that a large group of lead discs (see below) was also found in Complex A, where again a workshop for textiles was located in the upper floor? (Michailidou 1987). I think not, and the physical representation of the special measure for wool (LANA = 3 kg) by the lead disc no. 16 in Table III, already recognized by Petruso (1986, 35) and Melena (1987, 400), gives strong evidence that the set could mainly serve for measuring wool.

Of course the signs of M, N, P were not symbols used at the time of Akrotiri: there was a clear difference between Linear A and Linear B in the way of recording weight values (Chadwick 1976, 102), but: 'If we assume that the fractional signs have been adapted to units with similar ratios, we may guess for instance that M may have represented something like 1/30 in Linear A.' (Ventris and Chadwick 1973, 36.) In Table III, all weight values are fractions or multiples of either M or LANA and the disc with the weight value of M is the only one marked in the set (see above and Fig. 16). I think that the absence of a disc with the weight value of a Mina (520-480 g) in the set may indicate that the physical representation of this particular value was not necessary; the amount of 1/2 M could be weighed with 2 discs of the value of N and in fact there are two discs of that value in the set. This may be the reason why a special symbol for Mina is not present in the tablets, and I propose that the Mina's part in the system (Petruso 1978c, Table 27) should be reduced in favour of the denomination of M or N. The reason for the presence of discs nos. 13 and 12 is to evaluate the yield of a sheep and also a half of this quantity (see also Petruso 1986, Tables 30-31), while no. 15 represents half of the wool unit.

The distribution of the weights within the settlement

So far, the following picture emerges from the excavation in various parts of the settlement: Complex A: 19 pieces; House of the Ladies: 2 pieces; West House: 26 pieces; Complex Δ: 49 pieces; Complex Γ: 1 piece; Xeste 3: 1 piece; Unknown Provenance: 5 pieces.

Since we have at least two instances of concentration in one room (room 6 in West House and room 8 in Complex Δ), we cannot ignore the possibility that in the House of the Ladies, Complex Γ and Complex B, this particular room has not been excavated yet and that the above numbers do not represent the quantity originally present in these buildings. This may even be the case with Xeste 3, where room 10 (probably of the same function as room 6 in the West House) has been only partially excavated, though we must mention one more weight from this building — the stone disc with the mark of a small circle (see above). So, unless all the buildings revealed are totally excavated, no patterns of distribution are safe. We can only suggest that it seems as if there was a group (set?) of lead discs in most households, and notice that the majority found were on the upper floors.

Concluding remarks

All lead weights were cast in moulds. It is probable that stone moulds would have been used, at least for the standards (something like the shallow dish mould from Mallia 'pour miroir de bronze': Van Effenterre 1980, II, Fig. 665), though tiny holes like those on the reverse of weight no. 4174 (Fig. 21), which are very different from holes caused by oxidation, were sometimes noticed on one surface of our experimental weights, and were due to the cracking of the unfired clay mould, caused by the heat of the molten lead.

The stone weights from Akrotiri are very few, coming from a settlement where so much of the original equipment has been preserved. This may indicate that they did not use stone weights for more accurate weighing (as not expected) and that lead was easily available (from Lavrion at least). Up to now there is no reason to suggest two different systems (one called Minoan and another called non-Minoan: Petruso 1978b, 547-553). The contribution of the Cyclades is very large in number but there are no grounds to call the system Cycladic, for the stone weights found in Crete are more reliable and very carefully made. But, taking into account the long tradition in working lead in the Cyclades (in contrast to Crete), we may think that the use of lead for the manufacture of weights was a Cycladic innovation and in that case that the lead weights were not only 'tools of trade' (Petruso 1979, 139) but objects of trade as well; could it be that heavy discs like those of 6 or 4 kilos could also function as ingots of specified weight for exportation? Anyway, since lead was very useful for evaluating large quantities of commodities, the presence of great numbers of lead weights in three Cycladic islands (Thera, Kea, Milos), emphasizes their role in the circulation and exchange of goods within the Aegean. The heaviest lead weight known, of *c.* 15 kg, comes from Akrotiri and its value is equivalent to 5 wool units (LANA) of the Linear B tablets. In the same sense, the collection of 11 lead weights coming from Mochlos, Crete — another important port for navigation — is no surprise to us.

Concerning the suggested equivalences in Table III, one must mention Parise's scepticism, especially with regard to the instances of P12 or P20 in the tablets, which put in question the ratio of P = 1/12 N (Parise 1986, 308). But if the ratios established between the higher values of L, M and N are right, then the equivalences given by the close set of the West House in Table III strengthen Petruso's association of the real weights with the denominations in Linear B. Since this system of weight measurement already existed when Linear A evolved to Linear B, the difference in the method of recording weight values in the two scripts (as Bennet 1950, 221) may not necessarily imply a radical change in the existing ratios. The ratios in Table I and Table III are not far from the fractions possibly recognized in Linear A (Wass 1971, 49) and yet they are paralleled by denominations in Linear B. The physical presence in Akrotiri of the wool-unit of the Linear B (LANA), and of its subdivisions and multiples, is strong evidence against a radical difference in weight measurement. So, it is possible after all that 'despite the difference of usage (of the signs in the scripts), it would not be surprising to learn that the basic units were the same.' (Chadwick 1976, 102.)

When dealing with the distribution of the weights within the settlement, one may notice that up to now there are two instances — at least — of a coexistence in the same house of a collection of lead weights with a great quantity of loom weights (West House and Sector A, see above). A third instance of a possible workshop for textiles in the upper floor of Complex Δ (room 13) is not an exception, since the adjacent room 11 (probably of a similar function to room 6 of the West House) has not been excavated yet and may reveal in the future the expected collection of lead weights. The fact that in the above instances raw material (wool or linen) and probably the finished products (textiles) were evaluated by weight, strengthens the view for specialized textile industry exercised in some houses (Tzachili, in this volume). The concentration of lead weights in room 8 of Complex Δ may indicate either the manufacture of the actual weights in this place (a shapeless piece of lead was also found there: S. Marinatos 1971, Pl. 87b) or the weight evaluation of a material that left no evidence in the region or was not always present there. Since in each household, at least some lead weights were found (this is also one reason for the great number of weights found in Complex Δ with more than one household), it seems that weighing was an everyday practice for all the inhabitants of Akrotiri and not a task done only by a central authority. According to Linear B tablets, the commodities evaluated by weight were metals, wool or linen, some textiles, beeswax, saffron (Ventris and Chadwick 1973, 51) and, why not, some aromatic or dyeing substances; in brief, raw materials and finished products rather than foodstuffs, where anything that could be poured was measured by volume. So the presence of the lead weights is another useful indicator that specialized household industries were an essential part of the economic structure of the LC society at Akrotiri, along with the resulting exchanges (both internal and external) and navigation.

The conceptual significance of the existence of systems of weight has been emphasized by Renfrew (1983, 13). The ability for mathematical calculations is well established by the repeated use of a fixed ratio in the series of the real weights, but how was counting practised? One method of adding was the use of tallying (as on the reverse of a Pylos tablet: Chadwick 1976, Fig. 20). That the inhabitants of Akrotiri were in fact accustomed to written records is shown by a sherd coming from this settlement, where no tablets have yet been found (publication of the sherd by the author forthcoming). On this sherd, a temporary record of commodities has been incised in Linear A, and this accounting practice has nothing to do with the bureaucratic activity of a central authority (exercised on tablets). It is again an everyday practice for everyday needs.

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DISCUSSION

ELLEN DAVIS: I have some evidence that I think supports the conclusions of your pioneering study, and that is two gold cups that were found at Midea, Dendra, one of which is almost exactly twice the weight of the other. I should think gold would be something they would be careful about and would be revealing. One of the cups, from Chamber Tomb 10, weighed 98 grams and the other, the Octopus cup, 195 grams, which are both within 1 per cent of the basic weight unit that you have reported in your paper; indeed, one figure is within one quarter of 1 per cent.

ELIZABETH SCHOFIELD: We have a similar situation at Ayia Irini, on Kea, of a very wide scatter of lead weights. We do not have what seems to be a complete set, as you do — and I'm very persuaded by your attaching it to the weighing of the wool — but the scatter otherwise fits in very well with the picture of small scale industries all over both sites.