G R E E K W E I G H I N G

by

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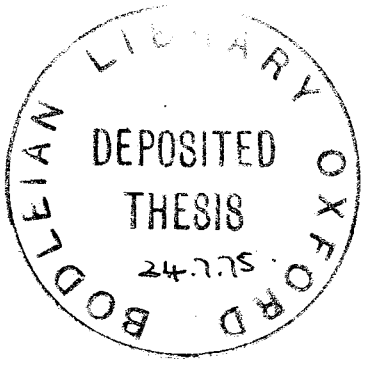

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G R E E K W E I G H I N G

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APPENDICES

NOTES

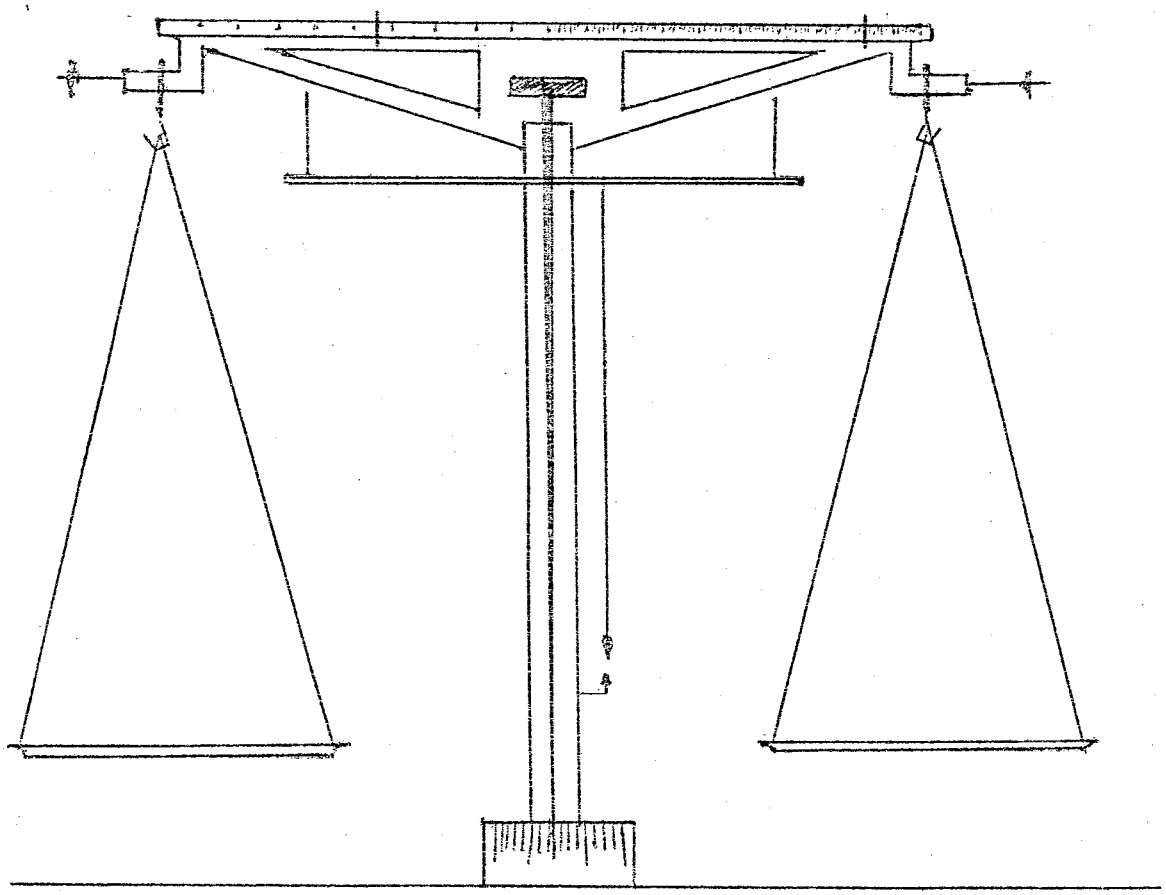
A P P E N D I C E S

APPENDIX A

Modern weighing machines for comparison: bibliography and basic theory (especially sensitivity-rating).

Description of the great range of modern weighing devices can best be sought first in such general articles as W.A. Benton's Weighing Machines in the Encyclopaedia Britannica, 14° edn. 1929, vol.XXIII.479-86. The types which most closely approach ancient weighing machines are now used for scientific work where a high degree of precision is required. Single-pan balances have however been developed to too high a degree of sophistication, and it is only the detailed analysis of the working of the two-pan balances that can usefully be compared here. Again a general article, as F.A. Gould's Balance in the Encyclopaedia Britannica, 14° edn. 1929, vol.II 950-3 could be helpful; exhaustive studies of the construction and performance of such balances will be found in R.T. Glazebrook, Dictionary of applied physics (London 1923) vol.III.p.107 and T.E. Thorpe, Dictionary of applied chemistry (4° edn. London 1937) Vol.I. pp.587-614; but most textbooks on chemical analysis contain chapters on their use, and more interestingly misuse: I have consulted, for example, ed. C.R.N. Strouts, H.N. Wilson and Others, Chemical Analysis: the working tools (3 vols Oxford 1962) especially I.ch.5. pp.110-124 (chapters 30 and 31, Vol.III, on micro-chemical balances and the determination of molecular weights, are eloquent testimony to the advanced techniques of modern weighing) and D.A. Skoog and D.M. West, Analytical Chemistry (New York 1963) ch.5. pp.79-127 "The techniques and tools of gravimetric analysis" (being a grandiloquent title for a chapter on weighing that contains a relatively clear account of the theory involved in addition to tedious detail on equipment). Though features of the performance of the micro-chemical balances are similar to the clumsier macro-models, the details are unnecessarily sophisticated for useful inclusion here (see further Strouts and Wilson as cited above; also R.F. Milton and W.A. Waters, Methods of Quantitative micro-analysis (London 1949) pp.11-17).

A standard analytical balance is illustrated on page 691. Such balances, with many minor variations in design, were until recently normal equipment in most school laboratories (being replaced, significantly, see below end , by the electro-balance that measures torque v mass much more



a modern chemical balance

rapidly); it is the sort of balance numismatists might use to weigh coins. The design of these balances and their operation, can be regarded as the ultimate development in terms of accuracy and precision of the two-pan balance principle used by the ancient Greeks. Clearly, practical considerations apply to such development, but it should be helpful to point out here the main elements of the modern design, noting their relation to the theory of weighing on these balances, and comparing inadequacies of the ancient models. [See ch.I on balance design and use; ch.VIII on precision and sensitivity; and following Appendix B on experiments with reconstructed Greek balances: I shall not give further cross references.]

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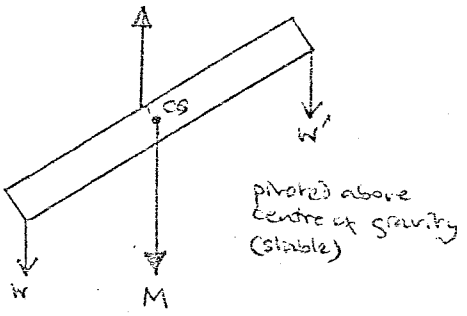
(1) Central is of course knife-edge suspension. Formerly steel, but more usually now agate knife-edges bear upon agate surfaces at the point of pivot and at the points from which the pans are suspended. These greatly reduce friction at the points of contact of moving parts, but they also ensure that these points of contact are always equidistant (given other factors are constant: see below). It is important to note that the knife-edges are all on the beam. The model illustrated has the usual three knife-edges, but some models incorporate further such edges to reduce the friction consequent upon lateral movement of the beam (on the illustrated model this is minimised by the plumb-line level for the whole assembly). The importance of these knife edges is such that a greater part of the surrounding mechanisms are designed to reduce wear and relieve pressure upon them while not actually weighing: thus a beam-support system, incorporating also beam arrests, and (though not on this illustrated model) pan dampers to reduce unnecessary swing of pans.

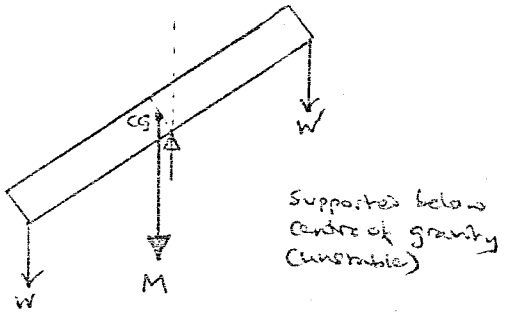
The effect of friction from other suspension and pivot designs can be considerable [see the results of experiments with models of Greek balances in Appendix B]. The effect cannot be usefully quantified as the possible variables are too numerous: e.g. the thickness, and stiffness of suspension cord, or, on later models, the size (diam.) and materials of the ring-type pivot. Certain ancient balances (e.g. the Egyptian predynastic model from c.3300 B.C. tested by Skinner, Weights and Measures (1967) pp.47-8) had collars that inhibited all but the most noticeable movement of the beam. [See further on Egyptian balances in ch. IX.1(1)].

More significant however is the variation ancient methods of pivot and

suspension impart to the effective lengths of balance beam arms. Although the idea of friction-free balance led to the use of pivots, especially in "shears" by the Roman period, it is noteworthy that very rarely (and so by accident rather than intent?) was the pivot-rod fastened to the beam, where it would remain central to the beam, rather than the suspending cord or shears. Further, the Egyptian style of tubular beam with the suspension cords passing out of it (so constantly equidistant from pivot-point) appears rarely to have been followed in Greek designs. These latter, with simple cords tied to the beam would greatly vary with the inclination of the beam (see further below).

(2) The modern chemical balance is <u>pivoted at a point above the centre of gravity</u> of the moveable parts of the machine (i.e. the beam with pans and their contents). This is necessary so that equilibrium can be attained; for if the centre of gravity were over the point of pivot the beam would tilt, and continue inclined, to one side or the other.





It is necessary to point out however that this feature is dictated solely by the chosen method of operating the analytical balance. Assuming equal dimensions on each side of the point of pivot, a machine could be constructed with centre of gravity over this point that would indicate directly inequality of weight between the two sides as the beam was lifted and one pan (the lighter) cleared the ground. Although ideal for <u>distinguishing</u> weights, such a machine could hardly be used to <u>measure</u> (where equality and balance are intended). Assuming equal weights, and initial balance with both pans free of the ground, other factors (in particular air-movement) would rapidly contribute to the deceptive overbalancing of the beam (and one should consider, in extreme cases, the variation in gravitational attraction between the object weighed and the ground: at the outset this would induce the denser object, though equal in mass, to appear the heavier).

[Aristotle] <u>Mech.</u> 2.850a3 was aware of the theoretical difference between

the two positions of the centre of gravity under discussion (see above ch.VI.1). In general I have suggested that much Greek evidence of classical and earlier date points to use of balances of the over-balance (centre of gravity above pivot) type. Both were possibly in use together.

The relation of centre of gravity to point of pivot affects the sensitivity of the balance. The closer the two the greater the sensitivity, but also the instability and (in practical terms) the length of oscillation time. On modern balances the distance (CG to pivot) can be varied by means of a moveable weight sometimes called the "gravity bob", on this model featured as the pointer. The effect of this adjustment will be considered below in connection with the mathematical theory.

(3) A further significant element in the design of the modern balance is the pointer. For practical reasons, including the incorporation of the "gravity bob", this extends below the beam on the model illustrated. Its function is to mark angular displacement of the beam from the horizontal position, such angular displacement being exaggerated by the length of the pointer. Alternative models allow readings to be taken straight off the beam itself by means of magnification apparatus. On all systems movement of the pointer is read against a scale, graduated equally each side of zero (horizontal beam). The markings on this scale do not represent anything, but relate to sensitivity (on which see below) and can be used to make the controlled observations of the oscillation of the beam that are necessary for more precise weight calculations (see the "method of swings" described for example in Strouts, Wilson etc. Vol.I. p.122).

For comparison with Greek machines the scale can partially be ignored, but not the pointer. [Aristotle] Mech. 1.848b-850a noted that larger balances are more accurate because movement of a larger beam was more easily detected: this the pointer achieves without necessitating the additional mass of a longer beam which would tell against weighing small amounts (from inertia and air movements). The pointer however more importantly marks deviation from the horizontal when the swing of the beam has ceased (on stable balances - that is with the CG below point of pivot). Some such indication of horizontal (or vertical if a pointer perpendicular to the beam is used) is clearly essential for the accurate balancing of the objects weighed. The function of the scale in this context is to indicate the rest point from the situation

where no loads were in the pans. Egyptian balances incorporated pointer and plumb weight for this purpose. No Greek balance however seems to have used either, which is probably one of the most surprising (and indicative) inadequacies of these machines.

(4) The modern analytical balance is built into a glass case and final weighings should always be made with the case completely shut. Mechanical devices are provided to enable the smaller weights to be added without opening the case. On the model illustrated can be seen a calibrated slide above the beam (and fastened to it) with two metal riders that can be moved along it by means of the rod controls that emerge from the sides of the case. With the object to be weighed placed in the left-hand pan and larger weights in the right, the riders add up to 1.1 gm to these weights, the right-hand scale operating in 0.001 gm divisions. The principle of the riders as counterweights is comparable to the steelyard; but the reason for their use here, and for the glass case, is basically twofold - to reduce the risk of contaminating unevenly with dust or moisture parts of the balance (on which, as related to materials, I shall say more below), and to prevent air-currents disturbing the balancing operation.

The importance of eliminating air-currents for accurate weighing should be obvious. It is difficult to quantify it usefully however as circumstances in open-air weighing vary (and depend as much on the air-resistant design of pans, though basically vulnerable by flatness to air disturbance, and on the awareness of the operator, as on the strength of the air-currents themselves). In my experience a small cushion feather weighing 0.004 gm in the closed case, cannot be weighed with the case open unless one holds one's breath for the considerably longer period of oscillation that occurs, and takes advantage of scale divisions to average out these oscillations.

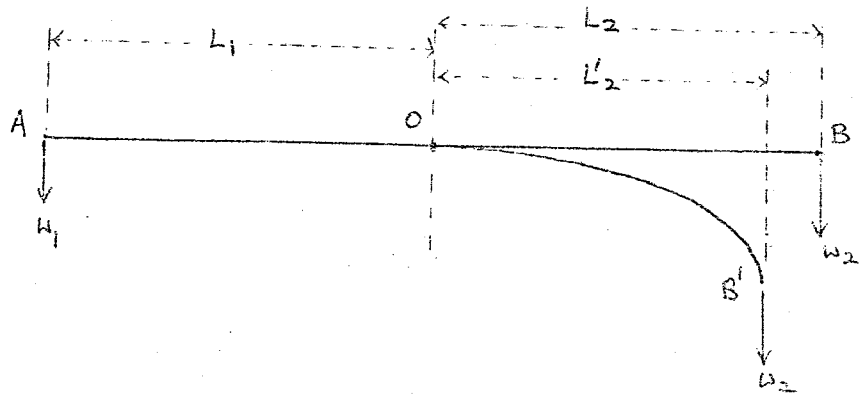
It would be wrong to overstress the inaccuracy of weighing without a case. Much sophisticated and precise weighing was accomplished before its invention (first illustrated in Thomas Norton's laboratory c. 1477 A.D., see Oxford History of Technology (ed. C.Singer, E.J. Holmyard etc. 1956) II.745 fig.677). Nevertheless the danger of inaccuracy in weighing without a case should always be realised, especially where such weighing was carried out without such realisation on the part of the operators. Further the inevitable effect, the lengthened period of oscillation, would greatly contribute to

the impracticality of such weighing except on the most stable (and therefore least sensitive) of ancient balances.

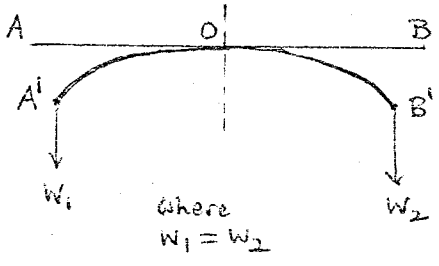
The enclosed case also leads to complications of its own. The smaller environment of the case is more subject to disturbance and air-currents caused by the introduction of objects of higher or lower temperatures than that environment. This must be overcome by cooling processes, and stabilisation routines (e.g. leaving the case open before weighing for 30 to 60 minutes : thus Strouts, Wilson etc. I.p.121).

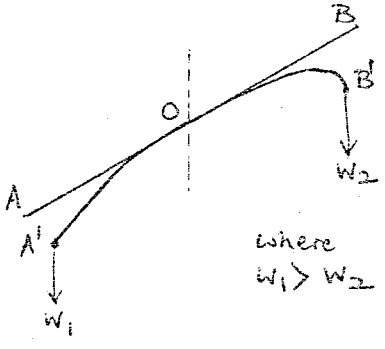
(5) Care has been taken in the development of the modern balance to ensure <u>stability in the materials</u> used and <u>rigidity</u> in the overall construction (in particular that of the beam). Elements of the former have already been mentioned: thus design to obviate contamination by dust, or moisture from contact with operators' hands; also weights, scales, beam etc. constructed of metals that resist corrosion, and do not expand unevenly where subject to changes in temperature (especially relevant for the beam); agate knife-edges and systems to protect them when not in use. Further concern has been expressed over the variations in air-buoyancy of objects of different substances in pans (including weights): the relative error due to this effect being most serious when objects of low density are being weighed unless some correction is made (thus for example 2.25 mg per gm should be added where a substance of density 0.5 gm/ml is weighed with weights of density 8 gm/ml: Strouts/Wilson Table I, Vol.I. p.124).

These errors are clearly small and are recognised as negligible for much "routine analytical work" (Skoog and West, p.95). Of slightly greater importance is the question of rigidity of the beam. Where flexibility occurs in one arm the effect of loading that side, bending the arm, is to shorten the distance of point of suspension of pan to point of pivot and so to lessen the overall force exerted by that side of the balance: i.e. the load will appear lighter than it should.



Compare diagram; a rigid beam $\overline{AB}$ is pivoted at its centre O (simplifying, this is here taken also to be its centre of gravity). The arms are of length L_1 and L_2, with weights W_1 and W_2 applied at each end of the beam, we can say, if they balance, that $W_1L_1 = W_2L_2$. If that part of the beam from O to B were flexible, say $\overline{OB}^1$, the same weight W_2 applied at B^1 will bend the beam such that L_2^1 is less than L_2. The difference is precisely the amount by which the weight at A must now be reduced for balance. Where flexibility, however, occurs in both arms equally, the error is cancelled out for symmetrical patterns about a vehicle axis through O (i.e. for balance point); as this is the most relevant configuration where balance is the end of the operation, it does not matter that the error recurs and increases with the inclination of the beam from this position, as is shown by the following exaggerated diagrams:





Though difficult to quantify, and for most cases of low order, the errors through non-rigid beams must be taken into account when considering the performance of ancient balances constructed out of flexible materials.

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In the course of discussing the main features of the modern chemical balance, frequent reference has been made to accuracy, error and in particular sensitivity. These terms should now be investigated, and a means of defining sensitivity derived that can be applied to the analysis of ancient balance performance as discussed above in chapters I and VIII. Such modern definitions as are usually found apply only to the modern balance, and are too vague for our purposes: thus Strouts, Wilson I. p.110 "The sensitivity of a balance at a given load is determined by the number of scale divisions by which the resting point [the position on the scale that the pointer would occupy at equilibrium if the beam were allowed to come to rest] is displaced by the addition of 1 mg. to one of the pans". Nevertheless as this is the

sort of way in which sensitivities of modern balances are expressed, it is clearly necessary to arrive at some expression for sensitivity that relates movement of beam to the addition of weight in one of the pans. Accuracy can then be determined by a combination of maximum sensitivity with minimum error.

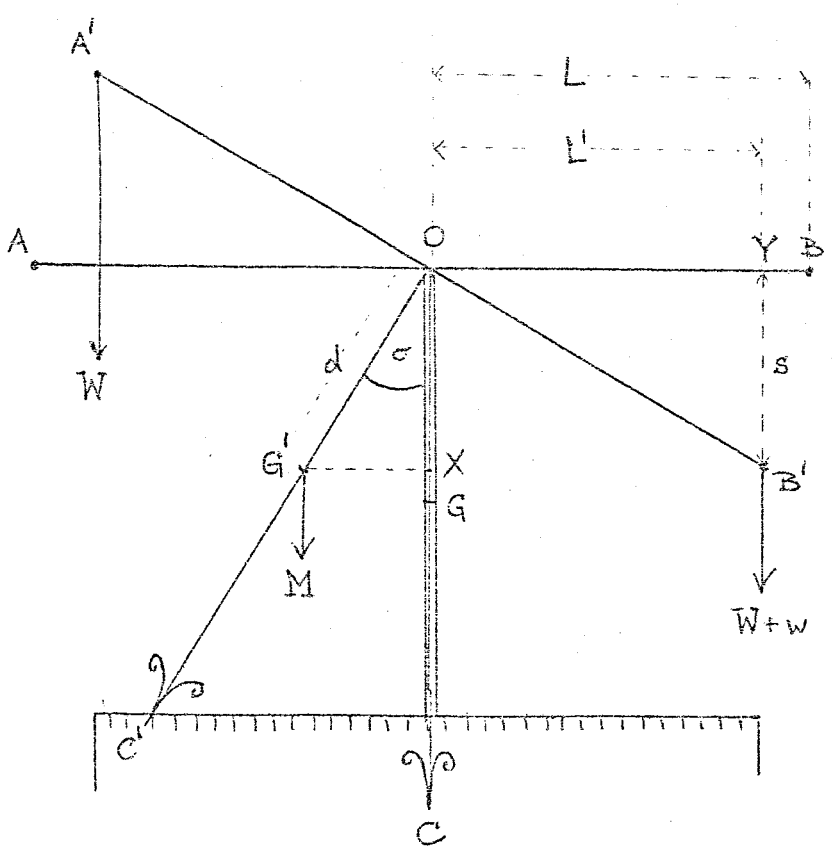
(a) Sensitivity. The following diagram shows the forces operating on an equal arm balance $\overline{AB}$ beam pivoting at O; at rest the direction of its pointer is vertical ($\overline{OC}$), and this same position is retained when loaded with equal weights W (see above under rigidity $W_1L_1 = W_2L_2$; the lengths of the present balance arms are both equal to L). The centre of gravity of the balance is at G, distance d from O; and the mass of the beam (and pans) can be represented as M. Adding a small weight w to the right-hand pan (at B) causes a clockwise swing, counteracted only by the displaced centre of gravity which moves to G^1. In the new position of equilibrium the forces acting at O are equal: thus

$$M\ (\overline{G^1X}) + WL^1 = (W+w)\ L^1$$

(where L^1 is the distance from the point of pivot at which both weights W and W + w act; assuming no friction and a rigid beam). Both G^1X and L^1 can be expressed in terms of the fixed dimensions of the balance and the angle through which it has moved (σ). So, rewriting: -

$$Md \sin\sigma + WL \cos\sigma = (W+w)\ L \cos\sigma$$

On simplification all reference to the load (W) drops out.



The sensitivity can then be expressed, by rearranging, in terms of the angular deflection:

$$\frac{\sin\sigma}{\cos\sigma} = \tan\sigma = \frac{wL}{Md}$$

or the linear deflection of the pointer (read on the scale) i.e. $\overline{C}\overline{C}^{1}$ which is equivalent to $\overline{O}\overline{C}\tan\sigma$: thus

$$\overline{C}\overline{C}^{1} = \frac{w.L.\overline{O}\overline{C}}{Md} \quad \text{whence also} \quad w = \frac{\overline{C}\overline{C}^{1}Md}{L.\overline{O}\overline{C}}$$

These last equations allow definition of sensitivity of a given balance (with dimensions $\overline{O}\overline{C}$, L and d, and mass M constant) in terms of scale divisions per unit mg (w), or, reciprocally, in terms of miligrammes required to cause deflection of one scale division.

On Greek balances with no pointer, however, such a definition is clearly inappropriate; the only guide to deflection by the additional weight w is the direct observation of beam deflection (as [Arist] Mech. § 1 clearly shows was done). Appropriate therefore is the expression:-

$$\tan\sigma = \frac{wL}{Md}$$

But, as the only means of observing angular change is against a vertical suspension string, when σ is small (from AB horizontal, when approaching the limits of sensitivity of the balance) the change is relatively minimal in the larger angle from the vertical (90° to $90^{\circ} \pm \sigma$). Thus it is more likely that Greeks observed the movement of the end of the beam, on the above diagram the distance $B^{1}Y$ (s). As $\tan\sigma = s/L^{1}$, the most useful expressions for sensitivity of Greek type balances, are therefore:

$$s = \frac{w.L.L^{1}}{Md} \quad \text{and} \quad w = \frac{s\,Md}{L.L^{1}}$$

For small σ, $L^{1} \rightarrow L$, thus $s \rightarrow \frac{w.L^{2}}{Md}$

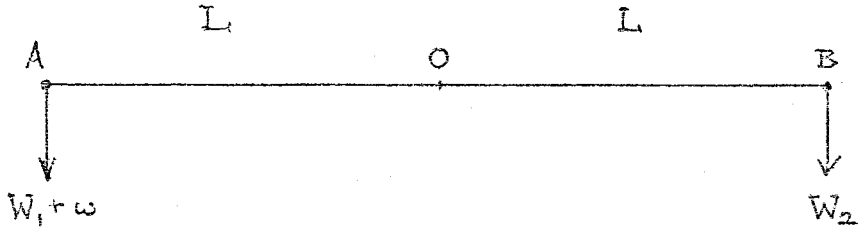
Certain other errors, inherent in design weakness of the Greek balance, must also however be taken into account before these formulae can be directly applied.

(b) Inherent weaknesses or errors in balance designs. These errors have been discounted in the sensitivity-formula, and are negligible in modern

analytical balances by virtue of their design. I have already referred to several in discussing this design, and shall merely summarise them here.

(1) Flexibility of beam. Where horizontal balance is attempted, flexibility, if even through a beam, is not a source of error. It is, however, when such flexibility is uneven, or when the beam is inclined. The error results from the decreased length of the effective arm. Though small, this decrease is squared in calculations of sensitivity, and is a direct factor in calculating the force moment applied at the central point of pivot.

(2) "Friction" or resistance to the turning of the pivot retards small movement of the beam and so again it is an important factor in determining sensitivity in practice. Its effect can be equated to a further weight added to one end of the beam. Thus, taking the configuration of beam ACB (pivoted at O, the central point of beam length L+L): first in a friction-free case:-



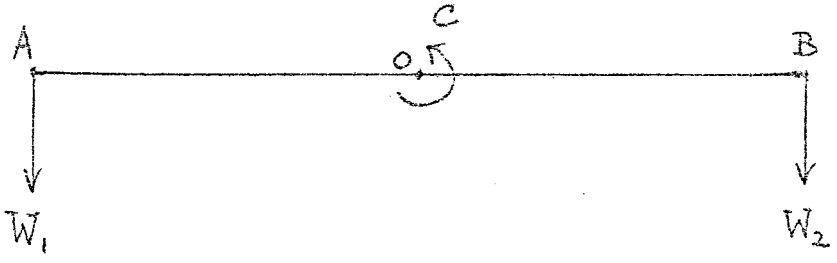
Where W_1 is lighter than W_2, horizontal balance can only be maintained by the addition of a counterweight w at A (such that $W_2 - W_1 = w$); this situation being represented by the equation of forces:-

$$(W_1+w)L = W_2L$$

Where friction exists however at O (represented by a couple, C), it will in this case retard the downward motion of the heavier W_2 as long as

$$C > L\ (W_2-W_1)$$

i.e., as long as, $C > Lw$.



The effect of friction will not vary directly with the mass of the beam or weights added, and so cannot be incorporated into the equation for sensitivity above. The most obvious divergence in its effect lies in the method of suspension: if the source of friction is the stiffness of a knotted suspension-cord, this friction will decrease in proportion to the increased mass of the beam; if however the beam is supported by a loop or rod passing through it, an increased mass of beam will also increase the friction.

(3) Air disturbance can be represented as forces acting anywhere on the balance apparatus, it is clearly most significant applied to the ends of the beam and on large balances is more likely to be localised on one beam end rather than on both. The most natural result of such disturbance will however be simply to prevent the balance achieving a state of equilibrium: in this it can be countered by either friction or a very low centre of gravity.

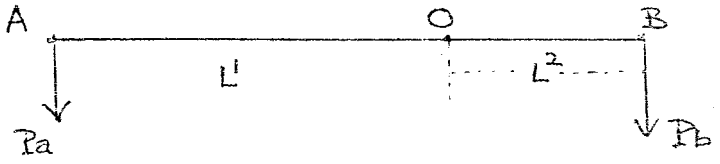
(4) Low centre of gravity. It is clear from the sensitivity equations that an increase in the distance (d) of the centre of gravity from the point of pivot directly reduces the sensitivity of the balance - in other words, the amount of weight needed to move it an appreciable distance. It should be noted that beams which thicken in the middle, and are suspended by knotted ropes or rigid hooks in their top surfaces, have effectively low centres of gravity. On chemical balances d is usually in the order of 0.1 to 0.2 mm (against a length of arm, L, approximately 120 mm).

(5) Unequal arm lengths. The force on the point of pivot exerted by a weight (W) in a pan is expressed directly by WL (L being the length of the arm in question). For balance it is therefore essential that the arms be equal. Inequalities of arm length can be superficially cured by adding counter weights either in the shorter-arm pan or along this arm. Neither procedure however allows the subsequent use of weights directly read (at their face value) in weighing loads added to either pan. This can be illustrated by the following pairs of "equations" (the first for equilibrium, with no load, the second for equilibrium when loaded). In each case the two sides of the second equations cannot match.

a - counterweights added in the shorter armed pan (so pan weights, Pa, Pb, not similar)

unloaded $L^1 \times Pa = L^2 \times Pb$

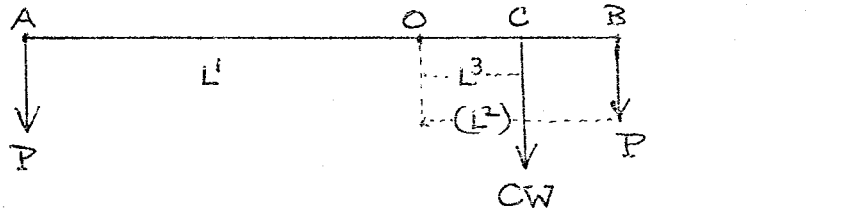
loaded $L^1 \times (Pa + w) \neq L^2 \times (Pb + W)$



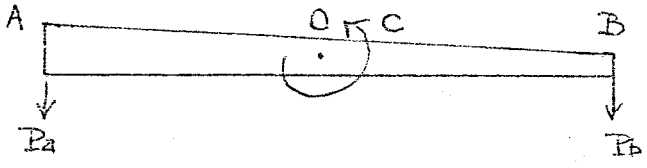
b - counterweight (CW) added on shorter arm at C (Pan weights now the same, P)

unloaded $L^1 \times P = (L^2 \times P) + (L^3 \times CW)$

loaded $L^1 \times (P + W) \neq L^2 \times (P + W) + (L^3 \times CW)$



The making of the shorter arm of heavier material (as envisaged by the purple-dye sellers at [Arist] Mech§1.849b34) produces the same effect: the centre of gravity of this heavier arm acting as a counterweight some way along it, or (perhaps more properly) acting as a couple on the point of pivot O. It is important to note that no deception would result from such a weighted arm, countered unloaded by a heavier pan on the opposite side, if the beam lengths were in fact equal. Thus in the following diagram, $\overline{AO} = \overline{OB} = L$; the additional mass of AO is represented by a couple C at O; and Pb > Pa such that



unloaded $L \times Pa + C = L \times Pb$;

but also, loaded, it is true that $L \times (Pa+W) + C = L \times (Pb+W)$.

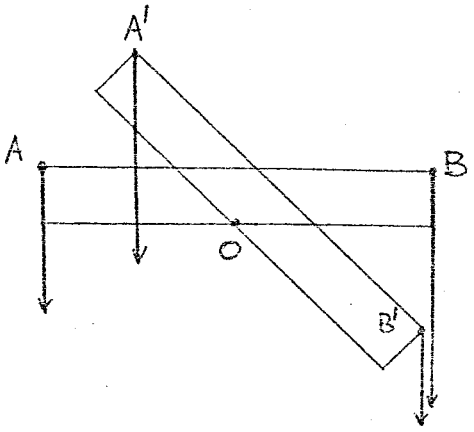
There is therefore no way of correcting for unequal arm lengths, and inequalities lead to progressive errors as loads are increased. The error can be detected moreover not by checking with unloaded balance pans, but

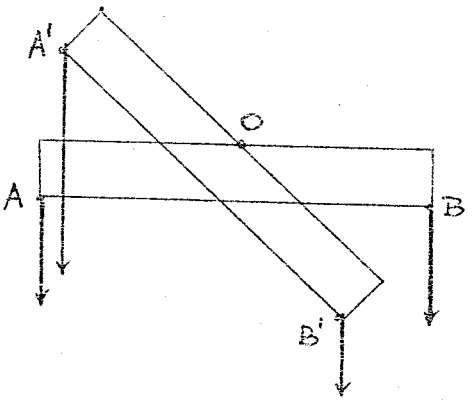
only by double-weighing of loads: i.e. changing round the loads of the two pans and reweighing. There is no evidence the ancient Greeks did this, though [Aristotle] Mech.1.849b34 at least shows awareness of error through unequal beam length and weighting; even if not understanding the mechanical principle involved [see ch.VI.1].

Before leaving the question of unequal balance arms, we might briefly note other aspects of ancient Greek balance construction that could lead to unequal arm-lengths developing during the weighing operation itself. This is probably the clearest way to indicate the faults in Greek balance design:

(a) looseness of suspension cording. Greek balances appear suspended by means of a rope around the midpoint of the beam. Where, as I have argued is generally the case, this rope is loosely tied around the beam, the tendency of the beam to slip when inclined is obvious. The same could occur with a top-knotted suspension cord working loose during operation. In both cases inequality of beam results in the weighing operation assisting the already heavier load . The fault can be overcome by notches underneath the beam and is of course also applicable to pan-suspension cording in precisely the same way.

(b) point of pan suspension above or below the point of pivot. With a relatively thick beam the distortion from points of pan suspension and pivot not being on a line can be considerable, and amounts to an effective change in arm lengths. This change is all the more important as it acts on both arms at once in opposite directions (lessening one, while extending the other). In an unstable (bottom suspended) balance , the effect is to increase the force exerted on the point of pivot by the already heavier weight; in the stable balance, the reverse occurs and the difference in weight is reduced. In both cases the effect is least noticeable towards the horizontal beam position. See diagrams - where it is clear that the distance from which a weight at A^1 operates on the point of pivot (0) is no longer the same as that from which a weight at B^1 operates on the same point: though on the horizontal beam $\overline{A}\overline{B}$ these distances were identical.





Other factors causing unequal arm-length can be discounted for the purposes of comparison with ancient balances (though I have mentioned above variable expansion with partial heating, and could include contamination of one arm by handling: this properly falls under operational errors to be considered below).

(6) Unstable materials used in the weighing operation are another direct cause of error. Mostly, however, this consideration applies to error over a fairly long period of time: we could enumerate variation in humidity content both of objects weighed and, in wooden balances, of the beam itself (this variation was noted by ancient Greeks: cf. laws against selling wool wet, and various remarks in [Aristotle]'s Problems on differences in weight, between dry and humid substances), also metal corrosion which applies most acutely to weights used if made of metal. Lead, ironically enough as the commonest substance used for extant Greek weights, is particularly unstable in this context (and should not be used nowadays even for adjusting weights made of other metals "as small amounts can cause significant increases in mass owing to conversion of the lead to basic carbonate" Strouts, Wilson etc in I. p.118 and see pp.117-118 on the metals allowed for modern chemical analysis; the uninitiated may be surprised, for example, to read that "brass weights are regarded by authorities on the subject as unsatisfactory for laboratory standards").

(7) Weights remain to be mentioned as the most important single source for unintentional error in weighing (thus Skoog and West, p.95). Their standardisation, calibration, and maintenance are discussed at great length

in most of the detailed accounts of modern weighing technique. As this present appendix is mainly conerned with weighing balances and techniques, I shall not pursue these problems further here. No reasonable comparison can be made between the painstaking precision with which weights are now made, checked, and maintained, and the wild variations apparent from Greek weights assembled above in chapter II.

Correction for buoyancy, air displacement, density has been mentioned. The need to fatigue balance-arms before use on high-sensitivity models is hardly relevant for comparison with ancient practice (see however on rigidity and further Strouts, Wilson etc. I. p.121). Similarly I shall simply note the hazard of static charges in modern balances using silica, borosilicate glasses, or plastics, for which the solution, according to Skoog and Gould p.95, is a damp chamois, according to Strouts, Wilson etc. I.119-120, a radioactive source.

— — — — —

I wish to pursue now the implications of the equation(s) derived above for sensitivity.

First, in theory it appears that sensitivity should be independent of the loading of the balance (as no W appears in the final equation). This is in practice not the case, as increased loading appreciably leads to variations (not always a related decrease) in sensitivity. The reasons given (e.g. by Skoog and West p.84) are the variable factors, friction, inertia and possible imperfections in the alignment of knife-edges. Both were excluded from the initial force equations from which that for sensitivity was derived. This variation in sensitivity should be more marked in balances not well-designed to minimise these errors.

Second, again in theory, it appears that high sensitivity can be attained simply by elongating the lengths of balance arms, L (which appears squared in the sensitivity equation) One Greek writer came to the same conclusion: [Arist.] Mech.1 .848b1-3ff. A difficulty in producing this effect in practice and without incorporating or introducing other sources of error, is the inevitable increase in mass (M). Even though not as significant a factor in the equation as arm-length, keeping the increase of beam mass to a minimum does raise the problem of beam rigidity.

Third, a further increase in sensitivity can be derived from reducing

the distance (d) of centre of gravity from point of pivot. Indeed, as noted, modern balances incorporate a mechanism to allow this reduction to a certain extent. The draw-back here is the great increase in the time of swinging caused by the increased instability of this reduction. This may be seen from the formula cited for the time, t, required for the completion of a cycle of swings by Skoog and West p.84, n.2:

$$t = 2\pi L \sqrt{2w/Mgd}$$

(where L is the length of beam arm, and d the distance between CG and point of pivot). The effect of reducing the distance is shown perhaps more clearly by the table in Gould p.952 which includes both sensitivity and time taken for swings. Such a time is also greatly increased by loading (w). This represents the effect of inertia. It is not however a reduction of sensitivity: contrast Greek observation of the speed of movement. It is instructive to note the frequent references to the impractical time delays of two-pan balance weighing in most modern literature (for example, Gould p.952: "in all work with knife-edge balances, it will be found that the instrument is relatively slow to use"). ~~Swings~~ Oscillation however will not occur with unstable balances.

Certain other practical considerations have determined the construction of modern balances, and have meant their performance falling short of the theoretical (and practical) ideal: thus, for example, expense (of materials or of auxiliary devices) and restricted load ranges (related to the likely use of a particular model, enabling maximum sensitivity for microchemical analysis only). These considerations need not detain us here.

The modern chemist therefore has highly specialised apparatus at his disposal for weighing (even the problem of unequal balance arm error "with a good quality balance...becomes vanishingly small", Skoog and Gould p.95). He can choose from a range of models according to his requirements, and he can assess mathematically the degree of error his various choices (and operational procedures) might incorporate. He can then disregard such as are negligible, or incorporate them into his findings. It is interesting, if a trifle unfair, to note here an operational error that might be of some comfort at least to his ancient predecessors. I quote from Skoog and Gould p.95 "A considerable number of weighing errors can be attributed to the analyst. The misreading of weights is a particularly common source of serious error."

APPENDIX B

Experiments with reconstructions of Greek balances for design, performance and operation

Because of the uncertainty in reconstructing types of Greek balances (see chapter I), the degree to which experiments can usefully be made with models of such balances is very limited. Possibly better impression of their sensitivity and accuracy can be derived from evidence of what the Greeks weighed and how precisely (see chapter VIII), but there are grounds for suspecting as over-optimistic several such accounts as well as for arguing that the performance of a normal balance in normal conditions may have been worse. As the experiments to be described here cover a range of possible conditions, they at least indicate the sort of performance likely, even if this is not demonstrable; and also clearly show the effect on performance of the range of designs involved. These results have been incorporated into chapters I and VIII on both balance design and its performance.

Quite a different area for which the experiments have proved useful is the problem of the weighing technique of the Greeks discussed in chapter I. 3 . It may be possible to make some sense of the absence of pointer and frequent representation of no-one paying attention to the angle of the beam even in stable balances. Nevertheless it is difficult to treat this question separately from the first as it is necessary at the outset to decide what might count as minimum observable movement - the basis for any assessment of sensitivity, as from it minimum weight difference detectable can be derived.

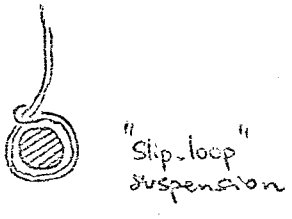
As the results of these experiments are incorporated into earlier chapters I shall give here the various considerations for design of the balances used and the conduct of the experiment; then briefly indicate the several comments on design, performance, and operation suggested by the experiments as a whole.

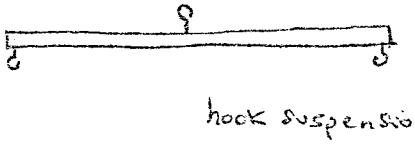
The experiments fall into two separate parts reflecting whether the balances are stable, and level balancing the aim, or whether they are unstable, distinguishing being the fundamental aim. The greater part of this thesis has been to introduce the latter as more typically Greek. The former has not been (and should not be) totally rejected.

Stable balances (Experiments (1) - (6))

Design

Only reconstructions of the two-pan balance were made - the evidence for single-pan design being insufficient in one case for proper reconstruction (Ar. Pax), in the other for general application ([Arist.] Mech.). Because of the lack of any indication of knotting of the usual two cords to the beam, for these stable balances a "slip-loop" was normally used, its thickness and tightness being varied. For comparison one hook suspension was tried in Exp. (4). This proved markedly more insensitive, but also more robust whereas the "slip-loop" occasionally skidded after the beam had been allowed to incline (most marked with twine for the loop on Exp.(6).b). The type of beam suspension used in all but Exp.(4) is likely to give a better-than-normal performance for sensitivity than such as would be more practicable in everyday use.





The beams were varied, with an eye to representations of Greek balances: from a 6' wood beam (adjusted to approach the tapering of the Arcesilas beam, Rep.C.1) for Exp.(1), through several 3' beams (metal tubing, wood), to a small 1' wooden beam based on the size of the Lefkandi scale-pans for Exp.(6).

The pans normally used were sheet brass with chains. This was done for the sake of strength and convenience, but also because clay pans were not easily available. The variation from Greek design was made good by ensuring that the method of attachment to the beam was by cord. The resultant total mass of beam plus pans cannot have been very different from Greek using wood, cord, and clay (or lead). For the smallest beam, however, two pans were made of lead reproducing as closely as possible those from Lefkandi (ch.I. 1(1)). These were suspended by four twine cords, looped over the beam. Notches here proved necessary to prevent slipping while allowing a loose loop (and so effectively hanging from near the top of the beam). Again it should be noted that this form of suspension maximises the sensitivity of such a

balance. In the comparative experiment (4) hooks were used for pan suspension below(as well as beam suspension: see diagram above). This maximised insensitivity via maximum stability.

In all cases the balance was hung from a hook (on tree or door frame) and measurements taken from a stationary scale against one of the two pans. There is no ancient authority for such a scale (against pans or beam) just as there was no pointer at the centre of Greek balances. The scale was introduced simply to enable consistent measurement of inclination to be made and did not interfere with the functioning of the balance. The ancient authority for the rigid suspension (by hook etc. to stand or frame) exists only for the largest balances (in fact most probably unstable sorts) and the frame type; otherwise all balances are shown, and mentioned, as hand-held. This procedure was attempted, but proved impractical for measurement of finer differences in weight by the balancing technique.

Both considerations - scale against which to note balance beam movement, and a rigid suspension - lead to certain observations on the operation of balance-weighing, which will emerge from consideration of how the experiments were conducted.

Method

The experiments were not meant to reproduce the normal operation of a Greek balance. Their purpose was the artificial one of establishing (and comparing) the sensitivity of stable balances. There is no ancient evidence for Greeks' doing this, and the use of hook-stands and scales for measuring pan movement were artificially introduced. However, the question immediately arose as to how to measure sensitivity. Its modern equivalent is expressed in terms of inclination (angle) or movement of a pointer and is comparative (see Appendix A). In the experimental balances movement was best observed from the beam-end, or the equivalent (and in practice more convenient) pans. Thus comparative sensitivity could be established over several balances for a given declination.

The relevance of sensitivity is also its effect on precision and accuracy in the use of a balance; and it is as important to be able to say how small a weight difference can be detected in the use of these Greek-type balances as it is to show what sorts of weight differences result in what sort of movement or declination. In practice many factors interfered with

readings of such "maximum sensitivity": air disturbance, wobble at beam-pivot, instability of pans, in addition to built-in resistance to move at all until a certain force was applied. These factors were however negligible compared to the difficulty of noticing whether any movement had taken place in properly simulated Greek conditions (i.e. without a scale). How small a movement was to be taken as "detectable".

A subjective judgement was unavoidable at this point. Two possible areas were first considered: (a) the inclination of the beam (without pointer): and (b) the movement of its ends or the pans.

On (a) no consensus of opinion was possible (and several people assisted at this stage)-on what counted as a minimally observable beam inclination. With a long suspension cord, quite small angles were appreciable, especially if the movement to them was rapid; it made little difference whether the beam was long or short as the eye was able to discern a fairly consistent angle (projecting the smaller beam); with hand-held beam, and the hand close to the point of pivot (as indeed on most Greek representations) inclination of the beam was much more roughly detectable. In fact no results on method (a) improved upon those from method (b).

Method (b) (judging from movement of beam-end or pans) seems supported by a certain amount of ancient evidence - thus [Arist.] Mech 1, especially 849b24, in explaining why large balances are more accurate, shows that accuracy is determined by observable movement of the beam ends, in fact by the speed of their movement here which is I believe a reference to over-balance weighing (see above in ch.I.2.(3)); also Heron Mech.34.C refers to pan-depression though the phenomenon he recorded seems difficult to reproduce; furthermore Greek representations show people concerned with each, or one in the case of Arcesilas C.1, scale-pan and not, as in Egyptian scenes, with the area of the pivot (where in fact the pointer is shown on Egyptian). Art Rep.C.3 (Taleides) shows two people seated, one by each pan: such an arrangement in fact proved very much the most convenient way of conducting the experiments with the larger stable beams. Without a fixed scale, the consensus of opinion was that movement of around or under 1" was virtually undetectable. This naturally applied to both 6' and 3' beams. This limit was therefore used for the folling measurements of sensitivity derived from minimum observable weight differences.

Where methods (a) and (b) can be combined, as with the small balance,

stand-supported, a smaller movement is detectable. 1 cm. seemed the most reasonable limit.

Hand-held balances raised the possibility of a further method (c): the order in which pans leave the ground as the balance is raised; and, the reverse, (d), the order in which they reach the ground as the balance is lowered. Such a procedure may be indicated by representations of hand-held balances with pans only just clearing the ground; it also seems at first sight to be Zeus' method as described by Homer. Experiment showed that these methods, especially (d), could be highly precise <u>if</u> repeated sufficiently and <u>if</u> the balance's geometry had been first scrupulously checked for level unloaded. Both conditions are absolutely crucial, as otherwise totally irrelevant factors (the twisting of irregularly suspended pans or slightly non-vertical raising of the balance) can give erroneous results to startling degrees of insensitivity (for example see Exp.(6).c.end). But there is no ancient evidence for such careful preparation or repeated weighing procedure; and further the parallels are not necessarily convincing. Homer's balance is held <u>after</u> being raised, and the relative positions of <u>both</u> freely suspended pans are what count for the result. It seems in fact most appropriate for <u>un</u>stable balances.

The use of hand-held stable balances must therefore be considered to be an extremely crude way of balance-weighing. The operator can neither see the inclination of the beam, nor can he view the movement of the pans. If he lefts the beam to eye-level (suppos ing it to be not too heavy), this motion will impart considerable agitation to the beam and pans: though it is true the latter can be damped by the operator's free hand, and the former will be reduced by a very short beam suspension cord to the hand (as seems to have been the case). The lifting of such balances from the ground could be simply a reflection of the problem of inserting loads where pans are not held stable; but it remains difficult to understand how accurate balance-weighing could then result.

<u>Results</u>

Several measurements were taken and each of the figures represent an average over about three. Variation was generally insignificant but where variants are given, this is in connection with some additional factor which is noted. The following comments are made independent of the context of the results (for which see chapters I, VII, VIII).

(a) Sensitivity and precision. The smallest weight difference detectable seemed to be in the region of 0.5 gm on the smallest balance [Exp.(6)a]. The results of the lifting Exp. (6)c, I prefer to disregard for reasons already given. This weight difference of 0.5 gm was with no pan loading, and applies possibly up to under 5 gm loading (therefore allowing weighing of one Attic drachma to this figure: just below an obol weight). Higher loads on the same balance greatly increased the minimum observable weight difference. On larger balances unloaded, it was much greater; and loaded it ranged from 1 part in 166 [Exp.(2) at 2 kg load], up to 1 part in under 90 [Exp.(1) at 4 kg load] and most fell towards this more insensitive end. The precision of the balance of Exp.(4) should be compared with that for Exp.(3); and shows that the hook-type suspension can amount to reducing sensitivity by one third, especially for lower loadings.

(b) Accuracy. For general purposes the limits to sensitivity are the limits to accuracy. Considerable trouble was taken to ensure central and level suspension, also to ignore results where excessive swinging, observable air disturbance, displaced central suspension cord were present. Each of these factors could result in inaccuracy in the use of the balance.

The possibility of inaccuracy built into balance designed was recognised by [Arist.] Mech. 849 b 34 of the purple-dye sellers. An effective reconstruction of their lead-filled beam was made for Exp.(5): a wedge-shaped wooden beam, otherwise similar to that for Exp.(3) with which the results should be compared. The alternative ancient method of deceit (using wood nearer to the root for one side of the beam) proved to have occurred in Exp. (1): where the centre of gravity of the beam was found to lie 1" from its linear centre. This was unintentional, and should indicate the real difficulty of achieving an even, centrally-hung beam. The figures from these two experiments should show how serious the resultant error could be. This can amount to as much as $1/15^{th}$ of the load involved, and is nowhere less than $1/66^{th}$. It is from 3 to 10 times the limits to the sensitivity of these balances. Yet despite [Arist.] Mech.'s reference there is no evidence for double-weighing techniques in ancient Greece, which alone would reveal such errors as these .

(c) Heron Mech. 34.c gave rise to experiments to compare the effect of adding an additional weight to first a load 6 times its weight, then one 20 times: Exps. (1)(2)(3)(4). Because of the risk of collapsing no free

swinging was allowed, the pan being gently lowered till it reached a position of equilibrium. However only in the case of the hook-beam (Exp. (4)) did the effect of adding the weight to the larger load approach the observable limits for declination. This could suggest that Heron's balance was very much more insensitive than any of those reconstructed here. There remain problems of whether his balance was typical of earlier Greece, and of whether he was in fact only interested in the degree of increased inclination, or indeed of the speed of inclination. See in chapter VI.1 on ancient theory: the problem at present lies shrouded in the Arabic text. This balance cannot however have been of the unstable over-balance type which would easily overtilt for both cases.

Experiments (1) - (6)

Note. Weight given usually in grammes, lengths in inches and feet, but as this illogical step [which is in fact more convenient for Greek measurements] may offend, I give in brackets all equivalents [frequently approximating for immaterial measurements].

(1) Large 6' wooden beam (oak).

- length 72" (between suspended pans) [183 cms]
  dimensions (effectively) centre 2" x 3" [5 x 8 cms] tapering to 1" x 1 " [2.5 x 4 cm].
  weight 4082 gm.
  suspended by 1/4" (0.5 cm) rope.
- pans (in fact brass on chains) suspended from 1/16" [0.2 cm] looped cord.
  total weight each side 270 gms.

The Beam was constructed out of straightforward 2" x 3" timber; the tapering effect being achieved by "squares" of nails driven into each end [⁘] (as also for Exp.(7): see diagram below). The whole assembly was suspended from an overhanging branch of a tree. A vertical stick in the ground by one pan served as a measuring rod and marker. The experiment was conducted outside in relatively calm conditions.

With no load 1" [2.5 cm] declination from 5 gm to 9 gm added to one pan (Note: this higher weight was necessary when the suspension cord was tightened; the effect was not apparent at higher loadings).

At 2kg load	1" [2.5 cm]	declination ---	20 gms.
At 3kg load	1" [2.5 cm]	---	--- 30 gms.
At 4 kg load	1" [2.5 cm]	---	--- 45 gms.

For reference to Heron. Mech. 34.c :-

At 3 lb load, 1/21b gave		declination of	21" [53 cms]
At 10 lb load, 1/21b ---		---	--- 11" [28 cms]

Despite the apparent regularity of the beam it was noted that the level position was only achieved by suspension 1" off centre. The resultant error between the two sides was checked by double-weighing (Compare Exp. (5)). At various loads this error was as follows:-

At 1 kg load approximately 15 gm error (the longer arm being lighter by this amount)
At 2 kg load approximately 67 gm error
At 4 kg load approximately 256 gm error.

(2) 3' metal (copper) tube beam.
- length. 36" [c. 90 cms].
  diameter (constant) 1/2" [1.5 cms].
  weight 380 gm.
  suspended by 1/16" [0.2 cm] looped cord.
- pans as in Exp.(1).

In fact two sorts of pan-suspension were tried: cork-stopping into ends and simply looped by ends. No difference in performance was detected. Experiment conducted outside; measurements of declination from a paper scale alonside pan rims.

With no load 1" [2.5 cm] declination from under 2 gm. (but variable) added to one pan
At 2 kg load 1" [2.5 cm] declination from 12 gm.
At 3 kg load 1" [2.5 cm] --- ---- 17 gm.
At 4 kg load 1" [2.5 cm] --- ---- 21 gm.

For reference to Heron Mech. 34.c :-

at 12 oz. loading 2 oz. produced declination of 12" [30 cm]
at 40 oz. loading 2 oz. -- -- -- 8" [20 cm]

(3) 3' wood beam (deal)

- length 36" [c. 90 cm]
  dimensions 1" x 1" [2.5 cm x 2.5 cm] constant.
  weight 230 gm.
  Suspension as in Exp.(2).
- pan as in Exp.(1), simply loop-hung.

Outside.

With no load 1" [2.5 cm] declination from under 2 gm [variable]
At 2 kg load - -- -- -- 13 gm
At 3 kg load - -- -- -- 19 gm
At 4 kg load - -- -- -- 36 gm

For reference to Heron Mech. 34.c :-

At 12 oz. loading 2 oz produced declination of 10" [25 cms]
At 40 oz. --- -- --- --- 4 3/4" [12 cms]

(4) 3' wood beam (deal)

As experiment (3) but now fitted with hooks for beam and pan suspension: (additional weight to beam 12 gm). Outside.

With no load 1" [2.5 cm] declination from 9 gm.
At 2 kg load - -- --- -- 55 gm.
At 3 kg load - -- --- -- 76 gm.
At 4 kg load - -- --- -- 110 gm.

For reference to Heron Mech. 34.c

At 12 oz. loading 2 oz produced declination of : 3.75" [9.5 cm]
At 40 oz. --- -- -- --- 1.5" [4 cm]

or

At 3 lb loading 1/2 lb -- --- 5" [13 cms]
At 10 lb --- -- -- --- 2" [5 cms]
(At 10 lb. loading the beam appeared bent but not more than 1/4")

(5) 3' uneven wooden beam (deal)

- length 36" [c. 90 cm].
  dimensions; wedge-shaped from 1" x 1" to 1" x under 1/2".
  weight 120 gm.
  suspension as in experiment (2)
- pans as in experiment (1) simply loop-hung.

The beam was suspended just under 1" from centre in order to be level when the pans were unloaded. The resultant error between the two pans, checked by double weighing, was considerable. Compare Exp. (1) and [Arist] Mech. § 1. Again outside.

At 1 kg load error of 56 gm (the thinner arm being lighter by this amount)
At 2 kg load --- 130 gm.
At 4 kg load --- 260 gm.

(6) 1' wood rod beam.

- length 12" [30 cms] but pans suspended c. 11" apart.
  dimensions 1/2" [1.5 cm] diam. constant.
  weight 40 gm.
  suspended first by 1/16" [0.2 cm] cord; second by twine [0.05cm ?]: in both cases looped.
- Pans lead 5 cm diam. suspended by twine from loops into notches top of beam.
  Total weight each side 51 gm.

Several additional measurements were made with this balance in view of its representing maximal accuracy for the ancient Greeks. Despite my hesitancy over the lifting experiment, I include it here. The load of 4.3 gm. is an approximation to the Attic drachma: but no difference noticeable. The experiment was conducted inside; measurements taken from paper scale on stand against pan edge.

(a) With 1/16" cord suspension: stand mounted

with no load ?	0.2 cm	declination from	0.2 gm	added to one pan
	0.4	-----	0.5	----
	1.0	-----	1.0	(exactly) ----
	1.5	-----	1.5	----
	2, 2.5, 3	-----	2.0	(variations) ----

with 4.3 gm load:	0.4 cm	declination from	0.5 gm	
	1.0	-----	1.0	
	3.0	-----	2.0	(and repeatedly)
with 10 gm load:	0.4	-----	0.5	
	0.8	-----	1.0	
	2.0	-----	2.0	

with 20 gm load:	0.3 cm	declination from	0.5 gm.
	0.6	-----	1.0
	1.6	-----	2.0
with 50 gm load:	?	declination visible from	0.5 gm
	0.4 cm	declination from	1.0 gm
	1.0	-----	2.0 gm
with 100 gm load:	no declination visible from		1.0 gm
	0.7 cm	declination from	2.0 gm
	1.0	-----	3.0 gm
	1.3	-----	4.0 gm
with 200 gm load:	(Maximum loading: as on one occasion at this load the pan-suspension broke).		
	0.3 cm.	declination from	2.0 gm.
	1.0	-----	4.5 gm
	1.2	-----	5.0 gm

(b) with twine suspension: stand-mounted

with nc load:	?	declination determinable from	0.1 gm
	0.6 cm	declination from	0.2 gm
	1.25	-----	0.5 gm
	3.0	-----	1.0 gm (but returning only to —1 cm)
with 5 gm load:	0.8 cm.	declination from	0.5 gm
	1.4	-----	1.0
	4.5	-----	2.0 (returning to —2 cms)

In this arrangement the beam was noticeably unstable. Considerable oscillation occurred at point of pivot, and more importantly a distinct tendency was noted for the twine to skid when the beam inclined, which meant the need to re-adjust balance after every weighing.

(c) with 1/16" cord suspension: hand held

For this experiment the pans were repeatedly raised slightly then lowered onto a flat surface (table). At times it seemed that one side landed before the other, and when this seemed consistent the minimum weight difference was as in the following table:-

with no load:	difference	0.15 gm
At 10 gm load:	-----	0.1
20 ---	-----	0.15
50 ---	-----	0.2

Where time for swinging was allowed however the figures approached those for (a) above.

With spinning pans and non-vertical lifting it was possible to gain the impression that a 10 gm load in one pan was lighter than one of 5 gm in the other!

Unstable balances (Experiments (7) - (9))

Design

A similar range of balances were constructed using the same sizes of beams (6', 3', 1') as for Exps. (1)(3)(6). It did not seem practicable to fit anti-skid devices to the copper tube of Exp.(2), nor relevant to investigate the deviations of (4). All the beams had now to be notched underneath for the suspension loop to remain in one position, and a restraining clip seemed advisable over the cord in this notch to prevent accidents as the whole balance suddenly overtilted throwing weights forcibly out of the upper pans. This seemed also to point in favour of some device to prevent excessive tilting. Two devices were tried: (a) the horizontal plank from which the beam of Exp.(8) was hung: this seemed to work in a manner very similar to the frame types of Rep.H.1-2 [for some overtilting experiments the balance beam was however arranged at right angles to this plank and suspended from hooks equivalent to its width: see below and Exp. (8)]. Secondly (b) an extension to the spar of Exp.(7): see illustrations at end . This was done to simulate Rep.C.1 (the Arcesilas vase) as far as possible. It also provided a natural explanation for the hanging cord ends, as the extension had to be fastened most securely to the suspension cord where it met the spar.

Friction on the sides of beams, suspended albeit by simple loops was nevertheless observed to render them basically stable at low inclinations, unless the suspension loop was splayed out from the beam sides. Three ways of achieving this were used: (a) the wider plank for Exp.(8) avoided this problem; but (b) when the beam was to be suspended at right angles to the plank in Exp.(8), two hooks, some distance apart, were necessary. Most effective, however, as maximising the degree of splay just at the relevant point, was (c) the use of a "spar" as in Exps (7) and (9). This had to be notched; on (9) it did not skid, but on (7) with the additional weight of the beam, and with the further extension device (above) fitted, it tended to move out of position unless held in place by careful lashing knots to the side cording. This also appears to be very much in keeping with Rep.C.1.

The same pans were used as in the experiments with stable balances; care was taken to ensure that they depended from points <u>above</u> the beam centres of gravity (for "slip looping" quickly created an illusion of stability). Hooks were added into the ends for Exp.(8).

The resulting beam of Exp.(7) approached therefore as closely as practicable to that shown on the Arcesilas vase, C.1 (effectively a tapering beam, as explained above under stable balances). Features of Exp.(8) reproduced the frame balances of H.1 and 2. Finally, the pans of Exp.(9) were direct reproductions of those found at Lefkandi, and the geometry of the whole balance reconstructed from them.

Method

As with the stable balances, these reconstructions were examined for their sensitivity (which probably would not reproduce any weighing Greeks would have carried out on them); and secondly impressions were sought as to their actual use in practice. One or two other modifications were generated in the course of the weighing.

The first matter, balance sensitivity (a), proved simpler than the comparable experiments with stable balances. Because of their design, unstable beams, as soon as displaced, swing with increasing speed until checked (towards vertical, or very much before where anti-tilt devices are fitted). There is therefore no need to make any subjective judgment on what might count as minimum observable movement. Detecting sensitivity however is very much more vulnerable in practice with unstable balances because of the great difficulty of achieving proper level balance at the outset at set loadings before extra weights are added. Several extremely variable figures will therefore be found in sections (a) of the experiments: the cause can be put down perhaps to faults in balance construction, especially shifting points of pivot as the beam swings; perhaps to variations in the initial balance position (as, unloaded, an appreciable weight can be added before overtilting occurs, such a weight difference must be allowed in loaded experiments); perhaps to inaccuracies in the weights used (my collection is not in perfect condition); and perhaps to an innovation I used to simplify the repeated problem of balancing the machine: this was to rest one pan at balance position on some rigid surface, and then add small weights to the other pan until it overtilted.

This innovation not only simplified the experiment; it also seemed very much in line with representations of at least one operator standing, or sitting, by one pan while the other was being adjusted. Such an operator could hold, or simply rest the pan until it was lifted clear by the other's overtilting. It is clearly important that the balance be as level as

possible initially; but how much in practice could deviation from the level position interfere with accuracy? Two sets of measurement were therefore taken first, in sections (b), the effect of 1" incline below level (and 1 cm for the smallest beam) on the sensitivity of the balance (this amount corresponding to the subjective estimates made above for what would be likely to count for stable balances as observable inclination without the help of pointer or scale). What appeared to be more relevant was, secondly, sections (c) of the experiments: what amount of inclination was immaterial to the eventual proper setting of the beam. The idea here was to discover the extent of the danger of not levelling the beam initially, which might result in its overtilting in favour of the lighter weight where the weight differences were small. For both series of experiments the balances were first carefully checked for equilibrium with the beam level; for (b) it was then depressed one side by the 1" (or 1 cm), naturally being more stable in this position, and then weights were added to the other side until overtilting. For (c) a series of weights were added to one side (broadly speaking 2 x or more the sensitivity of the balances at each loading), and then the beam was artificially depressed against this overloading until the point of equilibrium was reached. The declination of the beam end from level position was then measured.

Results

The experiments were carried out with great care, and frequent measurements were retaken. Considerable variation was thereby observed, which has partly been concealed by the results I quote, as I give normally the better performances. In general however the possibilities of this sort of balance seemed much greater than those with the stable sort of suspension.

(a) Sensitivity and precision. The smallest weight difference detectable was around 0.2 gm on the smallest balance. Exp.(9)a, with twine pan-suspension, gave a possible 0.1 gm but cannot be relied upon. This is more than twice as good as the corresponding stable balance. The sensitivity appeared very little affected by increased loading, rising only slightly at greatly increased loads. One part in 4000 (for the large beam at 4 kg) can be compared to one part in 88 for the same beam in stable suspension. Registration of a difference of 5 gm in 2 kg on this large beam is equivalent to noting a drachma in over 4 mina: still not over-impressive compared to Greek claims (which, involving talents, can only have been made with balances

as sturdy as the largest used in these experiments : see chapter VIII).

(b) Accuracy and error. The possibility of error seems much greater with these unstable balances because of the problem of obtaining equilibrium at true horizontal. Further sources of error in the experiments may be due to design faults the Greeks corrected (as I could have done): slipping suspension loop, variation in point of pan suspension as the beam inclines, slight friction at the beam sides, air disturbance or support movement. Nevertheless sections (b) of the experiments, designed to explore this area, showed that the errors of inclination below an observable degree (1" and 1 cm) still do not affect significantly the sensitivity of the balances. Compare the results of sections (b) with those of sections (a). Furthermore considerable overtilt angles are necessary to compensate for relatively small weight-differences (see sections (c)), though these weight differences are in effect still below the sensitivities of the stable balances.

(c) Operational indications. These are the most successful results of the experiments conducted with unstable balances: and offer encouraging support for conclusions reached elsewhere in this thesis. First: the implication of the third series of tests, sections (c), is that successful detection of weight differences can be made with fairly crudely hand-held balances, even when these are raised from the ground. This was actually checked in the course of Exp. (9). Earlier I have noted that stable balances could not perform accurately in such conditions, nor could they be easily observed even by a second assistant. In unstable balances differences are detected by overtilting, which is most readily observed whether the operator is standing aside from the balance or holding it. Second therefore can be noted the graphic movement and eventual resting position of an overtilted unstable balance, that so well reflects general Greek attitudes and the experience of their own balances. Part of this is the decisive aspect of using the unstable balance. Third: is the obvious observation that unstable balances are best suited to distinguishing weight differences, for which they are besides decisive, also quick. Fourth: (and finally) the design features that seem to conform as well with the evidence for Greek balances: no pointer necessary; a cord around the beam; "spar" or something above beam; overtilting devices (on both Exps (7) and (8) these were tried and worked very effectively). To these could be added a comment that the important thing to note in the use of these balances to equate (where this is done) is the movement of the beam ends; this begins slowly and will accelerate. It is this movement

and not simply displacement, that [Arist.] Mech. comments upon as a reason for larger balances being more accurate (1.848b1ff).

Experiments (7) - (9)

(7) Large 6' wooden beam (oak)

- Beam and pans (including pan suspension) as in Exp.(1).
- Beam suspension was based on interpretation of Arcesilas vase (Rep.C.1): using a 1/4" (0.5 cm) rope loop, clipped to the underside of the flat beam (as an alternative to notching with restraining clips); a spacing "spar", 5" long, positioned just above the beam, kept the rope clear of the beam sides; this was lashed to the loop cord to prevent its slipping and an anti-tilt lever was lashed to it after measured experiments for observation of the effect; the loop ended in a toggle inserted in a ring above, hung by similar rope from a tree. See illustrations following.

(a) When balanced level at zero load, complete overtilting was produced by adding 4 gm (or more) to one pan. For other loads slightly more had to be added. (Note: no anti-tilt devices fitted for (7) (a), (b) or (c) experiments: but they would not have impeded the results)

at zero load complete overtilt from + 4 gm or more
2 kg -- ---- ---- -- 5-10 gm
3 kg -- ---- ---- -- 9-12 gm
4 kg -- ---- ---- -- 10-15 gm.

(b) After inclining one side by 1", these figures became, for the other to overtilt:-

at zero load (and 1" declination) complete overtilt from 4 gm or more
2 kg -- ----- ---- ---- -- 7 gm
3 kg -- ----- ---- ---- -- 12 gm
4 kg -- ----- ---- ---- -- 15 gm.

(c) Weight differences had to be compensated by the tilting of the beam (before equilibrium could be reached) as below:-

at zero load + 5 gm in one pan, equilbrium at - 5 1/2" declination for the other
---- + 10 gm ----- ---- - 8 1/2" ------
at 2 kg load + 10 gm ----- ---- - 6" ------
---- + 15 gm ----- ---- - 8" ------
at 3 kg load + 15 gm ----- ---- - 7" ------
---- + 20 gm ----- ---- -11" ------
at 4 kg load + 20 gm ----- ---- - 7" ------
---- + 40 gm ----- ---- -10" ------

In a further test, it was discovered that the balance was able to distinguish a 2p coin as heavier than a 1/2d coin, even when artificially depressed up to 3" the wrong way (the actual difference is about 1.55 gm); it did not however overtilt in registering this small difference.

(8) 3' wood beam (deal)

- Beam as in Exp. (3), as also pans.
- Beam suspension for measurements was from two hooks 4" above the beam and 3" apart; a single loop, of 1/16" (0.2 cm) cord, passed from hooks under beam where two notches (one each side) and a metal clip were fastened to prevent the beam's accidently slipping out of the cord.

  The pans were suspended from a hook extension at the end of each beam (thus above the CG of the whole beam).
- For observation the balance was remounted hung in the same plane as the 4" plank above it; the cord now passed simply round this plank, which served as an effective anti-tilt device.

(a) At zero load complete overtilt from under 2 gm added to one pan
2 kg -- --- --- -- 4-9 gm -- - - -
3 kg -- --- --- -- 5-9 gm -- - - -
4 kg -- --- --- -- 7-10 gm -- - - -

(b) After inclining one side by 1" these figures became, for the other to overtilt:-

At zero load complete overtilt from 3 - 14 gm.
2 kg -- ---- ---- -- 12 - 15 gm
3 kg -- ---- ---- -- 10 - 11 gm
4 kg -- ---- ---- -- 16 - 17 gm.

(c) Weight differences had to be compensated by declination as follows:-

at zero load	+ 5 gm	in one pan in equilibrium with other pan	- 6" declination
----	+ 10 gm	----------	-13" ------
at 2 kg load	+ 10 gm	----------	- 4" ------
----	+ 15 gm	----------	- 6" ------
at 3 kg load	+ 15 gm	----------	- 5" ------
----	+ 20 gm	----------	- 8" ------
at 4 kg load	+ 20 gm	----------	- 4" ------
----	+ 40 gm	----------	-11" ------

(9) 1' wood rod beam.

- Beam and pans (also pan suspension) as in Exp.(6).
- The beam was now notched underneath, a restraining clip added, and suspended by a loop from a single hook (about 2" above the point of pivot). This loop was made first of twine, but, this proving too unstable and erratic, 1/16" (0.2 cm) cord was later substituted. A wooden spar was placed to keep the loop away from the beam sides; its position was maintained by being knotted to the actual suspension loop.

- Section (c) of this experiment was repeated in part, by holding the loop on a finger and raising the pans from a flat table. This was done intentionally carelessly. Though measurement was impractical, nevertheless weight differences of more than about twice the sensitivities of the cord of section (a) were correctly indicated by overtilting (i.e. around 0.3 - 0.4 gm for low loadings and up to 0.6 - 1 gm without difficulty for those around 100 gm).

(a) with twine suspension, and then with cord.

at zero load	complete overtilt from	I(twine)	0.1-0.3 gm	II(cord)	0.2 gm +
2 gm	----	----	0.2-0.65	----	0.2
10 gm	----	----	0.2-0.5	----	0.25-0.3
20 gm	----	----	0.2-0.5	----	0.3-0.35
50 gm	----	----	0.2-1.2	----	0.2
100 gm	----	----	0.7-1.5	----	0.3 gm +

(b) After inclining one side by 1 cm, the figures of Section (a) cord, became, for the other to overtilt:-

at zero load	(-1 cm declined)	complete overtilt from	0.2 gm
2 gm	-------	----	0.2
10 gm	-------	----	0.2-0.3
20 gm	-------	----	0.3
50 gm	-------	----	0.5-0.7
100 gm	-------	----	0.5-0.7

(c) Weight differences had to be compensated by declination as follows:-

at zero load	+ 0.5 gm in one pan reached equilibrium with the other at a declination of	- 3.5 cm.
--	+ 1.0 gm ----------	- 4.5 cm.
at 2 gm	-- + 0.5 gm ----------	- 3 to 3.5
--	+ 1 ----------	- 4.5
at 10 gm	-- + 0.5 gm ----------	- 3.5
--	+ 1.0 gm ----------	- 4.7
--	+ 2.0 gm ----------	- 6.0
at 20 gm	-- + 0.5 gm ----------	- 2.75
--	+ 1.0 gm ----------	- 4.3 to 4.75
--	+ 2.0 gm ----------	- 6.0
at 50 gm	-- + 0.5 gm ----------	- 3.0
--	+ 1.0 gm ----------	- 4.1
--	+ 2.0 gm ----------	- 5.0
at 100 gm	- + 0.5 gm ----------	- 3.0
	+ 1.0 gm ----------	- 3.7 to 4.0
	+ 2.0 gm ----------	- 4.7

Further observations

The following general points were suggested by the experiments with both types of balance: they relate to design features, materials, as well as to operation and performance.

1. Lead proved very convenient for pans (and also for weights made to match the set I began with). The material is easily cut with kitchen scissors even when over 2 mm thick; holes for suspension present no difficulty.

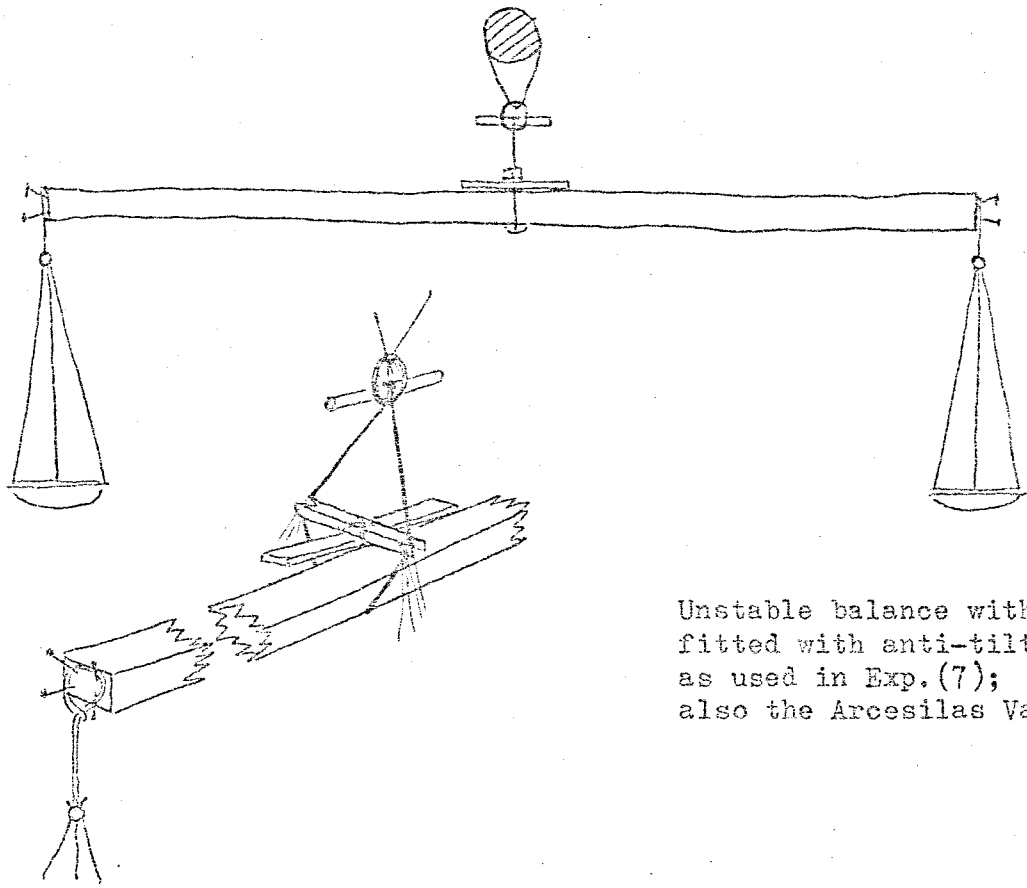
2. Two diameter lines, intersecting nearly at right angles, were reproduced from the Lefkandi pans, and proved a simple and satisfactory method of determining the position for 4 suspension holes.

3. Any permanent cut, notch, hook, or staple to the beam created the danger of inaccuracy, and was difficult to make decisively. Subsequent correction (by weighting one part of the beam) would of course lead to the errors noted from Exp.(1) in part, but also Exp.(5). Nevertheless the temptation to make such adjustment was strong, and no doubt many ancients would succumb to it.

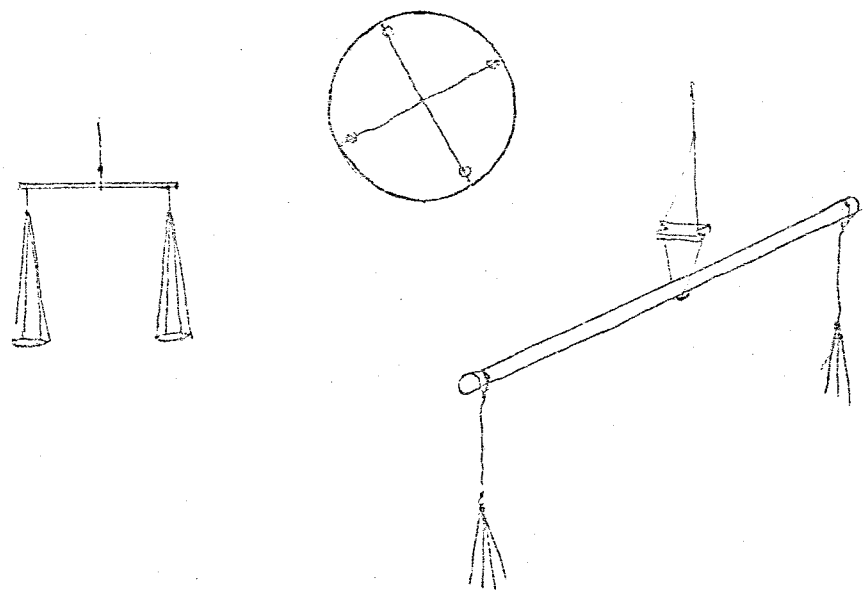
4. In general all variations in beam- and pan- suspension that made the balance more robust, also made it more insensitive. My experiments, designed to discover the highest possible performance, were conducted with balances that were certainly not child-proof (literally!), and could not be expected to last a day's wear in a market place.

5. The twisting of the beam suspension cording often proved inconvenient. This was only marked on the stable balance types; for the unstable the top suspension fixings tended to assist twisting; no Greek models seem to incorporate special features to prevent twisting and this may be a further argument in favour of the unstable balance.

6. The wobbling of stable balances at the point of pivot combined at times with the oscillation of the beam and the swinging pans to create considerable disturbance and incline the beam artificially still further. Modern balances, for several centuries, have counteracted this wobble by means of a weight depended at the point of pivot. No Greek balance is shown with such a weight. It is not needed on unstable balances.



Unstable balance with 6' beam, fitted with anti-tilt device as used in Exp.(7); compare also the Arcesilas Vase.



Unstable balance with 1' beam and lead pans (comparable in size and design with those found at Lefkandi): Exp.(9).

APPENDIX C

Coin Conversion

The conversion of coin has been mentioned above in the text in a number of contexts: in particular in discussion of whether weighing accompanied such operations, but also of the functions of the ὀβολοστάτης and κολλυβιστής, and of the importance of the weight and condition of coins for their acceptability. Here I wish to consider a few detailed points that lie less directly on the subject of my thesis, or which would have unduly burdened the text with controversy. The emphasis is on the practical aspect of conversion. I am not however concerned to give simple statements of equivalences in Greek or other ancient sources.

Fourth-century Delphi

That the accounts of fourth-century Delphi indicate two exchange rates between Attic and Aeginetan coin (of 7:10 and 3:4) appears now to be generally accepted: Keil Hermes 37(1902)511-529; SIG^3 for example 252 n.4 on vol.I p.448 "nemo negabit"; and finally the commentators in FdD III (5) on 48.II.21ff; note should also be taken of Bourguet, L'administration financière du sanctuaire pythique (Paris 1905). While the subject is far too detailed for full discussion here, I should like to assemble the evidence briefly for coin conversion (Attic and other) at Delphi, and examine in particular the reasons for the variation that it is thus assumed to display. The usual explanation is that the two rates distinguish an ideal exchange rate (Nominalgewicht, of 10 Attic to 7 Aeginetan drachmai) and a commercial rate (Realwert, "usité dans le commerce", of 4 Attic to 3 Aeginetan). I suspect that the distinction, which is not found outside Delphi, is largely a product of the method of accounting used at Delphi and does not in fact reflect anything more than the difference between exchange rates including and not including the actual charge (ἐκκαιδεκαλλαγή) for making the exchange.

The usual coin of account at Delphi was (as at Epidaurus) Aeginetan. This was coined as staters (2drs), drachmai, and obols. All conversion of coin is into this Aeginetan coinage (for accounting) or from it (for special payments required to be made in other coinage). The other coinages that appear thus converted are Attic (drachmai and obols), Itali (νουμμοι), Phocaic (ἕκται), and Darics. They should be considered separately rather than the assumption made (as apparently by Keil) that all were handled on the Attic model.

(a) Attic

The most straightforward conversions appear in the accounts of contributions to temple rebuilding: SIG^3 239-240, Tod 140. Not all Attic entries every year were converted, but conversion seems generally to have been the rule if only to match similar conversions in the accounts of expenditure (to which I shall return next below). The conversions are broadly on the 10:7 rate, with a sliding scale operating to avoid awkward fractions, and a 4:3 rate cannot be suggested:

10 drs Attic ... 7 drs Aeginetan
4 drs Attic ... 2 drs 4 ob Aeginetan (several entries)
1 dr Attic ... 4 ob Aeginetan

The corresponding accounts of expenditure, with totals of income and outgoings in various coin, involve similar conversion of this coin into Aeginetan coin values by virtue of an apparent need to present round totals in a single unit of account. These conversions are ordinarily not written out in full, but the totals can be reconstructed from off the inscription itself. As so many figures are fragmentary this problem of reconstruction is complex. A glance at the varying figures proposed will show this. It is however clear that conversion was mathematical (and not done by weighing - thus I reject [σταθ]μῳ in favour of [ἀριθ]μῳ in FdD III (5) 54.20 cf. 50.III.36ff and SIG^{3}253.II.11, and see note above ch.III n.138^a on silver-weighing in Delphi). It is also certain that the figures for talants and minai are consistent with the assumption that no conversion applied to them (though this does not imply that Aeginetan talants and minai were identical to Attic; the systems were different, and the talants and minai may initially have been counted from the Aeginetan point of view).

Beyond this point it would be rash to venture in detail. The texts have supported three interpretaions: (a) [Keil] that a 4:3 rate was used; (b) [Bourguet] that a 10:7 rate applied; and (c) [SIG^3 at least in note 18 to 250] that Attic was already partially converted (into Aeginetan drachmai

and obols) and is on these inscriptions being directly added with the Aeginetan. Of the totals themselves, the most fully preserved are FdD III (5) 50 [SIG^{3}251] III.32-47 and FdD III (5) 52 [SIG^{3}250] 1-13. I shall note of the first that the summation presupposed by advocates of a 4:3 rate [Keil and FdD III (5)] involves an unbelievable degree of unseen calculation (summation of two amounts not given in the text - one obtained by subtraction, the other by conversion, before the sum could be made - with another amount that is stated in the text). The figures restored for the second total in FdD III (5) 52, moreover, work badly with the 4:3 rate proposed. Furthermore the reliability of the text figures themselves is not beyond criticism, and Tod (BSA 37.246) has questioned Keil's belief that their being written out in full was a necessary guarantee of accuracy.

Given this state of uncertainty in the texts, I feel it fair to turn to more general arguments to resolve the problem. Bourguet appears here to approach the heart of the matter in considering the plus and minus factors of the exchange rates (L'administration p.22). I do not however entirely agree with his arrangement of these. The conversions, in so far as they are only on (or rather for) stone, are entirely academic; there is no justification for other than a straightforward equivalence rate being used to make them; remarkably Bourguet himself recognises that the συμπαν κεφαλαιον represents an imaginary sum (p.23). It is simply therefore a question of determining which of the two available rates (10:7 or 4:3) was the basic equivalence rate. As there is independent evidence (to be advanced below) that the 4:3 rate included exchange costs, I conclude, with Bourguet as it turns out, that the 10:7 rate operated for conversions in these accounts, as in the parallel records of contributions, also accounted, mentioned at the outset.

Coin conversion is a different matter. The evidence comprises two instances where Attic coin was required by the Delphi officials in connection with temple payments:

FdD III (5) 25 [SIG^{3}247] II.A.5-13. In purchasing 93 Attic minai weight of ivory in Athens, the Delphic Naopoioi paid 22 minai 74 drs, all in Attic coin. The record continues with what this cost in Aeginetan coin: του[τ]ο αἰγιναιου [ἐπε]κ[δοντ]ες [τ]α[ν] ἐπικαταλλαγα[ν] δραχμας χιλιας ἑπτακοσιας πεντε ὀβολους τρεις. It is not immediately clear whether these 1705drs 3ob Aeginetan included the exchange fee (ἐπικαταλλαγα, as FdD) or whether this was additional to it. Nor is it explicitly stated

where the change was done, at Athens or locally in Delphi. On the 10:7 rate, the equivalence (in Aeginetan) should have been 159 1drs 4ob. FdD argue that the difference represents the exchange cost, 113drs 5ob or exactly one-fifteenth (approx.7%). However it seems unreasonable to overlook the remarkable coincidence that the figure given for Aeginetan is precisely that which would result from the application of the 4:3 rate of conversion. I suggest that this 4:3 rate was indeed used here, and that the difference between it and the standard 10:7 rate was intended to cover exchange cost: ie. it included the ἐπικαταλλαγή without any special calculation being further necessary.

FdD III (5) 58 [SIG^{3}252] 13-15 indicates a similar conclusion. The Tamiai, asked to produce (it seems) the equivalent in Attic coin of 20 talants Aeginetan possessed by the Treasury, made the change and handed over 18 T 40 M in Attic coin: τὸ δὲ ἄλλο ἐπικαταλλαγὴ ἐγένετο. Assuming that the 4200 Aeginetan drachmai talant is involved here as in the other accounts, we find that the ratio between the two figures is again 4:3 (since coin is involved it is reasonable to work the conversion in drachmai). Again the cost of conversion is covered by the difference between the 4:3 and 10:7 rates, representing one-fifteenth (c.7%) of the (Aeginetan) principal. The only difference is that the cost of the exchange is not included in the account (τὸ δὲ ἄλλο...). This is however only a superficial variation as the cost is included in the 20 Aeginetan talants that the whole operation cost the Treasury.

In conclusion, I find no contradictions in the conversion of Attic and Aeginetan coin at Delphi. The equivalence was (as traditionally) 10:7, and this was used (with minor variations for very small amounts) for theoretical, accounted conversion; another rate, 4:3, included the costs of making actual coin exchanges. The flat-rate conversion fee of c.7% is comparable with rates in operation at Epidaurus (see following).
A mathematical statement of the procedure in changing Aeginetan coin into Attic should clarify this discussion:

x drs.Aeginetan — value equivalence $\frac{10}{7}$.x drs.Attic
total cost for changing $\frac{4}{3}$.x drs.Attic
difference (fee) $\frac{10}{7}x - \frac{4}{3}x$ Attic, so $\frac{2}{21}$.x drs.Att.
$\frac{2}{21}x \cdot \frac{7}{10}$, so $\frac{1}{15}x$ drs.Aeg. ← Aeg. equivalence of this fee

With this number of Aeginetan drachmai removed from the principal sum, the money-changer would proceed by means of such conventional tabulations of the 10:7 equivalence rate as illustrated by Tod.140 with which I began.

(b) Italiot nummi

Heraclea contributed νομ[ο]υ[ς] ἰταλιωτικους ἑκ[ατον] to the temple fund, and this figure is converted into Aeginetan coin as 124drs 4ob for the purpose of account (SIG^{3}240 I.2-8). The operation is exactly parallel to the first account-conversion of Attic coin considered above and the context is the same. The conversion of Italic coin therefore indicates an equivalence of 1 nummus to c.7½ ob. Aeginetan. This fact can now be used as evidence of the western coin weight standard. I cannot understand why both Keil and Bourguet seek to involve Attic coin here, as there is insufficient independent evidence of the western weight system, and certainly none that might identify the particular rate here accepted at Delphi. The awkwardness of the approximate equivalence might indicate the use of some sliding conversion scale (as can be seen from the several Attic entries).

(c) Phocaic coin

Some unidentified Greeks ἀπ' Ἰωνι[ας] made a similar contribution to this same Delphic fund of Φωκαιΐδας ἑκατον ἱκατι ἑξ , and this is converted as 259drs 3ob Aeginetan (SIG^{3}240 G.1-6). The coins are probably (as Keil) ἑκται , by far the most common Phocaic coin to travel. From this conversion it is taken as equivalent to 2.06drs Aeginetan. Again a sliding scale must be assumed to be being used. It is worth noting however that no difference in procedure is here adopted even though the Phocaides are electrum, rather than the silver of Aeginetan and other coinages so far considered.

(d) Darics

The conversion of gold Darics appears in Delphic accounts apparently in connection with the crown dedicated for Olympias (Alexander the Great's mother) and also in records of the manufacture of a gold perirhanterion. FdD III (5) 58 [SIG^{3}252] 5-8 και των δαρεικων [τω]ν εἰς τους στεφα-
[νο]υς οὑ ἐλρησαμεθα παρα τωγ πρυτανιων, Ὀλ[υμπια]δι,
[δα]ρεικων ἑκατον ἐνενηκοντα, ἐπικαταλλ[αγ]η ἐ[γ]ενετο στατηρες
[ἐν]ενηκοντα πεντε.

The conversion costs, involving actual coin exchange, were therefore set at 1dr Aeg. per gold Daric. The overall cost, or price, of these gold coins can be derived from the second reference: SIG^{3}253 II.11-12 ἀριθμειται δε ὁ δαρεικος ἑ[πτα στατησι | κ]αι δραχμηι . This shows that the Daric was equivalent to 7st 1dr Aeg. (15 Aeginetan drs.). Thus the cost of the Daric, including the exchange fee, was 16 Aeginetan drs, and so the fee very closely identical to that applied for the exchange of Attic coin (one fifteenth).

Keil deduced evidence of a varied exchange rate from the fragmentary lines II.30-32 of this last inscription (see SIG^{3}252 note 4). I cannot however see that [illegible] must be the end of an equivalence in Aeginetan coin of the 221 Darics (where the term has to be completely restored) in the earlier lines. Straightforwardly it should be 47 minai 12 staters 1 drachma, but on the rate Keil suggested of 7 Aeg.staters to the Daric, the sum would be 44 minai 7 staters. This fits the space only if no indication of the fact that the sum is in Aeginetan coin is to be included. But it surely must be to explain the difference. I fail to find sufficient indication in the text for this subtle restoration. The inference of a double Daric rate need in any case amount to no more than the double Attic rates - one for equivalence, and the other for coin conversion (and including the exchange fee).

Epidaurus

Two points on money-changing in Epidaurus can conveniently be considered here to correct Burford's oversuccinct treatment in Greek temple builders at Epidauros (1969) 125-6.

Burford assumes that the contractor was given the coinage he wanted, comprising the equivalent (in Aeginetan), plus (in Aeginetan) the fee for changing it. I find it difficult to believe that this changing was not done in advance of payment by the building officials themselves. Firstly, the contractor, if he was able to demand payment in specific non-local coin (for which the authorities would lose money), clearly very much wanted only such coin; in the case of the δέκατα ἐς Ἀθάνας one suspects that there was no possibility of using non-Attic coin when it came to the actual payment (just as for the πεντηκοστή paid at B.6.46: 120 Attic drs); it was therefore up to the Treasury to produce the correct coinage, whether or not this was immediately available. Secondly, exchange costs varied throughout the Greek world; in the Olbia decree (Pleket no.7, and see below Appendix E) only the rate for electrum was fixed while other coins were to be changed ὡς ἂν ἀλλήλοις πείθωσι ; Delphi, as already seen, operated its own rates and it is more than likely that the Epidaurus officials did likewise; otherwise they would hardly have been able to specify (or calculate) an exchange cost in advance, as Burford's interpretation would have us believe. Finally, Tychon is surely a money-changer, paid directly by the building commission; ἐπικαταλλακτή is

the fee for changing coin, not a rate for such exchange.

In connection with such exchange rates, Burford seems to arrive at far too low a figure. Possibly as a result of believing a variable exchange rate to be involved, in commenting upon B.6.41f she identifies Tychon's 25drs as the cost of changing the total paid for Pentelic marble (for which the δεκατα is recorded above in lines 36-7 as 420drs Aeginetan). As a result the exchange would cost just over ½% (or 2½ob per mina: Aeginetan). This would be amazingly low a cost; but there is no reason to suppose that ~~At least some of~~ the nine other payments (if they were made at all) were made in Attic coin ~~as required~~. Furthermore, why should Tychon either wait till this point in time to be paid, or be paid in advance for the total ? I prefer to take the 25drs as the charge for changing 420drs Aeginetan into Attic coin: this is nearly 6%, and so comparable with the Delphic charge of c.7% and that charged in the case of Laarchidas at Epidaurus to which I shall now turn.

At B.6.122f an entry records amounts as drawn out and paid to Laarchidas (possibly an Argive): 2310drs Aeginetan; 121drs Aeginetan καταλλαγα (a reasonable emendation: see Burford BSA 61(1966) ad loc); and 300drs Argive. Burford oddly assumed that Laarchidas wanted 2610drs Argive, but the actual exchange rate from Aeginetan to Argive is not known, and, in view of the costs involved, I should infer it was not very straightforward. The cost here works out at approximately 5.2%.

Second-century Thebes

IG VII.2426 is an account of the annual income and expenditure of Thebes. It is interesting in this context in that the sums are given in either συμμαχικον ἀργυριον or in χαλκος. One item in particular mentions the cost of 110drs (silver) bought from a private individual as 137drs 3ob (bronze): Καφισοδωρῳ ἀργυριου συμμαχικου δραχμων ἑκατον δεκα τιμην χαλκου ΗΔΔΔΓΡΡΙΙΙ (11.15-17; the 110drs are listed as income from the same individual in the earlier section of the decree). This operation may not properly be one of conversion, but rather of coin changing. Normally a one-to-one value equivalence existed between bronze and silver, for this is the reason for the simple accounting together of the two sorts of coin on this inscription. The cost of the coin exchange (given this value equivalence) works out as exactly 20%. This I have calculated on the principal of 137drs 3ob, and feel is confirmed by the fact that the difference, 27drs 3ob, is precisely one fifth.

APPENDIX D

Aristotle Ath.Pol. ch.10

Ἐν μὲν οὖν τοῖς νόμοις ταῦτα δοκεῖ θεῖναι δημοτικά, πρὸ δὲ τῆς νομοθεσίας ποιῆσαι τὴν τῶν χρεῶν ἀποκοπὴν καὶ μετὰ ταῦτα τήν τε τῶν μέτρων καὶ σταθμῶν καὶ τὴν τοῦ νομίσματος αὔξησιν. ἐπ' ἐκείνου γὰρ ἐγένετο καὶ τὰ μέτρα μείζω τῶν Φειδωνείων, καὶ ἡ μνᾶ πρότερον ἔχουσα σταθμὸν ἑβδομήκοντα δραχμὰς ἀνεπληρώθη ταῖς ἑκατόν. ἦν δ' ὁ ἀρχαῖος χαρακτὴρ δίδραχμον. ἐποίησε δὲ καὶ σταθμὰ πρὸς τὸ νόμισμα τρεῖς καὶ ἑξήκοντα μνᾶς τὸ τάλαντον ἀγούσας, καὶ ἐπιδιενεμήθησαν αἱ τρεῖς μναῖ τῷ στατῆρι καὶ τοῖς ἄλλοις σταθμοῖς.

Both Aristotle, in this passage, and Androtion, FGH 324 F 34, describe a reform of Solon apparently concerning coin, if not also other, weights. These passages have already been discussed in some detail in ch.V 5 (3) on the origins of Greek weights. At many other points in other chapters reference has been made to the Aristotelian account, or to interpretations offerred of it. A separate examination here in an Appendix will lighten the preceding text of controversy, though it should be noted that this examination relies greatly on the independent implications of other pieces of evidence considered in the course of this thesis as a whole.

The account of Solon's reforms in the Ath.Pol. is first and last a fourth-century account. Ath.Pol.1-41 was written in the 320's (between Cephisophon's archonship in 329/8, 54.7, and the fall of the Athenian democracy in 323/2). The problem of the possible survival of historical traditions about early constitutional history, and the dangers of more recent political motivation for the reconstruction of such history need not be repeated here (see for example Hignett History of the Athenian Constitution, and my earlier discussion in ch.V.5.(3)); it seems clear however that no clear rules exist for discerning what reform might be a late addition to the tradition about some ancient reformer from what might be genuine. A properly cautious approach is to examine first a reform and decide if its attribution to a particular period be at least conceivable.

Ath.Pol.10 describes a reform involving inter alia coinage, and assigns it to Solon of the early sixth century. As the date now suggested for the earliest Athenian coins is at least 30 or more years after Solon, the reform, describing a change in an already existing coinage, looks far from plausible. This may be the correct point at which to abandon the passage. Many scholars however have sought to see in it a reflection of some sort of early sixth-century actuality; others have simply questioned the attribution of the reform to Solon. While I remain myself most impressed by the resemblance of the passage to a correction of Androtion, and so believe it to be only of relevance to the fourth century, it seems important to make clear what the passage might be used to indicate about early Attic weights. This can also then be used more constructively in the later context of when it was actually written.

I take as a starting point the recent analysis of the passage by C.M.Kraay in Studies presented to Stanley Robinson (1968) pp.1-9 which has for us the advantage of considering the details of the reform involved apart from the problems of historical context, authorship and tradition. Kraay separates off the last section (ἔθηκε δὲ καὶ σταθμὰ πρὸς τὸ νόμισμα), as being the institution of special coin weights (5% lighter than their face value) and quite independent of the increase (αὔξησις) of weights, measures, and coinage described in the earlier section. His argument can be summarised thus. Both Aristotle and Androtion concur on the fact that the reforms involved increases, Aristotle listing three spheres of increase in which the last mentioned is initially distinguished from the other two by the introduction: τήν τε τῶν μέτρων καὶ σταθμῶν καὶ τὴν τοῦ νομίσματος αὔξησιν. Kraay feels this sufficient justification for seeing the increase in coin as on a different level from that of weights and measures. Taking the spheres of increase in the order in which they were introduced, he explains that as measures increased in size (μετὰ τῶν Φειδωνείων), the weight mina increased by 30drs to 100drs (an increase in the mina weightwith a constant drachma, the result being "the mina of 100drs" that Aristotle and his contemporaries knew), and coin was minted in 4drs as opposed to the former, smaller, 2drs (ἦν δ' ὁ ἀρχαῖος χαρακτὴρ δίδραχμον pregnant on any interpretation and to be explained by reference to the coinage of Aristotle's day). The remaining final sentence must, Kraay maintains, be a new subject as all the spheres of increase have already been described. σταθμὰ πρὸς τὸ νόμισμα suggests special coin weights: of the two possibilities, 63 normal minai to a 5% heavier talant or 63 (5% reduced) minai to an unchanged talant, Kraay

prefers the latter on the grounds that otherwise there would be no need for special coin weights. The mint, he concludes, is therefore being authorised to make 5% profit on its coins (no doubt to cover minting costs).

Despite the neatness of this interpretation, and despite the fact that it provides a possible reason for ignoring the wider implications of the uniqueness of Ath.Pol.10 and its dual weight structure (on the grounds that the structure is operated only by the Attic mint), I cannot accept that silver and coin were in fact weighed by different weights. I have already argued this above at some length in chapter IV.4 and most decisive is the general practice in Athens of accounting weighed silver together with counted coin in a single system of drachmai and obols. Simpler ways can be imagined for the mint to levy its charges.

There are several internal reasons for rejecting Kraay's interpretation. σταθμα προς το νομισμα may correlate weights and coinage as easily as introduce a new concept of coin weights. Secondly the line ἡν δὲ ὁ ἀρχαῖος χαρακτὴρ δίδραχμον explains nothing; if contemporary "increase" in the mina from 70 to 100drs is expressed in full, why is no mention at all made of the tetradrachm that Kraay supposes to be the only increase in coinage meant by Aristotle ? Further, on Kraay's view there is no increase in coin weights but in fact a decrease (of 5%). I feel it to be easier to take the whole section καὶ ἦσαν ... δίδραχμον together, abandoning the strict logical sequence demanded by Kraay's analysis and paraphrasing "the mina was made 100drs instead of 70drs but (Aristotle notes) these 100drs were in olden times (in Solon's day as opposed to the present) minted in didrachms". The change from didrachms to tetradrachms came much later, as Kraay knows, and why not also Aristotle ?

A more fundamental weakness in Kraay's argument was anticipated by Lang who noted that the stater here must be a reference to a weight and not to a coin (Agora X pp.2-3). As I have noted above in chapters IV and V, the term is not used of silver coinage in Athens, but applies very frequently to a (commercial) weight, very much larger that of any coin. The 5% reduced coin weights of Kraay's hypothesis cannot therefore be spread over the stater and other weights (as Aristotle says), as these weights are not (including the stater) weights applicable to coinage. This point can be pursued further and taken also against Lang: as the term

mina is not only not applied to actual coined or bulk silver weight, it is also reserved for ratios and percentages in silver accounting until relatively late (see ch.IV n.13); although intermediate in value between the talant and the drachma the mina does not appear of silver in straightforward official accounts, and the higher and lower terms are used instead. On the other hand the mina is clearly attested for the weighing of commodities other than silver and gold, thus for iron for example. Stater occurs more frequently in this non-silver context also. On this basis I propose a new approach for Ath.Pol.10.

If mina is only a notional subdivision of the talant of coin or of silver, then the raising of the number of drachmai to this mina (καὶ ἡ μνᾶ κτλ) is either notional or not connected with coin and silver weights at all. The section ἐποίησε δὲ καὶ σταθμὰ... however is definitely about weights. I suggest it concerns non-coin and non-silver weights (where both the stater and the mina are valid weights). Unless the passage καὶ ἡ μνᾶ ... δίδραχμον is about coinage there is no proper description in Ath.Pol. 10 of any increase of any sort in coinage (rejecting the hidden reference to the enlarged tetradrachm in the phrase ἦν δ' ὁ ἀρχαῖος χαρακτήρ). I suggest that καὶ ἡ μνᾶ κτλ therefore is about coinage, describing a change in subdivision and not a change in weight (there was, again, no mina coin weight). This interpretation is strongly supported by a contrast that can now be noted between ἡ μνᾶ πρότερον ἔχουσα σταθμὸν ἑβδομήκοντα δραχμὰς ἀναπληρώσῃ τοὺς ἑξήκοντα and later τρεῖς καὶ ἑξήκοντα μνᾶς τὸ τάλαντον ἄγουσας : only the last verb, ἄγειν, is used of weight (for ἀναπληρώσεις compare Xen.Poroi 4.24 of numbers and amounts). Thus the only weight increase that remains in the passage is that of the talant from (presumably) 60 to 63 minai, with these 3 additional minai added proportionately to all weights lower than the talant. These weights are general weights (staters etc). I can see no reason now for πρὸς τὸ νόμισμα not to include also the weights of coins, namely drachmai and obols (though not, as already argued, minai). Drachmai and obols appear to have been in practice the preferred system for weighing gold and silver, and to have been reserved for the weighing of these commodities even though occasion might allow small amounts of other commodities to be weighed in a similar system (see conclusions to chapter III). There is nothing in Ath.Pol.10 to counter this general picture: it simply describes the 5% increase of two or more weight systems.

It is now possible to conclude that there is no reason to infer from Ath.Pol.10 the existence of dual standards for weights of silver and silver coin (Kraay), or for silver/coin and other commodities (as Lang and more generally). The terms, and the subdivisions of the talant, used for silver and coin (drachmai and obols) differ from those used for other commodities (staters, minai, and their fractions). This has been noted from simple observation of Athenian accounts, it also came out of the earlier analysis of the actual Attic weights (which showed mina and stater fractions that could not be expressed in drachmai or obols). There is however no other officially-recognised difference, and there is no justification for speaking of coin drachmai and silver drachmai as if they were quantitatively different. It is interesting to note that the same situation occurs as late as IG $II^2$1013, where only coin drachmai are mentioned, and the mina again redefined. At that late stage official recognition of the commercial mina and the commercial talant constitutes a radical difference, amounting to the establishment of dual standards. One can conclude however with some degree of certainty that no such dual standard was officially recognised in Athens of the classical period (or a fortiori earlier) down to the late fourth-century date of Ath.Pol.10.

The historical aspect of Ath.Pol. 10 and in particular its relation to Androtion fragment 34 might now briefly be considered (see ch.V.5.(3) for a more traditional approach). Both describe a coinage reform as well as one involving measures; weights may have slipped out of Androtion's version by accident (it being the earlier account by about ten years and there apparently being no other reason for Aristotle's involvement of weights than that they were contained in some common source); both speak of the reform as an increase of some sort. In so far as the coinage reform can only (as of Solon) be unhistorical, it is tempting to look no further than Teisamenos of the late fifth century (ap. Andoc.i.83 and see ch.V.5.(3) for political background) as the basic source for Androtion's and Aristotle's reconstructions. Perhaps available to contemporary research was the fact that early Attic coins had once been didrachms; certainly at hand was the observable ratio of 100:70 for Attic and Aeginetan coin drachmai (expressed at the mina level perhaps); also contemporary was the view that Pheidon's measures were small (cf.Tod.140 and later Theophrastus Char.30.11). This will explain the figures and details of Androtion (correcting 73dr to 70dr per mina) and of Aristotle (with the exception of the extra 3 minai). Alternatively there was something further in the tradition that led to Androtion's additional 3 drs and Aristotle's 3 minai. The coincidence is striking. That Aristotle

can be better made to make sense is a simple reflection of his having thought the matter (theoretically) out more thoroughly; he was after all writing to correct Androtion. The sense however is sense in terms of the later fourth century. At no stage should it be felt that these passages offer evidence of archaic Attic practice. Nevertheless the importance of the possibility of dual standards even as early as the late fourth century has demanded this analysis.

I hope to have removed the possibility of dual standards. In its place I have been able to reassert the differentiation by commodity of weight terms and systems. The earliest evidence for dual standards remains IG $II^2$1013 of the end of the second century; weights analysed in chapter II would indicate that the heavier variant standard (of 138 drachmai to the commercial mina) did not obtain for long before the decree changed it (to 150drs). Even the operation of dual standards however at this late date continued the commodity-differentiation of systems. As has already been noted there were no heavy drachmai that formed part of it.

APPENDIX E

Greek legislation concerning coins, weights and measures, with an additional note on the Treaty of Apamea of 188 BC.

(a) Athens

- Imperial decree enforcing the use of Attic coins, weights and measures ? 450-446 BC (although dates later in the fifth century have been proposed): ML.45 (67) with bibliography in Pleket no.3. Lewis has since argued for further changes to paragraph 8, but these do not affect the part of the decree relevant to this thesis.

The scope of the decree is inferred from an extract to be added to the Bouleutic Oath (para.12):
ἐαν τις κοπτηι νομισ[μα] ἀργυριου ἐν ταις πο[λεσι κ]αι μη χρηται νομ[ισμασιν τοις Ἀθηνα]ιων ἠ σταθμοις ἠ μετ[ροις ἀλλα ξενικοις νομισμασι]ν και μετροις και σταθμοις, πιμωρησομαι κα]ι ς[ημιωσω κατα το προτε]ρον ψηφισμα ὁ Κλεαρχ[ος εἰπεν·
The remaining sections however describe (apart from administrative details and announcement of the decree to the Allies) only the operation and effect of the stipulation about coinage. Frequent reference is made to the Athenian mint that apparently was in charge of the proposed change-over (paras. 5-8, 13-14). Description of the conversion of foreign into Attic coin is confined to a statement of exchange costs (para.5 -- τρεις] δραχμας ἀπο της μν[ας --).

- Coinage decree of 423/2 BC: SEG X.87

Although very fragmentary, this inscription mentions the Laureion mine (line 11), presumably meaning the source for silver; later it stipulates τῳ αὐτῳ νομισμ[ατι χρησθαι although also mentioning ἀλλο βολονται νομισ[μα (lines 14-16); by line 19 the Bank, or exchange stage, is reached: τραπ[ες -- .

Of the stages from mine to circulated coin in Athens (and ancient Greece in general) extremely little is known, and it is most unfortunate that so much of this promising inscription is lost. While other texts give accounts of the conversion of other coin into Attic, there is no

record of the basic process that is perhaps being described on this inscription. The Laureion records that have survived seem themselves exclusively concerned with the operation of the mines only. A possible reconstruction of the procedures involved, from mine to mint to public, is attempted in ch.VII.1.(2) and (3).

- Teisamenos' decree ap. Andocides 1.83 and ascribed to 403/2 BC.

The reference to Solon's weights and measures is introductory and incidental to the main constitutional interest of the decree, and is anyway, in my opinion, totally unhistorical. See above ch.V.5.(3). Teisamenos claims that the Athenians should use the laws, weights, and measures of Solon.

- Law on false currency 375/4 BC: Attic Stelai I.7180 (but unpublished)

This law insists on the importance of silver content and on official stamping in a series of regulations concerning the acceptability of coin. A public dokimastes is to assess these factors, and one is to be available at the Peiraeus as well as another in Athens itself. Penalties are laid down both against the dokimastes for abusing his position and against the refusal to accept coins he has passed. An accidental omission here may be that there are no penalties for passing false money in the first place; there is the further problem that a coin looking as if it were Attic, or one subsequently stamped as Attic, seems still to have been decreed acceptable (lines 8ff). The main interest in the decree however for our purposes is first that it disadvantages the commercial operators, and second it makes no provision at all for acceptable coins being of full weight. Weight is in fact nowhere mentioned. Lines 3-4:

το ἀργυριον δεχεσθαι το [Ἀ]ττικον ὅτ[ι ἂν φαινητ-]
αι ἀργυρου και ἐχη τον δημοσιον χα[ρακτηρα] ..

- Inscription of the Metronomoi 222/1 BC: E.Vanderpool Hesperia 1968.73-6.

The preserved text names the officials and records that they handed the weights and measures on to the next year's Metronomoi. Unfortunately it breaks off before any weights are mentioned. On the activities of the Metronomoi see above ch.I 1.III and V, and ch.VII 1 (4).

- End 2nd century decree establishing new commercial weights and measures: IG II^2 1013 (Pleket 14).

This decree has been discussed at length in preceding chapters, and especially ch.IV. There can be no doubt but that it establishes official weights specially for commercial use, and defines them in terms of contemporary coin weights. Though this is the first attested reference to such commercial weights, it is clear from the inscription that commercial weights in fact preceded the decree, which itself simply revised the commercial standard (from 138 to 150 coin drachmai to the commercial mina). I have argued that the earlier establishment of a commercial standard cannot have antedated this decree by long (analysis of Attic weights and also references to the commercial standard in literary and other texts). This view, it should be pointed out, is not that held by most scholars in the field (and noteably Lang in Agora X).

Use of the new weights is stipulated in the decree for everything πλην ὅσα προς ἀργυριον διαρρηδην εἴρηται πωλειν (32); and all weights in use are to conform to the specifications of the decree [εἶναι] δε συ]να[ω]να παντα τοις ἐν τωι ἐμποριωι μ[ε]τρ[οις κ]αι στ[α]θ[μ]ο[ις] (36-7).

Officials are appointed to make and to maintain both weights and measures (37ff), and there are regulations on the safe-keeping of the standards and on the use of official sekomata (41ff) with penalties fixed against those who damage or alter them (56ff). A final postscript apparently requires the officials to check (?) with a marked (? stamped) measure whenever such a measure is not used; it does not seem to have been obligatory for all traders to use such marked measures themselves however (63ff).

Athens: literary references

- Aristophanes

Aves 1040-1 (produced in 414 BC). The Decree-monger proposes
χρησθαι Νεφελοκοκκυγιας τοισδε τοις μετροισι και
σταθμοισι και ψηφισμασι καθαπερ Ὀλοφυξιοι.

Bergk emended ψηφισμασι to νομισμασι, missing surely the paraprosdokian joke. The lines have generally been accepted as a parody on a decree similar to the Imperial Decree (listed fist above: ML 45), even to suggest an argument for the later dating of that particular decree (see ML p.114). It is likely that other similar decrees existed however, as the next passage might indicate (for nothing similar to it appears in the Imperial Decree).

Thesmoph. 347-8. κεἰ τις καπηλος ἡ καπηλις του χοως
ἡ των κοτυλων το νομισμα διαλυμαινεται...

cf. Plutus 435-6 ἀρ' ἐστιν ἡ καπηλις ἡκ των γειτονων,
ἡ ταις κοτυλαις ἀει με διαλυμαινεται;

Even though only measures are mentioned here, a decree of wider application could be inferred unless of course it was the case that the Greek wine-seller (as the Babylonian) qualified for special legislation (see the Code of Hammurabi ch.108 with variants, discussed in ch.IX 1(3) above), or simply for closer personal contact from the upper classes (cf. Ar.Lys. 466 and Ehrenberg People of Aristophanes ch.5).

- Plato

Leges 746 d-e. Among the ideal decrees for a law-giver, faced with the basic legislation of a state, is listed the specification of weights, measures and coinage. The closest historical parallel seems strangely to be the third-century Achaean League (see below). Other unconvincing, and entirely theoretical, features of the account make any historical basis for Plato's remark here unlikely (note in particular the duodecimal notation that runs throughout the earlier legislation and may even be supposed to apply to the metrological). It may perhaps be reassuring that weights and measures are linked with coinage, but then both Zaleukos and Lykurgus traditionally forbade the use of it.

- Aristotle

Ath.Pol.10 describes Solon's weight and coin reforms from a fourth-century view-point. The passage is too often taken as the starting point for Greek metrology. It is discussed in detail in ch. V 5 (3) and in Appendix D.

Ath.Pol.51 lists those officials concerned with commerce in late fourth-century Athens: the Agoranomoi (essentially concerned to maintain standards of purity and to prevent deceit), the Metronomoi (to ensure weights and measures used were "just"), and the Sitophylakes (whose control of the various stages by which grain became bread included the fixing of prices by a set weight they might decide: καὶ τὸν σταθμὸν ἄγοντας ὅσον ἂν αὐτοῖς τάξωσιν· ὁ γὰρ νόμος τούτους κελεύει τάττειν). Also mentioned are the Harbour Officers. The list as a whole is interesting as it shows legislation existed for the control of weights and measures that is otherwise unattested for the period; the bread weight requirement is particularly revealing. Other evidence of such control (as the inscription of the Metronomoi or IG II^2 1013) is much later.

Politics 1257 a. This account of the origins of coinage is discussed above in ch. V 5 (5). It is included here on the grounds that the term ὁρισθέν might imply some form of official specification; it is of course impossible that this was other than a chance standard stone. The passage also nicely illustrates why so little concern is later found expressed for the weights of coins (... ἵνα ἀπολύσῃ τῆς μεκρήσεως αὐτούς).

(b) Achaea

- Execution of counterfeitors. Dyme 3rd-2nd century. $SIG^3$530; SEG XIII 274; Pleket 11.

The charge is that ἱεροσωρέων [καὶ νο]μισμα ἐκοπτον χαλ[κεον]; one individual involved seems to have worked in the mint as he is described as χρυσοχοος. The inscription however reveals little. On the acceptability of coin see ch. VII 1 (3).

- Achaean League

Polybios 2.37.10: μη μονον συμμαχικην και φιλικην κοινωνιαν γεγονεναι πραγματων περι αὐτους, ἀλλα και νομοις χρησθαι τοις αὐτοις και σταθμοις και μετροις και νομισμασι, προς δε τουτοις ἀρχουσι, βουλευταις κτλ.

The ideology of the third-century Achaean League is consistently, and exaggeratedly, praised by Polybios (but see also Plut. Philop. 8), and this general statement of totally consistent institutions, weights and measures is probably no exception. To the extent that coinage survives as an indication of the effectiveness of this standardisation, it seems that considerable independence existed; even a league coinage is not certain (see Walbank HCP I ad loc and the doubt expressed over Siegfried's comparison with the Stoic cosmopolis of Zeno). On the other hand, the passage Plato Leg. 746d-e, already noted above, shows that systematisation of weights and measures was very much a part of fourth-century political theory. It might well have been the initial intention of the Achaean League without it's having been put into effect. Peloponnesian weights are little in evidence at any period; but Walbank is probably correct in suggesting that a roughly common system (based on the Aeginetan) was "already widespread in the Peloponnese before the Achaean League rose to importance" (HCP I p.218). Official recognition of this fact then is indicated by Polyb.2.37.10. [For earlier discussion see Larsen ESAR IV 328-9 and Head HN^2 416-8].

(c) Delphi

- Late fourth-century mint accounts: FdD III (5) 74.57f

--- Σκυκρ[ατει Δελφοι στηλ]ης ἐν ἡι των νομισματω[ν παντων, της] ἀργυροκοπιας ἐξετ[α]σθε[ισης, ἡ ἀναγ]ραφη ἐγενετο μισθο[ς ---

This reference to mint activity is both brief and obscure. The stele referred to is lost. FdD (p.265) comment "ici encore nous ignorons beaucoup" but nevertheless suggest that the man here is the same as also minted the New Amphictyonic Coinage 338 BC and later (cf. FdD III (5) 48. II.18-28). There is no evidence that ἐξετασις took any special form or, in particular, whether it involved weighing: see ch. VII 1 (2-4).

- Decree establishing the Attic Tetradrachm as Amphictyonic currency

124-100 BC: FdD III (2) 139; Pleket 13; Larsen ESAR IV 332-3 (with tr).

ἔδοξε τοις Ἀμφικτιοσι τοις [ἐλ]θουσιν εἰς Δελφους δεχεσθαι παντα[ς] τους Ἕλληνας το ἀττικον τετραχμ[ον] ἐν δραχμαις ἀργυριου τεταρσι (2-3)

The preeminence of the Attic New-Style tetradrachm was also recognised by Rome (see below on the Treaty of Apamea). Its wide use has clear relevance to the definition of commercial standards on it as base in IG II^2 1013 (and the lost preceding decree). Equally however the fact that the commercial standards varied to as much as 50% of the common coin weight is an indication of the little regard generally paid to the weights of coins.

(d) Chersonesus

H.Michell The Economics of Ancient Greece^2 (1957) p.228 notes Chersonesus along with Olbia (see below) as a place where "blocked exchange" operated and only local coinage could be used for buying and selling. He cites J.Zingerle Klio xviii (1927) p.64.

(e) Delos

- Law regulating the charcoal trade ca.250-200 BC: ID 509; SIG^{3}975; Pleket 1

This law does not directly concern weights and measures, but I include it here as it enforces the use of specific commodity measures (of wood and charcoal: 33-4 and 40) along with price controls. Both measures and weights are apparently held by the Agoranomoi and are to be borrowed from them along with machines for weighing. Note the regulation that selling should not be done from a seated position (5-6).

(f) Olbia

- Coinage decree of the fourth century: SIG^{3}218; Pleket 7.

The main points of this decree can be summarised: (1) free movement of coined gold and silver into and out of the city; (2) buying and selling to be done at a specific place; (3) and always with the bronze and silver Olbia coinage; (4) a fixed price for the electrum ("gold" - 10½ Olbia staters to 1 Cyzicus) but all other coins exchanged at market values; (5) no taxes to be levied on these exchanges.

The decree only relates to the coin "trade"; foreign coins could not however be used for any other transactions. Note that even where a precise exchange rate is given no mention is made of the weights of the respective coins. See also Appendix C on coin conversion.

(g) Crete

- Gortyn law about bronze coins (third century): SIG^{3}525.3-9.

νομισματι χρητ[θαι] τωι καυχωι τωι ἐθηκαν ἁ πολις· τοδ|ὲ δ' ἐδελονς μη δεκετθαι τονς ἀργυριος.| αἰ δέ τις δεκοιτο ἢ το νομισμα μη λεοι|δεκετθαι ἢ καρτις ὠνιοι, ἀποτεισει ἀρ|γυρω πεντε στατηρανς.

This specification of the use of bronze obols in commerce is backed by a penalty in silver staters. The stater-obol terminology (also with drachmai) is attested from the early fifth-century Law Code of Gortyn (Willetts 1967 ed. Col.I.5; II.9, 15); Head however cites only silver staters, drachmai and half-drachmai prior to the third-century issue of bronze coins (HN^2 465-7). It is therefore not clear what silver obols are being declared illegal in the present inscription: coins of Olos (HN^2 472) or Rhaucus (HN^2 477) are at least perhaps close. In such a situation, the motive for the decree may be political, to insist upon the use of local Gortyn coin.

The bronze coinage introduced by the decree would of course be of token value. It is worth noting however that the transition to token coinage can be illustrated by Greek inscriptions without any mention being made at any stage to the weight of the earlier (supposedly weight-based) silver/gold coin.

(h) East Greece

- Early fourth-century monetary agreement between Mytilene and Phocaea: IG XII (2) 1; Tod GHI 112; Pleket 6; Bengtson Svt 174ff.

The agreement concerns the amount of gold in the electrum coinages of the two states. Severe penalties are prescribed if this should be less than it ought to be (ὀδαρεσ τε[ρ]ο[ν] 14); however there is no indication of what the correct proportions should be, no indication of whether these are to be assessed by weight or other means, and no specification of the sizes or weights of the actual coins. Seltman GC^2 113 gives staters and sixths of 15.42gm and 2.57gm, but this is an inference from the exstant coinage. A further problem would seem to be how a malefactor might be detected. It is possibly better to interpret the decree as a statement by the two states of their confidence in their own coinage (against pressure from Attic ?) rather than a technical or practical agreement.

(-) Additional note on Roman legislation concerning Greek coinage, weights and measures. The Treaty of Apamea, 188 BC.

The Treaty of Apamea was the result of the campaigns of 191-188 BC and settled Asia Minor between Antiochus, Eumenes and Rhodes. The terms are given in detail by Polybios and Livy. Their relevance here lies in the fact that the indemnity was apparently calculated in Attic talants with a weight and quality definition.

Polybios 21.42.19: Ἀργυρίου δὲ δοτὸν Ἀντίοχος Ἀττικοῦ Ῥωμαϊκοῖς ἀρίστου τάλαντα μύρια δισχίλια (over 12 years, with an annual payment of 1000T) - μὴ ἔλαττον δ' ἕλκειν τὸ τάλαντον λίτρων Ῥωμαϊκῶν ὀγδοήκοντα.

Livy 38.38.13: Argenti probi talenta Attica duodecim milia dato intra duodecim annos pensionibus aequis - talentum ne minus pondo octoginta Romanis ponderibus pendat.

Thus Larsen ESAR IV 332. However there are other passages, and especially other descriptions of early Roman indemnities, which raise the question of whether a minimum weight was actually specified in this treaty or whether the 80 lb talant is an equivalence added by the historical writers. The problems of early Roman metrology are too involved for discussion here, and I shall simply suggest a provisional solution in the context of the implications for Greek metrology of the provisions of this treaty.

At a relatively late stage the Greek weight system was combined with the Roman and the denarius identified with the Attic drachma (Pliny NH 21.34 ch.185). Up to the reform of Nero this denarius was 1/84 lb, and subsequently 1/96 lb (Hultsch GRM^2 149; SM Index sv. ὀγγία 2 and 3, where ὀγγία , consistently 1/12 lb, is shown as equivalent to 7 then 8 denarii). Before the identification, in earlier Roman periods, the situation is much less clear. Livy 34.50.6 gives an account of the slaves redeemed in 194 BC; it seems that he has calculated the number of slaves (1200) from the total (100 talants) and the individual price per slave (500 denarii). Polybios unfortunately is missing at this point; but the equation of denarius with drachma at this date (implied by Livy's calculation) is contradicted by another statement in Livy (34.52.6) which categorically gives the weight of an Attic tetradrachm as three denarii (Larsen simply assumes that this is an error for some other coin, such as the Cistophori [ESAR IV 328]; and Priscianus goes too far the other way, see Hultsch SM II.84-5 with the comment on p.22 "futiles Prisciani

argumentationes"). Leaving this on one side we can note that the equivalence of 80 lb to the talant gives a drachma (if it be Attic) equal to 1/75 lb. Hultsch was in fact tempted to derive a Roman lb equal to 75 Solonian drachmai (GRM^2 135-8, 151, 267ff summarised on p.271 n.1 and tabulated in Table XVIII.B on p.710; see also SM Index sv. λίτρα 2 (e) and Introd. p.67). Hultsch's use of the 150 standard (halved) found in IG II^2 1013 is patently impossible; and his deduction of an initial Roman coinage that used a denarius of 1/72 lb, which has little factual basis, hardly helps our difficulties.

IG II^2 1013 does however have a relevance here, as it established a distinction between coin weight and commercial weight of 2:3. It is important therefore, given such a difference, to establish whether the late references to Greek weights and Roman pounds are using the coin or the commercial Greek weight. This applies to Livy, to the Sullan annalist Valerius Antias (who gave the 196 BC indemnity in Roman lbs: ap.Livy 33.30.8), and also to Pliny (who gives the 202 BC Carthage indemnity in the same form: NH 33 (15) ch.51 - a passage that goes on to cite M.Varro [116-27 BC] for the Egyptian talant as 80 lbs: talentum Aegyptium pondo lxxx patere M.Varro tradit). It probably does not however apply also to Polybios (despite his being a major source for the Roman writers, and certainly for Livy at 33.10.10), but this does not really matter for it is only on the occasion of the Treaty of Apamea, where an equivalence is ruled out by the expression μὴ ἐλάττονα κτλ, that Polybios mentions Roman lbs.

The indemnities relevant for this question (apart from Apamea) are as follows:

203 BC proposed for ending the Second Punic War

Polybios 15.8.7: 5000 talants

Livy 30.16.12: pecuniae summam quantam imperavit parum convenit: alibi quinque milia talentum, alibi quinque milia pondo argenti, alibi duplex stipendium militibus imperatum invenio.

Appian Pun.32: 1600T (this seems close to the Roman lb tradition, but is of course rather later than Livy)

202 BC after the Battle of Zama, and ending the Second Punic War

Polybios 15.18.7: ἀργυρίου τάλαντα μυρία ... ἐν ἔτεσι πεντήκοντα φέροντας καθ' ἕκαστον ἐνιαυτὸν Εὐβοϊκὰ τάλαντα διακόσια.

Livy 30.37.5: decem milia talentum argenti (paid over 50 years)

Pliny NH 33 (15) ch.51: octingenta milia, XVI pondo annua in quinquaginta annos (the context is silver indemnities in general)

196 BC Settlement of Greece

Polybios 18.44.7: δοῦναι δὲ καὶ χίλια τάλαντα, τούτων τὰ μὲν ἥμισυ παραυτίκα, τὰ δ' ἥμισυ κατὰ χρόνους ἐν ἔτεσι δέκα.

Livy 33.30.8: First Livy gives the indemnity as 1000T, half of which is to be paid immediately the remainder equally over ten years (as Polybios). He then goes on:- Valerius Antias quaternum milium pondo argenti vectigal in decem annos impositum regi tradit; Claudius in annos triginta quaterna milia pondo et ducena (MS ducentum) in praesens (MS prassens) viginti milia pondo.

It seems clear that Livy had before him both Polybios' version (with sums in talants) and subsequent Roman versions that had converted these talants into Roman pounds. Moreover, Livy follows Polybios closely enough in those passages that can be checked for us to conclude that the calculations he made in 34.50.6 and also 34.52.6 were his own. The difficulties surrounding the equivalences of the indemnities and other figures from the period can therefore be separated from the historical question of what form the original Roman demands took. I should conclude then that the Treaty of Apamea required no more than a minimum weight; whether this was the source of subsequent attempts at equivalence for this period is a possibility it is not necessary to argue here; more important is the result that the treaty becomes the first instance of ancient legislation to specify the absolute weight of Greek coin. As argued in earlier chapters it is significant that such specification should be first made in Roman weights and by Romans.

APPENDIX F

Distribution tables
weights of Athens and Olympia

Notes

A standard scale is used for all the graph tables (from 0gm upwards in 5gm squares). Breaks in this scale are marked ≀ .

Groups largely follow the analysis of weights in chapter II, though small and doubtful groups have been omitted.

Each weight is represented by a black dot (or where bronze by a red), except for drachma weights where, because of their number, only the range is indicated.

Projections to a certain (or conjectured) base unit (stater or mina) are marked x------x. Usually the fraction involved is indicated.

Reductions (for comparison purposes) from the stater to the mina are marked x------x R.

Corrections to the standard 100dr coin mina are marked ^{150}~~~~C or ^{138}~~~~C, depending upon the standard from which it is supposed correction is to be made.

The order of the weights is as in chapter II:

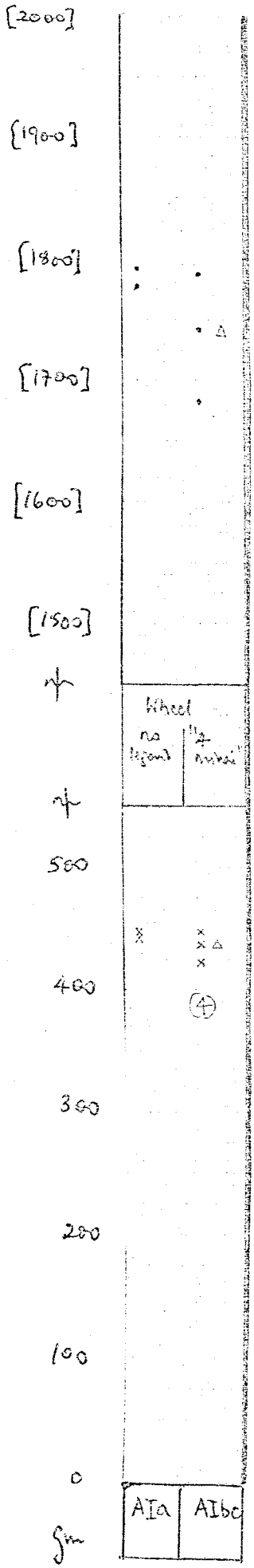
Attic - Wheel
Boukranion
Astragalos
Dolphin
Amphora
Turtle and Tortoise
Shield
Crescent and Cornucopia
Owl
Without symbol but marked with value

Olympia

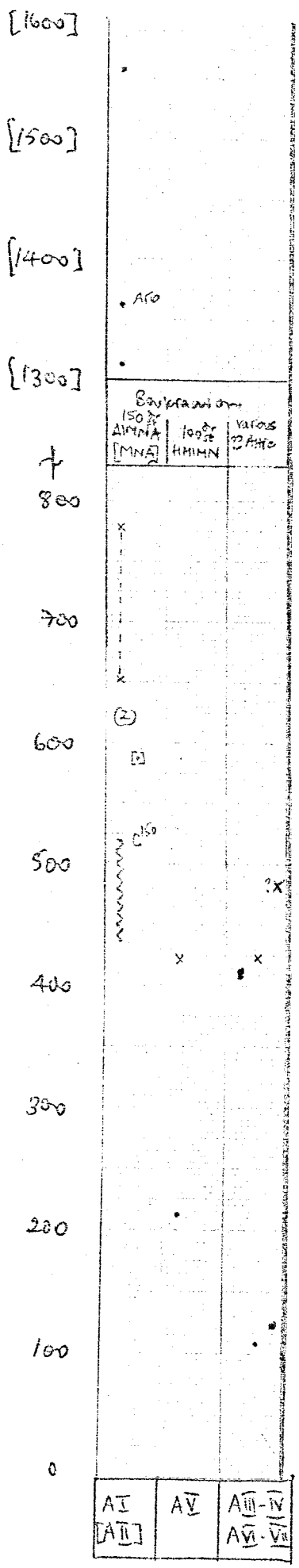
For discussion see especially chapter II.1.(1).VI on the precision of Attic weights, and chapter II.1.(2).II on Olympian weights.

Attic

Wheel

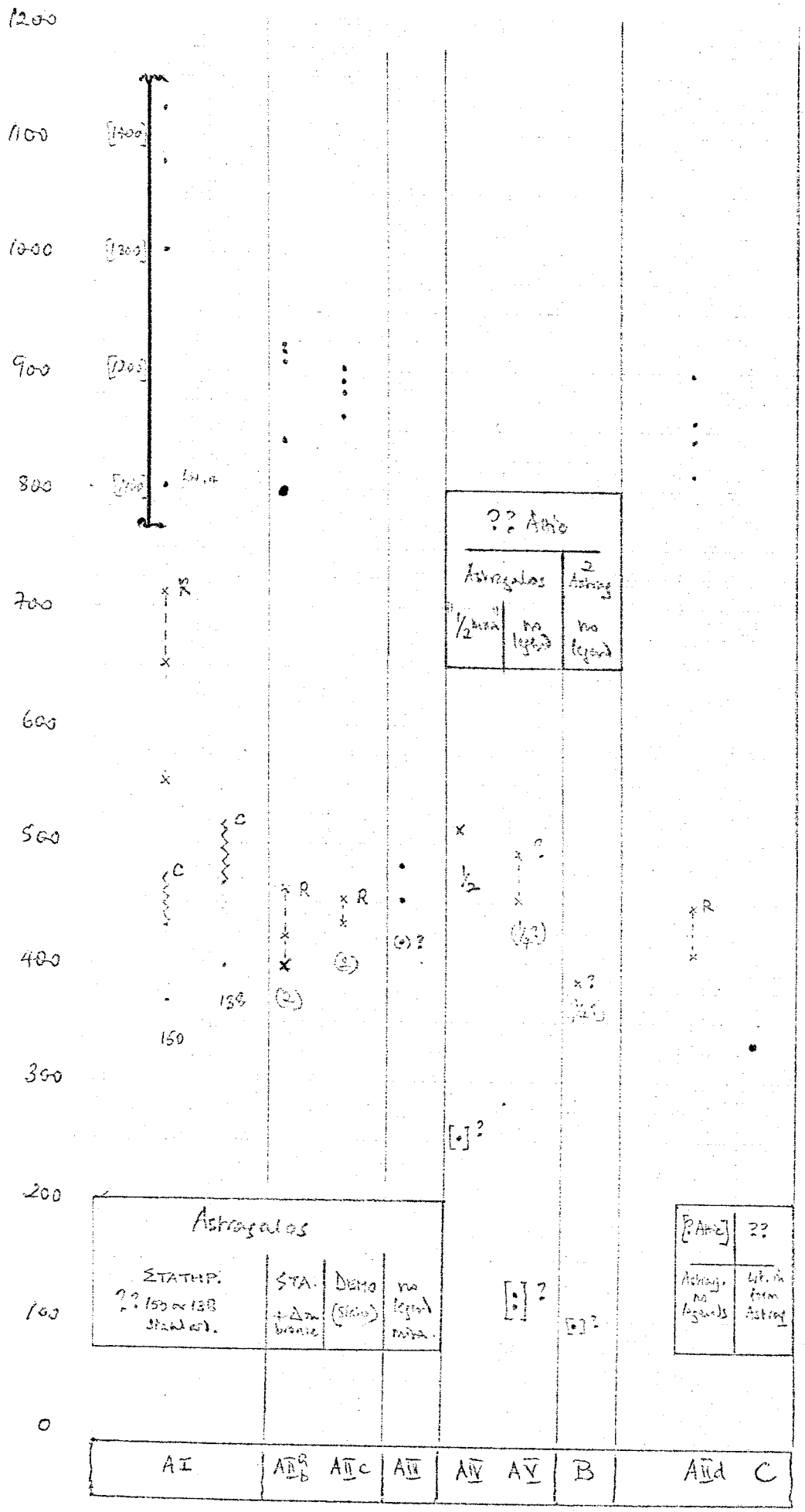


Boukranion



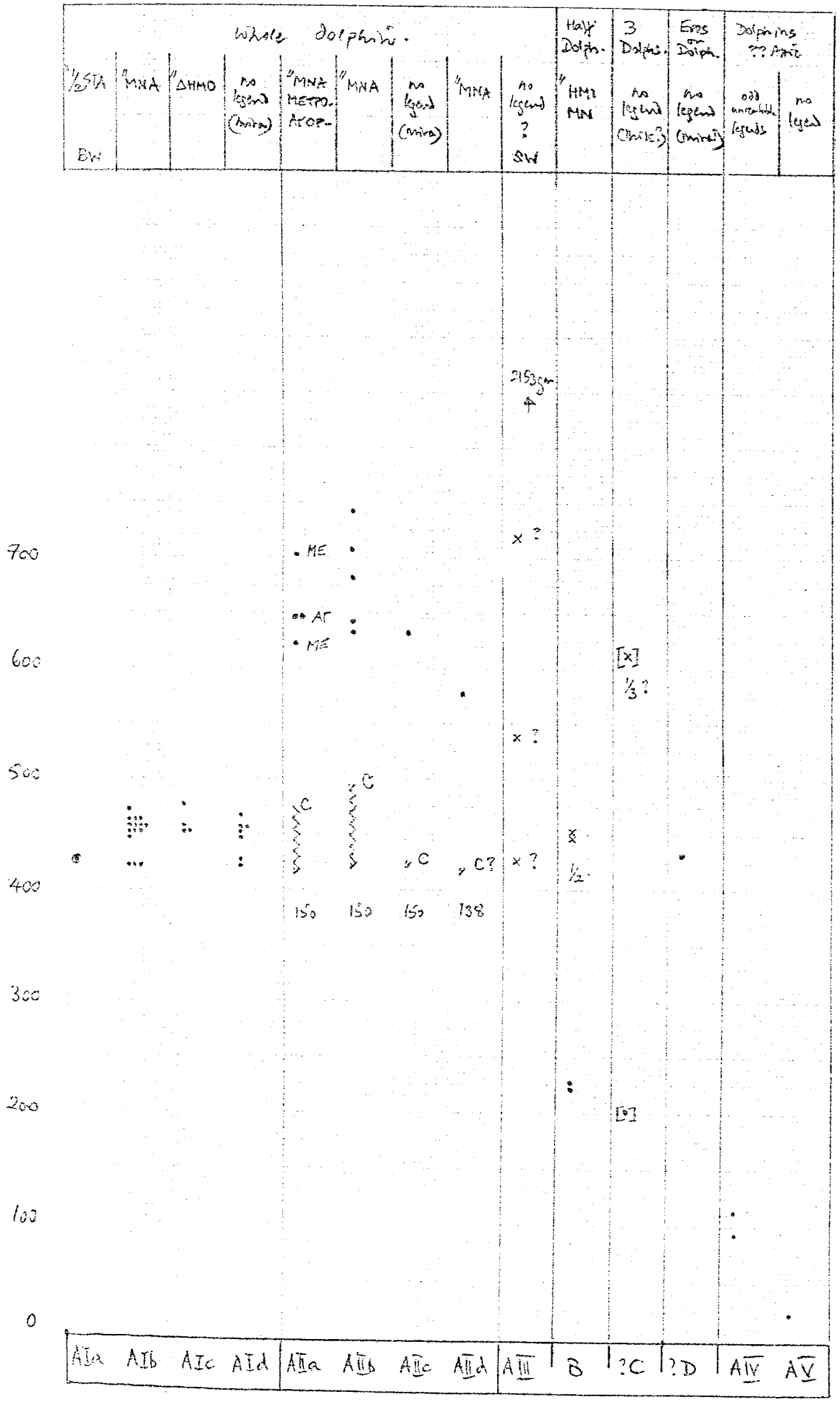
Attic

Astragalos

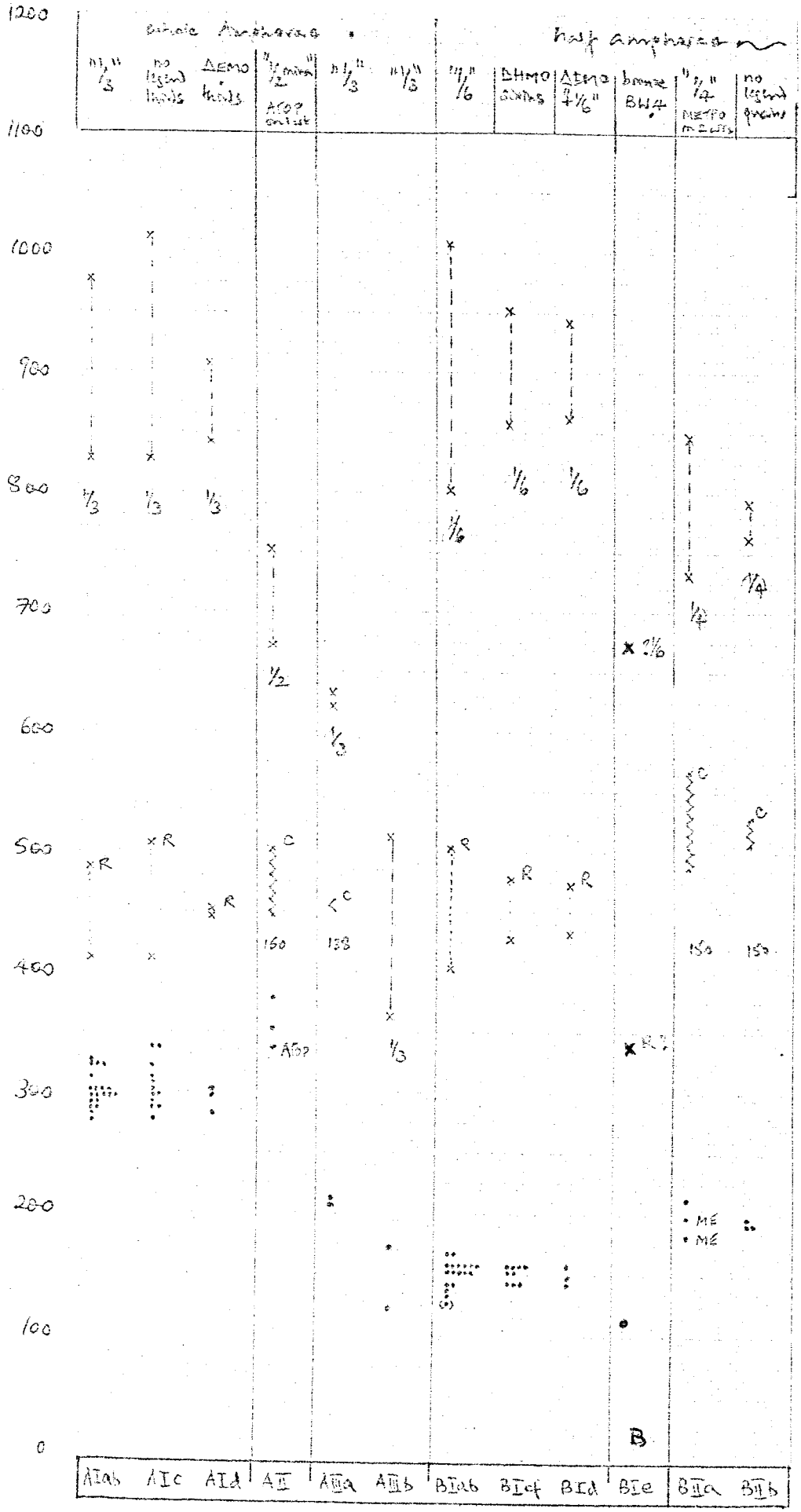


Attic

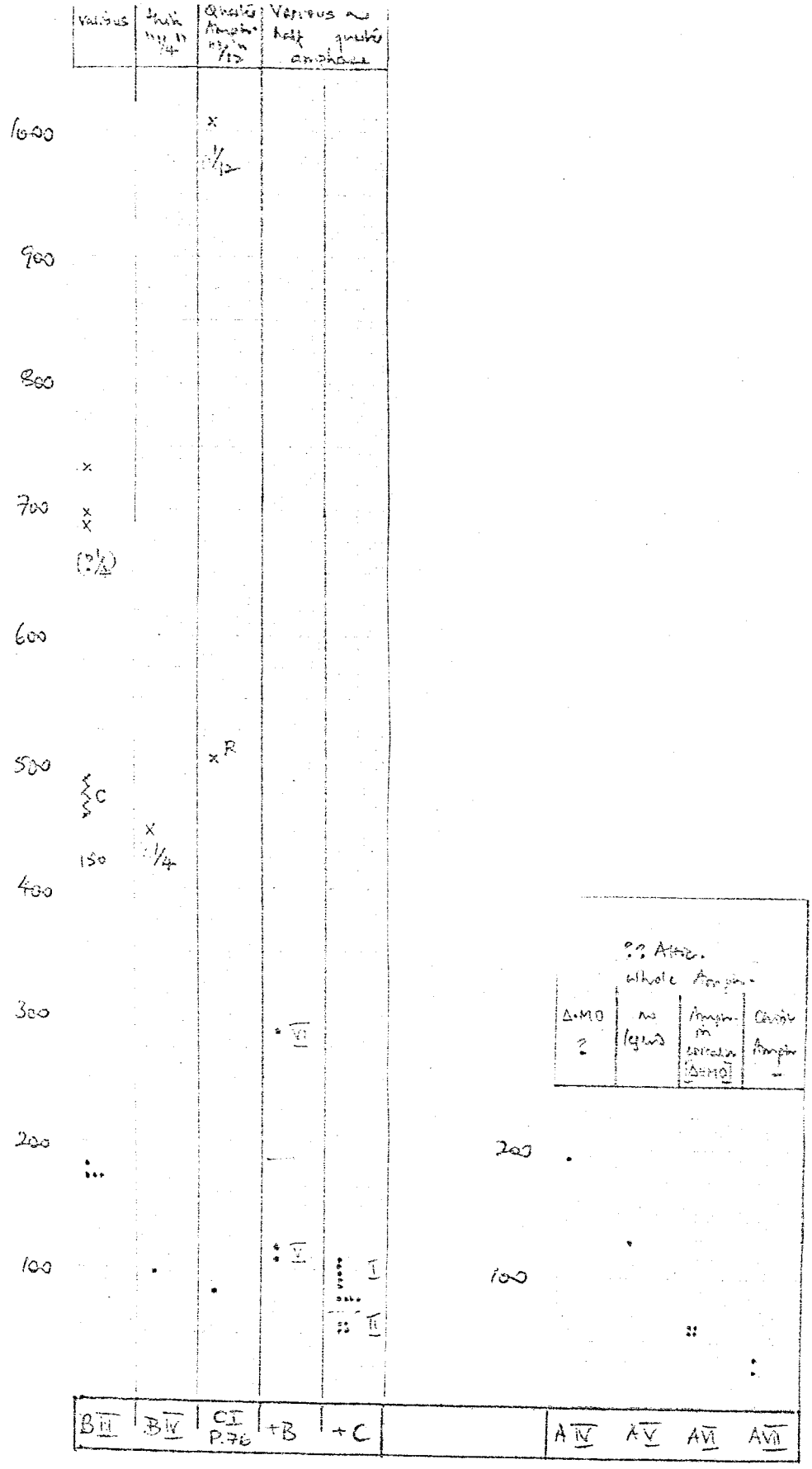
Dolphin (mina corrected to the 100dr standard: C)



Amphora (main groups part one; corrected to 100dr standard - C; reduced to mina projection - R)

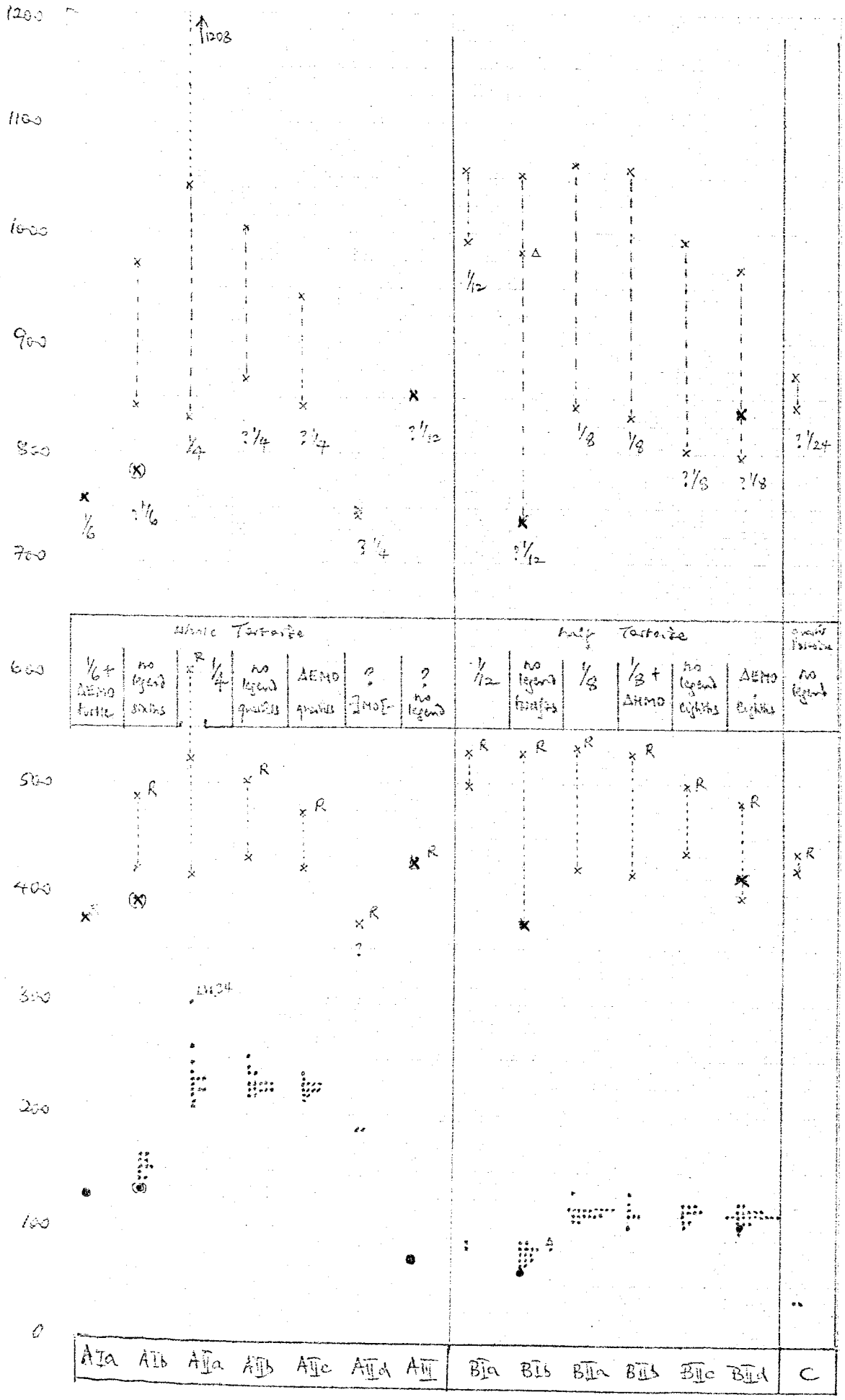


Amphora (contd)



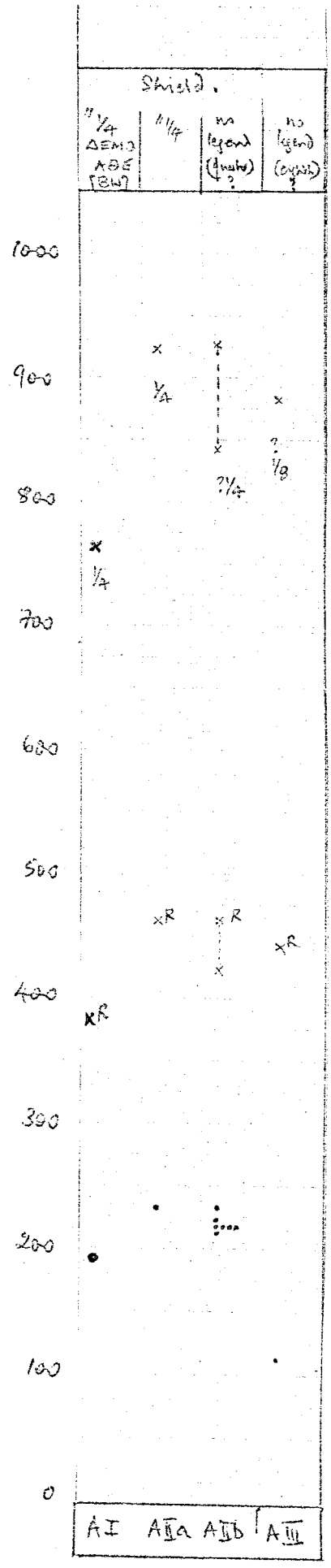
Attic

Turtle and Tortoise (all stater projections also reduced to minai)

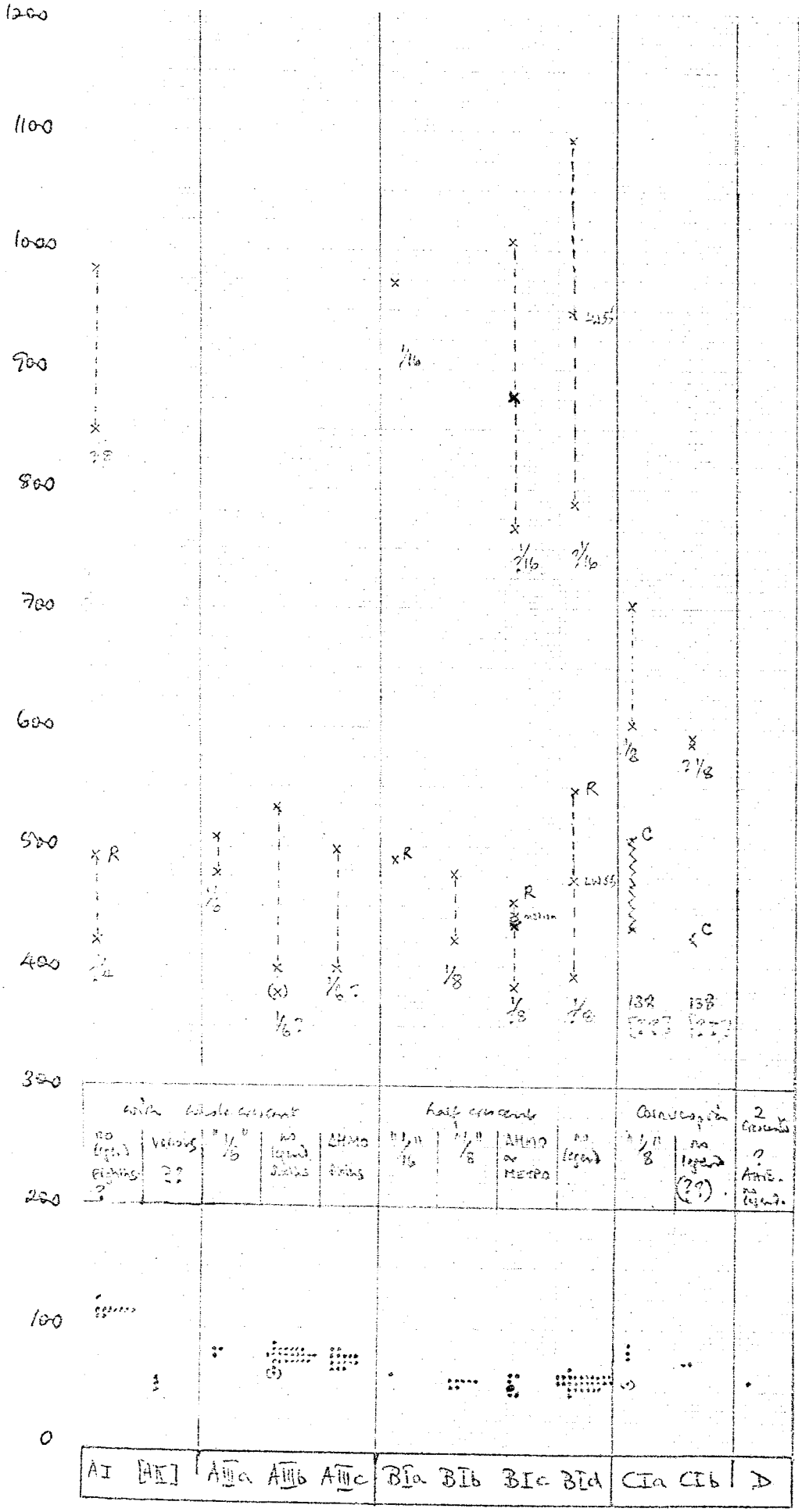


Attic

Shield (stater projections reduced to mina)

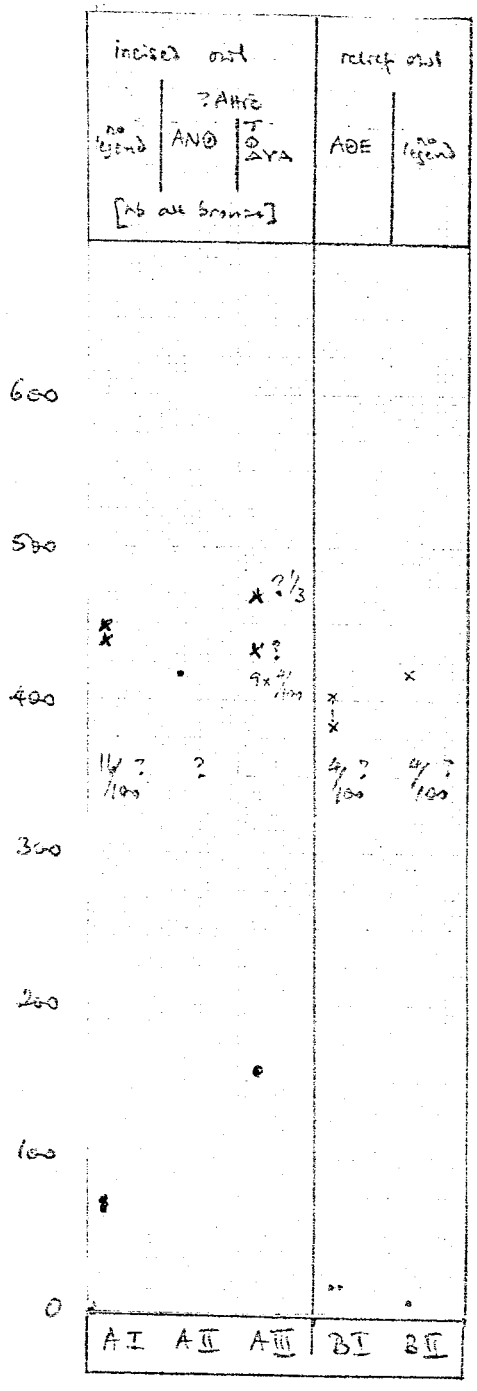


Crescent and Cornucopia (projections reduced where necessary to minai - R; corrected to 100dr standard - C; also two weights of Gp.C.II)

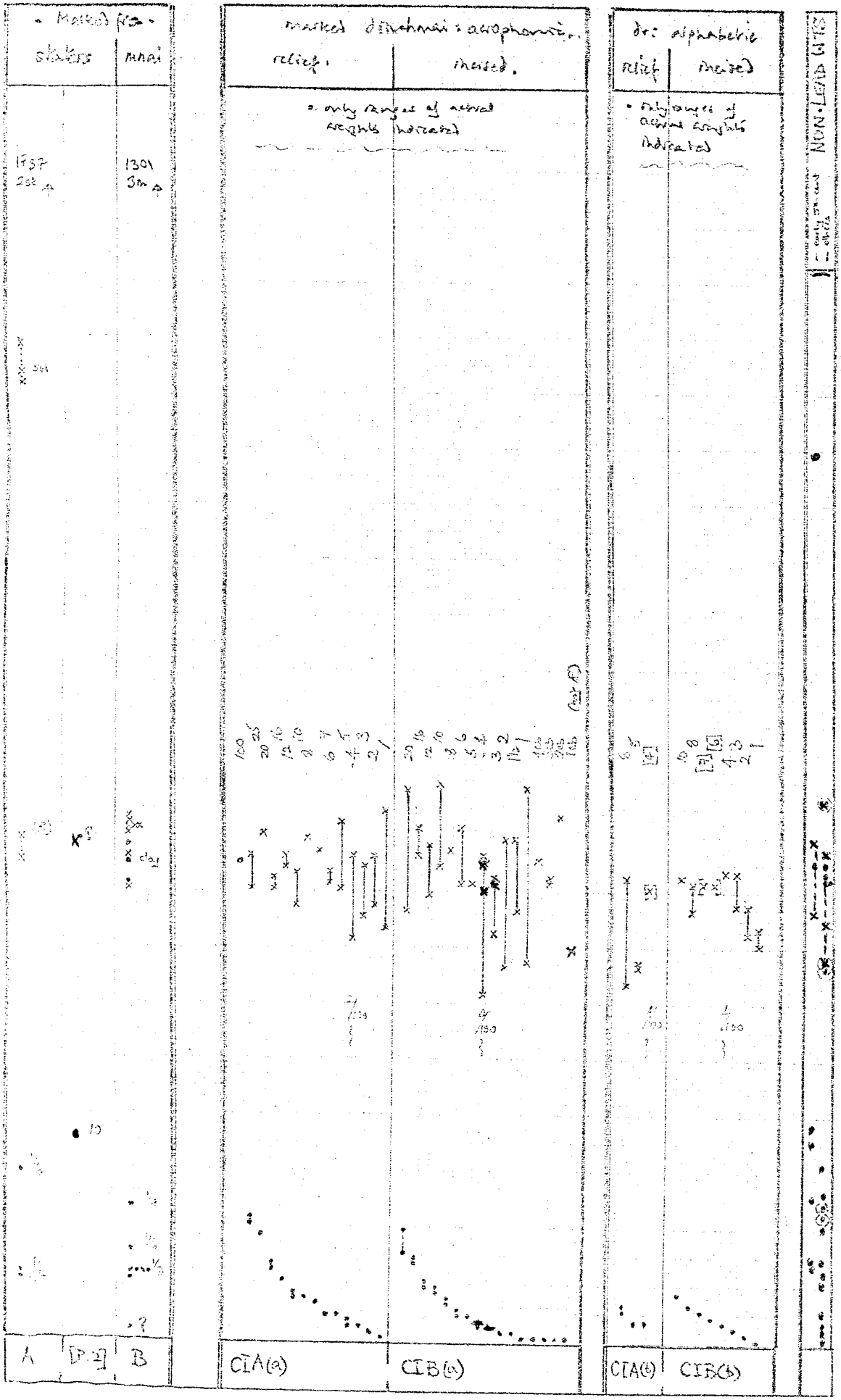


Attic

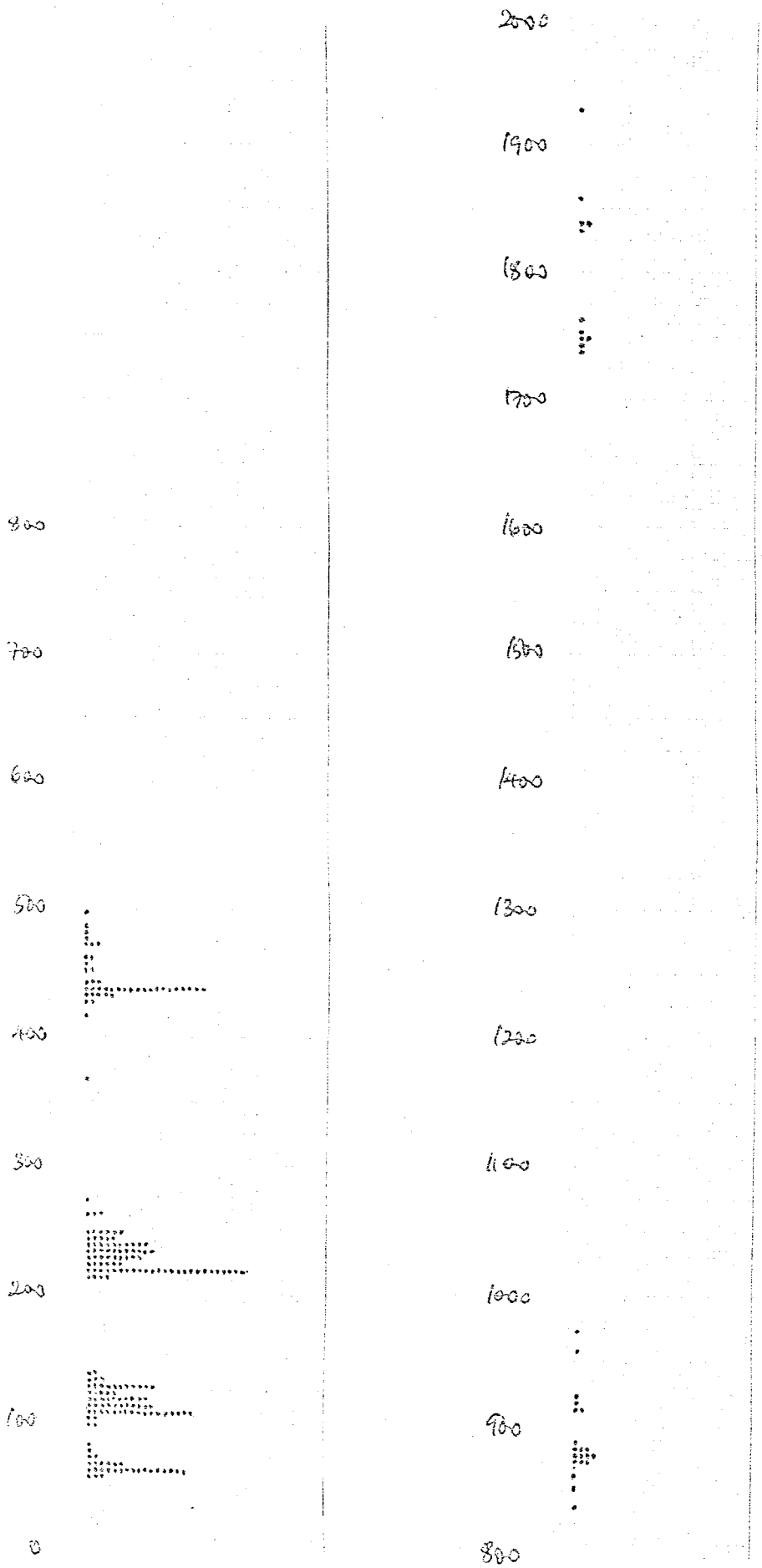
Owl


incised owl
relief owl
?Attic
no legend
AN⊙
AΘE
no legend
[nb all bronze]
600
500
400
300
200
100
0
A I
A II
A III
B I
B II

Weights without symbol but marked staters, minai, drachmai and fractions



Olympia weights



NOTES

Chapter I

1. Thus for example B.Kisch Scales and weights: a historical outline (1965) and F.G.Skinner Weights and measures (1967).

2. See in general ch.IX and IX.1.(6) on the fair number that have survived even from the Greek bronze age.

3. The twelfth-century balances from Enkomi formed part of a foundry hoard: H.W.Catling Cypriot bronze-work in the Mycenaean world (1964) esp.278-81.

4. See below ch.I.2.(2).

5. Standard abbreviations are used (see introduction to Beazley's Attic Black-figure Vase Painters [ABV]). The following works are more specifically related to the present subject however: J.Frel "Erotostasia" Klearchos (1963)125-8; J.W.Graham "The ransom of Hector on a new Melian relief" AJA 62(1958)313-9; T.Ibel Die Waage im Altertum und Mittelalter (1908); E.Michon Daremberg-Saglio Dict. Ant. sv.Libra (1904); Erika Simon Die Geburt der Aphrodite (1959); F.Studniczka "Das Gegenstück der ludovischen 'Thronlehne'" JdA 26(1911)50-192.

6. The length of beams is indicated where practicable in terms of the length of the operator's forearm (from elbow to wrist as LSJ sv.πῆχυς). This provides a convenient relative guide to sizes. For absolute measurements, if they are required, I should suggest 30cms or 1 ft (to judge from my own experience) rather than 0.462m (Hultsch GRM Table p.697).

7. See esp.ch.VI.4-5.

8. On both C.3 and C.4 the point of beam-suspension is out of sight. It is therefore unclear whether the balances are portable, or had some sort of stand.

9. See further below ch.I.2.(3)-1 [central suspension].

10. See ch.VI.4.(1) [Kairos].

11. On this sort of device, which on experimenting I suspect Greek balances needed, see below ch.I.2.(3).

12. Ch.VI.5.(5) and note VI.3.(2).iii [Greek Justice and the balance].

13. Arist. De Caelo 311.b.9ff, discussed below in ch.VIII.1.(1)-1.

14. On which doubts are raised (and the evidence cited)in ch.III Conclusions and ch.IV.

15. See further below ch.VIII.1.(1)-2.

16. G.Wiessner Lexicon der Alten Welt (1965) sv.Musikinstrumente B [9] coll.2029-30 with Abb.160 col.2027.

17. The modern term apparently is the bismar, or Danish steelyard.

18. I.Düring RE Supp. XI sv.Aristoteles (1968) 315; E.W.Marsden Greek and Roman artillery: historical development (1969) 71 n.4; P.Fraser Ptolemaic Alexandria (1972) 427-8. Morrison and Williams Greek Oared Ships (1968) 291 however regard the author as fourth-century, and T.Ibel Die Waage im Altertum und im Mittelalter (1908) 30, despite "aus der Schule von Aristoteles", refers to the treatise as in fact by Aristotle.

19. P.Duhem Les origines de la statique (1905) I.79ff: Ibel Die Waage 44f, 52f; E.J.Dijsterhuis Archimedes (1956) 14-18.

20. Plut. Marcell. 14.7-8.

21. As Duhem, cited in n.19 above.

22. See below in ch.VI.1 [Ancient theory of weighing]: Arch. Equilibr. I.

23. As cited above in n.19.

24. And so third-century AD.

25. With apparently metal bracing on H.1 at least.

26. An example has survived from the third shaft-grave of Mycenae of a tube of gold-plating around the (now charred remains of a) wooden beam: H.Schlieman Mykenai (1878) 228 and Abb.301/2.

27. Certainly wood as well as lead for balance pans seems ruled out in the model Aristotle used for the experiment at De Caelo 311.b.3-4.

28. See references LSJ sv. root πλαδ- (rather than πληθ-).

29. Disregarding the evidence of bronze beams and pans (above 2 and 3).

30. See above in evidence under Olynthus for examples of such disks.

31. Ch.IX.1.6.

32. On Homer see ch.III Conclusions. It is clearly ridiculous to suppose that the ἀνθρακηρὰ μέτρα (also ID 509) were made of charcoal.

33. See below ch.VII.2.(11) and (12).

34. For ancient Greek theory see below ch.VI.1.

35. See ch.VI.5.(3).

36. See Appendix A on modern theory.

37. As reconstructed by Skinner Weights and measures (1967) 33, 39, 48 and pl.V from the mid-fourteenth-century Tell el 'Amarna model. See below ch.IX.1.(1) [Egypt] n.8 no.(11).

38. Unless the dotted line indicates a features of beam suspension not being used on this occasion as the balance is hand-held.

39. Ibel Die Waage 60 fig.18, and the steelyard of type Rep.U.I drawn on ibid.63 fig.20 (also Michon DS sv.Libra fig.4479).

40. Agricola De re metallica (Basel, Froben, 1556) 267 - reproduced by C.Singer, E.J.Holmyard etc. A History of Technology (1956) II 746 fig.678.

41. See below ch.VI.1 [ancient theory] and in this chapter following discussion of checks on beam swinging/overtilting.

42. See ch.VI.2 and 5.

43. Ch.VI Conclusions.

44. See discussion of the metaphor involved: Ch.VI.4.(1).

45. And see further diagrams there of reconstructed balances using the principles here inferred for ancient Greece.

46. Of stable types were the balance of Heron Mech. 34c, one type in [Arist] Mech.§2.850.a.6 and the bismar at §20.854.a.10, possibly Rep.P.8, and that used by the purple-dye sellers, [Arist] Mech. 849.b.38ff.

47. See further for references ch.VI passim.

48. Also Il. 15.410 etc, the tug-of-war metaphor ἐπὶ ἴσα μαχὴ τέτατο, and see below ch.VI.4.(2). Despite Dietrich and West, the image is not that of the balance.

49. See Appendices A and B on the problem of non-rigid beams in theory and practice respectively; there is no evidence however that the Greeks were aware of (and so might use the verb τιτωνω to describe) this possible weakness in design.

50. For πῆγμι in this context cf. Plato Tim.63b.

51. The verb ἑλκειν, as here, is later more usually applied to the amount something weighs (ie. pulls over the beam), and αἴρειν is used for lifting the whole balance (thus Plato Tim. 63b). ἕλκειν however occurs again in the same sense as here in ἀνέλκει Il.12.434 (on which see following).

52. See experiments (Appendix B) which showed that sensitivity was not much affected by minor deviation from the horizontal in the initial beam position.

53. They are patently inadequate representations of minute weight differentiation by a stable balance. This the artist would have surely exaggerated. Moreover it was not at all appropriate to the life/death situation to which the weighing related.

54. Hence my reason for uncertainty over the interpretation of the dotted line (see n.38 above).

55. References in LSJ.

56. That is, C.1, C.3, C.4 (no side operators; was this for simplification for the artist ?). The frame types H.1 and H.2 are possibly different, but it is not possible to elucidate how they were used if other than for C.1 etc.

57. As discussed above on the materials out of which Greek balances were constructed: ch.I.2.(2).

58. If the weight was simply an ad hoc amount of wool this difficulty is very much reduced: ch.V.

59. An alternative could be noted, although it casts doubts on the reading of the MSS that give this passage. The usual simile of balance is a stretched rope; could not the weight (στάθμον) be part of a secondary spinning operation (stretching the thread) ? This operation is also included on the wool-manufacturing scene C.2.

60. She is doing something. ἴσασουσα, transitive, rules out any reference to the swinging of a stable balance as it approaches level.

61. On the point of the simile (and especially its last line) see below ch.VI.4.(2).

62. But see below ch.VI.3.(2) on Justice.

63. Appendix B. The difficulty is a practical one, namely to notice the initial movement of the beam and so determine whether absolute balance has at the outset been achieved. This affects the speed of the operation, and is in turn affected by damage to the balance (such as could have occurred in previous overtilting).

64. See M.Lang "Numerical notation on Greek vases" Hesperia 25(1956)1-24; also below further in ch.VII.1.(5).

65. Appendix A on the modern balance.

66. This is, admittedly, a theoretical argument, as no doubt the Greeks progressed beyond the limit where suspension error was greater than the accuracy of the method used.

Chapter II

1. E.Pernice Griechische Gewichte (1894); M.Lang in The Athenian Agora vol.X (1964) Part I pp.2-38.

2. See especially ch.IV.

3. Agora X p.5

4. For example Woodhead, Study of Gk. Inscriptions (Pbk.1967) pp.109,111, dates the acrophonic down to 100BC, the alphabetic from 200BC.

5. The presence of weights not belonging to the main Attic series in Athens or Attica is however evidence of the lack of official standardisation in practice. As there is sufficient variation in even the main series to question that such official control amounted to very much (see below VII.1 and VIII), analysis of the few atypical, non-Attic, or un-marked weights from Attica would seem unlikely to add significantly to the overall picture.

6. The same problem of inadequate marking recurs of course for Greek coinage, especially the fractional: compare further below ch.II.2.

7. Pernice GG 16-19; Lang Agora X 6ff.

8. Incised with "ANΘ" and from Sicyon (P.686); cf. also P.779.

9. As by Lang; see above discussion of Turtle/Tortoise type.

10. Note further that several are without parallel on even the most varied of Attic coinage (the early Wappenmünzen) - e.g. Shield and Dolphin.

11. BW.1-3, also P.492,503. The weight P.Supp.1 however was found in Asia Minor.

12. This fact may however be a distortion resulting from the difficulty of identifying weights of the less well-known non-Attic series unless they are explicitly marked.

13. See further below ch.II.1.(1) V.3 and note 93.

14. Thus Pernice GG 15-16

15. P.685,693,696-7,699(?),727-8,694(?),731,733,746(?); Pernice GG.p.62 (two weights from Smyrna); P.Supp.1; also the Olynthus weights if they are not local copies of Athenian.

16. For example the Corinthian bronze discoid weight with relief Boukranion but incised inter alia [K]ορινθιον (see ch.II.1.(2) sv Corinth). Other non-Attic weights are more doubtful, but perhaps P.272,583, 670 are such. That weights did travel between states is also shown (apart from Athens) by the Smyrna weight found at Abdera (see Pernice GG.p.68 numbered P.707).

17. Contrast Pernice's individual analysis of stamp types, GG.19-23. The whole question of stamps is considered in detail below ch.II.1.(1).V.

18. Pernice GG p.23 "Den besten Beweis wird jedoch erst die metrologische Erklärung der einzelnen Gruppen liefern..." (to end of paragraph).

19. The Attic "mina" in fact presents a range from around 310gm to over 775gm. Such a vast range, constructed legitimately on Lang's principles by overlapping projected, corrected and actual mina-weights, surely counsels caution.

20. See following (this page).

21. LW.55 (½Crescent BId) with "5th-4th century" context, and LW.56 (a marked Stater weight) with "late 5th - early 4th century" context are almost certainly to be placed late in such contexts.

22. Though quite early in the fourth century in view of LW.56 (n.21).

23. See further below ch.II.1.(1).IV and ch.VII.1.(2) and (4): the manufacture of weights, control, and whether weighing was part of the process.

24. See Pernice's illustration of P.1.

25. Exceptional are the early bronze weights of the main group (where the inscription is incised but must be contemporary by letter forms, especially the three-barred sigma) and at least one relief "M(NA)" on the weights without symbol (P.277, which may be non-Attic as so exceptional, although both provenance and [dare one admit it?] weight are right).

26. All dr-relief weights are lead except for the bronze P.563 (IIC), which is extraordinary in shape and wrongly marked.

27. See below ch.II.1.(2) sv.Argos (P.681) and Seleucid (P.158,272) for examples.

28. Non-Attic provenance is only certain for P.Supp.12 (from Asia Minor; but the oval stamp oblitterated by a later incised "MN(A)" may well have been put on the weight prior to its being taken away from Athens; the present condition of the weight precludes inferences from its very low weight of 409.75gm). I should argue that the ½Tortoise P.158 probably received its Seleucid-type stamp abroad (if it was not actually found there, for Pernice notes doubtfully "vielleicht aus Athen"). Presumably return-journeys (? with the same ship) were equally possible: see for example the ½Crescent P.728 (found on Aegina, with the inscription "ETOYΣ MH MH", a Seleucid date).

29. With the names of Agoranomoi or with more specific geographical relief legends (but see n.12 above ch.II).

30. River-gods on P.626, 628; cornucopia and branches on P.648; emperors on Michon DS sv.pondus fig.5744.

31. Pernice GG p.19; Lang Agora X p.22; Kroll Hanfmann Studies p.88.

32. See ch.VII.1.(4) below.

33. Pernice's only illustration, of the ATHENA I (Metronomoi) stamp, appears, somewhat idealised, on the title page of GG in a line drawing.

34. Pernice GG p.22.

35. Including both stamps and relief types (see section V.3 following).

36. Loc.cit. n.31 above.

37. See Head HN^2 388-9, dividing third-century Attic bronze coin-types between early Attic, Macedonian, Eleusinian and Delian parallels.

38. Contra Lang, Agora X 21f, who argues towards the general rule from this particular "countermark" on LW.17 and P.6. See further below part 5 of this section.

39. Stamping was more difficult on bronze, and at times repeated attempts were necessary before a clear image was obtained (thus I argue against Kroll's assumption that the multiple stamps on his weights were to cover the surface of the weight and prevent defacement).

40. Assuming that it preceeds the Boukranion of similar weight and that $IG.ii^2$ 1013 introduced the 150dr-mina for the first time around 100BC.

41. Kroll Hanfmann Studies 90 n.13.

42. Elsewhere in the inscription, where weights as well as measures are meant, they are also specified, despite the tedious repetition involved (eg. 8,10,11,15,17f,38,39 etc).

43. Further difficulties surround the phrase μὴ πλέον πραττομένους τριωβόλου (l.65). In view of the parallels noted with the owls on fourth-century 3-obols and 2-obols, the reference may be to the stamp and may indicate a direct use of coins for stamping (with the cost or duty represented by the coin used). This would explain why we read πραττομένους rather than πράττοντες, as the officials would of course pocket the coin involved. However the charge may equally be for some other activity (unspecified) in which the officials are required to use the standard measures - the checking procedure itself perhaps. "πραττομένους" may indicate that the fee was what the state paid the officials for conducting their proper policing duties.

44. See below ch.VII.1.(4).

45. Arist.Ath.Pol.51.2

46. Along with other minor ad hoc adjustments as, for example, the notorious nut-measure in ll.21-25 (see Lang Agora X 43 and DM.66 which, though clay, she identifies with the wood measures specified by the inscription, l.25).

47. Line 39: Diodorus, the son of Theophilos.

48. See inscriptions listed and discussed in ch.III below (sv.Athens).

49. They are of course supplemented by weights with relief types explicitly naming the Metronomoi, and, in a later period, by those bearing "AΓOP" (which I argue below section V.2 to refer to the Agoranomoi).

50. I suspect that such attribution in Pernice derives simply from the weights in question being in Athens museum.

51. The Acropolis set certainly is never mentioned as being used (compare the weights sent there to be kept in the earlier fourth century IG ii^2 1401.2-3, 1407.40-1). In IG ii^2 1013 the Skias is the main Athenian centre for practical purposes.

52. See further below VII.1.(2) and (3) on the problems surrounding the conversion of silver mined at Laureion into Athenian coin. There appears to be absolutely no evidence of how this was in practice done.

53. As "K" on P.381, and "EV" on LW.26 as noted by Lang.

54. This was Pernice's explanation for several odd types, but as he admitted "ohne einen bestimmten Beweis dafür liefern zu können".

55. Thus perhaps the Seleucid merchant who used Seleucid coins to stamp his weights (or to decorate them as P.272 - there is little doubt but that the weight was originally Athenian).

56. Kroll Hanfmann Studies 89f; see above (ch.II) n.39.

57. In fact about 32 of the 52 collected.

58. Both standard and absolute weight (see further below on the precision of Attic weights, section VI) can be understood here.

59. See Table (above end of sect.II) on Distribution of weights.

60. OWL stamps appear on three blank, but possibly drachma weights; also on one incised 8dr. weight.

61. See further below ch.IV.

62. Compare the cut-down ("thin" and "false weight" Lang) Amphora weights or the Astragalos "stater" (P.9) later incised "dimnoun".

63. Agora X p.21 of the stamp on P.6 and LW.17.

64. Hanfmann Studies p.88.

65. Such as indeed applied to the LW.17 (from fourth to third century) !

66. Seen on the market by Conze to have an Athena head stamp on one side and a double-owl stamp underneath (Pernice); the weight has since disappeared.

67. Agora X p.22 for LW.26; it seems also true of P.272 (with four stamps and only one partially legible).

68. Kroll suggests (p.88) that the number of stamps was necessary to cover as much of the surface of the weight as possible and so prevent defacement. This view is absurd: it is only true of his first weight that anything like the total surface is stamped, and it is not approached on any other surviving weight; yet if the motive was as Kroll supposes we should expect all stamped weights to bear many stamps. Like the first stamp on LW.26, most of the stamps on Kroll's weights are unclear, which suggests a different reason for repetition. (see above ch.II n.39).

69. Namely in the offices where weights were to be kept (as detailed by the inscription) and only involving the officials who were then to use the stamped weights.

70. Above ch.II n.45; subequent changes probably include the further offices of the officials concerned with weights, and possibly a change in the titles of these officials (see further section V below).

71. Pernice GG.23

72. An uneasy contrast can be noted here with the state attitude to coin, where the type was apparently the most important feature (see below ch.VII.1.(3) and Appendix E); I am not sure that the contrast is of any real significance however.

73. See further below ch.VII.1.(2).

74. Thus the change from Turtle to Tortoise, and the closeness of Amphora types on coins and weights.

75. Discussed in detail below ch.IV.

76. By drachmae of the 100dr mina standard, which are coin drachmae.

77. It cannot however without circularity be advanced here as an argument in favour of mint manufacture of weights.

78. Collected in Appendix E.

79. Hence the insistence on charaktēr; see below ch.VII.1.(3) and further in ch.VIII.3.

80. Discussed in section VI below.

81. Δεμόσιον Ἀθεναίον on BW.1 (Astragalos AIIa), BW.2 (Shield AI), BW.3 (Turtle AIa) and on P.1 (Dolphin AIa).

82. Owl BIb, possibly a special category.

83. I omit the confusing "Δ" on drachmae weights; it is impossible to decide between "Δ[ημόσιον]", "Δ[έκα]" (10drs acrophonic), or "ϛ" (4drs alphabetic numbering).

84. See analysis of Amphora weights above at note 3; this exception is unfortunate as it occurs in an area of considerable uncertainty in the whole Amphora series: its significance cannot therefore be easily assessed.

85. The weights are: P.604 (Boukranion AI, apparently on the 150dr mina standard); P.598-599 (Dolphin AIIa); and P.97 (Amphora AII). See earlier analyses of these types for further details.

86. Pernice GG pp.54-7, followed by Michon DS sv.pondus p.558.

87. See the detailed discussion of ἀγορά and related terms by de Sainte-Croix, Origins of the Pelop. war (1972) 267ff and 396f.

88. SEG X 368 and H.A.Thompson in Hesperia 37 (1963) 61-3

89. Closely comparable would then be the weight with relief type "HMI METPO" (BB.2233); see following discussion of the Metronomoi.

90. See below ch.VII 1(2)1, 1(4)4; ch.VIII.1(1)1 - (example 6 on the weight variation between stale and fresh bread).

91. The Peiraeus had its own Agoranomoi (and also Metronomoi) according to Arist.Ath.Pol.51.1 (and 2).

92. Pleket 10 [IdD 509] with IG xi(2) 287.B.142f., both third-century Delos. In first-century Andania (Messenia) regulations for the duties of Agoranomoi include that they ensure people use σταθμα και μετρα συμφωνα προς τα δημοσια (IG v(1) 1390.100) as well as that they sell ζυγα και σταθμα (1.99), which comes closer to the earlier Athenian Agoranomoi duties. Elsewhere weights bear the names of officials called Agoranomoi: Memmius Agathocles of Tegea (IG v(2) 125, first century AD); Menexenos of Phocis (Kroll C, argued to be third century BC); etc..

93. The weights are: P.597, LW.10 (Dolphin AIIa; both on the 150dr mina standard; possibly a further weight noted by Michon DS sv.pondus p.557 n.30 belongs to the same category); LW.31, 32 (½Amphora BIIa; again 150dr mina standard); BB.2233 (Amphora ? class.); stamp ATHENA I METPO on P.271, 405 (Wheel(?)CI and II; 100dr mina standard); stamp DIONYSOS METPO on P.6 (Astragalos AI; 150dr mina standard) and on LW.17 (Amphora AIa; for weight standard see above type analysis); METPO stamp on P.323 (½Crescent BIe; again see type analysis for weight standard).

94. Published by Vanderpool Hesperia 37(1968) 73ff; dated 222/1 BC. Unfortunately the inscription breaks off after the measures held by the Metronomoi have been listed; it is not known what weights they held, though that they held a set is clear.

95. The only areas of doubt in the weight arrangements proposed in my analysis of Attic weights are (a) whether any 138dr mina standard weights can be securely identified (all are in fact hypothetical), and (b) the weights that appear too heavy for the top 150dr mina standard (½Amphora BIIabc, although they are associated with the Amphora AII weights of a more reasonable range). There is no serious question of identifying on the evidence of weight weights any further standards intermediary to 100dr and 150dr mina standards.

96. Eg. P.261 and see Lang Agora X p.5. I discuss the implications of official control above sv. Stamps and see further ch.VII 1(4).

97. Pernice's "heavy drachmae": see above in the analysis of drachma weights (Classes IAB and IIC).

98. Pernice GG 12-13; Lang Agora X 17-18. See also Robinson Olynthus X (1941) 450 and Davidson Hesperia Supp.7 (1943) 27.

99. A problem here lies in the fact that many bronze weights seem to belong to different (especially earlier) periods than the lead. The few that do overlap however are sufficient to make correction possible.

100. Especially Wheel weights: see Table Actual variations in Attic lead weight groups (following) with graphs (Appendix F) on which it is based.

101. Admittedly this argument is tentative; the bunching in question could be entirely due to chance.

102. See Table: List of non-lead weights (following).

103. Pernice GG 50-53 (100dr tables); and Lang Agora X 13-18.

104. Larger weights only to a certain extent need involve greater inaccuracy, and the question of precision (in terms of preciseness) in weighing is determined by other factors than the weights and machines used: see further ch.I 2 and 3 with Appendix B on Greek balance design and possible performance, and ch.VIII for a discussion of accuracy, precision, and the practice of Greek weighing.

105. As in Lang's tables Agora X pp.13-16; though the projected unit base is given in brackets, the weights are arranged in orders determined by this base weight and the theoretical reconstruction of Attic weight systems proceeds from it.

106. It may be helpful to quote Lang here. On p.17f (Agora X) she argues (and the square brackets are mine) "The concentration around 900-920gr. [ie. the projections] obviously belongs to the 105 standard, which on the basis of a drachm of 4.36gr. would be 915.6gr. [ie. projected to the stater]". Further standards she suggests are 1203.36gm (twice 138dr mina), 1308gm (150dr), 1098.72gm (126dr), 1526gm (175dr), and 976.64gm (112dr). Earlier (p.4) she is less specific: "everyone would agree that the Solonian coin drachm must be somewhere between 4.2 and 4.4gr"; she cites Hultsch GrM 208 for 4.366gm, Viedebantt Forschungen 51-56 for 4.26-4.32gm, and Seltman GC 41-45 for 4.25gm (4 n.5), but then goes on in the same paragraph "since we shall be dealing for the most part with larger units it will be more convenient and no less accurate [!] to use the most generally accepted coin drachm of 4.36gr. rather than the more cumbersome range". There are two critical errors in this approach: first it cannot be assumed that the Attic drachma is a weight to be more closely expressed by increasing decimal figures of grammes; and second the vagaries of a drachma weight will be very much greater when multiplied (by as much as x200 for stater projections). Lang's approach to the Greeks weights is exactly similar to the method she uses with the Roman (p.23) "the weight of the Roman pound has long been established as 327.45gr [citing the figure Hultsch reached some time ago]. The ounce is therefore 27.29gr."

107. I have omitted however the poor ½Amphora BW.4, and the Dolphin P.261 (stone) and "ΜΝΑ (Φ)ΑΣΙΜΗ" MW.6, of which the weights are uncertain. Drachma restorations are included, though I have noted where the range given is dependent on such restoration.

108. I am excluding bronze weights here even though they frequently lie within the ranges of the lead; on two occasions however they would distort these ranges.

109. See Tables: Ranges of Attic lead weights and Ranges of Attic non-lead weights (above pp.152-3).

110. The two-mina Astragalos is marked 206drs where 200dr would be expected, and the quarter-mina ½Tortoise is marked 26dr 1½ob rather than 25drs.

111. I am uncertain how to take the limits in these cases; a factor of three is involved in every one.

112. Superficial precision (preciseness) should perhaps be suspected: see further ch.VIII.2.

113. Especially in BW.6, where the "X" of the incised "ΓΗΧ" need not be read as part of a weight (as Lang) but could be simply a mark of bad weight (compare Olynthus 2413-4 below). I very much doubt that Greeks ever weighed in "chalkoi" (which were essentially bronze coins, whose value rather than weight was equivalent to an eighth obol): see below ch.VIII 1(1)2.

114. See references in n.104 of this chapter above.

115. Discussion of the various issues raised in this analysis of Attic weights is resumed below in ch.IV.

116. The absence of weights at Delos strikingly contrasts with the abundance of capacity measures found there. 58 (more than anywhere else in the Greek world) elaborate "sekomata" are described by Deonna Delos XVII 167-85.

117. Davidson explicitly commented on the small number of Greek weights from Corinth Corinth XII 204: and see further below sv.Corinth. Comparison with the notorious imitation Bird-bowl that Orsi failed to bother cleaning at Gela (Adamesteanu "Vasi gelesi arcaici di produzione locale" Arch.Class. 1953 244-7) could be argued here; but the identification of objects as weights has in the past tended to over- rather than under-estimate the number of actual weights.

118. I am thinking here of recent work by Kroll Hanfmann Studies (1972); Zancani-Montuoro Annali (1965-7) for which see below on the small South Italian group of weights with "Ɗ" (following Corcyra); and Lang, especially in this context in ANSMN (1968) for which see following under Cos, Smyrna, etc.

119. The best recent survey is by Cahn "Etalons monétaires en Asie-Mineure" CIN 1961 (1965) II.19-23. The provisional nature of Head's treatment of coin weight standards (see HN^2 p.xxxix) is apparently often disregarded. Perhaps most fundamental is the question of how coin and weight standards were related, and I consider this in the following part on coinage, but in greater depth in chs.IV-V.

120. Barron Silver coins of Samos p.7 and n.1: see further below under Samos.

121. D.1581.

122. P.687; P.388; and the unnumbered weight cited by Davidson at 127.15gm and marked "ꟻ" in relief.

123. Weights of Chios (qv) indicate three possible standards, but they cannot be dated precisely enough to show that these standards (if different) were contemporary.

124. This development towards internationally recognised standards is pursued in chs.IV-V.

125. Corinthian weight incised "πεντταιον" (Davidson); Olynthian weights 2401 and 2415 (Robinson). In any case five multiples of a lower unit are an equally possible interpretation; it is much more reasonable for example for the Corcyra weight P.764.

126. See also graph in Appendix F.

127. See chs.IV-V.

128. Annali 12-14(1965-7)21-30: see further at the end of Corcyra in the following section.

129. The mina lies between 642.8 - 636.6gm, equivalent to 100 coin drs. of around 6.39gm: see Soutzo CIN (1900) 116-20 and below sv.Thrace. I have already doubted Barron's correlation of the early Samian bronze weight with the coinage of the period.

130. For the use of weights in general (and by temple officials in particular) see ch.VII (esp.1(4)).

131. Olympia, Miletus, and Thracian Heracleia.

132. The Cos bronze square with raised lettering (see below sv.Cos) is unique; the piece may not be an actual weight.

133. I have however noted two Seleucid-type stamps: HORNED HORSE HEAD and the accompanying [BASI]ΛE[ΩS] SEΛ[EYKOY] (see above lists in ch.II.1(1)III). For Roman, see for example Michon DS sv.pondus fig. 5744.

134. For two-sided relief note especially the plain lattice reverse on the Antiocheia weight (Michon fig. 5736). The same weight has carefully-defined edges, though this feature is most noticeable in the weights from Thrace, for example see Tomis.

135. See ch.VII.1.(9) for evidence and full discussion.

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136. See the general introduction to ch.II above.

137. Aristotle Politics 1256b40-1257b10; M.Lang Agora X (1964) 2ff; L.Breglia Le antiche rotte del Mediterraneo documente da monete e pesi (Rendic.Lincei. 1956); see below ch.V.

138. C.M.Kraay "Hoards, small change and the origin of coinage" JHS 84 (1964) 76-91.

139. See further in ch.V below. Contributing to the debate, after Hultsch GRM^2 (1882), can be noted: W.Ridgeway The origin of metallic currency and weight standards (1892); B.V.Head in HN (1911) introduction; C.T.Seltman Athens: its history and coinage before the Persian invasion (1924), hardly altered in Greek Coins (2nd.ed. 1955) chs.I-II; E.Will "Réflexions et hypothèses sur les origines du monnayage" Rév.Num. 1955 pp.5-23; R.M.Cook "Speculations on the origins of coinage" Historia 7 (1958) 257-62; K.Christ "Die Griechen und das Geld" Saeculum 15 (1964) 214-229; K. de B. Codrington "The origins of coinage" Bull.Inst.Arch.Univ.Lond. 4 (1964) 1-24 and "The basis of coinage" ibid. 6 (1966) 15-28.

140. Hultsch GRM^2 tab.XII p.705; a better example, perhaps, could be S.C.Langher's estimate of the Sicilian litra as "precisamente 0.8683gm" ("Aes rude e monete utensili del thesauros di Mendolito di Adriano (730-650 BC)" CIN 1961 II (1965) p.13 n.23).

141. The question should be asked of whether this eighth-obol was a real weight or merely a theoretical. Its value of under 0.1gm was less than half of what I have shown to be the minimal detectable difference on Greek balances: see following note, but further detail in ch.VIII.1.(1).2 below.

142. This question forms the subject of ch.VIII below. Minimal detectable weight difference should be distinguished from minimum measurable. A convenient way to regard the difference is that the former expresses the accuracy of any weight measurement.

143. See especially ch.III.3 Conclusions; IV-V; VII.1.(2) part 3; VII.1.(3); VIII; and Appendices C, D, E.

144. See the works cited above in n.139.

145. IG II^2 1013; see below esp. ch.IV.1.

146. A.S.Hemmy "The statistical treatment of ancient weights" Ancient Egypt 4 (1935) 83-93 and "Weight standards of ancient Greece and Persia" Iraq 5 (1938) 65-81. See earlier: G.F.Hill "The frequency table" NC 1924 pp.76-85; and more recently: D.D.Kosambi "Scientific numismatics" Scientific American 1965 pp.102-111; L.R.Laing Coins and archaeology (1969) 100ff. In practice however the procedure is very subjective; for example, W.P.Wallace in NNM 134 (1956) 68-71, but esp. p.70.

147. C.M.Kraay "Caulonia and South Italian problems" NC 1960 pp.53-82 on pp.64-6. Kraay detects a dramatic fall in the weight standard between Noe's groups F and G by taking the percentage of coins over 8gm. He equates this drop with a fall elsewhere and uses his chronological subdivisions to date the Caulonia series. This is somewhat unconvincing for the reasons I have already indicated. Two further points can be added: as the standard declines (undeniable, but very gradual) so apparently does the accuracy of minting improve (contrast the vast range of the earliest group A) - an effect of which could be said to be less coins minted over-weight; secondly, why choose to draw a line at 8gm rather than 7.9gm etc ? - there is good reason to connect declining standards throughout the area, but to argue the precise standard of one city was absolutely equal to the next, begs serious questions about the operation of Greek mints.

148. N.F.Parise "Obole e litre" La monetazione arcaica di Himera fino al 472 AC (1971) pp.15-20 and 114. See further in the "general survey" of Sicilian mints in the following Excursus.

149. See below in ch.VII.1.(2) part 3 on coin-manufacture, where I suggest it might have been possible, by means that did not involve weighing, to produce coins with a weight accuracy higher than could be measured or detected (see also above nn.141-2).

150. Some authority for the wide interpretation adopted here comes from Arist. Ath.Pol. 10, where a change in denomination of usual coin appears not to affect the (notional) basic unit, and is clearly distinguished from the change in weight standard also mentioned in the passage: see further below in Appendix D. In the Excursus that follows I have indicated where terms are those supplied by numismatists, and where they are explicitly marked.

151. See my Preface above, explaining my general approach to the question of Greek weighing.

152. See chapters IV and V below.

153. The situation is parallelled in the use of pottery imports to the Western colonies to indicate changing patterns of trade. Only periods where such imports were most varied offer grounds for interesting conclusions, whereas none can be drawn from the exclusive importation of Attic pottery in the classical period. See further my The archaeological evidence for Greek trade in the archaic period (B.Phil. Thesis 1968).

154. Kraay JHS 1964 (above n.138) on pp.86-7.

155. Aristotle ap. Pollux IX.80f (cited by Hultsch SM p.292); on the litra see the following Excursus, and on both see further in ch.V.3.

156. It could be argued that at any one time in antiquity there would be a considerably reduced number of fractional coins in current use. I do not however feel that a trader, moving from one state to another, would be very much consoled by the thought.

157. HN^2 p.xxxix.

158. These staters were the inspiration of Breglia's Antiche Rotte.

159. 1948; reprinted, surprisingly without alteration, in 1968.

160. H.A.Cahn "Etalons monétaires en Asie-Mineure jusqu'au Ve siècle" CIN 1961 II (1965) 19-23.

161. I have not included similar results obtained from a survey of the remaining South Italian colonies. Each mint-analysis involves a large amount of discussion that the bare tabulation conceals and it would be unreasonable to impose my views further without considerable elaboration. Furthermore the Sicilian mints as a group are less unwieldy than the South Italian. Of course the division is artificial, and Reggio appears inevitably in the Sicilian area.

162. M.I.Finley Ancient Sicily (1968) pp.200-1 emphasises the more general problems of chronology and interpretation of coin use; he does not however mention nomenclature and systematisation as difficulties at all, and indeed uses the traditional coin names throughout without any apparent reserve.

163. Further income, from indemnities (as Siracusa after the battle of Himera), from confiscations, or from the sale of captives (see Finley, above n.162, pp.48-9, 100), could have come in either form. It is interesting to note that the Segestan contribution to the Athenian expedition was sixty talants "of uncoined silver" (Thuc. VI.8.1).

164. Or, as Finley, above n.162, p.36 "a singularly Greek passion".

165. There is no contemporary reference to the early coins beyond the comic writers cited by Pollux. Inscriptions of later date do however support my argument: thus expenses in the Taormina accounts of c.100 BC are listed in large numbers of litrai and talants (SIG^{3}954; IG XIV 422-30). Athenian writers need not always have been as precise as Aristotle in describing the local coins. Possibly the statement that Dionysius I demanded individual contributions of "two staters" relates to local terminology ([Arist.] Oikon. II.2.20b); but the account of his issuing coins countermarked to twice their value τὴν δραχμὴν δυὸ δυναμένην δραχμάς, though from the same source (20h; and certainly late fourth-century if not by Aristotle: Budé ed. p.xiii), must have been rewritten for the Attic audience (quite clearly the manoeuvre was not restricted to a single denomination, and so the drachma value is given solely exempli gratia). Other sums of money mentioned in Sicilian contexts are usually too vague or too high (expressed in talants only) to indicate coin terms: χρήματα πολλά Hdt.VII.163.2; sixty talants of uncoined silver Thuc.VI.8.1 (and presumably by Attic weight); 2000 talants estimated by Nicias in Thuc.VII.48.5; 50 and 100-talant deposit and profit Arist.Pol. 1259a30; 3 minai per person exacted by Dionysius I from Reggio [Arist.] Oikon.II.2.20g; 300-talant indemnities or contributions Diod.XIV.75.1,4 and 106.3; 1000 and 500-talant booty Diod.XV.14.3-4. This list is not complete. Significant however is Diodorus' account of coins made from the 480 BC Carthaginian indemnity (the

165 contd.

Demareteion: Diod.XI.26.3); the coin that was produced (and the problems of Diodorus' confusion between gold and silver can for these purposes be disregarded) was apparently called "50-litrai" by the locals because of its weight: εἶχε μὲν Ἀττικὰς δραχμὰς δέκα, ἐκλήθη δὲ παρὰ τοῖς Σικελιώτας ἀπὸ τοῦ σταθμοῦ πεντηκονταλίτρον (see also C.M.Kraay "The Demareteion and Sicilian chronology" Greek coins and history: some current problems (1969) ch.2 pp.19-42).

166. It is not clear to which coin the term "stater" was applied (see [Arist.]Oikon.II.2.20b) but it is likely to have been the commonest Syracusan coin of the period - thus the 20-litrai "tetradrachm" (to use modern terminology) as I suggest below following in this paragraph.

167. Similarly the 4x, 2x, and 1x indicated by the horses on Syracusan coins.

168. Further. The fact that no price markings on pottery exported to the West refer to litrai or to ozs. must be taken as a fairly firm indication that such price marks as do appear on these vases were placed on them at some stage before they were sold on the island.

Chapter III

1. See below ch.VII.1.(3) and VIII.1.(2).

2. For discussion see ch.III.10 [Herodotus]; III.8 [Pausanias]; and in general V.2-3.

3. M.N.Tod JHS 33(1913)27-34; BSA 18(1911-12)98-132, 28(1926-27)141-57, 37(1936-37)236-58 on acrophonic numerals; BSA 45(1950)126-39 on Attic alphabetic numerals.

4. Discussed in Appendix C.

5. See VIII.1.(2), VIII.2 and in conclusions VIII.3.

6. A similar problem was encountered with the actual weights discussed in the last chapter (see for example chII.1.(1)-VII, conclusions to the review of Attic weights).

7. See ch.II.1.(1)-III.4 (on stamps) and -V (on relief types with such markings).

8. On the use of chalkous as a weight and as part of the silver drachma weight system I am doubtful: see below ch.VIII.1.(1)-2. It is just possible that the term was applied to the silver weight equivalent to the eighth obol, that was the value of the bronze coin. The inscription on whigh the chalkous is indicated (by an "X" concluding a weight) is IG II^2 1485.3. It is not uncommon on accounts however.

9. Head HN^2 367, 369f, and additional note on 391. The main arguments appear to me to be three. First, 2 pellets appear on some of the Wappenmünzen Gorgoneion "tetradrachms" (BM Catalogue pl.XXII.10). Second, Aristotle Ath.Pol.10 mentions that the earlier standard denomination was the didrachm ἦν δ' ὁ ἀρχαῖος χαρακτὴρ δίδραχμον. For this interpretation of χαρακτὴρ see Kraay Robinson Studies (1968) pp.5-6. [Arist.] Oikon.II.4b need prove nothing in this context (despite Head) as Hippias' profit was already made by the tax he imposed (τάξας δὲ τιμὴν); clearer is Philochoros 328 FGH 200 (Schol.ap.Ar.Aves 1106), which incidentally also allows the identification of the "4dr" standard coin as specifically "ἡ γλαῦξ" compared with the earlier "2dr" called "βοῦς"; as "type" however makes nonesense of Ath.Pol.10. The position I am taking here depends further, third, on allowing some overlap in the Wappenmünzen and Owl series, and this has recently been in fact advocated by both Kraay and Hopper (Robinson Studies p.23). The so-called "obol" Gorgoneion and Wheel groups are natural sixths of the Wappenmünzen Wheel and Horse-hindquarter "drachmai" (4.3 - 4.0gm) and would be awkward if associated with the "didrachmai" as twelfths.

10. Head HN^2 375.

11. See ch.IV.2.(3).

12. And see further Appendix D (on Aristotle Ath.Pol.10) and ch.V (on the origins of Greek weights and standards).

13. As on the fifth-century Rhamnous inscription mentioned by Tod BSA 37(1936-37)237-38. For the same reason I would restore the first line of the Parthenon door inscription (IG $I^2$388), which has a drachma figure well over 6000, as a price rather than a weight. See further ch.IV.2.(3).

14. See ch.I.3.(3) but more immediately ch.VIII.2.(5).

15. Respectively groups I, III (but very rare), and IV of the weights listed above in ch.III.1 [Athens].(1).

16. IG $II^2$1686.24-5; 1687.5 etc.

17. δυνασθαι τον χρυσουν παρα τους Ἀττικους δραχμας δυο ; and for another reference see Hultsch SM fr.100.5 with introd. c.102.II.

18. Hultsch SM introd. c.97 (p.156) is cautious.

19. That the 2dr weight was very much more basic to Attic coin has been suggested above in n.9; it was also used for the Lachares issue of gold coins in c.295/4.

20. [Plut].Vit.X.Orat. 852b.

21. IG II^2 cite Koehler-Kirchoffium Hermes I.318 and Larfeld Handb.att. Inschr. (1902) 547.

22. On the loss of weight involved in melting down the gold (ἀφεψησις) compare the entry ἀπουσια on the early third-century account IG $II^2$839.84 (which is of a similar melting down of silver objects: and see in detail below ch.VIII.2.(4)).

23. See following discussion of Side A of this inscription. There is no reason to compare here the conversion factor of x24 for fifth-century Cyzicus staters (IG $I^2$301 with SEG X 233); their weight of c.16gm would give a ratio of around 6:1, but the metal is electrum and not pure gold.

24. 3819st 1dr $\frac{1}{4}$ ob should cost 14T 3837drs plus 11.5drs plus $\frac{23}{48}$drs ie. rather 14T 3849drs at 23drs per stater than the 14T 3525 plus of the inscription. Alternative conversion rates (such as 20drs 3ob) would not reach 14T.

25. Other parts of these stater weights are not in the Accusative but the Nominative: δραχμη χρυσιου and ἑννεα ὀβολοι. They are not in the Genitive either and the introductory phrases (ἀνθ' ὧν το χρυσιον ἐλαβομεν as well as στατηρας) are sufficient to suggest scribal laziness.

26. They cite Arrian Anab.III.6.2; Diod.XVII.48.6; Quintus Curtius IV.8.12.

27. "Populus iusserat ut collegium quaestorum et curatorum coronas a se decretas conficiendas curaret" IG II/III^2 part II fasc.I p.100.

28. Arrian Anab.III.6.2 (as above) but also VII.23.2 (when Alexander was in Babylon in 323 BC).

29. It may be doubted whether Athens was involved in SIG^{3}312.14-16, but what of Arrian Anab. III.5.1 and VII.19.1 ? This evidence is sufficient reason to discount Koehler's Attic law that forbad the voting of crowns above 1000 (silver) drachmai and which, on his view, the vote of a double crown so ingeniously avoided.

30. Cf. Plato Rep. 371d ἀντ' ἀργυρίου ἀλλαξασθαι . LSJ sv. ἀντί AIII(3) cite passages in which ἀνθ' ὧν can be translated "wherefore", but even in these some sort of reciprocal, if not retaliatory, point is involved: thus Thuc. VI.83.1; Soph. OT 264; and certainly Aesch. PV 31. Arist. NE 1110a21, translated by LSJ as "for the sake of", is better rendered by Ross "in return for". This argument can be supported by the genitives στεφανου and στεφανων in the earlier descriptions of the crowns themselves.

31. As IG II^2 rightly infer from the fact that all the surviving crowns are around 48-49 staters (weight or value) and are likely to be ἀπο χιλιων δραχμων (the maximum found for gold crowns). Even if it is assumed that the other scrowns were of the same weight (rather than less, which is more likely to have been the case), seven times 50 staters is less than 620 plus, the numeral surviving in line 64.

32. Related to the Lamian War after Alexander's death ?

33. Above p. 227 (a).

34. One could add here another significant variation on the weighing of gold although it does not point to a different weight system: the gold leaf bought for gilding the column volutes on the Erechtheum was purchased in sheets at one drachma per sheet (IG I^{2}374.282f).

35. At the start of this section on the evidence of Attic inscriptions, p. 223.

36. Delphi FdD III (5) 25 II.A.5-13 (see "Miscellaneous" at the end of the preceding commentary).

37. I do not however believe a weight is involved here (IG II^{2}1184) as argued above under "Demes".

38. IG II^{2}659 (see above under "Miscellaneous").

39. None of these commodities reach sufficiently high weights (over 60 minai or over 30 staters) for it to be possible to exclude talants from the weight systems involved. It is however clear that the stater and mina systems are mutually self exclusive.

40. For example ch. II.1.(1)-VI, and in general ch. VIII.

41. See ch. V esp. Conclusions.

42. The late fifth-century inscription IG IV 39 belongs to the period of the Athenian cleruchy on Aegina and so is properly further evidence of Attic procedure.

43. See above ch.II.1.(2)-III [Aegina].

44. Esp. ch.IV.3; ch.V.5.(2); and Appendices C and D.

45. Derived from coin conversion rates and the interpretation of Arist. Ath.Pol.10.

46. Essentially Pollux IX.86-7.

47. FdD.III (5) 25 II.A.6f ὅλκα ἀττικου [μν]|α ἑνενηκοντα τρεις.

48. SIG^{3}239 (Tod GHI 140), and see further below Delphi and Appendix C.

49. Tod BSA 18(1911-12)103.

50. See ch.II.1.(2) under the cities concerned, noting especially -II [Corinth] and -III [Argolid and Sicyon].

51. For example to Argive coinage in the Epidauros Tholos account (Burford BSA 61(1966) no.6.122f): see next section and also Appendix C.

52. Note however the definition of the Sicilian Dekalitron in terms of the Corinthian coin stater (Aristotle [?] ap. Pollux IX.81; IV.175): see ch.II.2 Excursus on Sicilian coins (pp.204-17). For Pheidon of Argos see ch.V.5.(2).

53. On which however see my review in JHS 91(1971)204-6.

54. Head HN^{2} 441; Babelon Traité III.483ff; Kraay Greek Coins no.519; see also Ἐφ.Ἀρχ. (1903) 96-116. The only reference I have yet discovered to an Epidaurian coin is third-century Delos IG XI (2) 161.37 (apparently to the Epidaurian triobol).

55. He is therefore likely to have been himself a Corinthian although his name does not appear elsewhere.

56. I am not accepting Burford's identification of Aeginetan drachmai on the fragmentary Theatre accounts : B.14.Side A.5,8,10,13 (see her note on BSA 61(1966) p.298). The specification does not appear on the less fragmentary Side B of the stone. On other inscriptions Αἰγινατιον <σε.ἀργυριον> or a total with Αἰγινατιου appears, not Αἰγινατιας as here (and contrary to the claim made by Burford). For Aeginetan stones used at Eleusis compare IG I^{2}313.92f; II^{2}1672.52, 310. I suggest τετραπεδιας should be understood here, or λιθια as in the Delian third-century theatre (IG XI (2) 287.92).

57. As with Kleostratos above (n.55) one may presume that contractors were in fact simply being asked to be paid in coin of their own cities.

58. Καταλλαγα τουτω and see below Appendix C.

59. Ἐπικαταλλαγα ἐπι το καταλλαχθεν ἀργυριον ἐς Ἀθηνας. This is paid to a certain Tychon, who appears nowhere else and must surely be a money changer. Burford on the other hand has suggested that he be a building commissioner or agent (p.280).

60. Although 16, 18, 20 and 24 have been proposed, 12 seems the most recent conclusion (Burford loc.cit. p.322).

61. As these drachmai have been argued above to be Aeginetan, the fact that 70 make the mina is relevant for discussion below of the upper ranges of the Aeginetan system (references in n.44 above).

62. A figure that Burford consistently misreads as 6169 both in her BSA article and in The Greek temple builders at Epidauros.

63. See B.7 Side A.19f and below in 4(3).

64. Possibly to be reconstructed from B.18 Side A.16f.

65. On B.2 (of similar date) everything apart from χαρπον and μιλτος is unspecified.

66. The Greek temple builders at Epidauros ch.IV.

67. Which also should explain the apparent variations in prices. Burford seems to have been unaware of the difference terrain could have on the cost of trench-digging for example (The Greek temple builders p.197 considering the prices in B.20 and 21: see in general JHS 91(1971)205).

68. Thuc. V.68.2.

69. Plut. Lys.17, Lyk.9. The first Spartan coinage was minted in the early third century (Seltman GC^2 256).

70. See below ch.V.2.(2). The group mentioned is from the Argive Heraion (Seltman GC^2 37).

71. Plut. Apophth.Lac. 903 (το σιδηρουν νομισμα) ἐστι μνα ὁλκη Αἰγιναια, δυναμει δε χαλκοι τεσσαρες and Hesychios πελανόρ· το τετραχάλκιον· Λακωνες, Cf. Hultsch GRM^2 534-36. One cannot let pass without comment however the word χαλκους applied to what was specifically an iron coin-substitute. Δεκα μνων ἀμοιβην (for silver) in Plut.Lyk.9 refers to value equivalence, and not weight.

72. See ch.II.1.(2) -III [Laconia].

73. Though most scholars have been happy to place the inscription in c.427 BC, Lewis now inclines towards 396-5.

74. Hultsch GRM^2 535 n.2 attempts to exculpate Dikaiarchos by supposing that an equivalence is indicated by the approximation περι δεκα τινας Αἰγιναιους ὀβολους. All Dikaiarchos' figures however are approximations, and it is difficult to see why he could not also have given some figures for the cheese and figs. Some confirmation for Plutarch's figure of 5 minai of cheese may on the other hand be seen in the Arcadian regulation (recalled by Harmodius Lepreates): see below 7.

75. Ch.I.1.(2) no.C.1.

76. IG V (1) 1390.100.

77. Cited IG V p.107.

78. Head HN^2 sv. Arcadia, and specifically the coins of Heraia, Alea, Cleitor, Mantineia, Pallantium and Tegea. The most usual denomination to be marked is the ½-obol (marked "E").

79. Ch.II 1 (2) II-[Olympia].

80. Paus. V.7 - VI.21.3.

81. Andrewes The Greek Tyrants (1956) p.58 noting obscure variations that it is not necessary to pursue here.

82. It should be dated before even the earliest possible date for Delphi (Hdt.I.50-51 on which see further below in this chapter sv. Delphi). Homeric talants, if relevant at all here, are only of gold. See further ch.V and especially V.2.

83. The variations in the later talant are to some extent documented. These are discussed in ch.IV.3 below.

84. The lighter Homeric talant, as a gold talant, is not available.

85. Plut. Per.31.3; Thuc. II.13.5; Philochoros 328 FGH 121.

86. Hdt.I.50-51.

87. I do not mean to imply that there was a difference (there is no specific evidence for either talant being peculiar); the problem is to which of the two states can the weighing of bronze in talants at this date be attributed.

88. Myron's victory is dated to the 33rd Olympiad (648 BC): Paus. VI. 19.2.

89. See in general on this question ch.V.

90. This might for instance support the evidence for"talant", as the name of a weight, being related in some way to the performance of primitive weighing machines: see further ch.VI.5 (1).

91. Note in this context Pausanias' reaction to Pheidias' statue of Zeus: Paus. V.11.9.

92. Cf. the Corinthian plan for the financing of the Peloponnesian War in Thuc.I.121.3 and 143.1 (with Gomme HCT p.418 n.1); for the 360's see Xen. Hell.VII.4.33.

93. Although the first cited is dated by the publishers as sixth-century.

94. Tod BSA 18(1911-12)108. For the third/second century execution of counterfeitors from Dyme (Achaea), recorded on SIG^{3}530 etc, see Appendix E below on legislation concerning coins.

95. Ch.VII.1 (5).

96. IG V (1) 1390.100; see above ch.III.6 [Messenia].

97. There are no Achaean weights to be listed in ch.II.1.(2).III.

98. Head HN^2 392-4.

99. I except the undated and unimportant fragment about wall building: SEG XIX 333.

100. Hdt. I.52 and cf.49. See further following section on Delphi.

101. Line 20: ἀποστησατωσαν, παραδοτωσαν δε παντα ταυτα σταθμῳ μετα πολεμαρχων και κατοπτων.

102. The item at the end of line 71, Εὐφροσυνης τ[ιτθ]ος ὁλκη ΠΙ (5drlob), may be an exception; but I suspect it is a mistake for ΠΙ- (6dr).

103. Ἀργυρωματα του Θεου Ἀνφιαραο. The IG transcript here is faulty; for commentary see B.Keil Hermes 25(1890)598-623 "Ein Silberinventar des Amphiaraos von Oropos", and in particular pp.608-15 on numerals. Those of this shrine are not discussed by Tod BSA 45(1950)134.

103^a The identification of the chalkoi-obol system is based securely on the following groups:

ΝΕΧΓ (line 58) - 55drs 3ch
ΝΕΧΣ (line 59) - 55drs 6ch (Keil)
ΞΖΧΣ (line 26) - 67drs 6ch (,,)
ΟΧΘ (line 4) - 70drs 9ch (from ⌒∨O on the stone)

The 12-chalkous obol can be also inferred from an Orchomenos inscription that accounts sums involving chalkoi up to 11 but not beyond (IG VII 3193). A similar system obtained in Boeotia: see the following section.

104. Keil as cited in n.103 above, pp.617-8, compared Delos BCH VI 6f and Miletus CIG 2855. See also Delos ID 442.B.120ff.

105. Late third-century IG VII 2420; but then again the same weights may have been used for weighing gold and silver earlier at the same site (IG VII 2424).

106. See above ch.II 1(2).III-[Boeotia].

107. Head's term, HN^2 344.

108. SEG XXII 370; the equivalence is possibly indicated by IG VII 235.

109. I am disregarding the δεκα δραχμαων εἰλυτας δεκα of Lebadeia (IG VII 3055) as this is virtually certainly a price.

110. The same problem surrounds the late third-century donations to Thebes on IG VII 2419; in a list of coins there appear Μαλιοι τα[λαντα?](II 8) and Φιλοκλης [-ταλα]ντα ἑκατ[ον δραχμ] (end).

111. This is shown for Boeotia in the first-century Tanagra inscription SEG XIX 335.

112. See above under Oropos and n.103a.

113. Ἀρχ. Ἐφ. 1936 Παραρτ. p42 no.219 l.4:

114. IG VII 3073; SEG XXII 440; SIG^3 972.

115. For such a sort of contract compare Eleusis IG II^2 1675.17-33.

116. M.Feyel BCH 60(1936)27-36.

117. A.D.Keramopoulos Ἀρχ.Ἐφ (1936) Δελφ, p.42 no.219, being the left-hand side of IG VII 2423.

118. Line 4: δακτύλιον ἀργυροῦν ἄγον ΗΕ.

119. Ll.4-5: δραχμὰς ἀγούσας ΙΙΙ.

120. BSA 37(1936-37)245.

121. IG II^2 1184.15-17 : see above ch.III.1(3) [Athens].

122. Ὅρμοι vary down from the 156drs of Eriphyle's notorious gold necklace (IG XI (2) 161.B.42) to, for example, 18drs (ibid.199.B.58); δακτύλιοι vary from 5dr 3ob to 1dr 2ob within the single inscription IG XI (2) 161.B.43-7.

123. See the following note 9(4).

124. The higher figure may be the basic unit or its double depending upon the interpretation of the Lebadeia weight: see Ch.II 1(2).III [Boeotia].

125. As cited in n.116 above.

126. Hultsch SM 269.13.

127. See the indices in SM and also Hultsch GRM^2 543 with tables.

128. As cited in n.116 p.32 n.2.

129. Ἀχαννή , a corn measure of 45 medimnoi apparently peculiar to Orchomenos (Arist. fr.525; Hesych. sv.); σείτης (and its half ἀποφ(ρ)υμα) again possibly a corn measure (Epiphanius SM 264, and Eusebius SM 278.7); κοφῖνος likewise (IG VII 2712.65 and Strattis fr.13 cited Pollux IV 168). I discuss capacity measures in a separate treatise.

130. Thus for a start, Epiphanius is incompatible with the Lebadeia weight.

131. 520-355 BC (with interruptions): Head HN^2 340-1, listing obols, 1½ obols, three-quarter and quarter-obols.

132. See Kroll Hanfmann Studies (1972) p.92, and the discussion of the weights from Phocis above in ch.II 1(2)-I [general] and -III [Phocis].

133. FdD III (5) esp. 74.57f with a reference to the mint.

134. See Tod BSA 37(1936-37)246-7 contra Keil. I should like to add the observation that so much hidden working accompanies the figures on these accounts that the normal numerical notation would be extremely obscure.

135. FdD III (5) 58.13-15.

136. Compare Epidaurus, above ch.III 4(2), where by the second century at the latest the Attic mina was used for accounting (made up of 70 of the local Aeginetan drachmai).

137. On this see in detail Appendix C.

138. It has therefore been included in the Athenian section above ch.III 1(3) end (under Miscellaneous).

138[a] Ἀριθμῷ appears frequently in the accounts, and at FdD III (5) 50 III.36ff is surely a better restoration than the editors' [στα θ]μῷ which I should reject. Compare ἀριθμητὸν for Daric-equivalences on SIG[3] 253 II.11 (with ἠριθμημένοι in preceding lines). However obscure the conversion factors may be (and see Appendix C), there is no justification for introducing weighing.

139. Hdt.I.52 cf.49, and see above ch.III 9(2)-[Oropos].

140. They were probably drawn up after the Persian Wars when Delphi was receiving the promised dedications from loyal Greek states.

141. On which see Hdt.I.50.3; II.180; Paus.X.5.13.

142. See ch.I 3(3); long series of unit strokes on some containers used to measure capacity show a comparable progressive measurement procedure.

143. Rather than being Lydian for example; Hdt. was aware of the difference (I.178.3).

144. Producing "a talant not elsewhere heard of viz. one of 130 lbs (French)":Rawlinson Herodotus (1875) ad loc.

145. Rawlinson.

146. Stein Herodotus, misread by How and Wells.

147. Pearson CR 1931 118-9.

148. Nor any necessary connection with coin weights: see further ch.V.

149. As cited in n.147, on p.118.

150. Diod.XVI.56 and 50.3. The subsequent remaking of copies was undertaken at Delphi but could prove nothing about the earlier measurements. For Croesos' craters see SIG[3] 250 F and 253 II.5-12 with n.30 vol.I p.432-3.

151. Ephoros, or ? Demophilos, 70 FGH 96.

152. IG XI (2) 161 B.42: and see further below ch.III 12 [Delos].

153. I am inclined to doubt that Myron's thalami were weighed in the seventh century: see above ch.III 8 [Olympia] on Paus.VI.19.1-4.

154. Diod. XI.51; Theopompos 115 FGH 193 tells how Hiero obtained his gold from a private source in Corinth; also Bacchylides III.17ff and 63ff on the magnificence of the offering.

155. This is perhaps over-cautious. The problems derive from the lack of explicit mention of either gold or Hiero on the inscription, from the uncertainty of where the inscription was located (see SIG^3 n.6), and from the fact that Bacchylides (III.63ff) claims for Hiero the largest gold dedication at Delphi (though that made by Croesos would, if taken as a whole, greatly outweigh the 50T 7M noted here for Hiero).

156. See note to excursus on Sicilian coin: ch.II 2. Alternatively nummi (Pollux IX.87 citing Aristotle). See also in ch.IV 3.

157. As also the Samian dedications to be considered next: SIG^3 276 A and B.

158. Despite the need for considerable restoration the formulae and the units are certain: στάθμον τοῦ χρυσίου δαρεικοὶ εἴκοσι, ἡμιδακεικιον, ἡμιωβελιον.

159. Cf. IG II^2 1437.20; 1443 II.89f.

160. Following Bourquet BCH 24(1900)472ff and also SIG^3 253 n.13. Darics (presumably equivalent to χρυσοῖ) recur in subsequent parts of this same account where they are totalled as a separate, partially restored, item (SIG^3 253 II.48-53). These must be coin, though it is clear it was in this form that gold was indeed most usually handled in Greece generally (thus also presumably Architeles of Corinth in Theopompos 115 FGH 193 συναναιρούμενος κατα μικρον).

161. SIG^3 239-240, see 239 III.2f, 18-20; 240 0.15, and contrast the Attic, Italic, and Phocean coin that is converted. The whole question of coin conversion is extremely complex: the details are discussed in Appendix C, but the implications for this thesis are considered in chs.VII and VIII below.

162. Keil Hermes 37.511ff; SIG^3 252 n.3. Olympias is Alexander's mother.

163. Hdt. II.180. Older editors prefer to understand 20 minai of silver here and so would exculpate the Greeks of Egypt (Stein, Rawlinson, Sayce). Legrand is more honest, commenting "D'alun ou d'argent ? L'offrande, semble-t-il, était peu généreuse" (Budé). The reference is hardly comparable to Croesos' dedications or to those made by Myron at Olympia. See further ch.V 2 (4).

164. Compare therefore Datis' gift of λιβανωτος to Delos: Hdt.VI.97.2 (and see below ch.III 12 (1)).

165. On the white-washing of the part played by Delphi during the Persian Invasion and Herodotus' access to both official and unofficial Delphic sources see Hignett Xerxes' Invasion of Greece (1963) App.XIII pp.439-47.

166. Thus the weights of Croesos offerings.

167. Tod BSA 18(1911-12)123-4.

168. Fourth-century; Pleket no.7. See further Appendices C and E.

169. [Arist] Oikon. II.2.22 (1350a) with which is generally compared [Dem] 50.46. See for further elaboration Cloché REA 1923 pp.5-32. Callistratus is only known to have organised regulations concerning the collection of harbour dues.

170. The early history of Delos is given in Thuc. III.104.3-6, citing the Hom.h.Apollo.

171. Hdt. I.64.2 (see again Thuc. III.104.1 on the second purification in 426/5 BC).

172. Hdt. VI.97.

173. Hdt. VI.97.2; see Hultsch GRM^2 129 and n.5 where the weight is calculated as 2.52kg.

174. Head HN^2 485.

175. ID 406 A.22 contains a fragmentary reference to a contract involving wood and priced by the mina. This would be most significant if it was clear that the material being weighed was also wood. The editors of ID make no comment.

176. IG XI (2) 203 B.98 τάλαντον ἡμιτάλαντον χάλκουν . It is uncertain whether two weights are involved (of 1T and ½T) or simply one (of 1½T). See also n.182 below.

177. See chs. IV and V.

178. It has to be assumed that the 76 broken vessels weighed here are in fact silver. Bronze however is not an impossible alternative. For further discussion of this important passage see ch. I 2 (1) [on the size of balance beams], ch. VII 1 (3) and VIII 2 [on the use of coins as weights], and ch. VIII 1 [on precision implications].

179. See ch. II 1 (2). III- [Delos].

180. Contrast the situation at Olynthus where a majority of the surviving weights can be argued to be in fact Athenian (see above ch. II 1 (2). II- [Olynthus]).

181. Delos XVII (1938) pp.167-85.

182. ID 509 contains regulations about ξύληρα σταθμία including their use (note 11.1-2 [ὃς ἂν μὴ χρῆ]ται τοῖς σταθμοῖς τοῖς ξυλήροις): IG XI (2) 203 B.98 refers to a bronze 1½T weight (but see above n.176) and to a stone 10M weight. These references could be said not to amount to very much: the bronze weight (if of 1½T) is peculiar in being the largest ever recorded and a possible lead weight passes unnoticed in a later inventory (ἀνκυρα σιδηρα και λιθος μολυβδους, ὁλκη ταλαντον μνα ΔΔΠΙ ID 372 B.36-7).

183. See below ch. VII on the use of weights.

184. Head HN^2 485.

185. For example IG II^2 1635 (Tod 125), 1643, and BCH 10(1886)461 compared with the Delos Libera accounts ID 135-498 (of which 161, 287, 372, and 442 are a full and representative cross-section).

186. I should prefer to read "M" in IG II^2 1635.138ff as mina fines rather than the 10,000drs Tod suggests (GHI II p.81). Fines are generally expressed differently from accounted sums in Athens: see above Ch.III 1.

187. See ch.VIII, and especially the introductory section on the definition of such terms as "precision" and "accuracy" in this context.

188. For examples see BCH 10(1886)461.33, 35, 45, 75, 76, 148. On one occasion the quarter-obol weight appears: ID 161 B.107 (as inscribed).

189. Most recurrent is the gold-plated κάνουν ... ἐπιγραφὴν ἔχον σταθμὸν ΧΗΗΔΔΔΗΗΙΙΙC = ID 161 B.37-8 etc down to 444 B.29 over a hundred years later; on 161 B.107 appears the gold crown inscribed as weighing 100drs $\frac{3}{4}$ ob, and the twelfth crown in the same series was weighed to the $\frac{1}{2}$ob (line 111).

190. The crowns are listed in 161 B.107-114: see below in ch.VIII 2 (3) where the list is reproduced and the implications of the corrections made discussed.

191. I am assuming that the items in IG II^2 1643.5ff are gold or silver and am ignoring for the present Hdt.VI.97.2 (λιβάνωτος on which see above ch.III 12 (1)).

192. The necklace was first dedicated at Delphi by Eriphyle's son, Alcmaion, but was later taken by Onomarchos and his associates: Apollodorus III.iv.2, vi.2 (with Frazer's notes in Loeb ed.); Ephorus (or Demophilos ?) 70 FGH 96 (ap. Athen. VI.232E); Plato Rep. 590A; Homer Od.XI.326f.

193. Ch.I.1.(2) C.1 for description of the Arcesilas Cup scene; and see also ch.I.3 for weighing procedures.

194. Head HN^2 864-74.

195. See further ch.VII.1.(3) on the handling of coin.

196. Tod as cited in the Sources to this section, followed by SEG IX.11.

197. SEG IX.11-18, 24, 34; XX.716. In XX.716 occurs also ΜΝΑΝ.

198. SEG IX.39ff, and also IX.4.42 (of the first century BC).

199. Ch.III.1 esp. 1.(4).

200. The different approach to weighing of the near-eastern civilisations is established in detail in ch.IX (see conclusions IX.2.(1)). The evidence for Italian and Sicilian local attitudes is less copious but basic difference with Greek attitudes nonetheless clear: see ch.II.2 (excursus on Sicily). I propose to consider the origins of Roman metrology in a separate study, but that the (Roman) treaty of Apamea is the first occasion on which a specification is given in absolute terms of Greek coin weights is discussed in Appendix E.

201. Hdt.I.50-51 (Croesos' dedications), II.180 (Amasis' gift of alum) on which see above ch.III.10 [Delphi]; Pausanias VI.19 (Myron's thalami) see above ch.III.8 [Olympia].

202. Attic coinage might push this limit into the sixth century. See on pre-coinage weighing ch.V.2.

203. See further also ch.IV.3 and V.2. For bronze age Greece see IX.1.(6).

204. Iliad IX.122,264; XVIII.507; XXIII.269,614,751,796; Od.IV.129; VIII.393; IX.202; XXIV.274.

205. Iliad XXIII.262-70, 740-51.

206. See Hdt. as cited above n.201.

207. Iliad XXIII.826-35.

208. Iliad XXIII.850-51.

209. See further below ch.VIII.2.(2).

210. See concluding section above ch.III.1.(4).

211. These are discussed above in ch.II.2, but the question underlies also much of both chapters IV and V following.

212. Ch.V below reaches this conclusion.

213. See ch.II.1.(1) I and VII.

214. Ch.III.1.(2) and ch.IV.2.(3) with Notes.

215. Ch.III.12 and esp. 12.(3).

216. Compare perhaps in this context the instructions on IG XII Supp. 644.4-6 to measure what was measured and weigh what was weighed (see above ch.III.13), and note that the date is as late as the second century BC (Euboea).

217. One of the ways by which weight terms have been identified is indeed by their occuring also sub-divided: thus the Homeric "axe" and "half-axe" terms (above ch.III n.208), and compare the Delian "basket" and "half-basket" charcoal measures (IG XI (2) 161 A.109; 203 A.59 below ch.III.12.(2)).

218. See above ch.III nn.203-204. This talant was clearly much lower in absolute value than the silver talant based on Attic coin drachmai. See ch.IV.3.

219. ID 509 [SIG^3 975; Pleket no.10] 2, 33-4 ξύλινα σκάφα: see above ch.III.12.(2).

220. See further his commentary p.120f.

221. II.102 (ANET^2) and see below ch.IX.1.(2) on Hittites.

222. See ch.VI.5.(1).

223. Above ch.III n.208.

224. See below ch.V.3.

225. IG $I^2$371 III.12-13: see above ch.III.1.(3).e (Athena and Hephaistos c.420 BC).

226. Ἀνθρακηρὰ μέτρα ID 509 [Pleket no.10] 40 (3rd.-century Delos); χοᾶς ἐλαιηρούς IG XI 161 C.46 (Ibid); ὀξηρὸν κεράμιον Ar. fr.723; ταριχηρὸν κεράμιον Arist. HA. 534.a.21; τὰ οἰνηρὰ καὶ σιτηρὰ μέτρα Arist. NE. 1135.a.1 etc.

227. This whole question is discussed in detail in a separate study I have made of Greek capacity measures.

228. Above ch.VI.5.

229. See ch.IX.1.(1) on Egypt, and IX.2.(2) on possible influence on the Greek approach to weights and weighing.

230. See ch.III.1.(4) attempting to isolate the characteristic procedures of this market, and ch.VII.1.(1) on the use of weighing in general Greek commerce.

Chapter IV

1. Ch.VII below.

2. The text is most conveniently found in Pleket no.14. To the bibliography there add Lang Agora X (1964) 3, 42-3, 48 and BCH 1952.23-4.

3. Robert Étud.Num.Gr. 1951.105-35 and Lang Agora X 3 n.2. This is to be preferred to the former interpretation, "Mint coins", derived from the fact that a temple of the hero Stephanephoros was situated near the Athenian Mint (LSJ).

4. Ch.I.2-3 (on balances and technique), ch.VI.5 (on vocabulary, and especially 5.(3) on ῥοπή).

5. Ch.VI.5.(3).

6. N. I do not wish to imply that they could be, or ever were, so expressed.

7. Lang Agora X pp.2-3 arrives at a distinction between coin and silver weights on the one hand and those used for other commodities on the other yet does not really justify the position.

8. On ὁλοσχερῆς "full weight" see ch.VII.1.(3).

9. See further on precision and accuracy ch.VIII; on the different weight systems used for gold see ch.III esp. Conclusions (end).

10. Thus Eleusis c.330 BC IG II^2 1672.

11. IG II^2 1485.3 should be ignored: see ch.VIII.1.(1)-2 and VIII.2 (with ch.III n.8).

12. Note on the method of weighing and accounting of sums over 6,000drs in Athens. In the fifth century there appears to have been no obvious preference for either thousands of drachmai or talants, though perhaps talants are commoner. Several inscriptions illustrating either method can be listed:-

High drachmai	Talants/drachmai
fines IG I^{2}16 and 57	deme accounts IG I^2 186-7
Parthenon building	Eleusis accounts IG I^2 312-4
Propylaea	Athena Treasurers
Parthenon door IG I^{2}388 (cf.below)	Logistai
Athena Promachos SEG X 243	Pheidias' statue of Athena
Nemesis (Rhamnous) SEG X 210	Athena/Hephaistion IG I^2 370-1
	Attic Stelai
	Timoria of 5T in IG I^2 28

High drachmai and talants appear together on only two inscriptions. Kallias B (ML 58 B) sets a 10T building budget (lines 3ff) and a limit on money used for other purposes can be restored as 10,000drs (lines 12-19). Lewis has recently expressed dissatisfaction with the text at this point, and 10,000drs (μυριάς) as a round figure is less convincing than an accounted total. The other inscription is IG I^{2}377 (Tod 54, of the Delian Amphictyony 434/2 BC) where debts

12 contd.

are totalled as 𐅄𐅄HHHHΔ--(in line 9), new leases and loans however as 1T 110drs and 13T 3010drs (in lines 23 and 13). It may be the case that a year elapsed between the two sets of entries and so different personnel may have been responsible for the changed accounting style.

Apart from these two exceptions, the use of drachmai over 6,000 or talants/drs (but not both) holds for all fifth-century Athenian inscriptions where money is accounted. High weighed sums however are normally expressed in talants/drs: the only exception is an apparent lapse on the Pronai inventory for 434/3 BC (IG I^2 232.7: SEG X 184): σταθ]μον τουτον ΜΠ[--- . This entry is not repeated in subsequent years, and the increased weight of the item (silver flasks) is there expressed in talants/drs. For this reason the first line of the Parthenon door inscription IG I^2 388 (the identification has been recently made by Lewis) should be restored as a price (or cost) but not as a weight.

Fourth-century practice is less complicated. Talants/drs are invariably used for both weights and accounted amounts over 6,000drs. The only slight exception is mention of a fine of 10,000drs (again the understandable μυριαι δραχμαι) on the Navy List IG II^2 1629.237. Fifth-century parallels for this legalistic limit have already been indicated, and it need not shake the overall picture.

The convention of using talants over 6,000drs seems fairly well established. It may possibly relate to the weighing procedure (though talant weights are not very much in evidence). See further ch.VIII on precision.

13. Note on minai in fifth- and fourth-century Athenian accounts. As is said in the text, most straightforward uses of the term mina are in expressing fractions or percentages. Most well-known perhaps is the rate μνα ἀπο του ταλαντου restored for the fifth-century prescript to the Athenian Quota Lists (it does not however appear in subsequent lists even where these reach the mina, 100drs, or above). Compare with this the tax of 10drs to the mina on the fourth-century Navy List IG II^2 1612.224-7, and the fines κατα μναν του διαγραμματος on IG II^2 1629.502 and 1623.156. On IG II^2 1013 all references to the mina (as also to the talant) are to the commercial mina (and talant).

Other references to minai are few and problematic, largely because they raise the question of whether a weight of some other commodity (other than silver) is to be understood. I shall list them here:-

IG I^2 10 (ML 40) 3-4. Erythrae is to contribute corn to the Panathenaea (ML), or meat (IG), ἄ]χσ[ιον μὲ ὀ]λεζον]ος ἓ τριὸν μνὸν. ML offer no comment. I suppose such a formula is understandable here in the light of the normal method of expressing the allied contributions (μνα ἀπο του ταλαντου as above). Otherwise the retention of meat (κρεας as IG) would seem preferable.

IG I^2 41 and 78. Minai are restored in IG. Are these legal limits ?

IG II^2 334.16, 23. A Panathenaic inscription referring to των τετταρακοντα μνων και μιας in the context of oxen. Comparing the Erythrae decree as above, I wonder if this is not also a reference to meat weights.

See further, in connection with this point, the discussion below in Appendix D of Arist.Ath.Pol.10.

14. See the following section on the possible distinction between the weights of silver coin and the weights used for weighing silver.

15. Precisely where can only be guessed. The remarkably high loss in weight through melting (ἀπουσία) of 12drs presumably covers the possible amount that the 18drs coin were underweight (it being a normal Greek practice to offer old coins to the gods: cf. IG I^2 310. 195), so the 2drs discrepancy should be spread out over the coin paid out for the work done (a total of 35drs 3ob), if not lost (as I go on to consider) in the successive weighing operations.

16. See below ch.VIII.2.(4).

17. The most likely source to have helped here - accounts of the process of converting Laureion silver into Attic coin - has produced nothing so far relevant: see most recently R.J.Hopper BSA 48(1953) 200-54 and 63(1968)293-326. Below ch.VII.1.(2-3).

18. Below V.5.(3) and Appendix D.

19. See ch.I.2.(1); III.12.(2); VII.1.(3); and generally VIII.

20. Thus my review of Burford Greek Temple-Builders of Epidauros in JHS 91(1971) pp. 205-6.

21. Only on IG $II^2$1479 B. See above ch.III.1.(3)-g.

22. Δοκιμώτατα τάλαντα or the Delian "full-weight Attic drachmai".

23. For discussion see ch.III Conclusions with nn.219-222.

24. IG $I^2$371 III.12-13 (see also ch.III Conclusions with n.225); and in general on the possibility of shape-determined (even though perhaps also implying actual weight similarity) "weights" used in pre-coinage weighing see below ch.V.2.

25. This is implied by the fourth-century Olbia decree (Pleket no.7.26f).

26. See for details ch.VII.1.(3). Some problems connected with the conversion of coin are discussed in Appendix C.

27. FdD III.5.25 col.II.A.5-13. Specification of the Attic mina here is interesting, as in coin totalisation minai are equivalent in both Attic and Delphic coin: see further in Appendix C.

28. See further below V.5.(2)-[Pheidon].

29. Although on the same inscription conversion of coin was done by means of a sliding scale: see Appendix C.

30. Discussed above in ch.III Conclusions.

31. Hdt.III.89.2 and 95. See above ch.III.16. The emendations to the MSS to read 78 minai in the first passage (and so on to the second) are necessary, and now generally accepted.

32. If not also of Aeginetan coinage: see following.

33. Pollux cites them under the headings of both weight and coinage without making clear which was Aristotle's meaning. That Aristotle was primarily thinking of coinage is however clear from his frequent comment on types.

34. See ch.VIII.2.(2) on the credibility of official records.

35. See discussion above in ch.III.5-[Laconia].

36. Seltman GC^{2}113.

37. Though an earlier silver stater was 10.72gm (Seltman GC^{2}61-2).

38. The silver siglos was 5.60gm (Seltman GC^{2}62-3 n.5).

39. Assuming it be the didrachm.

40. Head HN^{2}222-3 gives 8.75gm.

41. Though a 6gm coin also existed, the term seems best applied to the more usual coin of 12gm.

42. Seltman GC^{2}40 (giving a 2.8gm "drachma").

43. Apparently Thasos, despite its mines, did not coin gold. The so-called "didrachms" were first 9.44gm, then rose to 9.72gm; in the Athenian Empire Thasos was forced to follow the Athenian weight standard (Seltman GC^{2}66, 110-1).

44. Wappenmünzen: R.J.Hopper "Observations on the Wappenmünzen" Studies to Robinson (1968) 16-39.

45. Mid fifth-century.

46. Despite Hiller von Gaertingen's "therafische Sondermine von etwa 2½ Verkehrsminen" (IG XII (3) 1640).

47. Barron Silver Coins of Samos p.7 and n.1. See above ch.II.1.(2)-III [Samos] for the figures.

48. Δεκα γαρ ὀβολους Ἀττικους ἰσχυεν : which naturally raises problems of equivalence.

49. Burford BSA 61(1966)254ff no.1.103f and 4.B.III.5-6.

50. Exceptional is the use of Attic coin to weigh at Delos (ID 287 B.142f of the middle third century). See n.19 above for cross references.

51. In the section on coinage ! and not his earlier section on measures (4.170ff).

52. Και τἀλλα ἀναλογον. ἡ μνα δε ὡς παρ' Ἀθηναιοις ἑκατον εἰχε δραχμας Ἀττικας, οὕτω και παρα τοις ἀλλοις τας ἐπιχωριους δυναμενας προς λογον του παρ' ἑκαστοις ταλαντου κατα τε προσθηκην και ὑφαιρεσιν ...

53. Pollux cites Arist. fr.589R for the earlier value: το μεν ἀρχαιον, ὡς Ἀριστοτελης λεγει, τετταρας και εἰκοσι τους νουμμους, το δε ὑστερον δυοκαιδεκα· δυνασθαι δε τον νουμμον τρια ἡμιωβολια. With all figures converted into Attic, it seems fairly certain that Attic ½-obols are meant here.

54. See Hultsch SM index sv. ταλαντον 4: it must also be assumed for Pollux in the passage upon which the above table is based.

55. Consistently Pollux 9.76 equates the Aeginetan drachma with ten Attic obols.

56. As was generally the case: see Appendix C.

57. As Pollux' conversion into Attic weights at 9.86 would indeed suggest.

58. Note his general introduction Τουτο γε μην οὐκ ἀκαιρον (9.85 end). Surely all this should have appeared earlier under measures and weights. The mistake may of course be due to Pollux' editor and not to Pollux himself, but this raises a host of critical questions that I shall not tackle here.

59. The variation may not have been officially recognised: see below ch.VII.1.(4).

60. Rather more, that is, than the usual ratio of 7:10.

61. This situation would enable rather more sense to be made of the αὐξησεις in Ath.Pol.10, as it would mean that the change to a 100dr mina would involve a larger mina (in absolute terms).

62. Only "stater" as a term implies an absolute (if variable, depending on context) weight: see further ch.V.3.

63. The Rhodian "cannon-balls" are by no means certain: below ch.VII.2.(9).

64. Ch.III Conclusions.

65. I believe it was with this sort of fractional value that it enetered Greek metrology from the Near East: below ch.V.3.

66. Ch.VIII.

67. See the Eleusis accounts or the sale of gold or rope recorded on other inscriptions (ch.III.1.(3-4)).

68. As found in the Agora, and as clearly-marked units of the larger, non-coin stater.

69. Agora X (1964) 2-22.

70. I admit that this is to generalise perhaps doubtfully from the Athenian evidence. There is however not much room for argument either way outside Athens as the evidence is so inadequate.

71. From, at the latest, the late seventh century BC.

72. Alternatively put, Ath.Pol. distinguishes two terminologically distinct systems and fixes one absolute weight.

73. Ch.VII.

74. See further in ch.VIII, especially VIII.2.(2).

75. Exceptions, such as the duties of Metronomoi, are irrelevant as they are not official legislation.

76. Ch.VII.1.(3) with the evidence discussed in the whole of chs.VI-VII.

77. Ch.I.1.(3)-d [Athena Promachos].

78. Kraay Coins of Ancient Athens (Minerva 1968) p.12; M.Thompson, The New Style silver coinage of Athens (1961); earlier Seltman GC^2 260-2 and Head HN 378ff, though even then it was still placed in the late third century.

79. Seltman GC^2 261 describes it as "an academic coinage", and goes on (p.262) "a sign of the Athenian delight in complicated accountancy, and finds a parallel on no currency earlier than the paper and bank-notes of modern times".

80. See Kraay, as cited above in n.78, pp.11-16.

81. Could one argue that the amphora under the owl was a reference to the new relation between coins and weights (which had been amphora marked for some time) ?

82. From the table in Kraay Greek Coins (1966)

83. Thus Thompson (as cited in n.78). Svoronos' figures, quoted by Larsen ESAR IV 327, average 17gm with the majority of coins falling between 17 and 16gm and the range extending rather more below than above this.

84. Plut. Flamin. 10.

85. Seltman GC^2 225.

86. Above ch.III.12; see esp. ID 509; Pleket no.10; and Appendix E.

87. Ch.VII.1.4, see above, for Athens only, ch.II.1.(1)-IV and V.

Chapter V

1. For a general discussion of the metrological problems related to coinage see ch.II.2: on the origins of different standards see the concluding section to this present chapter and, on a more practical level, ch.VII.1.(2)-3 [coin manufacture].

2. See Kraay JHS 84(1964)76-91. The main features of his argument, which is generally accepted, are the high values of earliest coins and the fact that these could not therefore have been used, and a fortiori produced, for commercial transactions.

3. Ch.VII.1.(4) but see also above ch.II.2.

4. Here I should take issue with the hypothesis of those who advocate bimetalism as a general explanation for the absolute values of Greek weights, coin and other. The ratio of 1:400 for relating silver and iron (Seltman GC^2 p.37) went far beyond the metrical abilities of archaic Greeks. On the gold:silver ratios see further below ch.V.4.

5. The Homeric references are collected above in ch.III n.204; for ancient interpretations see Hultsch SM pp.298-300.

6. See above ch.III Conclusions.

7. Iliad XII.433-6; see above ch.I.3.(2).

8. See ch.IX.1.(6) and IX.2.

9. Plut. Lys.17; Pollux IX.77 and further SM 348.27ff.(Etym.Magn.).

10. Seltman GC^2 32-8. In agreeing, R.M.Cook Historia 7(1958)257-62 adds a further dedication at Perachora in the first half of the sixth century before the start of Corinthian coinage. The only ancient evidence for treating the spits as weights is the view of Heraclides of Pontus (fourth century) ap.Orion Etym. and cited by Seltman pp.34-5.

11. Plut.Lyk.9; Lysand.17. The key to Aristotle's account of the origin of coinage (to be considered below in ch.V.5.(5), and contained in Pol.1257.a-b) is that they were pieces of metal ὁρισθέν μεγέθει καὶ σχήματι. He does not however mention Lykurgus' spits.

12. See Seltman GC^2 pp.35 and 37.

13. Lead κρατευταί in Athens present a similar problem: IG I^{2}371 III.12-13 (c.420 BC). As suggested above in ch.III.1.(3) and esp. III Conclusions however, the possibly standardised shape may involve a roughly standard weight without this being itself an established absolute amount.

14. G.Buchner Arch.Reports (JHS) 1970-1 p.66. The last fill above the dump in which the object was found was dated as end 7th cent/ init. 6th cent. and even this date would be remarkable for a weight.

15. The earliest weights from Athens are end 6th/init 5th cent. (BW.1-3); from Samos third quarter 6th cent. (Barron Samos 7 n.1); Thera possibly sixth cent. (IG XII (3) 1638); from Sybaris end 6th cent. (Montuoro Annali 1965-7); from Acrai in Sicily "archaic" (Jenkins Gela 127). The earliest aes signatum is that found in Gela (Bitalemi Sanctuary) and dated to around or before 550 BC (Orlandini Kokalos 1966 and Annali 1965-7).

16. See above ch.III.10 [Delphi] and III.8 [Olympia].

17. Hdt.I.50.3; Herodotus' explanation, that part was lost in the fire of 548 BC, is not however at all impossible, and in fact has been preferred in the discussion of this passage above in ch.III.

18. See above ch.III n.163 and text.

19. Tod GHI no.1 (=ML 8) side B.

20. See general Conclusions ch.III; the same point can also be made from the inscribed weights assembled in ch.II.

21. Discussion of its origin is continued below ch.V.3, and see also VI.5.(1) on derivation.

22. Above ch.IV.3.

23. This is to point directly to the conclusion of this chapter, that weight measurement did not antedate coinage; on oscillation etc. see ch.I.2 and 3 (with Appendices A and B), and VI.5.(1).

24. Ch.II.2 and IV. On coin conversion see Appendix C, also ch.VII.1.(3).

25. So Aristotle (ap.Pollux IX.81); just as the same writer defined the litra as equivalent to the Aeginetan obol (Pollux IX.80-81).

26. I shall not consider here names applied to specific coins that are derived simply from their point of origin (eg. Darics, Croesids, or state adjectives as "Attic" etc), from their size, shape, or metal content (eg. παχεῖα , the Aeginetan drachma according to Poll.IX.76; στάρεος of Byzantium Poll.IX.78), or from their usual type (Athenian γλαῦκες from Laurion Ar.Av.1106; or Phocéan φωκαΐδες and Corinthian πῶλοι Poll.IX.76). Such terms tell us nothing about weight, nor do those indicating simply the fractional value of the coin (eg. the east-greek ἕκτη).

27. See above ch.III.1.(3)e and Conclusions with ch.V.2.(2) n.13 above.

28. Ch.VI.5.(1) [ταλαντεῖον] and (4) [στατήρ]; for absolute values see in general ch.IV.3.

29. Apart from the uncertain "cannon-balls" from Rhodes, see below ch.VII.2.(9), I have only noted the listing of a possible 1½T bronze weight on IG XI (2) 203 B.98 [Delos 269 BC]: see ch.III nn.176 and 182.

30. Exceptional is the system that apparently operated in Cyrene in the fourth and third centuries, and for this reason it was discussed in some detail above in ch.III.17. Cyrene of course was by no means central, and the argument being advanced here concerns essentially the mainland area of central Greece where the possible influences of non-Greek metrology were least strong.

31. See general review of the evidence from ch.III in ch.IV.3.

32. See the comparative tables of commodities weighed ch.III.

33. If it applies only to coin weights, then the development of small non-coin weights naturally followed in time on the basis of the coin weights and the argument advanced remains valid.

34. Tod GHI 140.81f.

35. K.de B.Codrington "The basis of coinage" Bull.Inst.Arch.Univ.Lond. 6(1966)15-28 on p.25.

36. W.Ridgeway Origin of metallic currency and weight standards (1892) p.338.

37. Head HN^2 p.826.

38. As cited in n.35 above, on p.24.

39. Apparently convention set the ratio of silver:electrum at 10:1, but as late as fourth-century Olbia the problem was more directly solved by legislation fixing the exchange rates ($SIG^3$218; Pleket no.7; and see below in Appendix E). In the earlier Parthenon accounts items of electrum were kept separate, and apparently proved difficult to dispose of.

40. At least in the central Greek area to which this argument relates (as above n.30).

41. Cf.ch.III.1.(2) on the emergency issues of Athens (407/6 and c.295/4).

42. Note has been taken in ch.III of the several occasions where gold χρυσοῖ were used to weigh gold (Athens, Boeotia, Miletus and Delos). The significance in that context was that a different system was being applied from that used more normally of silver. Here however the distinction is not significant, as invariably the χρυσοῦς was equivalent to two silver drs.; it therefore simply represents a different unit, not a different absolute weight standard. The more significant difference in the weighing of gold was in the precision (or accuracy ?) with which this was done. Again see the comparative tables of ch.III and further below on the general question of precision ch.VIII.

43. Compare the argument of varying transport costs of silver producing the different standards of Himera, Naxos, and Zankle (H.A.Cahn Die Münzen der Sizilischen Stadt Naxos (1944) pp.78-79). Such considerations are of quite a different order from the choice of basic standard on which they might have effect.

44. Hdt.III.89.2 and 95; see above ch.III.16.

45. See recently for example W.E.Thompson "Gold and silver ratios at Athens during the fifth century" NC 1964.103-23; D.M.Lewis "New evidence for the gold:silver ratio" Robinson Studies (1968) 105-10; and also commentary on ML.54.

46. I am thinking here of the picture of incessant fluctuation assumed by Lang Agora X in her reconstruction of Attic weight standards (which according to Lang varied with the gold:silver ratio).

47. See Codrington "The origins of coinage" Bull.Inst.Arch.Univ.Lond. 4(1964)1-24; on p.9f he lists six different basic seed-weights from India.

48. Hultsch GRM^2 150 and SM p.89.

49. Philo Bel.51.24 (third to second century BC).

50. Hdt.I.50.2, 51.2: and see above ch.I.3.(3) on the weighing procedure that seems implied by his formulation of the weight.

51. See below ch.VII.1.(2)-3 on coin making.

52. With lack of natural constants should also be understood the lack of a definition of weight in terms of other measurements. In the metric system 1gm is defined as the weight of 1 c.c. of water at a certain temperature. A definition of this sort was well beyond the ancient Greeks. Later metrological writers tabulated the different weights of set measures of a range of commodities (eg. SM 223f, 247); it is even noted in Galen that an Attic kotyle of oil weighed 60drs (from his pupil Heras: SM 215 fr.47), but Galen missed the importance of the idea if reversed. The possibility of weight definition by measure may be admitted in the first century of this era, but there is no evidence for it having been attempted. I am not convinced by the common derivation sought for μνᾶ and μέδιμνος. Further discussion of the relationship between measurement of weight, capacity and length is to form an important part of a general survey I hope to complete on Greek metrology.

53. Most clearly set out in several passages of Apollodorus.

54. Gorg.Palam.30 (Radermacher Artium scriptores p.65)

55. Achill.Isag. ad Arat.Phaen., Maas p.28.1-11. The text is uncertain at critical points; that reproduced here is Pearson's (Soph.Frs.) but for σταθμῶν the MSS read σταθμη(ν) δ' and Maas suggested σταθμης.

56. Κἀκεῖν' ἔτευξε πρῶτος, ἐξ ἑνὸς δέκα κἀκ τῶν δέκ' αὖθις ἦρε πεντηκοντάδας.

57. Apoll. Rhod. I.134 and see further RE (XVI) s.v. Nauplios.

58. For example ἀνθραγαλλοι.

59. Except in the textual emendation of Sophocles.

60. Vitruvius does not mention Palamedes in his list of famous men associated with measurement

61. Hdt.VI.127.3

62. Tod GHI 140.80-7.

63. Theophr. Char.30.11.

64. Delphic conversion rates occasionally operated on scales rather than on straight-forward factor systems (see further below of coin conversion in Appendix C). This could explain the impossibly awkward factor involved in turning 3000 into 1875. However I know of no Greek to Greek measure exchange rate (those in Herodotus and other travellers are explanatory not official).

65. Pollux X.179 cf. XI.1.

66. I of course completely reject any such implication's being historical.

67. Ephorus possibly first mentioned coinage, but it is not clear whether weights were also involved (70 FGH 176, ap.Strabo 8.6.16): Ἔφορος δ' ἐν Αἰγίνῃ ἀργυρον πρωτον κοπηναι φησιν ὑπο Φειδωνος.

68. Pollux IX.83; fuller in Orion's Etymologicum (derived from Plato's pupil Heraclides of Pontus, and so possibly a fourth-century tradition) on which see n.10 above, with text.

69. Thus D.Kagan "Pheidon's Aeginetan coinage" TAPA 1960.121-36. Note also Marmor Parium 45f (239 FGH 30 of the early ninth century CE) ἀφ' οὗ Φ[ει]δων ὁ Ἀργειος ἐδημευσ[ε τα]μετ[ρα και στ]αθμα κατεσκευασε και νομισμα ἀργυρουν ἐν Αἰγινῃ ἐποιησεν. The three verbs distinguish the three different points more clearly than any other ancient source.

70. From Seltman GC^2 34ff and R.M.Cook "Speculations on the origins of coinage" Historia 7(1958)257-62 to W.L.Brown "Pheidon's alleged Aeginetan coinage" NC 1950.177-204.

71. Cook, as cited in n.70 above.

72. W.G.Forrest The emergence of Greek Democracy (1966) 237; A.Andrewes The Greek Tyrants (1956) ch.III.

73. Brown NC 1950.177-204; Jacobstahl and Robinson JHS 71(1951)85-95 and 156-67; Kraay NC 1956.43-68 and Greek Coins (1966) Introd.. This view seems now generally accepted.

74. Andocides 1.83. The law is generally taken as reliable evidence of Athenian legal practice of the end of the fifth century: see M. Ostwald Nomos and the beginnings of the Athenian democracy (1969) 1 n.2 etc making only slight modifications to Hignett HAC 300ff.

75. Hignett HAC 18-19; note Ar.Aves 1660ff.

76. Ibid. 300ff; note abuse of Teisamenos in Lysias 30.28, and the contemporary oligarchic propaganda in Arist.Ath.Pol.29.3.

77. So Lang Agora X 2-3; Kraay Robinson Studies (1968) 1-9.

78. The Ath.Pol. account seems to have been written in the 320's, between 329/8 Cephisophon (54.7) and the end of the Athenian Democracy in 323/2; Androtion's Atthis was probably finished by c.340, the last dateable event being in 346 (324 FGH 52 and Jacoby Atthis p.1).

79. Jacoby suggests the emendation of τμην to ξης τμης (?) and accepts Reinach's ἑβδομηκοντ' ἀμουσαν in place of the 73 dr mina. But see following discussion.

80. Lang Agora X 2 n.1.

81. She believed that the Ath.Pol. reform achieved the same result.

82. Kraay "An interpretation of Ath.Pol. ch.10" Robinson Studies (1968).

83. Solon 1.47; 3.23; 24.5ff for examples (Diehl). Ruschenbusch Solonos Nomoi (1966) F.143 seems to accept references to prises as fixed in drachmai as genuine Sononian legislation; I would dispute these details (Plut.Sol.23.3 and Diog.Laert.1.55 are the only sources carrying the tradition).

84. As also the reference to Pheidonian measures, on which see above ch.V.5.(2).

85. I wonder if a context for the start of the tradition could be reaction to Lysander's bringing back booty after the Peloponnesian War: an incident related by both Ephoros and Theopompos (see Plut.Lys.16ff).

86. Ironically the inadequacy of standardisation and the reluctance evidenced by the Greeks to measure weight were in fact obstacles to the development of commercial practice. This concerns the conclusions to my whole thesis (qv), also see ch.VII.1.(1) and VIII.3.

87. Ch.II.2. Aristotle was certainly correct however in implying that people of his day did not check the weights of these stamped pieces of metal: see ch.VII.1.(3) and Appendix E.

88. Which are not part of the Aristotelian tradition.

89. Measures are more problematic in this context, but the standardisation of them seems equally delayed (see further my study of Greek capacity measures).

Chapter VI

1. Although it should not be necessary to defend the activeness of the Greek literary imagination (especially that of the fifth century), it is noticable how frequently, for example, weighing similes are preceded by metaphorical references to weighing (the one sparking off the other ?). See below ch.VI.6.

2. Hebrew: see ch.IX.1.(5).

3. This is definitely the implication of the alternative title to Archimedes' work περὶ ἰσορροπιῶν (Pappus 8.24 and 8).

4. See ch.I n.18 for date and authorship (in discussion of the bismar described at [Arist] Mech § 20 and type II.2 of those I have distinguished).

5. Both steps are essential (see Appendix A), and both seem moreover to be implied (τέ...καὶ... , with alternatives only for ways of weighting one arm).

6. Such as counter-torque on the point of pivot: see Appendix A where these problems are discussed in terms of modern weighing machines and weight theory.

7. See following Heron Mech.34c on a similar issue.

8. It has therefore been used in reconstructing this performance in ch.I.2-3.

9. Contrast my own experience with the same problem: Appendix B.

10. As Ibel believed, Die Waage (1908) pp.32-6.

11. Above ch.I.2(1) in discussion of the Charistion.

12. Dijksterhuis Archimedes (1956) restricts discussion to an introduction only; see also Fraser Ptol.Alexandria (1972) I.425-6; II.614-5 and nn.393-4.

13. Text in either Mugler (Budé) or Heath The works of Archimedes (1897) [to which a Supplement on The Method appeared in 1912].

14. Heron Mech. I.32 [Nix and Schmidt p.86].

15. Ap. Heron Mech. I.33 [NS p.88].

16. Heron Mech. II.7 [NS p.114].

17. The author and date are uncertain, but Hultsch SM II.88ff gives the text and for recent discussion see Dijksterhuis Archimedes (1956) 18-21. The most relevant lines are 124-162.

18. For example Ibel Die Waage (1908) illustrates "the balance of Archimedes" on p.52 (fig.12) from Duhem Les origines de la statique (1905).

19. G.J.Toomer OCD^2 sv.Archimedes; Pappus 8.24 and 8.

20. Nix and Schmidt (ed.) and Ibel Die Waage (1908) p.44.

21. See further Dover ed. Aristophanes Clouds p.xl and n.143ff.

22. Ch.VII.2.(8) and VIII.1(1).1.

23. Ch.VII.2.(7).

24. Ar. Pax 1240-9.

25. Ch.I.2-3 also Appendix B; on the likely results see ch.VIII.

26. Ar. Ran. 798, 1364ff; the procedure in the latter scene is discussed in detail above ch.I.3.(1). For the metaphors see LSJ sv. especially βαρος, βαρυς, βαρυνω, κουφοτης, κουφος, κουφιζω I have not attempted to compile (here or in ch.I.1.(3)) an exhaustive list of these passages. Of more direct relevance to the question of weight I should however add here Eur. Heracl. 690 σμικρον σηκωμα added to friends, and Aesch. Phrygians τον ἑλκον του Ἑκτορος in Hesychius sv. ἀντιρροπον (but is this referring to Hector's being dragged or weighed ? or, with poetic ambiguity, to both ? See ch.VI.5.(2) for the weighing sense of ἑλκειν). Neither passage however contributes to my examination of the Greek attitude to weight proper; both are neutral on the interesting questions that arise, and many more could no doubt be added to them. A detailed analysis is not necessary.

27. Following in ch.VI.3.(2).

28. Anthropological and comparative studies are I think anyway ruled out by the importance I shall show attached to the type of weighing apparatus the Greeks used and by the direction their own peculiar theory dictated. The problems concerned with light and heavy when they first appear are bound up with the language in which they are phrased, and so it is not possible to consider the practical side of the question as simply contingent. Nor is there any direct evidence, as the use of the balance first occurs with the earliest Greek reference to light and heavy in Homer, and there can therefore be little possibility of assigning priority to either the use of the balance or the concepts light and heavy for the period before Homer (where there was no written literature). To argue about these unrecorded strata (the Dark Ages if not also the Mycenaean period before them) is pointless (see further ch.IX.1.(6) and IX.2).

29. The class of opposites is of course a very mixed bunch. Though light/heavy and hot/cold are relative and expressible absolutely in terms of points on a continuum (of weight or of temperature), pleasure/pain is relative but not measurable, and true/false is neither. Although the question of pleasure/pain is relevant to this discussion (the calculus calls upon a weighing parallel: see following), I cannot follow the ramifications of the other subjects here. See however G.E.R.Lloyd "Right and left in Greek philosophy" JHS 82(1962)56-66, and "The hot and the cold, the dry and the wet in Greek philosophy" JHS 84(1964)92-106; M.C.Stokes One and Many in Presocratic philosophy (1971). The survey of the Presocratics that follows here owes much to G.S.Kirk and J.E.Raven The Presocratic Philosophers (henceforth PP), and my references are to the fourth impression of 1962.

30. As PP p.119.

31. See PP p.229f.

32. Especially Arist. Metaph. 985.b.23ff (PP 289).

33. See PP 326

34. Other opposites, sameness/difference, light/heavy (ἐλαφρον / ἐμβριθες), and so on, are either variants or developments from the basic pair. Contrast Theophrastus in PP 353 with 354 and Aristotle PP 355.

35. PP pp.280-81.

36. Timaeus 62c - 63e discussed below ch.VI.2.(4).

37. Kirk and Raven seem to imply for Democritus a much too developed theory (PP p.415f) and rather beg the question in using as an argument that "the concept of weight as an essential attribute of body did not occur to the early physicists". Simplicius' οἱ περι Δημοκριτον οἰονται παντα μεν ἐχειν βαρος (PP 575) may not be used in this question. Not only is the view that everything has weight not attributed by him to Democritus himself, but the context is the weight of compound bodies, as the example clearly shows (an explanation of why fire rises).

38. See Lucretius II.184-293 on the downward fall of atoms and clinamen with Cicero De Nat.Deorum I.25.69: Epicurus...invenit quo modo necessitatem effugeret, quod videlicet Democritum fugerat; ait atomum cum pondere et gravitate directo deorsus feratur declinare paululum. On the inadequacy of Democritus' account of the original notion of his atoms see Aristotle's criticisms De Caelo 300.b.8 (PP 576 and commentary p.417f).

39. Again I am ignoring Simplicius (see n.37 above); but note in any case κουφον δοκειν , the appearance of being light, not less heavy.

40. It follows immediately that "φ is". The non-distinguished existence of objects and qualities is precisely the Presocratic position already discussed.

41. Rep.438b-c explicitly argues that comparatives require something compared (Και τα πλειω προς τα ἐλαττω ... και αὐ βαρυτερα προς κουφοτερα) and the problem in the Phaedo only arises when the comparatives are dropped (102b).

42. It is not clear to me whether Plato at this stage would have analysed the comparative "x is heavier than y" as (i) [x partakes of the Form Heaviness and of the Form More]:[y partakes of the Form Heaviness and of the Form Less] or (ii) [x partakes of the Form Heaviness]:[y partakes of the Form Lightness]. The distinction is important, and I think the latter (ii) more likely as it is implied by the reduction of the comparative that I have just mentioned and also by the inference "x is not heavy" so "x is light", to which I shall return below in considering the Sophist.

43. That an identity statement, "x is heaviness", might be implied or lie behind this explanation is ruled out by the special existence accorded the Forms by Plato; it is anyway not necessary. 'Parmenides', arguing later against the theory of the Forms (Parmenides 128-35), forces 'Socrates' (Plato ?) into an explicit statement of the distinction between the Form and an object participating in it, and then shows this to be either too strong or too weak (esp. 135a-b).

44. Though κουφοτης and βαρυτης do not occur, το κουφον and το βαρυ are frequent, and surely also the more usual expression of the Platonic Form. Both modes are used for the great/small pair in the same class of opposites in which the light/heavy pair appears (μεγεθος and σμικροτης Phaedo 102b6 and το μεγα και το σμικρον 102d-e), but this is unusual. κουφοτης seems only to be used by Plato in Tim. 65e, of objects rising δια κουφοτητος , a passage in which I think Plato has abandoned the idea of independent existence of the concept of Lightness (below VI.2.(4)).

45. Dissatisfaction with the theory of participation in the Forms was certainly felt (see Parmenides) and modifications were introduced (thus Timaeus and the related alternative of Μεγιστα Γενη that is proposed in the Sophist). The "friends of the Forms", refuted in Soph. 248a, need not be taken to include Plato of the earlier Dialogues, nor is the refutation itself a recantation by Plato of his whole theory but simply of a part of it: the distinction in terms of εἶναι and γιγνεσθαι (contra Crombie An examination of Plato's doctrines II.419-21, where it is argued that there is no recantation at all for the inadequate reason that recantation is not total).

46. Shades of Parmenides (see above ch.VI.2.(2)). In a passage echoed by Rep. 516e6 and following, Plato argued that, as direct access to the Forms was impossible (as blinding), the oblique approach was necessary (εἰς τους λογους καταφυγοντα εν ἐκεινοις σκοπειν των ὀντων την ἀληθειαν , just as one looks at the sun in its reflection in water, Phaedo 99d). The point is made more explicitly in the Republic simile of Sun and Cave, and the distinction between objects of the world and the Forms is more clearly stated there as not merely one of brilliance. In part the legacy of Heraclitus, the mutability of the real world, a constant state of γιγνεσθαι , contrasted with the immutability of concepts (τα ὀντα). Plato eventually withdrew this monopoly of realness from the Forms when he became aware of the distinction between the "is" of existence and that of predication (Soph.249b).

47. Το ἑτερον ἀει προς ἑτερον , Sophist 255c-d.

48. 133c8 et seq.

49. Furthermore, light and heavy are properly no longer included at this stage (as I shall show below). That the problem should have become entirely linguistic, and that light and heavy dropped out of it, are not easy to reconcile except in terms of basically physical aims of Greek philosophy: see Phaedo 99d quoted in n.46 above.

50. The whole section Theait.151e - 187a considers the definition of knowledge as αἴσθησις and the problems raised by the contradictory data this produces (154b - 155b beginning εἰ μὲν ᾧ παραμετρούμεθα ἢ οἷς ἑκάττομεθα μεγα ἢ λευκον ἢ θερμον ἦν). Heraclitus and many others are considered together - all reducing (though for different reasons) to οὐδεν εἶναι ἓν αὐτο καθ'αὑτο (152d, 157a): Heraclitus because everything changed, Protagoras because everything was subjective. Separate treatment of οἱ ῥεοντες occurs at 179c - 183b. The extent to which Plato accurately represents Heraclitus' and Protagoras' views is debated, and, with the introduction at 156a of a "secret doctrine of Protagoras", largely suspected. For our purposes however it does not really matter: see VI.2.(2).

51. Certainly at least in the context of the Theaitetus: see last note.

52. The form that Plato's refutation of 'Protagoras' took, that to state the thesis implied its falseness, was in terms of truth and statements (170e - 171d); it did not raise questions concerning any explanation of the real world.

53. Irrelevant, that is, for Plato's purpose. Thus the sort of puzzle posed in the Euthydemus, "one wants Cleinias to be not what he is (ignorant), but what he is not (knowledgeable); so one wants him not to be (ie. be alive or exist), that is one wants him dead" (238d), is completely out of place in the Sophist. This rescues Plato from a lot of unnecessary muddle, but only at the expense of greatly restricting the field covered by the dialogue, which is therefore not so much about sense and reference as those who see in Plato an early Wittgenstein would like.

54. The analysis of the last paragraph, that brought out the difficulties of Plato's explanation of negation in terms of other-ness, does not of course prevent Plato, himself unaware of the limitations of his position, from putting "x is not heavy" into this open-ended form.

55. The Sophist is based on the question of "is" and "is not", and the example of light and heavy is nowhere actually used even though the appearance of great and small shows that the usual general class of opposites is being considered (257bc). Hot and cold also occur, but only in a "third man"-type argument concerned with the definition of το ὂν where the pair is cited as an example of earlier physical theories that sought to reduce the world to a pair of opposites: such a pair of opposites has nothing to do with the logical problem of opposites that we are considering (Soph.243d8). I shall suggest that the omission of the light and heavy pair is, by the time of the Sophist, probably significant.

56. The sense in which a change in Plato's position could have occurred would be that "heavy" was no longer seen as a simple antithesis to "light" as before, but was thought of as relative to something else (weight in the absolute). "Other than", however, can hardly be said to provide such a concept; it simply directs us to look elsewhere than under heaviness to find the reality to which "x is not heavy" corresponds.

57. H.D.P.Lee, in his translation of the Timaeus (Penguin Classics 1965) p.24, claims that the case against the grouping of the dialogue with Plato's last works "has not been established"; J.E.Raven, in Plato's thought in the making (1965) p.225, accepts "the general supposition" that the dialogue is late.

58. G.E.L.Owen, "The place of the Timaeus in Plato's dialogues" CQ ns.3 (1953)79-95, and more recently G.Ryle Plato's progress (1966) 238-43. I do not feel competent to decide this question here, but the treatment of ὄντα and γιγνόμενα ,at least,in the Timaeus would appear to be unaware of such advances as are made in the Sophist. In any case I hope to show that the question of priority need not be so very significant for the argument I am advancing here, as the advances each Platonic dialogue made on the question of weight lie on quite different levels.

59. Βαρυ δε και κουφον μετα της του κατω φυσεως ἀνω τε λεγομενης ἐξεταζομενον ἀν δηλωθειη σαφεστατα 62c and ὁθεν ὀνομασθη 63a. Plato seems aware of the hold exercised on the concepts by the words used; he is attempting to break out of this linguistic straight-jacket.

60. Το μεν γαρ ὁλον ... σφαιροειδες ὀν, τοπον τινα κατω, τον δε ἀνω λεγειν ἐχειν οὐκ ἐμφρονος 63a. If it was the Earth, and not το ὁλον (where the outside of the sphere keeps all inside, 58a4-7), that the man is imagined as perambulating, this would be a striking anticipation of the force of gravity. See further in n.62 below.

61. Διιστάμενον I take to mean "distinguish by weighing": see below ch.VI.5.(4).

62. The model of a balance can be shown to be retained throughout this section, but while the weighing of parts of fire away from its aggregate mass, and of γεωδη γενη away from earth, offer no difficulties, the argument from 63d4 to the conclusion 63e3 is rather obscure. Whereas πλαγια appears to evoke the inclined beam of a balance, this interpretation should be considered cautiously.

The passage is an attempt to generalise the explanation of light and heavy, already offered for fire and earth, for the whole real world. It should be remembered that in the Timaeus Plato divided matter into four elements: earth, air, fire and water: each of these occupied its own particular, but not necessarily fixed, place in το ὁλον (57c2-4 each kind of matter collects together wherever its bulk, πληθος , might be; cf. also 58c1-2). The places (τοποι) occupied by the various elements were contiguous and to a certain extent (with composite bodies or accidental movement) over-lapped; all however were bounded by the spherical limits of το ὁλον (58a). 63d4 - e3 goes beyond the separate example (of fire and earth) and considers all four elements together (with their variations: τα πληθη των γενων 63d5-6).

Plato's description of a man walking round the sphere of το ὁλον (63a and see n.60 above) indicates that he meant to explain up/down as away-from/towards the centre of the sphere (ἀντιπους graphically supports this view, and πολλακις proves it (63a3), for, unless the man's feet were always towards the centre there would be only one occasion when he was directly underneath where he had earlier been; ταὐτον (63a3) refers to the central στερεον τι). As already

62 contd.

remarked (n.60) τὸ ὅλον is not the Earth or even earth, and Plato is not always consistent in his use of up/down in relation to individual elements (as 58b8 where ἄνω κάτω μεταφέρεται (sc. πάντα) πρὸς τοὺς ἑαυτῶν τόπους contradicts much of 63, which establishes that only motion κάτω can be πρός). As 63d4 - e3 comes so close upon his denial of overall up/down, there is no reason to allow for inconsistency in the general picture of up/down and light/heavy that it presents.

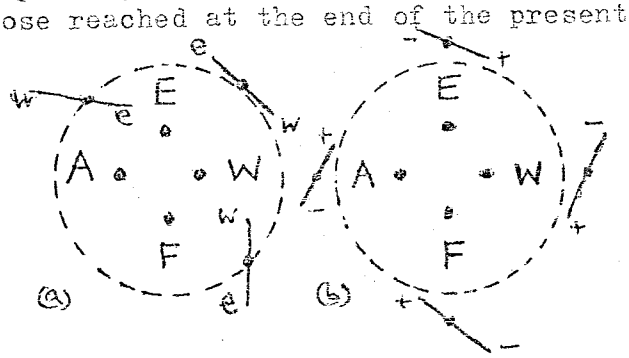
This section does however presuppose some outside (fixed) standpoint from which the changes in these terms can be viewed - a standpoint which is neither that of τὸ ὅλον (which has no top nor bottom) nor of any aggregate mass (as these are not fixed, and as a general picture applicable to all such aggregates is to be given). I think this problem is avoided by considering the intersecting lines of the balance-beams registering inequalities of weight around and about the various aggregates.

I translate as follows:

> "These terms (light, heavy, up, down) must vary between themselves because the aggregates of the types of matter occupy distinct positions. The reason for their variation is that what is 'light' in one place will be found to be (and become) the very opposite of (inclined to, or absolutely different from) that which is 'light' in another distinct place; and the same is true for 'heavy', for 'up', and for 'down'."

Ἐναντίος (of τόπος), that I have translated "distinct" to differentiate it from "different" or "opposed", recurs in both parts of the passage, and the connection between the two (γάρ 63d6) implies that the "light" etc. vary between weighings carried out around different aggregates (earth, air, fire, water) rather than that these weighings occur merely at different points around a single aggregate. This case has, after all, already been considered in the two particular examples (of fire and earth) that precede the generalisation.

The passage can therefore be expressed graphically in the following diagram(s). This makes clear that the differences in "lightness" are the different angles of the balance beams: indeed πάντ' ἐναντίαν καὶ πλάγιαν καὶ παντῶς διαφοράν. Interest in inclination is by no means surprising as my general conclusions on Greek weighing (and especially those reached at the end of the present chapter) show.



63. "He defined heavy and light not absolutely, but with reference to bodies such as earth. It would appear that of such bodies the heavy is with difficulty moved to a place not its own, whereas the light is moved easily": thus Sambursky The physical world of the Greeks (Pbk.2nd.ed.1963) p.90. I cannot understand why Sambursky does not refer to the Timaeus passage just discussed, as Theophrastus clearly had it in mind. Perhaps however this is why Sambursky can write: "since the 'place not its own' of a heavenly body is above...", which is not what Plato says.

64. Sambursky (as cited in n.63) attributes the identification to Theophrastus on the evidence of this passage alone.

65. See above end of ch.VI.2.(3). One is tempted to associate the continued inclusion of the hot/cold pair with the lack in ancient Greece of thermometers; certainly the parallel of the max-min type would be accurate.

66. Such as is represented in diagram (a) in n.62 above.

67. See in ch.VII.2.(8) and, for detailed examination of Aristotle's actual"experiments", ch.VIII.1.(1).1.

68. Plato can legitimately be said to have removed the barriers that formerly existed between opposites. The importance for physics of the relationships between light/heavy (weight), hot/cold (temperature), hard/soft, rough/smooth, and wet/dry (all friction) is well brought out by Sambursky Physical world p.91-2.

69. [Arist] Mech. is discussed under ancient theory in ch.VI.1.

70. Physical world p.41.

71. I do not intend circularity here, but rather hope to draw out those aspects of this discussion that will be seen to be of wider significance in the context of other evidence.

72. Equally, the lack of a concept of absolute weight prevented the simple invention of a machine, as a spring balance, that directly measured it.

73. Thus Kirk and Raven,"Greek Science" in The Greek World ed.Lloyd-Jones (Penguin 1965) and especially pp.120-121, give a diametrically opposed picture of the relation between Plato and Aristotle to that which I have reached here on the question of weight.

74. That the climate of opinion was a major factor inhibiting technological progress in the ancient world is well argued by D.W.Reece, "The technological weakness of the ancient world" Greece and Rome 16(1969)32-47, and esp.34-36. Though the change of emphasis is generally, and probably correctly, put at the start of the fourth century when ethics really became the popular subject, the influence and direction of the early Parmenides should not be overlooked (see above ch.VI.2.(2) and PP p.319).

75. Plato Philebus 55e distinguishes ἀριθμητικὴ μετρικὴ and στατικὴ from other τέχναι ; and in 56d-e ἀριθμητικὴ τῶν πολλῶν is distinguished from ἡ τῶν φιλοσοφούντων , and λογιστικὴ and μετρητικὴ are divided between ἡ κατὰ τεκτονικὴν καὶ κατ'ἐμπορίαν and the calculations of philosophers (compare Republic 525b-c).

76. The two-pan balance is of course initself no obstacle and proves nothing. Use is the deciding factor, and, as for all intents and purposes, no other types of balance are attested, it follows that the Greeks (philosophers and traders alike) used only the two-pan balance and only thought of weighing in terms of its use. My point is that through this use nothing can be learnt of the concept of absolute

76 contd.

weight, nor would it occur to people using such a balance to look for any such concept. The linguistic problems offer a more powerful, if indirect, motive for such a search.

My analysis has therefore had two functions: [1] to examine the evidence and show that Greek philosophers and writers were restricted to practical and theoretical experience of only the two-pan balance; and [2] to consider, as a question in its own right, the relationship between this and the development of the concept of absolute weight. On the origins of the concepts light and heavy and the impossible question of their priority see above ch.VI.2.(1). It is interesting finally to note that the problems encountered in the course of this analysis - the origins and limitations of the theory of weight - reflect precisely the two most important questions of Greek science in general: on which see Reece as cited above in n.74; Edelstein "Recent trends in the interpretation of ancient science" Jnl.Hist.Ideas 13(1952)573-604; Finley "Technical innovation and economic progress in the ancient world" Econ.Hist.Rev. 18(1965)29-45; Sambursky Physical world chs.I and X.

77. With the variant title The Ransom of Hector.

78. Rather differently a personification of Ares is weighed against Ἔρως at Plato Symp. 196c.

79. See ch.I.1.(2) representation U.I.

80. At Ar.Aves 1240 Δικη also wields the μακελλα of Zeus.

81. See ch.I.1.(2) representation U.VII.(1).

82. The procedure of weighing involved is discussed at ch.I.3.(1).

83. Thus τέρας νεοχμόν (1371f) is sarcastic.

84. L.Stephani in Compte-rendu St.Pét. 1873 p.81.

85. B.C.Dietrich "The judgement of Zeus" Reinisches Museum für Philologie iv.f.107 (1964) 97-125, on pp.120-21, citing Wüst.

86. The only possible reference I know to Eros in a balance pan is Plato Symp. 196c ἐις ἀνδρείαν Ἔρωτι οὐδ' Ἄρης ἀνθίσταται.

87. For example S.G.F.Brandon The judgment of the dead (1967) p.97.

88. Contra D.Daube The scales of justice (1951) p.114.

89. Contrast for example Leaf and Bayfield's note on Il. 8.69.

90. Although some passages are uncertain, none need be as illogical as Christian (quatrocento and later) panels showing St.Michael and a balance, where whether the same figure or two different figures are in the pans is awkward to decide (see for example Brandon Judgment of the dead pl.8 and p.126). This illogicality springs, as I hope to show, from the superimposition of two incompatible balance allegories. The challenge is to disentangle the Greek from the Egyptian (see further ch.IX).

91. This last however begins to stray into the idea of changing fortunes (but not irrevocably changed), below ii, were it not for the fact that different people's κῆρες occupy the pans and several are unlikely to return.

92. See ch.VI.5.(3).

93. Gnomai Monostichoi 465 [Meineke FCG iv p.353].

94. Compare the alternative metaphor of dice: κυβευτής Soph. fr.947, fr. 895; Aesch. Ag. 32; Thuc.I.25.

95. For modern discussion see most recently H.Lloyd-Jones The justice of Zeus (1971).

96. See ch.IX.2.(1).

97. I cannot at present make certain sense of Herodas 7.33ff. It seems to suggest that the balance was able to detect something very small - even a lie (ψεῦδος), rather than that it was able to distinguish a lie from the truth.

98. Shakesp. Merch.Venice IV.i.331f.

99. D.Daube The scales of justice (inaugural lecture 1951)

100. Thus for example on the covers to the following books: W.R.Cornish The jury (1968); J.C.Smith and B.Hogan Criminal law (2nd ed.1969); R.S.Summers Essays in legal philosophy (1968) also More essays (1971).

101. Comparison is not impossible using such a balance, but the procedure is somewhat indirect; an immediate explanation should surely be sought for such precise change in normal symbolism.

102. Daniel 5^{25} (the writing on the wall): see further below ch.IX.1.(5).

103. As cited above in n.99, on p.129.

104. Even in suggesting this example I may possibly be thought out of date by many nuclear physicists.

105. For example Brandon Judgment of the dead p.96.

106. In general see J.Harrison Prolegomena to the study of Greek religion (3rd ed.1955); Brandon Judgment of the dead ch.IV; W.F.Jackson Knight Elysion: ancient Greek and Roman beliefs concerning life after death (1970).

107. The miniature, decorated gold balances in the Mycenaean graves are plausibly impractical. See further on Bronze Age eschatology and weighing in ch.IX.1.(6).

108. Brandon Judgment of the dead p.78.

109. The Furies could possibly pursue a man after death, but more relevant is their pursuit of him while still alive: Orestes to Athens and Oedipus to Colonos. The Furies were not however usual, and seem to have confined their attentions to spectacular criminals.

110. Hdt.II.81.2, 123.2 (with How and Wells notes); Kirk and Raven PP p.270; Eur. Bacchae 13ff.

111. Thus C.Sourvinu-Inwood in a paper to be published shortly.

112. Empedocles frs.115, 117 (PP 471, 476); Plato Phaedrus 248-9; see further Jackson Knight Elysion index sv.reincarnation.

113. Above s.v. Dionysos and Pluto; the connection can theoretically, and with ingenuity, of course nevertheless be suggested: cf.Hdt.II. 81.2 relating Orphic and Bacchic rites to a common origin !

114. Brandon Judgment of the dead 88 n.76.

115. Reference has already been made to metempsychosis in the fourth century (Plato Phaedrus 248-9 above n.112).

116. Pap.Bologn. 3 (Brandon Judgment of the dead 97)

117. Perhaps as a result it is also part of the Hebrew: see ch.IX.1.(1) [Egypt], and (5) [Hebrews].

118. See Brandon Judgment of the dead ch.V esp.122f. The key points are two early Christian works written in Egypt: The testament of Abraham and The history of Joseph the carpenter.

119. The latest Attic representation is of the second half of the fifth century (P.8); the fourth-century amphora on which P.9 appears is Campanian.

120. This is the illogicality of later Christian iconography in combining the Kerostasia with the Egyptian Psychostasia.

121. Thus Encyclopedia Britannica sv. Libra; also R.Brown Primitive constellations (1899) p.71.

122. D.R.Dicks "Solstices, equinoxes and the Presocratics" JHS 86(1966) 26-40, esp.at 27, 39-40.

123. Arist. Metaph. 1073.b.20; Mete. 343.a.24.

124. Despite Brown Primitive constellations p.71.

125. Ed.Manutius (Teubner) 3.1.5.

126. Ch.IX.1.(1).

127. It is this weather that is precariously balanced and unpredicatable.

128. I shall return to consider the simile, and the implications of the phrase ἐπὶ τῶν ἰσχόντων ζυγῶν further below ch.VI.6 and VI.4.

129. Cf. Koster's note on Tzetzes' scholion 1962; Nilsson OCD^2 sv. Apatouria; L.Deubner Attische Feste (1932) 232ff.

130. Ch.VII.2.(14) reconsiders the ceremony as a practical context for weighing.

131. For example Dietrich "The judgment of Zeus" Rhein.Mus.f.Phil.1964. 102 n.16; Cook Zeus ii (2) 860-2; Loeb note to Theognis 557-8 (J.M.Edmonds); Daube The scales of justice 114.

132. Or just speed, as in Poseidippos' explanation for Lysippos' statue: ἀεὶ τροχάω.

133. The later representations are not relevant for the fourth century.

134. Zeus ii (2) 859-68.

135. Ch.I.1.(2) Reps.K.6-7, KR.1.

136. M.L.West Hesiod: Theogony (1966) p.341 (n.to line 638); cf.Dietrich "The judgement of Zeus" who slides from tension to balance for the words τανύω and τείνω .

137. Leaf and Bayfield (ad loc.) hesitate between a plumb-line or a tightened string for σταθμή .

138. See above ch.VI.1.

139. Discussed,as a simile,below in VI.6.

140. And doubtfully more: see above ch.I.3.(1) on procedure, and VI.3 s.v. Minos, Pluto, Dionysos.

141. See, for Apatouria, ch.VII.2.(14); for the other commercial contexts, ch.VII.1.(1).

142. For lists of passages upon which the analysis is based see ch.I.1.(3); I have kept references here down to a minimum.

143. Nor indeed would one expect them to be, given the very different principles on which the Greek and near-eastern balances worked (see further ch.IX and Conclusions).

144. ταλαντιαῖος "weighing a talant", but also "worth a talant": see below ch.VII.2.(16).

145. This point has been anticipated above in ch.IV.3 and V.2-3.

146. Ἀναμάλως , because the forces were alternately acting and being acted upon. The passage goes on to note the separation of light from heavy: see further in VI.2 above.

147. The relative aspects will be considered in the next sub-section: VI.5.(2).

148. The word is used of the water-clock in the sixth century AD: see ch.VII.2.(15).

149. This is relevant immediately to VI.5.(4) below where I investigate what "stationary" aspect there might be in Greek weighing. The conclusion reached in the present section however is of general importance to the whole of the thesis being advanced here on the nature of Greek weighing.

150. For light and heavy see VI.2; the same applies to ἄνω/κατω φερεσθαι, βαδίζειν etc. that I shall not discuss separately here.

151. Compare further: (1) Aeschylos' reading of ἐρυσασθαι at Iliad 22.351 (see scholiast) and Theognis 77 -8 (ἀντερυσασθαι); (2) the idea of ἄγειν Arist.Ath.Pol.10.2, 51.3; Dem.24.129; IG II^2 1013.29 is similar but weaker; (3) φερειν and compounds, especially Dem.5.12; Plato Tim.63c; [Arist.] Mech.850.a.4; and (4) the idea of ἔχειν , Xen. Mem.III.10.11 though possibly too weak to press the point far.

152. In Homer (Iliad 8.72 and 12.434) the verb is reserved for lifting hand-held balances off the ground. This use is not of course relevant to the present discussion.

153. Compare the other words used: ἑλκειν, ἐρυσασθαι, βριθειν, κλινειν.

154. It introduces the parallel at Plato Tim.63c and the joke at Ar. Vesp.41 δημον βοειον ... διοσται.

155. Note ἀφιστανται cf. Xen.Symp.II.20. Διασφειν at Plato Laws 733B is outside the comparison of weighing procedure with that of making the hedonistic calculation (Protag.356B).

156. Such as is obvious in κλινειν etc: Iliad 19.223; Plato Phaedo 109A. Both thsse passages could be held to define ῥοπη as effect.

157. Discussed in VI.3.(2).ii above.

158. Although this passage and those cited above for σμικρα ῥοπη (Soph. OT. 961 and Eur. Hipp. 1163) might, I admit, be interchangeable.

159. See VI.2.(5).

160. I doubt the figures of the text: above ch.IV.1.

161. Cf. esp.Plato Laws 733c.

162. It may possibly have been so even for Archimedes, and need not have preventing his attempts to weigh by the method.

163. See Appendix B for experiments. On"stable"balances a real difficulty surrounds measurement of swing: see mathematical theory in Appendix A (on modern balances).

164. On procedure see ch.I.3.

165. Gardiner Egyptian Grammar (2nd ed.1950) 521 Sign U.41.

166. At [Arist] Mech. 849.b.25, 850.a.23-4, 850.b.1-2 movement of the beam is simply described by κλινειν .

167. Cf. Polyb. VI.10.7 μηδαμου νευειν.

168. If the suggested reading [τιταινει] is correct, it may be that Zeus' balance is still about to be lifted from the ground (cf.Iliad 8.69 and above ch.I.3.(1)).

169. See following VI.6 as a simile.

170. Μεσοῦν does not seem to have been used in any identifiable weighing context.

171. Thus IG V (1) 1390.100 (Andania, first century BC) σταθμοις και μετροις δεμοσιοις ποτι τα δαμοσια cf. IG II^2 1013.37. For the reverse ἀσύμβλητος is used (IG II^2 1013.17).

172. Contrast ancient Egyptian, where the same verb, mḫɜ, meant to balance and to equal (Gardiner EG^2 570).

173. Most other references cited by LSJ are simply to equalisation in non-weight contexts.

174. See Appendix A.

175. I am uncertain about σκεθρῳ ταλαντῳ in Lycophron 270.

176. What particular skill Plato thought the operator to need at Protag.356a-b is unclear. Probably the reference is to the difficulty of making the distinctions in real life - or the importance of correct distinctions being made (see further below in VI.6 as another simile).

177. I do not include here references to balances and weighing in Greek theory (VI.1) or experimentation (VII.2.(8) and VIII.1.(1).1).

178. Ch.VII.1.(1).

179. Thus H.Tredennick's note to the Penguin translation (1970) 239 n.11.

180. See above VI.5.(5) on ὀρθος and related words.

181. See following ch.VII.1.(4-5) and VIII.3.

182. Ch.VII.1.(1) considers the commercial contexts of weighing.

183. VI.3.(1-2).

184. VI.3.(2).iii, and see n.97 above.

185. Kerdon, a cobbler, is speaking the lines: see Headlam note ad loc, and further discussion above of the word ῥοπη VI.5.(3).

186. It could be added here that the balance was not invoked by Parmenides as a symbol of symmetry (Parmen. ap. Theophr. de sensu 3; Kirk and Raven PP 357).

Chapter VII

1. See chapter V.

2. I have argued that several later weight standards may have originated from earlier commodity ad hoc units. These are however now all lost to us apart from the Homeric gold talants. For references to Homeric weights see ch.III n.204 and ch.V.2 (1).

3. Illustrated by Lang Agora X Plate 12.

4. Ch.1 Rep.C.1.

5. Discussed above in ch.I.3.(2).

6. Arist. Ath.Pol. 17.4. Aristotle has mistaken the term as a capacity measurement (wet and dry). This would not have been a distinction possible before the fourth century as I hope to establish in a separate study of Greek capacity measurement.

7. Ch.III Conclusions.

8. Doubts could be raised about the date for the introduction of coinage which is possibly overstepped by some of these examples. However as the picture hardly changes in the immediately following period, I think this reconstruction of the earlier relatively secure.

9. Ch.I.3.

10. This applies to weighing in general. The Greeks were well aware of the problem of the variable packing characteristics of different commodities; their solution, different lip sizes for heaping up different commodities, is as remarkable as it is impractical (IG II^2 1013 18-29). The problem was universal: cf. Luke 6.38 "good measure, pressed down, and shaken together, and running over..."

11. C.M.Kraay "Hoards, small change, and the origins of coinage" JHS 84 (1964) 76-91.

12. Ch.III.8.

13. I am far from certain however that the statement of Aristotle NE 1134a35-35a3 (οὐ γὰρ παντα χοῦ ἴσα τὰ ὀνητὰ καὶ σιτητὰ μέτρα, ἀλλ' ὃ μὲν ἀνοῦνται, μείζω, ὃ δὲ πωλοῦσι, ἐλάττω), which though made of wet and dry capacity measures could be applied by inference to weights also, in fact refers to other than the difference between buying in bulk and selling in small quantities. My point, admittedly needing some elaboration, is based on the observable variation in weights and measures across parts of the Greek world.

14. Thus ivory purchased for Delphi in Athens with Attic coin that had to be "bought" in Delphi: FdD III (5) 25.II.A.5-13 (see ch.III and Appendix C on coin conversion).

15. Even the literary evidence for such sets is late: IG II^2 1013 and the 222/1 Metronomoi Inscription (Hesperia 1968 73-6). See the evidence collected in Appendix E.

16. See following ch.VII.1.(2).4 and (4).

17. On metal handling see below VII.1.(2).

18. Later cf. Thera c.200 BC IG XII (3) 330.18f, 186f; Athens c.350 BC Cholargeis Deme IG II^2 1184.13ff. On the Laconian IG V (1) 363.12 cheese is listed simply by slices. There may possibly be an early origin to the 5-mina monthly contribution of cheese expected in Spartan syssitia (Plut.Lyk.12); but, see also below on σύκα , this tradition is not particularly reliable.

19. See ch.VI.3.(4) and VII.2.(14).

20. Hdt.II.168.2, 5-mina rations of gruel and beef, applies only to Egypt.

21. See detailed discussion above ch.I.2.(1).

22. Add for later: Lesbos (Methymna), end third century, IG XII (2) 498.16f; Amorgos, end second century, IG XII (7) 515.64.

23. Though country-folk were vulnerable to dishonest traders (Ar.Equit. 316-7), there is no suspicion of such deceit in Pax 1248-9. It would surely be out of character for Trygaeus.

24. Figs most often are handled dried (ἰσχάς) cf. Ar.Pax 1217; eventually a special measure was decreed for them IG II^2 1013.24-7. Only Plut.Lyk.12 refers to figs by weight units (σύκων ἡμναίας πέντε - the Spartan contribution, cf. on cheese above n.18).

25. Ch.VI.6, VII.1.(2), and VIII.1.(1).1.(6).

26. See above ch.III passim, but esp.nn.219-22 and text.

27. On the nature of their fraud, which Aristotle seems not to have understood, see ch.VI.1 and Appendix A.

28. Phoenicians ? (see ch.IX.1.(4)).

29. As expensive as silver; IG II^2 659.27 (Athens 3rd cent), IG XI 203.73 (Delos 3rd cent) show πορφύρα and φοινικίς weighed on public accounts; μίλτος by contrast appears to have been much cheaper (cf. IG II^2 1672.12,184, where the price is between 3 and 3½ob per stater).

30. Argument from weight system alone (see ch.III conclusions for Athens section) could indicate for Athens from official inscriptions also: rope and sails (a specialised context, see further below ch.VII.2.(11)); glue, pitch and ruddle (also possibly associated with shipping); and garlic.

31. The detail is especially noticeable on the fourth-century Eleusis accounts IG II^2 1672, 1673 if contrasted with those of the fifth century IG I^2 313, 314; it is also apparent in the third-century Delian self-administration (see ch.III.12) when contrasted with periods of Athenian control.

32. See below ch.VII.1.(4) part 6 following.

33. See further the next chapter (VIII).

34. See especially A. Burford The Greek temple builders at Epidauros (1969) with my review in JHS 91 (1971) 204-6. Such animosity as may be detected in what follows should be ascribed to my own attempts at supervising building operations.

35. Suspicion can I feel be cast on some of the contracts which are manifestly over-elaborate: thus δικελλαι on IG II^2 1673.51 which are weighed at 1½staters each as well as being priced at 1dr 2ob per stater; why were they not simply priced at 2drs each ? The temptation for officials, with public records to produce, to over-elaborate these records must be reconsidered further below.

36. IG I^2 374.190ff, 279ff and 352.21ff.

37. See further ch.VIII.3.

38. Homeric Greeks were exceptional; see also V. Ehrenberg The people of Aristophanes (Pbk 1961) 258.

39. Commercial weights are more relevant here than coin (on which see following ch.VII.1.(3)), and their inaccuracy has been already discussed at length above in ch.II.

40. As noted above (n.23), there is no deceit implied in the weighing of figs on the trumpet balance of Ar.Pax 1248-9.

41. Thus Gorgias Palamedes 30: μέτρα καὶ σταθμὰ συναλλαγῶν εὑρόμενος διαλλαγάς.

42. A rare word, though not to be associated with money-changing as might appear attractive: see below VII.1.(3).

43. See most conveniently R. Seager "Lysias against the Corndealers" Historia 15 (1966) 172-84.

44. Thus Cos, PH.37.48-9, ἄρτοι δυο ἐξ ἡμιεκτου is more what one would expect.

45. Measuring-out or whatever other form it took. Capacity measurement can be just as complex as weight measurement.

46. Compare the absence of weighing in the context of the Greek kitchen: below ch.VII.2.(6).

47. The weighing of baskets of loaves, if they are baskets of loaves, on Eurysakes' Sarcophagus (Rep.CR.1).

48. Forbes makes no mention of weighing and related problems in his many studies of Greek technology, and in particular in Metallurgy in Antiquity (1950).

49. A. Burford BSA 61(1966)254-334 (revising IG IV (1)^2).

50. See chh.IV-V and below IX.

51. Especially [Dem.]49.48-52, see above ch.VII.1.(1).

52. Above chh.III-V.

53. As with medical recipes: below VII.2.(7).

54. See ch.I.1.(2) for lists of representations of the balance.

55. H.W. Catling, Cypriot bronze-work in the Mycenaean world (1964) pp. 278-81, describes the context of the smithy, including the new bronze tools meant for sale. The balances are patently too small to handle the unworked 81 lb 10 oz copper ingot also present.

56. Reps.CR 11 and 5,7,8 respectively.

57. This seems to be the basis of Seltman GC^2 ch.2, especially his remarks on p.21f.

58. Flans and a stone mould have been found in a Hellenistic mint at Paphos (Cyprus). They are illustrated in JHS Arch.Report. 1968-69 p.51 figs.21-2; several coins were evidently produced in one mould.

59. This is my own suggestion, and is developed further below in this section.

60. See above ch.II.2 on coinage and chs.IV-V.

61. Below ch.VII.1.(3) and (4).

62. Particularly striking is the gold series of Alexandrian tetradrachms described by C. Kraay "On the weights of ancient coins" Num.Circ. 71 (1963) 116.

63. See Appendix B on experiments carried out with reproduction balances.

64. And see further in ch.VIII where a similar point is reached in considering the maximum precision possible.

65. I have doubted the Sybaris weight discussed by p. Zancani-Montuoro in Annali 12-14 (1965-7) 21-30 and attributed by her to the late sixth-century Sybaris mint: above ch.II.1.(2).II.

66. IG II^2 1388 etc; W.S. Ferguson The Treasurers of Athena (1932) 86-7.

67. Compare floor sweepers: [Arist.] Prob.xxiv.9, 936b25ff; a bellows operator: SEG X 394/5 (Athens c.420 BC); and a counterfeiting χρυσοχόος from third/second-century Dyme: SIG^{3}530, Pleket 11.

68. As opposed to the general ruling on the weight standard: IG II^2 1013 for an example.

69. See the discussion of Arist. Ath.Pol. 10 in ch.V.5.(3) and Appendix D.

70. IG XII (2) 1, Pleket 6; see Appendix E on legislation and further ch.VII.1.(3)-(4). Perhaps a simple ratio - as in metalworking above - was used.

71. To be swept up by the cleaners of [Arist.] Prob. xxiv.9 perhaps.

72. For example Eleusis, from IG II^2 1542.10 to 1544.12f.

73. See esp. M.Crosby "The leases of the Laurion mines" Hesperia 19(1950) 189-312 and 26(1957)1-23; and R.J.Hopper "The Laurion mines: a reconsideration" BSA 63(1968)293-326.

74. See Appendix E (c).

75. Further on coin: Ch.VII.1.(3); VIII; and above II.2.

76. See ch.VII.1.(3) and VIII.

77. See Table ch.II on the Distribution of weights in the major Attic series (at the end of ch.II.1.(1).II).

78. This I myself found convenient when supplementing my own weights with pieces of lead for the experiments of Appendix B. The 1/8" lead sheeting was easily and accurately cut with kitchen scissors.

79. Noted by Lang Agora X p.5.

80. See ch.II.1.(1).IV.

81. M.I. Finley in Proceedings of the 2nd International Conference of Economic History, Aix en Provence 1962 vol.I, p.15, claimed that only electrum was beyond analysis before Archimedes; that it has only recently been possible to analyse the composition of silver coins without destroying the coins in the process (by neutron activation: C.M. Kraay and V.M. Emeleus The Composition of Greek Silver Coins 1962) casts doubt on this claim.

82. See Appendix E for text and further discussion.

83. For ἀνεπαφος cf. [Dem.] 35.11, used of ὑποθηκη ; 35.24, of χρηματα held until money should be paid; and further 35.37, 38; 56.38, 40. Ἀσυλος and ἀτελης παντων are clear.

84. Contra Baynes as cited in their note to [Dem.] 35.24 by Paley and Sandys, Select Private Orations^3 (1898). δεκιμαστα ταλαντα, of Alexandrian coins in IG II^2 1492.101-2, pose a problem; I understand that the talants were to be made up of coined current silver; this also works for the third-century Delos IG XI 161.B.20 ἀργυριου Ἀττικου καὶ Ἀλεξανδρειου δοκιμου.

85. Or is this gold plated ? Cf. IG II^2 1424 a 105 χρυσιον ἐπιτηκτον ὑπεργυρον.

86. From ῥινάω "file down" (LSJ).

87. The implications for inaccuracy I pursue in the next chapter.

88. Compare mint buying and earlier general commerce (above VII.1.(1)). Such weighing is simple, immediate and accurate.

89. Compare the Aristophanic parody τόκοι τόκων : see Dover ed. (1968) note ad loc.

90. Cited by Seltman GC^2 (1955) pp.34-5.

91. Lysias fr.149 (Sauppe); Menander fr.1023; κολλυβιστικος τραπεζα Ostr.Strassb. 9 (third century BC). I do not feel that there is much point in pursuing the possibility of small coin "makeweights" used for conversion. Advanced tentatively by C.M. Kraay, "A propos des monnaies divisionnaires de Crotonne" Schweizer Münzblätter 1958 99-102,

91 contd.

discussing a very small, and peculiar, series of coins bearing the symbols of larger mints, the suggestion lacks plausibility. There are insufficient such makeweights; if weight is to be "made up", then simple weighing would achieve this without the need for special tokens; the variation in coin weights is too great for a practicable makeweight system; and, finally, small coins offer themselves quite sufficient for the purpose of presenting the foreign trader with small change. κολλυβος can, I conclude, keep its possible derivation from the Hebrew hālap ("change" or "exchange", as LSJ) because of the context, yet also be a viable Greek fractional coin.

92. Illustrations of money-changers (or even of bankers) show no balances, but rather a simple table with lists of figures (sums lent or exchange rates ?): thus possibly the Darius Vase, found at Canusium but probably painted at Taranto in the late fourth century (Furtwängler Gr.V. II.142ff; Tod BSA 18.124 and 28.150)[2]; and a later representation, from Pannonia (illustrated in SEHRE pl.XLIII.1).

93. The problems of variable exchange and conversion rates are briefly discussed in Appendix C.

94. In normal life: Ar. Vesp. 606ff, 791f; Aves 502; frs.3, 48, 614; Plutus 379; Pax 645. Even after this two obols were carried as "Charon's Fee": Ar. Ran. 140, 270 and see Boardman and Kurtz Greek Burial Customs (1971) esp.211.

95. Tests that I have conducted with modern coins show some difference as a result of holding coins in the mouth: ½p being 1.771gm dry, but 1.780gm wet; and a 1p coin being 3.541gm dry, but 3.578gm wet. Although Marsden contemplated the sprinkling of artillery balls with water to bring them up to weight in the heat of an ancient Greek battle (see below ch.VII.2.(9)), no numismatist to my knowledge has acknowledged the deleterious effects of the usual manner in which Greeks kept their small change. Yet numismatists have claimed that these coins were minted to limits of 0.03gm or even 0.01gm. See further below in ch.VIII.1.(2).

96. See above ch.VII.1.(2).

97. Ch.VII.1.(2) with n.66 above.

98. Neither this point nor the last applies to weights marked simply with the legend δημοσιον (see above in ch.II.1.(1).V).

99. For, as argued above in ch.II, stamping does not seem to imply public certification.

100. Uncertainties of date, however, cannot be resolved by considering the coin evidence without begging the question of the efficiency of the decree (thus also ML.45 and commentary pp.115-7).

101. This is to be derived from the several lead weights with rounded edges or hollowed underneath, from the fair overall accuracy of coin, and above all from the extent to which the contemporary Greeks accepted them on trust.

102. Cf. ἐπανισοῦν and ἀσυμβλήτῳ on IG II^2 1013.15, 17.

103. This argument can apply to Aristotle as much as to Lang or Hultsch.

104. Chs.IV-V.

105. A further context for official legislation about weight is ship capacity. I discuss this below in ch.VII.2.(12), and conclude that the question of weight is there superficial.

106. See above ch.VII.1.(1) end.

107. See comments at the end of this section (VII.1.(4)) and further discussion of the credibility of accounts in VIII.2.(2).

108. Ch.III conclusions.

109. I have intimated above (VII.1.(2)) that it was probably more likely by bulk than by weight, comparing plaster or, better, marble chips.

110. VII.1.(2).

111. See ch.III under Athens, and again ch.IV.2 and VIII.2.(4).

112. This evidence has been largely assembled in ch.III.

113. Note however that at Athens the Agoranomoi, Metronomoi, Sitophylakes, and Harbour Officials were all elected by lot; so too the Temple Builders (Arist. Ath.Pol.54.6).

114. Comparable checks were required on length measurement: IG XI (2) 199.78f, 84f, 86f; 287.90 (third-century Delos); Burford B.21 C.103f and D.120ff (third-century Epidauros). One begins to wonder if these elaborate check-requirements are not as superficial as the resultant accounts.

115. Ehrenberg The People of Aristophanes (Pbk 1961) ch.IX esp.236-7 with n.1 p.237; G.E.M. de Sainte-Croix "Demosthenes' TIMHMA and the Athenian Eisphora in the Fourth Century" Class.et Med. 14 (1953) 30-70 esp. p.41.

116. Pausanias III.8.4; V.4.7; VI.1.3 (mentioning his son Archedamos); VII.10.2.

117. The OCT reads: βουλόμενοι οἱ περὶ Ξενίαν τὸν λεγόμενον μεδίμνω ἀπομετρήσασθαι <τὸ> παρὰ τοῦ πατρὸς ἀργύριον δι'αὐτῶν προσχωρῆσαι τοῖς Λακεδ... Either Xenophon is meaning to disparage this traitor to the democratic Elean cause by recording an uncomplimentary anecdote to characterise Xenias, or (as this in Xenophon could be unlikely, and Xenias was Agis' friend) λεγόμενον ... ἀπομετρήσασθαι refers to the hasty and lavish donations issued by Xenias on this one occasion. A further ambiguity flows from the fact that the money was Xenias' father's and not his own.

118. See VII.1.(1) for references.

119. M. Lang "Numerical notation on Greek vases" Hesperia 25(1956)1-24 nos.71-78.

120. Lang's view stems partly from the observation that even 20 minai is a low weight for the contents. If the amphora is of normal size, c.40 litres capacity, then full of water it would weigh 40kg (plus its own weight); 20 minai however are only 8.5kg. The 8 minai contents that I am here advocating amount to less than 4kg. But this is not necessarily a difficulty as loosely-packed granular substances, weighing very much less than water, could well have been kept in the jar.

121. Thus in measuring the capacity of jars they marked each small measure poured in with a single unit stroke, crossing it out for a higher mark (the symbol for five or ten) when reached. See Lang as cited in n.119.

122. Cf. her reconstruction of DM.70 [διταλ]αντ[ον μετρον] (Agora X p.55 albeit hedged with "perhaps...perhaps...possible"); and the notion of a 32 cubic finger kotyle (ibid. p.44ff.). See further below ch.VII.2.(12).

123. Ch.VII.1.(4) above.

124. Cf. Hultsch SM Introd. §45 and p.217.17ff.

125. See further ch.VIII.1.(2).1 on the implications of this amount's being felt to be small.

126. For weight see especially Vitruvius VIII.i.7 and ii.1 (Loeb). It is somewhat surprising however to find no mention in iii ("on the nature of waters") and iv ("on testing water").

127. This is in fact separated from a much less specific point, attributed to the Περὶ Ὑδάτων , the calling of water, if good, πόσιμον !

128. Further discussion on the evidence of sensitivity from the ability to distinguish weights of different waters finds its place at ch.VIII.1.(1).1.(3).

129. Cited by Fraser Ptolem.Alexandria I.433 II.627.

130. This fact has been used above in the section on commerce (VII.1.(1)). For purple-dye sellers and meat-sellers see [Arist.] Mech. §§1 and 20.

131. See, for references, ch.VI.1 above.

132. Archimedes was indeed interested in the variable pivot points along a single beam where they illustrated the principle of leverage and the relationship between its force and the distance from point of pivot: Equilib. I and probably also the lost work "On the lever" (see Hero Mech. I.32 (p.86)).

133. Even if theoretical and not involving a level beam: see ch.I.3 and Appendices A and B on how to approach equalisation with an unstable balance.

134. E.W. Marsden Greek and Roman Artillery: Historical Development (1969) and ... : Technical Treatises (1971).

135. They were not known to Marsden, but see F.G. Maier "Excavations at Kouklia (Palaeopaphos) Site A" Report of the Dept. of Antiquities of Cyprus (1967) esp.42 and pl.x.1, and "Ausgrabungen in Alt-Paphos: 1950-1971" Chiron 2(1972)24-8 at p.25.

136. I should emphasise that this interpretation is my own.

137. Thuc.II.76.4-5; Diod.XIII.78.4.7; Marsden HD p.52.

138. Athenaeus Mechan. W.10.5ff.

139. Diod.XVI.74.4; 75.3 siege of Perinthus. The Navy Records, IG II^2 1627 B.328-41 (330/29 BC), include bolts "from Eretria"; Marsden (HD p.58) makes the attractive suggestion that these were taken by Phocion's 340 BC expedition, thereby adding to the evidence of Macedonian involvement in the area at that time (see also G.L. Cawkwell "Demosthenes' policy after the Peace of Philocrates" CQ 57 n.s.13 (1963) 120-38, 200-13).

140. Polyaenus II.38.2.

141. Arrian Anab. I.22.2.

142. Diod. XVII.42.7; 45.2.

143. Marsden HD 62, see 56-62.

144. During, that is, Arsinoe's preparations for the First Syrian War and under Ptolemy II (Marsden HD 62-3).

145. For the technical term see Marsden HD 20f; my interest here is only in the distinction between bolt- and stone-throwing catapults.

146. See Marsden HD 25ff for references and dimension lists.

147. HD 36-39 and see chap.IV.

148. This is Marsden's conclusion, derived from experiments with models and from descriptions of actual firing in ancient times (Josephus BJ V.270, the siege of Jerusalem AD 69).

149. Thus the advice for siege defences that is based on the known effectiveness of catapults against walls: Philon Pol.84.43ff.

150. B. Rathgen "Die Punischen Geschosse des Arsenals von Karthago und die Geschosse von Lambaesis" Zeitschrift für historische Waffenkunde 5(1909-11)236-44.

151. HD 81 and 91ff.

152. Cited by Marsden HD 62.

153. Diod.XX.48.3 (Salamis) "all sorts of stone-throwers of which the largest were three-talant engines"; ibid.87.1 (Rhodes) "one-talant stone-throwers".

154. HD 79-83.

155. E. Boehringer "Die Artillerie von Pergamon: die Steinkugeln σφενδόναι" pp.48ff and Taf.31 of Altertumer von Pergamon X: Die Hellenistischen Arsenale (1937), on p.54.

156. L. Laurenzi "Perchè Annibale non assedió Roma: considerazioni archeologiche" Atti del convegno di Studi Annibalici (Perugia 1961) in Accademia Etrusca di Cortona Annuario XII (1961-64) pp.141-51 with Tav.XXXV and figs.7,8; and also "Projettili dell'artiglieria antica scoperti a Rodi" Memorie dell' Instituto Storico-Archeologico di Rodi II (1938) (31)33-6 with Tavv.XXVIII-XXIX.

157. For this and subsequent information about this unpublished Salamis material I am grateful to Miss Veronica Wilson.

158. E. von Röder "Die Kaliber der antiken Geschütze" Zeitschrift für historische Waffenkunde 5(1909-11)311ff.

159. Boehringer as cited above in n.155, p.49.

160. Laurenzi 1938 (above n.156) p.34.

161. Ch.II.1.(1).VI.

162. HD 94.

163. The suggestion that underweight Pergamene shot were sprinkled with water by the artillerymen to maintain the correct weight for shooting (Marsden HD 81) is surely grotesque. Presumably Zeus held his scales while they busied with their's and the battle raged.

164. Or perhaps I should more cautiously call these simply identifiable "weight groupings" so as to be able to include the Rhodian.

165. In consequence these pieces should be included in the analysis of Greek weights: see ch.II.1.(2), although I have not been able to make much of them for want of comparative material.

166. See n.29 above (ch.VII).

167. Marsden HD 83 n.2.

168. Diod.XX.96.6. Laurenzi 1938 (above n.156) p.35 notes "usate soltanto nella difesa".

169. Ibid. The letter forms are inadequate for dating purposes.

170. There is no available detail, as the pieces have yet to be fully published: see above n.157.

171. Δ on an 18cm diameter ball, if "10", is not compatible with ΔΙΙ on a 22cm diameter ball, which would be read "12". The ratio of weights marked would be on these readings 10:12 (or 1:1.2) where that indicated by the dimensions is $9^3:11^3$ (the cube of the radii), i.e. 1:1.826.

172. See ch.II.1.(1).V and (2) Introd.

173. Other suggestions I have heard include stones for weighting down a tarpaulin or olive press. For the former, their elaboration is incredible; for the latter, their presence on a royal tomb no easier than in my interpretation.

174. The calibres can conveniently be summarised here:

30M (½T) - Polyb.IX.41.8 (Philip V v. Echinus: 210 BC)
Philon Pol.95.49ff (general utility)

1T - Diod.XX.87.1 (Demetrios v. Rhodes: 305/4 BC)
Polyb.IX.41.8 (Philip V v. Echinus: 210 BC - as above ½T)
Josephus BJ.V.270 (Titus v. Jerusalem: AD 69)
Philon Pol.84.43ff (general power of the weapon)

3T - Diod.XX.48.3 (Demetrios v. Cypriot Salamis: late 4th cent)
Moschion ap.Athen.208C (Archimedes' 3T or 12-cubit catapults mounted on Hieron's ship the "Syracosia")

It is presumed that the 10T stones of Plut.Marc.15.4 were dropped onto ships by cranes during Marcellus' siege of Syracuse (213-11 BC); they were surely too large for any catapult (Marsden HD 109).

175. Compare the javelin, to be discussed in the next section: VII.2.(10).

176. One or two relevant, if not illuminating, passages occur in [Arist]. Problems, eg. xvi.3,11,12 (on the flight of the diskos).

177. Bibliography: E.N. Gardiner "The method of deciding the Pentathlon" JHS 23(1903)54-70; "Phayllos and his record jump" JHS 24(1904)70-80; "Further notes on the Greek jump" JHS 24(1904)179-94; "Throwing the diskos" JHS 27(1907)1-36; "Throwing the javelin" JHS 27(1907)249-73; Greek athletic sports and festivals (1910); Olympia: its history and remains (1925); Athletics of the ancient world (1930).
H.A. Harris "An Olympic epigram: the athletic feats of Phayllus" Greece and Rome 7 (1960); Greek athletes and athletics (1964); Sport in Greece and Rome (1972).
J. Jüthner Antike Turngeräthe (1896) whence articles in RE V.1 (1903) 1188-9 sv. Diskos, VII.2 (1912) 2284-5 sv. Halter; Die athletischen Liebesübungen der Griechen (1965).
E. Lindner "Die Benutzung der Halteren im Weitsprung der Antike" Arch.Anzeiger 1956 128-30.
M.N. Tod "Greek record keeping and record breaking" CQ 43(1949)105-12.
Also articles in OCD² sv. Discus (by R.L. Howland) and sv. Halteres (by Howland and P.A. Wright).

178. Indeed jumping without such weights is unknown except on a single representation of about 400 BC: Gardiner 1930 (above n.177) p.145 fig.99.

179. For descriptions of jumping weights see Pausanias V.26.3 and VI.3.10.

180. Thus Howland and Wright; Jüthner 1912 gives a range of 2kg to 4.6kg; Gardiner varies from 2½ pounds (1925 p.305) or 2¼ pounds (1930 p.145) to over 10 pounds - this variation apparently stems from a revision of the weight of the British Museum lead halter; Harris 1964 p.81 gives "from four to eight pounds" [all references are to n.177 as also in the following notes of this section].

181. Gardiner 1910 p.299; "3¼ and 3½ lb" Gardiner 1930 p.146.

182. Gardiner 1904 p.182 citing Ἐφ. Ἀρχ. 1883 p.103; "about 4½ lb" Gardiner 1930 p.146 fig.100e.

183. See further weights cited by Gardiner 1930 p.146 fig.100. No weight is given for the early fifth-century Olympia weight described in Bericht über die Ausgrabungen in Olympia 1(1937)82-4 and pl.25.

184. Gardiner's evidence is the most helpful (1930 pp.151-2), but see also Harris 1964 p.80ff and Lindner 1956.

185. See Concluding note on Greek athletics to this section below. Modern starting blocks, which each athlete adjusts to his own requirements, are a similar case.

186. This weight is only conjectured; compare the marked Astragalos "stater" of c.500 BC (BW.1) at 795gm.

187. Gardiner 1910 p.298.

188. This line of argument is pursued in the discussion of accuracy and precision in ch.VIII.

189. Howland sv. Discus.

190. Gardiner 1907 pp.5-8 (repeated also 1910 and 1930).

191. There seems to be a confusion here. In Gardiner 1930 p.156 nos.8 and 10 are discounted for this reason.

192. Gardiner nos.5-6, 8, 10, 12-14. The queries are of weights calculated from substance and dimensions (with some parts of the diskoi missing). It is amusing to recall Gardiner's caveat even for the complete diskoi (1907 p.7) "The weights of the Olympia diskoi are only approximate. They were weighed, Mr Bosanquet tells me, in the village shop".

193. 1907 pp.7-8.

194. Compare σόλος αὐτοχόωνος Iliad 23.826ff and see Concluding note. This "solution" simply makes variation in size and weight immaterial.

195. Might this not partly resolve the long-standing controversy about discus throwing styles ?

196. Thus Loeb: "three quoits being used for the contest of the pentathlum".

197. See further in ch.III.8 above.

198. It is as reasonable an explanation as any so far suggested for the Phaistos Disk.

199. Harris 1964 p.92.

200. Gardiner 1907 (repeated 1910 and 1930); Harris 1964 p.92.

201. For modern experiments see especially Harris 1964 pp.93-5.

202. See further Concluding Note to this section.

203. Ch.VII.2.(9) above.

204. Gardiner 1910 p.83; 1930 p.53.

205. Gardiner 1907 pp.2-3; 1910 p.83; 1930 p.54.

206. Jumping: Gardiner 1930 fig.106; Discus: ibid. fig.115.

207. As was supposed by Tod 1949 (above n.177).

208. See Gardiner 1904 pp.77ff; Harris 1960.

209. Harris 1964 p.92.

210. Harris 1964 pp.84-5.

211. Dover ed. (1968),ad loc. and p.xl, considers the passage a parody of contemporary experimentation with measurement rather than a reference to the procedure at athletic festivals.

212. Tod 1949 p.110.

213. See Marsden Gr.and Roman Artillery: Historical Development p.74; this is a late and especially awkward example.

214. Gardiner 1910 Index sv.prizes for references.

215. For alternative treatment, as a post eventum rationalisation of artistic style, see J.Boardman Pre-Classical (Penguin 1967) 106.

216. If this means that his source was other than Egyptian, it would explain the lack of a unit weight for papyrus (that the Egyptians used on this occasion and was probably the reason for ship ropes being later weighed in Egyptian talants and minai at Athens: IG II^2 1479B).

217. See ch.III.1.(3) sv.Athens (on IG II^2 1479B).

218. Continuing the Homeric usage; Od.2.426; 15.291 ἕλκον δ' ἱστία λευκὰ ἐϋστρέπτοισι βοέῃσιν (see Morrison and Williams Greek Oared Ships p.300).

219. Especially his explanation of such open terms as μυριοφόρον (Thuc. VII.25.6) as volume rather than weight measures, and his excision of τάλαντα in Thuc.IV.118.5 (discussed in his App.II. pp.36-40).

220. It surrounds the controversial inscription from Temple G at Selinus (see W.M.Calder The inscription from Temple G at Selinus (1963) and Gr.Rom.Byz.Studies 5 (1964) 113-9; review by A.M.Woodward in JHS 86 (1966) 296-7; text in ML 38 [Tod GHI 37] with commentary pp.82-3), and also the interpretation of Diod.XI.26.3 (the Demareteion; but see C.M. Kraay "The Demareteion and Sicilian chronology" Gk.Coins and History: some current problems (1969) ch.2 pp.19-42). Above ch.II n165.

221. The ἑτέρα φορτία of (6).1 are uncertain however.

222. See Wallinga for full discussion of the evidence. I shall include it in a separate study of Greek capacity measurement.

223. For deletion of τάλαντα here after πεντακόσια see Wallinga Add.II. pp.36-40.

224. VII.1.(5).

225. Wallinga pp.2-3 lists variations in the modern "ton" as used in the context of shipping. This can express either weight or capacity or displacement. If weight, then tons can be "short tons" (907kg), "metric tons" (1000kg), or"long tons" (of dead weight 1016kg); if capacity, ton corresponds to 1 cubic metre or to 40 cubic feet (thus a "freight ton"), or to 100 cubic feet (thus "register ton"). If ships are described simply as of so many thousand tons, the unit refers to the number of 100 cubic feet of water displaced.

226. Only by the third century BC was mathematical consideration being given to the matter, and that in a fashion that few ship captains could readily have understood (see above ch.VI.1).

227. Compare the early Roman Empire funerary monument from Ostia: SEHRE^2 pl.XXVI.2.

228. The talant is a convenient weight to carry; similarly wine-jars and bales were surely sized according to such practical considerations rather than metrological (cf. the scene on the Arcesilas Cup).

229. Above ch.VII.1.(5).

230. From each 100 wine-jars, one jar could be taken as tax for example (ἑκατοστή). Alternatively its equivalent value be given.

231. Thus contra Wallinga's belief (p.9) that the heaviness of μιλτος was the reason for its being weighed.

232. Though a constellation Libra might have played a part in navigation, it was not recognised by the Greeks by this name until late (see above in ch.VI.3.(3).

233. See further in ch.I.2-3 where use is made of the inferences from this game and its description.

234. Bibliography: The major descriptions are collected in Schol.Ar. Pax 1242,1244; Schol.Lucian Lexiphr.3; and the lengthy discussion of Athen.XV.665a-668f. For modern work see Lafaye Dar.Saglio sv. Kottabos; Schneider RE XI.2 (1922) sv. Kottabos esp.1532-7; Rogers on Ar.Pax 1244. I have not been able to consult Boehm's monograph De Cottabo.

235. See further ch.V above.

236. 11 April 1973.

237. On τελωνεῖον see ch.VI.5.(1).

238. Ch.VI.3.

239. Or Achilles' corpse in a later part of the story (Lycophron 272). See note to section H in ch.I.1.(2).

240. For a comparison see Plut. C.Gracchus 17 (where an enterprising man is said to have filled Gaius Gracchus' head with lead to claim more than his fair reward), and further Strabo IV.4.5.

241. Above VII.1.(1).

242. See above VII.1.(5) and also Ehrenberg People of Aristophanes (Pbk 1961) 237 n.2.

243. See below in ch.IX (especially true of Mesopotamia and the Hebrews).

Chapter VIII

1. References collected in ch.VI and VII.1.(1), or implied in III, do not amount to anything significant.

2. Compare Marsden Gr. and Roman Artillery: Hist. Devmt. (1969) p.86, on the impossibility of theoretical assessment of catapult performance. The position is rather more difficult with weighing as a higher accuracy is necessary for the exercise to be worthwhile.

3. G.F. Hill "The frequency table" NC 1924 76-85 on p.85.

4. See ch.VI.1 (on theory) and VII.2.(8) (on experiment).

5. Assuming that the wood talant is part of the same weight system as the lead mina (see chs.III and IV above).

6. Taking, for convenience, the absolute values of Attic measures as used by Lang in Agora X (and in line with Hultsch GRM^2 Tab.X.A on p.703).

7. See Dover ed. (1968) note ad loc.

8. My own efforts with a car pump registered 2 lbs with little effort, but 3 lbs with difficulty: at least such a range gives lower limits. Similar experiments and tests accompanied the analysis of other claims made by the Greeks and discussed in this section.

9. κατεργασία does not necessarily imply this.

10. But note that water was not chosen here, as it might be in modern times, as a sort of theoretical standard for comparison.

11. Contrast the earlier occasion of weighed air, again in an askos, mentioned in both De caelo 311b9-10 and Prob. XXV 13 (939a33f), although it is omitted in Prob. XXI 18 (929a30).

12. Loeb translate ἔαλει as "stale" !

13. See above VII.1.(1) and (4).

14. Ch.II.1.(1).VI.

15. Cf. Eleusis 330BC, IG II^2 1672.2, 113, 226 etc.

16. See below VIII.2.(4).

17. For instance, Seltman GC^2 (1955) 179 n.1; Head HN^2 374.

18. For references see in ch.III under the respective area (as also for other than Attic evidence following).

19. Though later officials record weights down to quarter-obols, these are inscribed on objects, not measured by the officials in question.

20. I am ignoring as obscure δακτύλιον ἀργυροῦν ἄγον ΗΕ on an inscription from second/first-century Thebes (Cabiri: see above in ch.III.9.(3) and n.113).

21. Taking a very approximate drachma of 4.3gm.

22. Note especially the correction of earlier weights by Delian officials: IG XI (2) 161.B.107-114, on which see below VIII.2.(3).

23. Compare the impression of sensitivity of this order gained at times during the experiment (9)(a)I (see Appendix B).

24. I mean here of course only the impression of such increased sensitivity that comes from the figures given on Greek inscriptions.

25. The weights, that is, that were used to carry out inventories. See above in ch.II and VII.1.

26. This applies to the πρῶτος ῥῶμος, and also to the 76 broken vases weighed at Delos: IG XI (2) 287.B.142f (on which see below VIII.2.(4)).

27. See Appendix B.

28. There is in fact no explicit statement that the vases were silver; this is an inference from their careful recording and the fact that they were weighed against silver weights (coin). If they were bronze however, it becomes even more difficult to suppose high accuracy was being attempted.

29. I have discussed this controversial passage elsewhere: ch.VI.1 and Appendices A-B.

30. See Appendix B; lack of mention of accidents is another indication of how poor our general evidence is.

31. See n.3 above.

32. W.P. Wallace "Euboean League coinage: 5th - 3rd centuries BC" NNM 134 (1956) on pp.68-9.

33. See general discussion of coinage in ch.II.2; also subsequent consideration of the handling of coin, VII.1.(3), its manufacture, VII.1.(2), and the implications of coinage for measurement, below VIII.3.

34. The principle seems to have escaped Aristotle (and so also his contemporaries ?): see discussion in Appendix A.

35. See further below on money-changers and their possible interest in coin weights, which is a separate matter.

36. Attic (in Copenhagen) at 1.610 kg and 1.480 kg (Gardiner Gk.athletic sports and festivals (1910) p.299).

37. VII.1.(2) (manufacture), and (3) (money-changing).

38. See above ch.VII.1.(2).

39. Thus once a certain length of wire was decided upon, only this length had to be reproduced.

40. Note that the earlier mention of money-changers was by virtue of the rare, but interesting, reference to them as ἐβολοστάται; it does not imply they generally measured the weights of coins (see above VII.1.(3)).

41. Temple inventories: even if the practice was not widespread in such contexts. See further for details in VIII.2.(4). below.

42. See further VIII.2 and 3.

43. Marks of δημοσιον , or other official stamps and legends, do not seem necessarily to guarrantee, or to make any justifiable claim to, greater accuracy: ch.II.1.(1)-V and -VI.

44. See above VII.1.(4).

45. ἰσοτητα ... και τᾶξιν : see above, end ch.VI.6.

46. See introductory summary to this chapter.

47. See Conclusions to ch.III.

48. Gold: half-obol and quarter-obol are common, and even eighth-obol (see earlier VIII.1.(1)-2) occur in the fourth century.

49. Account of purchase of gold (ἐονεθε): IG I^2 355a [ML 54] 14f.

50. Eleusis: IG I^2 313.51 (uncoined gold).

51. Alternatively, if balance procedure can be introduced here - as I doubt, the care needed to watch swings and approximate to level could be added.

52. See ch.I.2.(1) for discussion of balance sizes and references from third-century Delos; also above VIII.1.(1).2.

53. Weighing was regarded as unnecessary as the object had not moved from the time it had last been weighed (an indication of the point of temple inventory ?). Exceptions occur when such moves were made, see Linders on the Brauron Accounts (1972) p.37 with IG II^2 1517.44.

54. This problem has not been fabricated. Ferguson, The Treasurers of Athena (1932) 53, 59, 72-3, uses the observation that the inventory for the Pronaos (but compare also other Athena accounts) had become fixed by 413/2 BC to make the suggestion that in 409 BC it was brought out in advance of the official date to which it referred. Political revolutions, major causes of disturbance for the items involved, are seen by him as responsible for the only occasional rechecking of items; they can in fact be inferred from changes in the inventory formula. It is noticeable however that Ferguson is first and foremost (? solely) concerned with inventory form, and does not give adequate consideration to the question of practice that might lie behind it.

55. Though that such a crowd might on occasion check the operation suggests dramatically the advisability of an overbalance procedure being followed.

56. Above in VIII.2.(1).

57. The relationship between state demand and mint production deserves special study.

58. I should emphasise that I claim no sophistication for these tables. They are designed to present a general impression of the extent of fractional weighing.

59. See above VIII.1.(1).2 for doubts for the weight, $\frac{1}{8}$ obol as derived from IG II^2 1485.3.

60. Thus W.K. Pritchett "The Attic Stelai:I" Hesperia 22 (1953) 226-30.

61. Ch.VIII.1.(1).

62. Woodward Ἀρχ. Ἐφ. 1937 p.171 n.1.

63. See ch.III.10 for more detailed discussion.

64. The only exception is the 20th Crown, which was earlier in very round (suspiciously so ?) figures.

65. IG XI (2) 287.B.142f.

66. See also the preceding discussion on sensitivity.

67. See also above ch.IV.2.

68. At VII.1.(3) and (4); VIII.1.(2).

69. These passages are noted above in ch.III.12 [Delos].

70. See ch.III.1 [Athens] and compare the conclusions reached in chs. IV-V on the derivation of weight systems in general from coin.

71. Cf. ch.III.4 [Epidauros].

72. For further distinctions between the weighing of gold and silver see the Conclusions to ch.III. The distinctions are not always to be explained in terms of coins of the respective metals used for each; in many cases in fact the same weights were used for both, or silver weights for weighing gold. The Parthenon item 50: τετραδραχμον χρυσουν σταθμον τουτο ΓΗΗΙΙC is perplexing.

73. The question of which coins should be used as weights was clearly a practical one.

74. Thus, assuming that each coin size has the same possible error (x), 400drs made up of 10-dr pieces incorporates an error of 40x; made up of 4-dr pieces of 100x; of 2-dr pieces of 200x; and if made up of single drachmai pieces the error could be as high as 400x.

75. Hence the relevance of this factor at VIII.1.(2).

76. Ch.IV.2; see also ch.III n.22.

77. Some qualification should be allowed for the possible non-equivalence of terms (see for example n.5 above ch.VIII). The present argument is unaffected by this point, however. See ch.III Conclusions and chs.IV-V.

78. 9572drs in IG XI (2) 161.B.17 etc, but earlier 1T 3600drs in BCH 10 (1886) 461.19 (i.e. 9600drs).

79. In certain cases the caveat that minai are accounted more usually than weighed sums (see ch.IV n.13), should be applied.

80. See ch.III.1.(3) and Conclusions.

81. 32 drs; again see ch.III.1.(3).

82. Discussed in ch.III.9.(3).

83. With the exception of the so-called artillery balls from Salamis in Cyprus that I have suggested are probably weights along with other similar material: see above ch.VII.2.(9).

84. See ch.I.3.(3).

85. For example, IG XI (2) 203.B.98 see ch.III nn.176 and 182.

86. See ch.II.1.(1).VI and especially the Table showing actual variations in Attic lead weight groups.

87. Again for the mina weight; an inference from P.685 and related weights.

88. See the table in ch.II referred to above in n.86.

89. Both half-talants and 30-minai appear on the third-century Delian Artemision inventory: IG XI (2) 161.B.

90. Staters and half-staters are used in conjunction with each other, and not with minai (while two minai equal on occasion a single stater): thus IG II^2 1673.51 (δικελλαι weighing 1½staters each) and 1673.28-31 (iron again). The smaller coin stater occurs however under talants and minai: thus IG V (1) 1 (ML 67). IG II^2 1672.160-1 ΔΔΣΣ are 22 staters (see ch.III.1.(3)-Eleusis), however, and not 20 minai 2 staters.

91. See ch.VII.1 and 3.

Chapter IX

1. But see further below IX.2.

2. More reliance has as a result been placed on secondary sources. The primary evidence has however been cited where relevant as fully as possible.

3. Compare ch.VI for the comparable Greek literary evidence.

4. A.J. Evans "'The Ring of Nestor': a glimpse into the Minoan after-world" JHS 45 (1925) 1-75 on p.60 n.46.

5. See further K. Polanyi and others Trade and Market in the Early Empires (1957); R. Firth (ed) Themes in Economic Anthropology (1967, Pbk. 1970); G. Dalton (ed) Tribal and Peasant Economies (1967).

6. Especially the work of Jean Piaget - for example Psychology and Epistemology (Penguin tr. 1972) 20-23 and parallel studies.

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7. S.R.K.Glanville "Weights and balances in ancient Egypt" Proc. Royal Instit. 29 (1935-37) 10-40; F.G.Skinner Weights and Measures (1967); S.G.F.Brandon The Judgment of the Dead (1967).

8. The Egyptian balances, and representations of them, on which the present analysis is based are as follows. Subsequent reference will simply be to the number in this list. The order is approximately chronological.

   (1). Red limestone balance beam. From upper Egypt. Predyn. c. 3300 BC. Beam 8.5cm long, but no stand or pans associated. [Glanville 1935 19; Skinner 1967 3, 47f (on performance)]. University College.

   (2). Representation of balances and a set of weights. Tomb of Hesy. Dyn III 2650 BC. Similar to (1) above. [Glanville 1935 19; Skinner 1967 fig.4].

   (3). Representation of standed balance. Bas-relief Gizeh tomb. Dyn V 2400 BC. Arc-shaped wooden beam with single-cord suspension. [Lepsius Denkmaler II.74; Glanville 1935 20; Skinner 1967 7 fig.5 and 47f.].

   (4). Representation of standed balance. Wall-painting Deir-el-Gebrawi. Old Kingdom c.2500 BC. Single-cord suspension with hooks; plummet shown. [Glanville 1935 20 and fig.2].

   (5). Similar. [Glanville 1935 20 and fig.3].

   (6). Representation of hand-held balance. ? source. Dyn V. [Glanville 1935 23].

   (7). Representation of standed balance. ? source. Middle Kingdom c.2000 BC. Old-Kingdon type balance. [Glanville 1935 27 and fig.4A].

8 contd.

(8). Representation of standed balance. ? source. Middle Kingdom c.2000 BC. Suspension cords and plummet. [Glanville 1935 27 and fig.4B].

(9). Representation of standed balance. ? source. Middle Kingdom c.2000 BC. More developed type; a box shown with the balance is presumably meant for weights. [Glanville 1935 27f and fig.5].

(10). Representation of balance. Bas-relief tomb Abd-el-Qurna (near Thebes). Dyn XVIII c.1450 BC. [Skinner 1967 frontispiece].

(11). Small hand balance. Tell-el-Amarna. C.1350 BC. Pierced tubular 30cm rod beam; four strings to each of two pans. [Glanville 1935 32; Skinner 1967 33, 39, 48, Pl.V]. Science Museum, London.

(12). Representation of standed balance. Wall-painting, ? source. C.1380 BC. Symbol of Maāt incorporated twice into the design; lotus-leaf ends to beam. [Glanville 1935 33 and Pl.III.A (from a drawing)].

(13). Representation of hand-held balances in a harbour scene. Wall-painting; tomb 162 of Kenamun (official of Amenophis II), Thebes. Dyn XVIII c.1450-1425 BC. [Glanville 1935 34f and Pl.IV; for dating see Skinner 1967 34 and fig.7].

(14). Representation of standed balance. Papyrus of Ani. Dyn XIX c.1320 BC. Post-mortem scene with Anubis, Thoth etc. [Brandon JD 1967 pl.1]. British Museum, London.

(15). Representation of standed balance. Sarcophagus cover of Espawershefi (Thebes). Eleventh to tenth century BC. Post-mortem scene as preceding. Fitzwilliam Museum, Cambridge.

(16). Small standed balance. Tell Defenneh. Dyn XXVI, 664-525 BC (Glanville 1935 33) or 664-341 BC (Skinner 1967 51, 60 and Pl. VIII). Beam 13.4cm. Skinner calls this a Graeco-Egyptian goldsmith's balance as it comes from a Greek colony. There is as far as I can see no reason to call it Greek however. Cairo Museum, with a copy in the Science Museum, London.

(17). Representation of standed balance. Papyrus. Second to first century BC. Post-mortem scene as above (14) and (15). [Brandon JD 1967 47 fig.4; Ryl. Hieroglyphic Pap. No.3].

(18). Representation of standed balance. Papyrus. First century AD. Usual post-mortem scene. [Glanville 1935 pl.V.A]. BM 9995, British Museum, London.

(19). Representation of standed balance. Ptolemaic papyrus. ? date. Post-mortem scene. [Glanville 1935 pl.V.B].

A further representation should be included in this list as no.(20): the standard Egyptian hieroglyphs for the balance and its parts. These show a standed balance, possibly with a plummet associated: A.Gardiner Egyptian Grammar (2nd ed. 1950) Sign U.38 (on p.521). A separate hieroglyph for the plummet alone exists also (U.41). Compare not dissimilar signs in Linear A and B: below ch.IX.1.(6).

U.38: 

U.41: 

9. See Skinner's experiments with the model of balance no.(11) [1967 47f]. 2.5° depression was achieved by adding 0.039gm to one side at zero load; 0.065gm at 6.48gm load etc. For the introduction of the glass case and other aspects of weighing technique see Appendix A. Experiments I conducted with reconstructions of Greek balances are described in Appendix B.

10. As on no.(11). Compare Greek Rep.P.5 (ch.I.1.(2) and discussion in I.2.(3)).

11. As on no.(12) and most subsequent large balances. The Greek artist of the Arcesilas Cup (Rep.C.1) copies this feature quite faithfully. No Greek balance representation however shows the pointer.

12. On no.(9) an odd assortment of objects fill both pans; as a box seems drawn to accompany the balance, and has been assumed to be for weights, it is possible that weights are here being checked against each other. The point of the scene is otherwise obscure to me. On the post-mortem scenes (as no.(14) etc) the symbol of Maāt () acts as the weight.

13. This is illustrated most clearly on no.(7). Most representations however depict the balanced position, which is, for Egyptian weighing, the only significant one.

14. Scribes are shown on nos.(8) and (14) and the weight measured is implied in the text of the latter (as indeed most subsequent post-mortem scenes).

15. Thus operators steady both plummet and beam ends, as on no.(19); less explicit, though more usual, is steadying the swing of the scale pan, as no.(18).

16. Gardiner Eg.Grammar^2 p.570. The hieroglyphs for the verbs at any rate are identical.

17. Represented on no.(2), if not also implied by the box of no.(9).

18. The basic analysis was made by Sir Flinders Petrie Inductive Metrology (1877), summarised by Glanville 1935 10-19; see also Hultsch GRM (2nd edition 1882) 372ff; A.E.Berriman Historical Metrology (1953) ch.VI; and recently Skinner 1967. The majority of Egyptian weights are unmarked, and the possible inferences of systems and standards seem endless. Nevertheless there is more validity in attempting to establish such systems (given the measuremental nature of Egyptian weighing) than there is for a similar analysis of Greek weights.

19. ANET^2 216: Iri-Nofret (Dyn XIX), with Gardiner The attitude of the ancient Egyptians towards death and the dead (1935).

20. For the weights see works cited in n.18 above. To anticipate the next point, the control of these weights might be supposed to be the responsibility of the Official of the Gold Houses: ANET^2 329a (Dyn XII).

21. Thus Hesy, on no.(2), was a high official at the court of third-dynasty Neterket (Sa-Nekht): Skinner 1967 5.

22. As represented on a painting of 2500 BC (Skinner 1967.pl.II.B and fig.6).

23. Such as the workmen in the Theban necropolis of Dyn XX-XXI . Weights have been found inscribed with their names and the word for a fish. Glanville 1935 p.37 and see further n.28 below.

24. This is the main thesis of Glanville's article (1935); it seems to have gained wide acceptance as it is reproduced by B.Kisch Scales and weights: a historical outline (1965) and Skinner (1967).

25. Cited by Glanville 1935 p.26.

26. ANET^2 407-10. The story of the Eloquent Peasant is of a peasant who went down to Egypt to fetch food for his family in exchange for the produce of his own area that he took with him. The value-base of his own area was in capacity measures of grain (R.1, 5ff), and frequent reference is made to the use (and misuse) of measurement with such measures (B.1, 295). A metal value-base is a reflection of a different natural area, or of one of greater wealth.

27. On two occasions: ANET^2 409a (B.1, 145ff) and 410a (B.1, 310ff; cited below in ch.IX.2.(1) end).

28. The Dyn XX-XXI Theban workmen appear to have had their fish-ration weighed out (see above n.23); Chester Beatty Pap.IV records soldiers' rations measured out in the scales (cited by Glanville 1935 pp.37-8); much later is the evidence of Herodotus II.168.2 that daily rations included: ἀπὸ σίτου σταθμὸς πέντε μνέαι, κρεῶν βοέων δύο μνέαι.

29. ANET^2 216-7. Iri-Nofret made up the purchase price of a slave girl by selling off various goods, the values of which are translated into silver weights. These goods include bronze jars, the weight of the bronze being measured and then converted into silver weights by a set (and approximately reconstructable) ratio: see nn.6 and 7 to ANET^2 at this point.

30. Above no.(13) in n.8.

31. Hdt.II.65.4 and see above ch.VII.2.(14) Apatouria.

32. It is fair to consider whether other weights given by Greek writers about Egypt (and especially by Herodotus) reflect Egyptian rather than Greek practice: thus Amasis' gift of 1000 talants of στυππηρίη (Hdt.II.180.2, and see above ch.III.10 [Delphi]), and ship-capacity expressed in talants (Hdt.II.96.5, on which see above c.VII.2.(12)).

33. IX.2.(1). ANET^2 409a (B.1, 310-15).

34. See above in n.8 nos.(14-15) and (17-19); the subject also influences no.(12).

35. See above in ch.VI.3.(2) esp.iv on Greek views of the afterlife.

36. For recent discussion of the interesting problem of this transmission see Brandon JD (1967) esp.122-6, tracing the mediaeval iconography back to the apochryphal Testament of Abraham and The History of Joseph the Carpenter, both of which were written in Egypt. I return to the question briefly below in my final conclusions.

37. See the following sections IX.1.(2)-(5). Other near-eastern cultures tend to associate judgment with the moment of death (and therefore are closer to the Greek attitude); only later is there development towards a post-mortem judgment with its concomitant morality. The "advanced" state of Egypt in this respect is only apparent, despite Brandon JD (1967) p.48. The Greeks, it is true, were considering the notion by the late fifth century, due probably to influence from Egypt that emphasised this area for judgment (see above VI.3.(2)).

38. Above ch.VI.3.(1) and (2).

39. H.Goedicke "Early references to fatalistic concepts in Egypt" JNES 22 (1963) 187-90, cites two Old Kingdom and two Middle Kingdom private texts that might refer to this, but recognises that this evidence is far from satisfactory (p.190).

40. I am following here Brandon JD (1967) ch.I 6-48, in general a clear and helpful account.

41. ANET^2 414ff, but esp.415b (apparently dating from the late twenty-second century BC, although the earliest manuscript is no earlier than the late fifteenth).

42. As Brandon JD (1967) pp.21 and 24.

43. ANET^2 467.

44. Cited by Brandon JD (1967) p.23.

45. ANET^2 410a (cf.409a). Dating apparently from the early twenty-first century BC, this piece is rather earlier than many of the Coffin Texts.

46. Above, in n.8, no.(12).

47. Brandon's doubts over this point (JD 43ff) appear to be unfounded, and are basically the result of a failure to take account of the significance for what Egyptians were aiming to achieve with their balance of the plummet (ie. to measure, not to compare).

48. Only part of the 125th chapter is translated in ANET^2 (34-6); the whole is summarised by Brandon JD (1967) 28ff, and his notes (81ff) give references to fuller accounts.

49. Brandon JD (1967) 35-41 argues convincingly in favour of an absolute morality. Montet Everyday Life in Egypt (in the days of Ramesses the Great) (tr.1958) pp.306-8 presents an alternative, if obscure, picture of a ritual in life approximating to confession: it is no less moralistic.

50. Variations include the deceased weighed against his own heart; and the figure of the goddess Maāt shown instead of her feather-symbol: Brandon JD (1967) 204 n.85.

51. Brandon JD (1967) 38.

52. F.L.Griffith Stories of the High Priests of Memphis (1900) 2-5; H.Gauthier Le livre des rois d'Egypte (1907-17) vol.iii 84ff; Montet Everyday Life (1958) 303; Gardiner Egypt of the Pharaohs (1961) 267; Brandon JD (1967) 43-5 and n.133 on p.207. Montet and Gardiner favour the dramatic date of mid thirteenth century (Ramesses II); Brandon simply places it before the parable of Dives and Lazarus in the Gospel of Luke. Satmi appears with variants Setna and Setem - the last apparently a word denoting the High Priest of Ptah at Memphis. This clealy weakens the likelihood of identifying the historical character

53. D.Daube "The Scales of Justice" Juridical Review 63 (1951) 109-29, while recognising the lateness of this comparison of good deeds with bad, is wrong to understand the earlier version of the Book of the Dead as a contest between the deceased and truth (p.123). Comparison with Shylock's predicament ("If the scale do turn but in the estimation of a hair, thou diest") is apposite, but not with Zeus' kerostasia (113-4, 123-4).

54. The more usual source, for which there is evidence throughout Egyptian culture and literature. Thus the would-be suicide argues in favour of death given the provision of shelter, cool, water, food and an heir to perform the proper offerings (ANET^2 405b: First Intermediate Period, towards 2000 BC). The problem of ensuring continued existence of this source of sustenance is the ancient Egyptian neurosis (Song of the Harper ANET^2 467 and also imprecations against desecration, for example of Hotephiryakhet, cited by Brandon JD (1967) on p.14). See also n.58 below.

55. Papyrus of Ani: after judgment, Ani is introduced to Osiris by Horus with the words "... Let there be given to him the bread and beer which passes before Osiris; let him be as the followers of Horus for ever"; and Ani says "Grant that I may be like the favoured ones who are in thy following, and that I may be an Osiris..." (E.A.W.Budge The Book of the Dead: the papyrus of Ani (1913)). Again, after the protestation of guiltlessness, the rubric of the 125th chapter of the Book of the Dead concludes: "Loaves, jars, bread, and joints of meat shall be given to him from the altar of the great god ... and he shall be in the retinue of Osiris" (ANET^2 366). This text of the Book of the Dead belongs to the same period as the Papyrus of Ani (Dyn XVIII-XXI or 1550-950 BC). Earlier evidence can be added of similar, if less developed, thinking: the Pharaonic solar cult of the fifth dynasty (Gardiner Egypt of the Pharaohs p.85 - identification with Rā); the significance of being maā kheru in the Old Kingdom Pyramid Texts (an Osiris element, see Brandon JD 9f); and identification of the deceased with Osiris in the spells of the Coffin Texts (for example "O Thoth ... justify Osiris N against his enemies ..." A. de Buck The Egyptian Coffin Texts (1935-) IV Spell 338 and Brandon JD p.22).

56. JD (1967) p.12. He also brings into it the idea of morality. If the living order cannot protect the tombs and the ritual then the gods must do it. However some moral outlook precedes this change and seems to be independent of it, just as the idea of judgment of the dead goes very much further than punishment for tomb desecration (even as early as Meri-ka-Rē in Dyn XI).

57. Compare the inscription on the tomb of Herkhuf (a noble of Dyn VI), cited by Brandon JD p.15 with references in n.44 p.201.

58. Add also the interesting concept of the rememberance of a person's name in the world - even in the lower grades of society. Thus the Eloquent Peasant "Justice lasts into eternity; it goes down in the necropolis with him who does it. When he is buried and interred, his name is not wiped out on earth, (but) he is remembered for goodness ..." (ANET^2 410a top).

59. See n.55 above.

60. Most vividly in the, admittedly late, story of Senosiris, son of Satmi: "It was decreed that he should be punished in Amentît [the West, ie. the underworld], and it was he, whom you saw, with the pivot of the door of Amentît planted in his right eye and rotating on this eye whenever the door is closed or opened, whilst his mouth utters great cries" (Griffith Stories of the High Priests (1900) 44-50 and Brandon JD 45-7).

61. See above ch.VI.3.(2); with the fourth century can be detected evidence for some judgment in general of all who entered Hades. There is no clear indication that this ever involved a balance, though certain mystery cults may have copied the Egyptian idea in this. The only place for judgment in typical classical Hades was in the day to day administration; it therefore parallelled the operation of justice in life itself on earth.

62. Omitting, that is, the late developments towards a universal application of morality, and the incorporation of the Greek idea of the balance: to distinguish good from bad.

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63. G.Roux Ancient Iraq (tr.1964) 185-9, accepting the suggestion that Middle Helladic reflects Indo-European migration. See conclusions below to this section on the Hittites, and also IX.2.(2).

64. Greek relations with other peoples at this point are mainly confined to the sea trade, either direct or through such intermediaries as the Phoenicians (see also IX.1.(4)). The references in Hittite texts of the fourteenth and thirteenth centuries to the Aḫḫiyawa have been interpreted to refer to the Achaeans, but it is far from clear that mainland Greeks are meant (despite the attractiveness of the idea); the identification of which particular East Greek state (? Miletus for Milawata) is not yet possible: see O.R. Gurney The Hittites (Penguin, 3rd ed.1961) 46-58 and bibliography 226-7. Some direct contact with their homeland may however be assumed for Greeks on the coast of Asia Minor; Hittite political control moreover extended to the western provinces of Assuwa and Arzawa, and this last, which included Luwiya, was certainly visited by Hittite merchants (Law Code 5), as also Pala (Palestine ?) and Alasiya (Cyprus ?: see the "Ritual for the erection of a house" ANET^2 356b obv.40).

65. Gurney[3] (1961) 18f argues, from the the possible identification of many non-Assyrian names in the Kaniš documents as Hittite, that these were already settled in the country: see below IX.1.(3) and n.216.

66. Hittite cuneiform differs from that used by the Assyrian traders, and its precise source is not yet known. The degree of Mesopotamian influence is also illustrated by the Hittite use of "allography", whereby Akkadian and Sumerian words are inserted as ideograms in place of Hittite words in some texts. Gurney[3] (1961) 20, 121.

67. Gurney[3] (1961) chs.7-8 pp.132-94 attempts to sort out original Hittite religious and mythological tradition from subsequent accretions, but his results go little further than the identification of local War-, Sun-, or Weather-gods and their consorts. See further his bibliography on pp.221f, 223f.

68. Gurney pp.100-1. The evidence however is mainly from the Law Code, on which see following note.

69. See A.Goetze ANET[2] 188-197 for bibliography and translation; Gurney[3] (1961) 88-92; E.Neufeld The Hittite Laws (1951). While the closeness with other Mesopotamian codes is brought out by Gurney (p.91), Neufeld argues that "what was accepted by the Hittites from the Babylonians and Assyrians, was rearranged...[and] adapted to meet their social conditions" (p.105-6).

70. The laws are preserved on two tablets (not overlapping) and there is evidence of a third. Though they refer both to past and to present practice (eg. I.5), no dates are indicated, nor is the period to which the fixed prices might apply specified or any allowance made for adjustments. The incompleteness of the provisions of the Code (with nothing at all on inheritance or contract) is parallelled by silence on its enforcement.

71. Gurney[3] (1961) p.91. It is probable that most Hittite administration was recorded (in hieroglyphic Hittite) on wooden tablets that have not survived (ibid. p.128). Contrast the indestructable baked clay cuneiform tablets of Mesopotamia.

72. Mesopotamia as a whole, but in particular the Canaanites of Ugarit (see IX.1.(4)).

73. Certain aspects (described by Gurney) will not be relevant to my subject, but the priest-king, the independent queen, and most importantly the early assembly and administration by elders, that eventually gave way to a more typically Eastern royal bureaucracy, are noteworthy (Gurney 67ff).

74. Two pans are indicated by KUB.XXX.15-- Vs.26-36. No temple inventories survive (as they do from Mesopotamia, and indicate that pans were made of copper).

75. No Hittite words for these features exist, and accuracy plays no particularly significant part in descriptions of their use (to be discussed in what follows). Contrast the fact of hieroglyphs of balance, plummet etc in ancient Egypt: above no.(20) in n.8).

76. See the rituals (below) for hand-holding; in KUB.XXX.15 the balance is dashed to the ground and could be standed as not explicitly described as hand-held.

77. Law Code II.169 "Thou hast planted my balance in the ground" seems best interpreted as indicating a standed balance.

78. Thus the treaty between Mursilis and the King of Amurru specifies tribute of "300 shekels of good, refined first-class gold weighed with standard weights" (ANET[2] 204a); and another treaty stipulates that tribute be weighed according to the"weights of the merchants of Hatti" (cited by Gurney[3] (1961) p.84 and see below n.95).

79. Glass and lead can be inferred from certain rituals (Šalliš ua̯štaiš and weighing long years for the king and queen) to be discussed below; the only argument however is the association of objects apparently of these materials with the balance. No quantitative element seems appropriate, at least in these contexts.

80. A ritual weight system is deduced from the names of weights that occur in normal commercial or administrative contexts (tarnaš and seah, pārisu and upnu: see n.82 below); a distinction between court administration and merchants seems indicated by the stipulations for weights in the two treaties cited in n.78 above.

81. That the Hittite shekel was slightly heavier than the Ugaritic can be inferred from a comparison of Hittite and Ugaritic versions of the tribute laid down by Suppiluliumaš (J.Nougayrol Le palais royal d' Ugarit IV.17.227 and RS 11.772: see below in IX.1.(4)). On the other hand Gurney[3] (1961) p.84 attempts to argue from late Carchemish weights that the Hittite shekel was rather light. The confused state of attempted deductions can well be judged from the fact that even the number of shekels to the mina can be an open question (see again IX. 1.(4) and notes 359 and 364).

82. The extent of the detailed weights and measures system is illustrated by the ritual meal at the festival of the warrior god: "The tableman <selects> two tunnaptas loaves weighing 2 seah ... the cup-bearer brings one sacrificial loaf of flour weighing a pārisu and 3 upnu from the outside" (ANET[2] 360b-361b), or the ritual for domestic quarrels: "The Old Woman [ie. priest] presents one sacrificial loaf weighing 1 tarnaš" (ANET[2] 351b). If as one might suspect these weights are as ritualistic as their context, not much general relevance can be claimed for them. Contrast the more practical shekel (šiqil) terminology of the weights in the ritual for the erection of a temple (ANET[2] 356-7). Despite these doubts on the units of weights specified in ritual, the extent to which weighing was required for the ritual is clearly shown.

83. Gurney[3] (1961) 64-6, 132 on the importance of the King as the head of state religion.

84. 12 minas 20 shekels of gold; 500 shekels of wool; shekels of silver. Treaty of Suppiluliumaš (above n.81), in the Hittite version.

85. Again from Ugarit, PRU IV.17.229 contains the verdict of Ḫattušilis III (1275-1250 BC) concerning the 1-talant fine of silver on the people of Apsuna (Ugarit) where merchants (presumably Hittite) had been killed.

86. The text gives ^{LÚ}DAM.GÀR ^{URU}Ha-at-ti. F. Imparati Le Leggi Ittite (1964) 194 n.3 favours the translation "merchant in Hatti" even though she believes a Hittite merchant to be involved; the structure of the whole paragraph however makes "merchant of Hatti" much more likely, and this is the translation supported by Neufeld Hittite Laws, Goetze ANET^{2}, and Gurney^{3} (1961) p.97.

87. R.B. Revere "'No man's coast' Ports of trade in the Eastern Mediterranean" in Polanyi (ed) Trade and Market at p.54 entirely misrepresents Gurney's argument by claiming that "in the Hittite Law Code the killing of a trader amounts to murder, the killing of others to manslaughter".

88. I am using the earlier version of I.5. The later version draws distinctions between the calculated murder of a "merchant" (penalty lost), murder in anger (penalty 6 minas), and accidental homicide. This version does not alter the problem of why it is only in the case of "merchants" that these distinctions are drawn, (though it does reduce the contrast with other people). Gurney^{3} (1961) 97-9 takes the view that normal premeditated murder would be dealt with by blood feud, but it is not clear to me why "merchants" should rate this special mention unless they are regarded with special favour. Despite doubts on the figures in I.5 (see Imperati Leggi Ittite 194-8 who retains them), 100 minas is considerably higher than the "four persons"of I.1 (slaves are put at a maximum value of 25 shekels, and even craftsmen could be worth only 10: II.176 (B) - 177). Thus contra Neufeld Hittite Laws 134.

89. 3 minas per "merchant" murdered was agreed in the original treaty PRU IV.17.146 and operated in practice eg. PRU IV.17.158 (180 shekels). This is of course far below the Hittite Law Code's 100 minas (I.5); nor does it appear that the Law Code exercised an idle threat unless there was a massacre at Apsuna that could otherwise explain the 1-talant fine there PRU IV.17.229.

90. PRU IV.17.133 (Queen Puduḫepa acting as regent for the minor, Tudḫaliyās IV: 1250-1220 BC).

91. Equally interesting is PRU IV.17.130, the restriction of the trading activity in Ugarit of these"merchants" of Ura by Ḫattusilis III as the result of complaints made to him by the King of Ugarit. For other texts see PRU IV Index (p.256), and on Ugarit see further below in IX.1.(4).

92. PRU IV.17.316 lines 7-11: the condemnation of Armaziti is witnessed by four named people called "men of Ura, merchants of the Hittite King" (the document is Hittite). In PRU IV.17.383 and 422 lapis-lazuli is being procured by the writer for the Hittite King (422.23 "le roi est grand amateur de lapis-lazuli").

93. As ambassadors they ranked high; their persons were heavily protected by special treaties: in addition to the evidence of the Law Code, the group of ten witnesses to the Carkemish/Ugarit case settled in PRU IV.18.20 may be interesting (a representative of the King of Carkemish, two high officials of the Ugarit Court, the chief of [Meše]da, a priest, one unknown and four men of Ura, including a "merchant").

94. Lapis-lazuli (see n.92 above); and from the ritual for the erection of a temple (ANET^2 356b obv.35ff) "The gold they brought from Birunduma, the silver they brought from... The lapis they brought from Mount Takniyara. The marble they brought from the country of Kanisha. The jasper from Elam. The diorite they brought from the earth. The black iron of heaven they brought from heaven. Copper and bronze they brought from Mount Taggata in Alasiya" (thus only diorite and meteoric iron were not imported).

95. The tribute of vassal states was specified in Hittite standards, and on one occasion the "merchants of Hatti" are mentioned by name in connection with the tribute weights (see above n.78).

96. According to C.H.Gordon "Abraham and the merchants of Ura" JNES 17 (1958) 28-31 on p.31, the Hittite word for merchant, tamkâru (and cogn. tamkarutum), is specifically related to foreign trade. Gordon is concerned to show that "Abraham was a merchant prince; a tamkârum from the Hittite realm", and more precisely from Ura, the merchants of which have already been noted above (eg. n.93). The Sumerogram DAM.GAR of the Hittite Law Code is equivalent. To argue from the terminology alone however is insufficient; compare the variation in Mesopotamia (below IX.1.(3)).

97. I.45 (theft of agricultural implements); I.57-92 (livestock); I.96 - II.104 (planted crops); II.178-186 (prices of everyday farming items).

98. See below IX.1.(5), for example Prov.11.1 "A false balance is abomination to the Lord; but a just weight is his delight".

99. Code of Hammurabi § P and 108; Šurpu (ed.Reiner) II.42; VIII.67. See further in IX.1.(3) following.

100. H.Otten Hethitische Totenrituale (1958) 131 n.2. This detail of Kantusilis' prayer is discussed in detail below.

101. Thus Goetze ANET^2 400 n.1, assigning him to the court of Suppiluliumaš (1380-1340 BC).

102. This will be argued to be the simplest explanation for the otherwise obscure reference to a "merchant" at this point in the prayer. Despite the fragmentary text, there is no apparent reference to a commercial context elsewhere.

103. Esp. II.178-186, note 184 "This is the tariff. As it is (valid) in a village [it is also valid in the Capital (?)]". Neither the Code of Hammurabi nor the Middle Assyrian Laws have such a conspicuous tabulation of the prices for commodities and objects.

104. Village II.184 (see preceding note); slaves I.12B (slaves given silver by their wrongdoers), I.97 (penalty for slaves stealing in a granary involves 6 shekels of silver).

105. The majority of prices fixed in the earliest version can be seen to survive to later versions, while the penalty for the murder of a "merchant" shows a considerable drop (II.5 with 5A). In fact this inconsistency has been emended by some editors (see Imperati as cited above in n.88).

106. Silver apparently was imported (see n.94 above). Without begging the question, its commonness cannot be inferred from the Law Code alone.

107. This is a surprising and significant omission in the Hittite literature.

108. II.185B and 186. This is not a simple scribal error (with the value of a sheep equivalent to one shekel: II.179), but occurs in all versions, both early and late.

109. See following IX.1.(3). The Assyrian Laws offer the variant of lead for silver but still retain the principle of weighed units of either metal.

110. References in IX.1.(3).

111. Thus the wages of harvesters (II.158) and the hire of a team of oxen (II.159). Other examples of grain payments are not consistent: the fine for the unborn piglets of the stolen "bearing pig" in II.83 (where the sow itself rates a 6-shekel fine); the fine for the theft of a copper nail in II.126; and the wages of the smith in II.160-1 (although the ateš he makes is hired for silver in II.157).

112. For grain see the last note; a number of offences are penalised in kind - a bolt of cloth II.126. 30 loaves of bread and 3 jugs of beer II.167 are however associated with an ancient ritual (see below on II.169).

113. The sheep prices of II.185B and 186 are all of meat, for grain see n.111 above.

114. Despite the parallels with Mesopotamian law, Gurney[3] (1961) 91-2 regards the Hittite Law as essentially practical and derived from the judgments of the Hittite courts.

115. The lapse into sheep prices at II.185B and 186 could be regarded as a literary slip with no pracical effect (one sheep is exactly equivalent to one shekel) and this might well explain how it was subsequently retained in later revisions. The grain payments of II.158-161 are not however explicable in this way. It must be emphasised that the wholesale rejection of the silver prices, argued here, is entirely my own: the problem does not appear to have been fully recognised by either Imperati Leggi Ittite or Neufeld Hittite Laws, and the brief note by Gurney (as cited in n.114 above) is hardly adequate. His suggestion that the Hittite prices are recommended maxima does not meet my objections about the availability of silver or the peculiarities of the "price table" (see also n.117 below).

116. A free artisan class seems implied by II.200B as opposed to the skilled slaves of II.176B and 177. It is not really clear whether the payments in grain to the smith of II.160 are to a free worker or to a slave (see however n.111 above).

117. ANET[2] 356b35ff (cited above in n.94) appears to list mainly imported metals even though the actual provenance of silver is missing from the text. Gurney[3] (1961) 82 infers that the silver is local from the fact that "it served as a currency". This however is precisely the point I am seeking to question.

118. Despite the fact that Alasiya is given as a source in ANET[2] 356b35ff, the cheapness of the metal as compared to silver (1:240) and the evidence of the Assyrian trading colony (see n.120 below) show its local availability. Cf. Gurney[3] (1961) 86-7.

119. II.157 rent varies according to the weight of bronze; II.160, 161 again the smith's pay varies according to the weight of the bronze object made.

120. These clearly played an important part in the development of Hittite commercial activity, although I should emphasise the early introduction they provided to the Eastern trade. Unfortunately the surviving tablets attest essentially to the internal organisation of the trading community (and its relations with Aššur) rather than to the Hittites: see below n.216 for bibliography.

121. As also the economics of their rental: 3 pārisu of spelt equal 1 shekel (II. 183) so that though the maker is paid the equivalent of a third of a shekel for a 2-mina ateš, the rental for one month is a half-shekel for a 1-mina ateš and 1 shekel for a 3-(? error for 2-) mina one.

122. II.182 (prices of garments); PRU IV.17.227 (tribute listing wool and tunics with shekel weights for the wool somewhat dubiously supplied by the editor, Nougayrol). There is no indication in the Law Code of a special class of workers involved in spinning and weaving, which probably therefore never rose higher than a cottage-industry with the occasional skilled slave helping out (as II.176B, in a list of craftsmen).

123. Cited by Gurney[3] (1961) 94. This figure is not improbable if the range of horse prices of II.180 (in silver shekels) and the copper: silver ratio of 1: 240 (II.181) are taken into account.

124. Therefore a trained accountant.

125. The same problem has been already noted for Greece, where wood again is handled in always-whole talants: see above ch.III Conclusions.

126. See Gurney[3] (1961) 92-4.

127. Otten Hethitische Totenrituale 131-2 collects all these passages but does not distinguish between what I think are several different groups.

128. See n.101 above.

129. Goetze translation (ANET[2]).

130. Šurpu II and VIII (see following IX.1.(3)); Job 31.5-40.

131. As if Kantusilis had said,"In performing cult for the Sun-god I did not upset the balance as might a merchant". The tenses however are somewhat problematic for this interpretation.

132. Heth.Totenr. 131 n.2 "der Kaufmann hält sie neben der Sonnengottheit und fälscht die Waage" (my underlining).

133. It is important to distinguish the very different contexts to which these two aspects of judgment relate: (1) human weighing of commodities (especially in the context of trade: cf. Mesopotamian and Hebrew IX.1.(3) and (5)), and (2) divine assessment of humans either by symbols or direct inspection (the scales of Osiris, a post-mortem context, are probably unique; Mesopotamian and Hebrew thought tended to concentrate these decisions to changes in the fortunes of life or to the irrevocable change, death; as a metaphor for the vicissitudes of life however the idea is Greek VI.3.(2)). Whereas the distinction is most straightforwardly brought out by who does the weighing and by what is weighed, the two contexts can in fact be related: a god's own weighing might be thought of as fair or unfair (thus Job pleads for an even balance, Job 31.6) and symbols might stand for individuals (thus the Egyptian heart weighed against truth). Furthermore the god's own judgment could be transferred to earth by a third-party, acting out the symbolical weighing operation on behalf of the god and in his presence. If the weighing was fairly done, it could then be seen by the god to have been so performed. Why should its result not then be as good a reason for action as the god's own calculations? In so far as there is some evidence for the Hittite Sun-god to be more concerned with judgment than with the fairness of such judgment (see further in text), it may not be necessary to introduce even the element of fair weighing at this point at all. The simple performance of the operation (even if rigged for the benefit of the appealing party) might be thought sufficient to take the matter out of the god's hands and so present the god with his reason for acting along the desired lines. This interpretation (a version of sympathetic magic perhaps) I shall pursue in the text. It is hardly appropriate to think of proving or establishing it on available evidence. However it is a way of explaining the puzzling references to the balance in Hit tite ritual, and it fits well with the general Hittite attitude to sympathetic magic and to the motivation of divine action. What is more uncertain is the step needed to explain an uneven balance in this sort of context, for here, as will be seen, the Hebrew and the Greek attitudes most widely differ.

134. See especially the Hymn to Šamaš ANET^{2} 388 b (ii) 51; W.G.Lambert Babylonian Wisdom Literature (1960)11.107-19; and below IX.1.(3).

135. Thus Otten Heth.Totenr. 131-2.

136. ANET^{2} 398 c (iii);"daily thou sittest in judgement upon man, dog, pig and the wild beasts of the field" Gurney^{3} (1961) 139.

137. Job goes on to list offences he has not committed. As already suggested there is a great difference between the god's view of these offences and what they may actually have been: n.133.

138. Contrasted to the line in question is "In times past...thou gavest (?) me abundance (?) ...". This might refer to an opposite inclination of the balance on an earlier occasion, or it may be figurative.

139. This is perhaps indicated by the Totenritual (2) below. However ritual (3) "weighing out of long years for the King" is a clear example of the attempt to use magic; it also, as Kantusilis, includes reference to a "merchant".

140. "Merchant" is unlikely to be a ritual name for a priest (as "Old Woman" clearly is).

141. This was the interpretation I alluded to above. Certainly nothing wider can be deduced from it. Comparable however is the third ritual on "weighing out long years for the King" to be discussed below.

142. Otten Heth.Totenr. p.19. "Gott wird", as a euphemism for "died", may have implications for Hittite kingship: see below nn.175ff.

143. Otten 49ff; KUB XXXIX 6 Rs III.14ff. Otten may be right in regarding the "Youth" and "Maiden" as prince and princess of the royal family. Most fragments of Hittite funerary ritual are placed by him somewhere in the Šalliš uaštaiš; few are relevant however for this analysis; 120/p (Otten 114f) does mention scales, but there are no grounds for locating it elsewhere at present.

144. Gurney[3] (1961) 165 interrupts his translation and omits (A). Of this gap he remarks, "There follow some magical operations ... but these are obscure and difficult to follow on account of the bad state of the tablet at this point". Caution should accompany what follows in my analysis.

145. Hittite šal-ú-i-na-an; Otten "Lehmmörtel".

146. "I-", a Sumerogram (cf. n.66 above), is obscure.

147. Otten makes no comment on these operations.

148. KUB XXX 24a --- Vs.6-11 (Otten p.59); this is B(2) below.

149. Lines 21ff.

150. There certainly seems no pejorative implication about the breaking of vessels in ritual as if they were defiled. The irrevocable completion of the action seems a better interpretation (as wine-glasses are smashed after certain toasts). Perhaps also this is why so often dirge and weeping follows: cf. KUB XXX 19 --- Rs IV.26ff (Otten 47).

151. Vs.3 "A huppar-vessel of silver of ½ mina and 20 <shekels weight> is filled with fine oil".

152. Pasture-land for animals represented by a clod of earth (in (3)). More important would be the right to a resting-place, but this does not seem covered in the surviving parts of the ritual at all (see the Hittite Law Code I.6A and 6; also Otten Heth.Totenr. 132-3 on the so-called "stone house").

153. Unfortunately all that is preserved of (5) is "Afterwards they break a warm loaf and [hold up (?)] a balance---". Various types of bread precede the formula quoted as (2), but the text is again fragmentary and does not indicate their relation to this formula (5).

154. J.Friedrich Hethitisches Wörterbuch (1952-4) 260; Otten Heth.Totenr. 33 n.6 "in diesem Zusammenhang unklar" and offers nothing more on p.131.

155. Compare "lead‹weights (?)›" in (4) below which present an identical problem, although the rituals should be kept distinct.

156. Otten Heth.Totenr. 131 n.2 "Wohl Symbolhaft-magisch gedacht", though no explanation is suggested of how.

157. Protection against the despoliation of the deceased's tomb is found in funerary ritual throughout near-eastern cultures practising inhumation. For Egypt see Brandon Judgment of the Dead (1967) 13f; for Canaan see the series of sepulchral inscriptions (from the tenth to the end of the fourth century BC) in ANET^{2} 504b - 505. Cremation would obviously have an effect on such an attitude.

158. See above n.152. Perhaps the Sun-god was felt to be an appropriate overseer of these regions for the second part of the day.

159. As in the Pyramid Text 386 a-b (cited by Brandon Judg.Dead p.8): "There is no accuser (representing) a living person against N.; there is no accuser (representing) a dead person against N.; there is no accuser (representing) a goose against N.; there is no accuser (representing) a bull against N.". See above IX.1.(1).

160. "See we slaughtered for you these animals ...Now deem this land legitimately dedicated...Now let no man...challenge his right".

161. On the Hittite funerary cult see Gurney^{3} (1961) 164-9. Otten Hethitische Totenrituale is primarily a philological study and does not discuss the extent of the practice of the funerary ritual beyond the texts, which are almost exclusively for kings of close relatives (see above n.143).

162. Gurney p.168 itemises "(1)The body is burnt; (2) the pyre is quenched with potable liquids; (3) the bones are dipped or wrapped in oil or fat; (4) the bones are wrapped in a linen cloth and a fine garment; (5) they are placed in a stone chamber...; (6) there is a feast". I shall hope to add the balance operation (symbolical) to this list.

163. Gurney "If there is any connection between the Hittite ritual and that of the Homeric poems, it must be due to a common tradition rather than to borrowing" (note on p.169).

164. Inhumation also occurs, though cremation was about twice as usual. See the figures from the Yazilikaya cited by Gurney on p.169.

165. Šalliš ua̯štaiš, dated around 1200 BC, antedates considerably of course the Homeric ritual (broadly 1000 - 700 BC).

166. See above in ch.I.1.(1) no.1.

167. Below ch.IX.1.(6) on Bronze-age Greece.

168. See ch.VI.

169. Gurney[3] (1961) 132-44 (especially in incorporating Hurrian elements); a similar process is shown by the late Empire change from the Hittite Tabarna to the Egyptian-style "My Sun" as the title for the Hittite King.

170. ANET[2] 400 b Obv.20ff; tr. Goetze.

171. Apart from the Hittites, cremation is virtually unknown in the Near East (found in isolated Canaanite cities and Homer: both of the early iron age). See also above nn.157, 163-4.

172. Texts cited by Otten Heth.Totenr. 13, 122-4. Egyptian influence on the Hittites can hardly support there being any relation between Kantusilis and the Would-be-Suicide (ANET[2] 405-7, and see above in IX.1.(1)); the human condition is the common element; compare also the Akkadian "I will praise the lord of wisdom" ANET[2] 434ff.

173. In view of the address cited above, in which the Sun-god is said to rise from the sea, an origin might be suggested in a time when the Hittites as a people dwelt on the west coast of the Black Sea (an extension of the point made by Gurney[3] (1961) 139).

174. Gurney[3] (1961). Note 145 (temples); p.191ff (associating elements of Hittite theogonies with the Greek traditions); p.63ff (on the origins of kingship).

175. S.H.Hooke Myth, Ritual and Kingship (1958) 114-5, 121.

176. Gurney[3] (1961) 65 avoids settling the question: "The Hittite King was never actually deified during his lifetime. But there was a recognised cult of the spirits of former kings, and so the death of a king is regularly expressed euphemistically by the phrase 'he became a god'" (my italics).

177. KUB XXXIX.I.Rs.III.9 (Otten Heth.Totenr. 23-4) and the outside šu-ritual of ABoT 56 (Otten 104-5). The existence of a cult of prominent deceased, a type of hero-cult, is no problem. The separate existence of fathers, grandfathers etc proves that reincarnation is out of the question for the Hittites.

178. Otten Heth.Totenr. 119-20. There appears to be no reason for supplying "divine" as Otten (113) translates KUB XVII.14 "Nun lasse mich ein zu meinem (göttlichen) Geschick".

179. See Gurney[3] (1961) 63-4.

180. Gurney 64-5, 211-2. The Hittite Kings even adopted the winged-disk monogram as a symbol of royalty.

181. Inferred from "out of doors" and the obvious concern for the king and queen shown by this god in Šalliš ua̯štaiš.

182. Friedlich Hethitisches Wörterbuch 235: uš(ša)niia - "feilbieten, verkaufen - einsetzen, aufs Spiel setzen". My translating "weigh out" is to reproduce Otten's "wäge ich ab"; but the queries are mine.

183. "But now when I, Kantusilis, performed the cult for thee with the merchant, a mortal, holding the balance for the Sun-god ...". See preceding discussion.

184. Otten Heth.Totenr. 132 cites the "ritual for long years for the king" (above (3)) as throwing light on the significance of the present ritual, yet offers no stronger argument than "derartig Ritualhandlung". The Ḫurrian formula, and the dual process of weighing and holding up the balance, seem however to establish a clear distinction between the rituals.

185. Otten confusedly translates "Blei(gewichte)" (plural) in the first, "Blei(gewicht)" (singular) in the second instance. The text indicates simply the substance, in the singular.

186. Above (B) and nn.154-5.

187. Otten Heth.Totenr. 132 n.1 deduces that lead weights are involved from the context (involving a balance) and the fact that Hittite lead weights are known. Neither is an adequate reason.

188. The King was involved in so much ritual that his presence here does not narrow down the context to such subjects as state safety or even justice.

189. My reasons are those that link the Hittites in a common Indo-European tradition with the Greeks (cremation and other funerary cult similarities in Homer; language; mythological elements). The Ḫurrians on the other hand cannot be placed in the Indo-European linguistic group at all: Gurney[3] (1961) 123-4.

190. KUB XXX.27 Vs.12;see Otten Heth.Totenr. 99 and n.1, citing 1378/c 12f where al-la-a-an-ne appears in a similar context to ^{D}UTU-un (the Sun-god) in a parallel text.

191. Gurney[3] (1961) 134-44. Most surprising is that around about the thirteenth century BC the Hittite Court adopted the Ḫurrian pantheon almost in its entirety.

192. Certainly the Ḫurrians are less likely to have witnessed the rise of the Sun-god from the sea: see above n.173.

193. See further on the origin of the Greek view of the balance in IX.2.

194. This conclusion is based almost entirely on the evidence of stated (set) weights. I have not yet found any reference to the process of weighing except the tribute specifications (above n.78). The rituals discussed clearly indicate however that a two-pan balance was in use (above n.74).

195. On ritual weights see above n.82.

196. The widest list of materials weighed (all stone and metals) occurs in the ritual for the erection of a temple ANET[2] 356-7. Symbolic doors of silver, gold, lapis, jasper, iron, bronze, marble and diorite are all prescribed for burial under the new temple door. On the foreign provenance of most of these materials see above n.94.

197. Were these state controlled ? The Law Code mentions the fee for training to become a smith, or a carpenter (II.200B), but not to whom this fee should be paid. The variations or anomalies in ateš-pricing, noted above nn.111 and 121, might be explained if a state- or temple-monopoly existed.

198. Traders at the Assyrian colony of Kaniš, even though this was within Hittite territory, retained their status as representatives of the city of Aššur: see Polanyi Trade and Market 17-22 and for further bibliography n.216 below.

199. The only "merchants" of the Law Code are such as travelled abroad. Although the Code is full of references to prices, and to selling and buying, it does not say how this was done. Indeed the only sales mentioned are by producers or manufacturers.

200. See above n.71: this is largely deduced from the paucity of hieroglyphic Hittite in which these records were most probably kept. The distinction between scripts in which these two classes of documents were written, and which has resulted in the one-sided picture we now have, was, it must be remembered, made by the Hittites themselves and not the chance fortunes of survival.

201. Where other Near Eastern Codes mention "just weights" and "just balances" it is difficult to see what is meant, especially by the latter, other than "just use of the balance"; this is certainly implied by such descriptions of crimes with the balance that have survived, though the purple-dye sellers of [Arist] Mech. 849b34 probably built deceit into their balance beams (see Appendix A).

202. S.R.K. Glanville "Weights and balances in ancient Egypt" (cited above in n.7). See IX.1.(1).

203. Kantusilis' prayer, and the first of the funerary rituals (2(A)) discussed above.

204. That is by Egypt, Mesopotamia, and Syria Palestine. Not only is the measuremental attitude to the use of the balance (to express weight etc) common to the peoples of these areas, but it is so absolutely both in commerce and, where the evidence is available, in literature and theology. The variant view on the other hand is not to be found.

205. Argued from the diffusion of the practice of cremation, with which the rituals in (2) are associated. (1),(3), and (4) cannot be related to any independently observable feature of Hittite culture, but they can be supposed to extend, rather than to restrict, the scope implied by (2).

206. Sun-god rising from the sea (above n.173), and Homeric funerary ritual (above n.163).

207. Above nn.65, 198. Continued in next section IX.1.(3) with bibliog. in n.216. Whether it was from these traders that the Hittite system(s) of weights was/(were) derived (compare their adoption of religious trappings from the Near East: above n.191), is beyond the scope of this present survey, but in the absence of reliable series of Hittite weights, is also impossible.

208. See last note. The particular features relevant here - state religion, centralised administration, royal direction of foreign trading, luxurious style of living with imported materials - reveal the extent of foreign, near-eastern influence on the Hittites.

209. Although it is difficult to assess this degree of reservation at all positively: see n.200 above.

210. Possible variations are inferred from much later evidence by Gurney[3] (1961) 84; contemporary divergence from neighbouring Ugarit has however already been noted (above nn.81 and 84). On the Ugarit weights see further below IX.1.(4).

211. Even if the courts,and the execution of justive in general,might involve weighing out set amounts of silver and measuring wood or bronze: discussed at the start of this section.

212. The importance of ch.VI for the Greek picture of weighing must here be stressed: for the Hittite we lack an equivalent of personal poetry and everyday comedy. Also missing are representations in Hittite art of their balances, and in particular ritual uses: the contrast here is with the Egyptian evidence.

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213. A.L.Oppenheim "A bird's-eye view of Mesopotamian economic history" in Polanyi (ed) Trade and Market (1957) 27-37. On the Mesopotamian economy in general see the important article by K.Polanyi "Marketless trading in Hammurabi's time" in the same book pp.12-26; and, more superficially, G.Roux Ancient Iraq (1964) 173-84, 287-8, 335-8.

214. Driver and Miles Babylonian Laws I.475 "By the time of Hammurabi however the normal system was one of a currency in silver, while corn, which was a relic of the old system of barter, was used almost exclusively for payments connected with agriculture".

215. Even if this is because the methods of bureaucracy permeated most levels of Mesopotamian society (because of the extent of administrative control). My conclusion is not (as will appear) derived from this direction, but is an inference from the practical effect of such close control. The emphasis in what follows is deliberately laid upon the earlier periods in order to isolate as far as is possible the general Mesopotamian weighing practice and to separate it from that particular type of weighing imposed by the state-controlled semi-currencies of later periods.

216. G.Contenau Trente Tablettes Cappadociennes (1949); B.Landsberger "Assyrische Handelskolonien in Kleinasien" AfO 24.4 (1925); also G.Contenau Everyday life in Babylon and Assyria (tr. 1954) 81-4; Polanyi (as cited above n.213) pp.17-26; Roux Ancient Iraq 190-1; ANET^2 217-8; Gurney The Hittites (3rd ed. 1961) 18-19.

217. G.Contenau Les tablettes de Kerkouk (1926) and Everyday Life (1954) pp.84-5; R.Pfeiffer and E.A.Speiser "One hundred selected Nuzi texts" Annual of American Schools of Oriental Research 16 (1935-6); ANET^2 219-220 H.(1),(5) and (6).

218. A.T.Clay Business documents of Murashû sons (1898); G.Cardascia Les archives des Murashû (1951); G.Contenau Everyday Life (1954) pp.85-6; Roux Ancient Iraq 344; ANET^2 221 K.(4).

219. This range is given by Driver and Miles Babylonian Laws I.120-1. A "merchant" of the last type is Šēp-sin, managing director of the merchants of Larsa who received a field of maintenance from the King (Hammurabi).

220. On the Mesopotamian merchant see further Polanyi (as cited in n.213) pp.24-5; W.G. Lambert Babylonian Wisdom Literature (1960) 122; A.L.Oppenheim "The sea-faring merchants of Ur" JAOS 74 (1954) 6-17.

221. This is especially true of literary evidence, which is frequently only preserved from a relatively late date in the transmission. Hence difficulties concerning the dating of particular sections relating to merchants: see below n.284 on problems encountered in the hymn to Šamaš.

222. Polanyi p.17 and Oppenheim pp.30-31 in Trade and Market (above n.213). These "port" areas associated with inter-city trade are presumably closer to the modern port (a place of packaging and a depôt prior to transporting material to one place or another) rather than to a port like the Peiraeus of ancient Athens (where actual bargaining and selling occurred).

223. Shops in bazaars or dotted around residential areas are most clearly seen at Ur (Roux Ancient Iraq 182). Contenau, Everyday Life 97-100, suggests these were run by potters, cloth-merchants, basket-makers, confectioners etc.

224. Contenau Everyday Life cites a text on p.100 but gives no reference.

225. Code of Hammurabi.108-109 (wine-seller and saloon); Eshnunna.15.

226. See above nn.71 and 200; this Hittite use of perishable material for hieroglyphic inscriptions is a problem parallel to the use of Aramaic in later periods of Mesopotamian history (Contenau Everyday Life pp.7, 85-6). Fortunately there is sufficient evidence for Mesopotamia before this occurred (Late Assyrian and Neo-Babylonian), and educated exceptions continue even after (Murashû of Nippur, above n.218, for example).

227. One element of such control that I shall return to later, is the enforcement of weight standards and the associated problem of what these were. See below nn.274-6, 297, 299.

228. For non-survival: Skinner Weights and Measures p.18. Number of pans: *zibana is preserved as a Sumerogram in Hittite ZI.BA.NA; the actual Akkadian for a balance pan is however itquru (CAD sv. zibānītu) and the inference is therefore slightly vulnerable; it does not seem necessary to be concerned by the occurrence of odd-numbers of pans in some temple inventories (CAD sv. itquru 2(a) translating references in BE 14.149:3 and Hussey Sumerian Tablets II.5.iii end).

229. The British Museum relief of tribute-weighing of Ashurbanipal II (c.883-859 BC) shows a large two-pan beam balance suspended from above (Kisch Scales and weights fig.5; Skinner Weights and measures p.37). This is the only representation I have yet collected from Mesopotamia.

230. Most of this available evidence is published only in cuneiform: see further Oppenheim in Polanyi (ed) Trade and Market pp.27-8. The Hebrews are closely parallel and can be seen to have had a very similar attitude to the balance: the Old Testament literature, although greatly circumscribed is also readily accessible as evidence.

231. I have found no counter-example, and the fact that none is included in the CAD references sv. zibānītu is most reassuring (given the standards of that dictionary). The point cannot however be taken as proven as more material is continually being unearthed. It can be said at present, I feel, that one or two pieces of contradictory evidence will not be sufficient to counterbalance the mass of material already supporting the conclusions I draw here.

232. It is not clear in the translation in ANET^2 whether the goldsmith himself, or a relative, bought the house.

233. For example ANET^2 217ff B.(3),(4),(5);C.(2);I.(3);K.(5).

234. There is a considerable problem of precise dating here. Tablet A, in which alone appears the prescribed equipment, was copied in the Seleucid period in the city of Uruk "from an old(er) tablet" (Colophon iv); other tablets however are copied in seventh-century Assur and Nineveh from even "older" tablets. Other ritual, such as ANET^2 331, does not reveal the tradition so decisively.

235. Tr. in CAD sv. zibānītu: 1(a).

236. The explanation that follows is considerably more complicated than the problem itself.

237. Tr. in CAD sv. zibānītu: 1(a) [Neo-Babylonian].

238. Compare Greek versions of the weighing of Hector's (or Achilles') corpse: ch.I.1.(2)- Rep.H and ch.VII.2.(16). Similar again is the Ugaritic tradition of the weighing of Hurriya in the legend of Keret (ANET^2 145a; and see below ch.IX.1.(4) with n.387).

239. On the dating of the Middle Assyrian Code see below n.267.

240. Above in IX.1.(2); the difficulty with the Hittite Code was the lack of any independent documentation of the practice of the Code.

241. Even though on occasion prices and penalties are expressed in other than silver (eg. sheep, grain, or kind), the Hittite Law Code contains no explicit indication of alternative means of payment being allowed.

242. Introduced into Mesopotamia before 2000 BC (Roux Ancient Iraq 135), silver nevertheless remained a relatively rare, imported metal (Contenau Everyday Life 94); it was certainly more valuable, in relation to copper, than it was for the Hittites (which is all the more remarkable if the Hittite copper came from within the Hittite empire: but see above nn.94, 117-8): the Hittite Law Code II.181 gives a ratio of 1:240 whereas Eshnunna.1 gives 1:120/180 (for unrefined/refined copper) and 1:180/200 is possibly valid for Mesopotamia in general (Contenau, as cited, 90-1 tables).

243. Although no direct evidence of weighing procedure survives, there is no reason to suppose it greatly varied given the use of two-pan balances (above nn.228-9) and weights. Contenau Everyday Life p.95 makes two important mistakes in describing the inconvenience of weighing in Mesopotamia ("having for each separate transaction to weigh the goods on one side of the scales, and the silver, representing an equivalent value, on the other"). Direct weight-for-weight equivalence is only applicable to single commodity weighing (as here silver), but, more importantly, scales were never used in Mesopotamia (unlike ancient Greece) for comparisons between unknown (measured) weights.

244. For examples of silver and barley for prices and penalties see following analysis of the law codes. That silver was weighed and grain measured is brought out most clearly by such regulations as Code of Hammurabi § P (that I cite in the text below).

245. This distinction between the evidential value of silver penalties and prices is most important (compare Hittites above IX.1.(2)). The court is clearly going to carry out the weighing of penalties, and it is to be hoped that the experience of such occasions by the average Mesopotamian was not extensive. Silver prices however directly indicate the use of a balance by those involved in buying or selling by them. If they paid in silver they had to be aware of the weight of metal they were using even if it was a stamped (pre-weighed) bar.

246. Eshnunna was one of the first city-states to break away from Ur III towards the end of the third millenium BC. The Law Code is dated to the very early second millenium; it antedates the Lipit-Ishtar Code, and moreso that of Hammurabi. Translation ANET^2 161-3 (Goetze); see also Roux Ancient Iraq 155-6.

247. As also §3, the hire of a waggon, and the rates of interest in §18A; but not for the hire of a boat (§4 barley only), the wages of winnowers (§8 barley), the hire of a donkey (§10 plus pay for driver - both in barley). Wages of a hired man in § 11 are in silver however.

248. Oppenheim (as cited in n.213 above) p.32 emphasises the role of equivalences (agricultural barley and industrial/artisan silver) in the symbiosis that he argues to have been the essence of the Mesopotamian economy. While equivalences clearly operated (see the example cited above from the Nippur temple accounts, (9)), it would appear that the silver-weight system of payment of the city bureaucracy extended in some respects deep into country life.

249. In fact he must be able to pay the penalties for criminal acts which are only given in silver. It is not too optimistic to assume that there were other more pleasurable items he would be able to spend his silver on.

250. Silver and barley equivalences occur in Eshnunna 1,3,7,18A (equals 20-21). My present difficulty is with the relationships between the barley measures (kor, pan, seah) even if the silver weight system is the "Babylonian" (180 grains to the shekel). Nevertheless it is clear from Eshnunna.1 (1 kor barley equals 1 shekel silver) that the principals on which the interest in section 18A is based are identical, whereas the interest paid varies (1 pan 4 seah barley: one-sixth shekel 6 grains silver - in 18A) when this section is compared with 3 (where the same amount of barley is equated with one-third shekel of silver). Goetze, in Sumer 4 (1948) 76-7, argues that a higher interest rate applied to barley loans; the same can be read in the Code of Hammurabi §§ L-M , where the silver rate is again one-sixth shekel and 6 grains on a principal of 1 shekel (see Driver and Miles Babylonian Laws I.173). The implication would appear rather to be that silver payment was encouraged than that silver (imported) was more easily available than barley (home-grown).

251. See end of preceding note.

252. Eshnunna.15, in which the tamkarum and woman wine-seller are forbidden to invest (?) in silver, barley, wool and sesame oil from slaves, might indicate that even other alternative methods of payment existed; the interpretation of the passage is however uncertain.

253. Hammurabi was king of Babylon c.1728-1686 and the Laws are placed early in his reign. The stele shows him commissioned by the Sun-god, Samas, though the prologue (v).12 cites Marduk. Translations by Meek ANET^2 163-180, Driver and Miles Babylonian Laws II (fuller and with a commentary in vol.I; the passages most relevant to my subject are only in this edition).

254. The passages are § 51 and § M, both of which concern the repayment in corn of a silver loan, and § R, which considers the further case where neither corn nor silver can be repaid and the merchant must be content with repayment in goods. The "ordinances of the King" are mentioned only in the first two of these passages.

255. Driver and Miles I.148 n.1 cite three such "ordinances of the king": Singašid (of Uruk c.2686-2672) in which one shekel of silver equals three GUR of corn; Maništusu (of Akkad c.2306-2292) in which it equals one GUR of corn; and Šamši-Adad I (of Assyria c.1814-1782, and so a contemporary of Hammurabi) in which it equals two GUR of

255 contd.

corn. That the Code of Hammurabi should refer to the "ordinances of the king" as a separate document is proof that this is not merely missing from that copy of the Code that has survived.

256. "If a man who has raised a (money) loan has no silver to repay (it) but has corn..." (§M); "If a man has received corn or silver from a merchant and has no corn or silver to give back but has goods..." (§R).

257. Thus Driver and Miles I.148. On p.186 they suggest that the law is substituting a new contract for the old one (stipulating corn and silver repayment) that cannot be fulfilled. It is likely that these contracts were fairly detailed, giving such things as interest rates and period of loan repayment (p.175).

258. Cited in n.255.

259. §§ L-M. Driver and Miles restore an inequal interest rate on the basis of the Eshnunna parallel and others (I.173). The silver rate, that needs no restoration, is precisely the same as Eshnunna - viz. one-sixth shekel and 6 grains interest on a principal of one shekel.

260. Which is precisely the situation in the Hittite Law Code as I argued above in IX.1.(2). Eshnunna presents a variation, with unnecessary complications, that must place it closer to the Code of Hammurabi (which only allows specified alternative methods of payment) than to the Hittite Law Code. Alternative payment did indeed exist in Mesopotamia (cf. wine-seller of Code of Hammurabi 108), but it should be noted that such alternation is not available for the payments prescribed by the Code of Hammurabi itself.

261. Compare the harvesters of Eshnunna.7 (for whom alternative payment was allowed). Driver and Miles I.475-7 argue from the method of payment (per diem) and seasonal variation (6 še to 5 še according to the month) that these people were from the town.

262. Such as the misuse of farmland (44, 56, 57, 58, 63). I do not include payment in kind as in 120 (where double the grain stolen is to be returned) or 121 (storage rates for grain).

263. Such as the penalties for personal assault (where only the amount of silver, not the fact of a silver fine, is varied according to social level: 195-214). Even in a specifically agricultural context silver penalties occur: although the hire of animals is to be paid in grain (242f, 268-70), the damage done by them or to them is liable to a silver penalty (247, 251f); so too is the cutting of trees (59).

264. Rates of pay are conveniently tabulated by Driver and Miles Babylonian Laws I.476. All corn rates are agricultural, but not all the silver rates are non-agricultural. The problems of relating the rates of the Code to extant tablets, and the possibility of semi-free labour, are not relevant here.

265. Lipit-Ishtar was king of Isin c.1934-1924 BC. The (now fragmentary) text of the Law Code was inscribed (in Sumerian) some time in the first half of the second millenium BC (F.R. Steele AJA 52 (1948) 425-50). Translation ANET^2 159-161 (S.N.Kramer).

266. These allow no firm conclusions on context as they range fairly widely - §10 ½mina for damage to trees; §9 10 shekels for stealing from an orchard; §33 10 shekels for failure to divide up an estate. In one place (§§34-37) damage to animals is expressed in terms of the price of the animal concerned, but it is not clear from the text how this price was paid.

267. The Middle Assyrian Laws are preserved on tablets from the reign of Tiglath-Pileser (twelfth century), but they may in fact go back further to the fifteenth century BC. Text, commentary, and translation in Driver and Miles Assyrian Laws (though with little on the economic aspects of the Laws); more recently Meek in ANET² 180-8 (whose references I cite here).

268. Although corporal punishment (the death penalty included) occur also in the Code of Hammurabi, they are there much less in evidence (see Driver and Miles Babylonian Laws I.494-9). In the Middle Assyrian Laws these punishments, and their careful control, were closely watched by the court (MAL.A.57-8); unfortunately however no directions are given for the weighing of the lead fines imposed.

269. Silver only in A.55f for rape (tablet 0.7 is too fragmentary). It is reassuring that the lead pricing, mentioned in the Laws, are found, as paid, in contemporary Assyrian documents (as in the sale of the house to the goldsmith of Assur: above no.(6) ANET² 221 I.(2)).

270. The lead weights given are: 15 minas, 30 minas, 1 talant, 2 talants, 2 talants and 30 minas (2½ T), and 4 talants; the highest is for the redemption of a female slave (C with G.1).

271. C with G.2: "If a seignior...sold [anyone else] who was living in his house, he shall forfeit his money [when they have persecuted him]; C with G.4: "[If a seignior] sold [either an ox or] an ass or a horse or any beast not [his own which] was stabled in his house [as a pledge], he shall give [a beast like it in value], (but) he need not return the money. If [he did not give] a beast, he shall forfeit [his money]"; C with G.6a: "...he shall take and...which for money ...two goats to the owner of the silver...". In all cases the word for money is that equivalent to silver.

272. The problem of how a slave might purchase wine need not be real - the proviso in question may simply debar these categories of persons from purchasing wine at all. Goetze (ANET² 162 n.7) explains the tamkarum here as "the official 'finance officer' who has a state monopoly on certain commercial transactions".

273. The interpretation of the passage (Code of Hammurabi 108) is discussed in detail below following.

274. Collected by A.E.Berriman Historical metrology (1953) 55-62 and F.G.Skinner Weights and measures (1967) esp. 15-16, 36-37, 50. Concern for accuracy is shown by one of the Shulgi weights, inscribed "To Nannar his lord has Shulgi the mighty man, King of Ur, King of the Four Lands, dedicated half a mina of correct weight".

275. The copy of Nebuchadnezzar's weight is BM no.91005. The closeness of the weight standard is the clearest evidence that the Shulgi weight was still in existence to be copied; it can hardly have been transmitted through several recopyings as the difference is close to the likely limits of contemporary accuracy. This Skinner (as in n.274) estimated at 0.15gm (pp.47-50); my impression, for Greek machines and for overbalancing (where higher sensitivity can be gained than in simple balancing with stable balances), was 0.2gm (see Appendix B).

276. Certain weights are inscribed with the king's name and a phrase like "two minas of the country", but as the king is also so designated, even on the same weight at times, this does not imply that the weight was specially for use in the country. Aramaic readers would not be excluded from acting as royal accountants, and bilingual inscriptions, in the late period, are no more than for the convenience of a bureacracy that included them.

277. My list derives in the main from Driver and Miles' note on Code of Hammurabi § P (below no.(6)) in Babylonian Laws I.183-4; see also Lambert Babylonian Wisdom Literature 321 and CAD sv. zibānītu 1(a). Not all the passages these sources cite have however been included here.

278. Edition, with translitteration, translation and commentary by E. Reiner (1958). The date of Šurpu is uncertain, and though parts may go back to the Old Babylonian period, the majority is thought to be Middle Babylonian (1700 BC or later). Part II is addressed to Šamaš; parts III and VIII to Marduk. The surviving tablets are mainly from Aššurbanipal's library.

279. I include this as weight might equally well appear for measure in the thought behind the verse. My numbering only begins after it.

280. "Oath" would appear to be a variant for "sin committed".

281. Driver and Miles Babylonian Laws I.183-4 list the offences.

282. H.Zimmern, Beiträge zur Kenntnis der bab.Religion (1901) p.50, translates last line: "Von Bann durch: falsche Wäge führen unrechtes Geld eines Gebannten nehmen desgl..."

283. Compare the part played by the Sun-god in Kantusilis' prayer and possibly the ritual weighing out of years for the king above in IX. 1.(2). I should maintain that the balance has a radically different value in the two cultures: Hittite and Mesopotamian.

284. Lambert Babylonian Wisdom Literature (1960) 121-38, 318-23 for translitteration, translation and commentary; also F.J.Stephens in ANET^2 387-9. As Šurpu, the hymn draws upon Old Babylonian tradition, though some details may be later (Lambert pp.122-3). Again the surviving text is from Aššurbanipal's library.

285. Sc. by Šamaš (line 119).

286. ANET^2 388 (ii).51ff translates lines 107-9 rather differently: "He who handles the scales in falsehood, He who deliberately changes the stone weights (and) lowers [their weight], will make himself lie for the profit and then lose [his bag of weights]". The offence, in the sense relevant to my argument, is not however generically dissimilar.

287. Both passages are to be found in Driver and Miles, Babylonian Laws II. The first is not included in ANET^2; the ANET^2 variation on the second will be discussed below.

288. "Or (if) she reduces the value of beer (given) against the value of corn (received)" Driver and Miles (see below n.293 where I argue against only this part of their rendering).

289. As Driver and Miles point out (I.205), the wine-seller is to be executed by drowning and not simply forced to endure the "ordeal by water" (for which the Babylonian phraseology is different). That wine-sellers came in for general ill-feeling seems as true for Hammurabi's Babylon as it was for Aristophanes' Athens (Thesm.347-8; Plutus 435-6). The status of the trader was very different between the two cultures, though it is interesting that wine-sellers and tamkarum are singled out together in the law at Eshnunna.15 (above n.252 and 272). See further below n.303.

290. As far as I can judge, the linguistic argument put forward by Driver and Miles (I.204), that there is a distinction between the "price of liquor" in the earlier part and the "exchange value of liquor" in the latter (whence their translation given in n.288 above), has no bearing upon Meek's translation (ANET^2) which faithfully reproduces the distinction. The arguments I give are therefore my own.

291. What is really happening in §108 on this interpretation ? Even an ingenious manipulation of the variation between silver-grain equivalences and interest rates fails to meet the translation that is offered.

292. If not in §108, sale by grain is clear enough in §111 (which also adds sale by credit).

293. On grounds of parallelism with other passages in this group (all of which give misuse of measures alongside misuse of weights), I prefer the latter case. Driver and Miles (I.203-4) argue for the former on the assumption that false grain measures are ruled out by the strategem devised in the first part of §108. I do not feel this sufficient reason, as the wine-seller might well have found a false weight easier to fabricate than a false measure.

294. On the "heavy" and "light" Babylonian weight standards see below.

295. For the bags of weights see Šamaš line 108 (ie. (5) above) and compare Proverbs 16.11 "A just weight and balance are the Lord's: all the weights of the bag are his work" (further below IX.1.(5)). The weights were invariably in stone (Babylonian for "weight") and large numbers have survived to attest their continued and general use.

296. See items cited in nn.219-220 above, especially, as overseas trading is relevant for this point, the article by Oppenheim "The sea-faring merchants of Ur"; [Note also W.F.Leemans Foreign trade in the old Babylonian period (1960), with his earlier The Old-Babylonian merchant (1950)]; such overseas trading ceased with the first Babylon Dynasty. Hymn to Šamaš lines 65-70.

297. Hultsch GRM^2 396; though it should be admitted that the marked royal weights offer a far more reasonable basis for such identifications than any other.

298. This does not imply an insistence on precise conformity to a single weight standard in general. That the kings themselves maintained a high degree of accuracy (Nebuchadnezzar's copy of Shulgi's weight noted above: see with n.275) is a different matter, as too the applicability of the standards presumably implied by the different exchange rates of the "ordinances of the king" (above n.255).

299. On the great variety of Mesopotamian weights see most metrological surveys. The general point is made by Contenau Everyday Life 87-8, who also mentions the sixth-century BC banker Murashu of Nippur who possessed his own weights and measures. Driver and Miles Babylonian Laws I.181-4 cite variant terminologies for weights and measures, including references to merchants speaking of weighing "by our stone". Compare the Hittite treaties specifying merchants' weights (above n.78) and the variations at Ugarit, a traders' city (discussed in IX.1.(4) following).

300. Hymn to Šamaš line 105: "As for him (sc. the merchant) who invests money in distant trading missions and pays one shekel per...". Perhaps a Middle-Babylonian usage of "merchant" (Lambert as cited in n.220).

301. Code of Hammurabi §L-M; Eshnunna.18A.

302. Above n.255.

303. See above n.289. One might guess this was because of the commodity sold: Contenau Everyday Life 72-3 discusses the importance of wine in the Mesopotamian economy. Wine-sellers had special responsibilities (Code of Hammurabi §109: handing over criminals to the authorities), and distinguished literary antecedents (Sidurii, the ale-wife Gilgamesh encountered in his wanderings after Enkidu's death: ANET^2 90-91).

304. See below in IX.1.(5).

305. "Taking untrue money and swearing (it was rightful)" Reiner (n.278 above); but why not "...swearing (that it was true)", i.e. that the balance was level. Considerable attention however was paid by the Mesopotamians to the refining of silver, and it is perhaps more likely that purity is meant here.

306. Especially as there is no evidence that the Mesopotamians incorporated a pointer in their balances.

307. [Arist.] Mech.1.849b34ff; and see further Appendices A and B.

308. Again the context is explicitly that of general commerce in the Hymn to Šamaš (line 110 etc). Even though an overlap with the weight offences (1(a)) might exist, it is important (in view of the Greek attitude) to give some emphasis to misuse of the balance.

309. The condemnation implied in the Hymn to Šamaš (and also, though less clearly, in the Šurpu ritual) is not that misuse of weighing conflicted with special interests (such as would be the case if the proper payment of royal-standard fines was all that was behind the references). The offence is simply seen as immoral in its own right.

310. Even the extensive lists of the Šurpu ritual are based on possible offences that an individual might have committed and surely not all Mesopotamians interested in the ritual would be merchants. I feel therefore that use of the balance and weights was very much a part of more general Mesopotamian everyday life.

311. Examples have already been quoted above; the Greeks on the other hand were chary of accepting even the notion of absolute weight (see ch.VI.1), a position that I have related to their lack of measuremental experience.

312. A.L.Oppenheim "Siege documents from Nippur" Iraq 17 (1955) 69-89 on p.87.

313. Brandon The judgment of the dead (1967) 49-55; Contenau Everyday Life (1954) 299-300; Roux Ancient Iraq (1964) 89-93 are all general surveys. For more detailed studies see T.Ebeling Tod und Leben nach dem Vorstellungen des Babylonier (1931); J.M.Aynard Le jugement des morts chez les Assyro Babylonians (in Sources Orientales IV, 1961); A.Kleveta "Le jugement infernal dans les croyances babyloniennes" Archiv.Oriental. 17 (1949) 374-83.

314. Service of the gods: ANET^2 99b (Old Babylonian) "He who shall serve all the gods, let him be formed out of clay, be animated with blood". Compare the later version, given on Creation Tablet VI, ANET^2 68b: "... out of his blood they fashioned mankind. He [Ea] imposed the service and let free the gods".

315. Described by Enkidu to Gilgamesh, Creation Tablet XII, ANET^2 98b. Enkidu's return is exceptional but instructive - the underworld god Nergal opens up a hole in the earth and "the spirit of Enkidu, like a wind puff, issued forth from the nether world".

316. The royal tombs of Ur III, with whole retinues buried with their master, may be reflected in the account of Gilgamesh's death: ANET^2 50-52. Enkidu (as in n.315) describes the fate of "him whose spirit has no one to tend it... Lees of the pot, crumbs of bread, offals of the street he eats".

317. Thus the Dialogue between master and servant IX, ANET^2 438b: "A man offering sacrifice to his god is happy, loan upon loan he makes". See the salvation by Marduk in I will praise the Lord of Wisdom, ANET^2 434-7, where the god has saved a patient from the very jaws of death.

318. Dialogue between master and servant IX, ANET^2 438b.

319. Thus the punishment inflicted by Šamaš is failure for the merchant in his trading, and the reward success: cited above Hymn to Šamaš 112ff. Similarly the Šurpu ritual is designed to free its user from present punishment.

320. Ebeling and Aynard as in n.313 above, cited and discussed by Brandon Judgment of the dead p.53.

321. Such as the judges mentioned in the account of the arrival in the underworld of Ur Nammu, prince of Ur III. Brandon p.52 suggests these judges were "probably in origin ancient chthonic gods of the Sumerians". One might compare the Greek Minos and Rhadamanthos: see ch.VI.3.(1) and (2).

322. The evidence for this category is the least convincing, but can be inferred from the general impression that the afterlife may be a reflection, albeit pale, of the present one. Gilgamesh seems to have been called Lord and Judge of the Underworld (Brandon n.23 on p.210) and in this position reflected what he was on earth. Similar reflections can be found in such facts as that relatives are still, for the Mesopotamians, relatives after death (ANET^2 97ff). Aynard's view of the Ur Nammu judges seems better applied to this category - "Ils sont chargés de la police du monde souterrain" (p.91 of the work cited in n.313 above). The comparison with Minos, Θεμιστεύοντα νεκυεσσιν (Homer Od.11.569), is thus obvious.

323. The patient in I will praise the Lord of Wisdom reaches the place "on the holy shore (in the underworld) where the (last) judgment of men is manifested" (supplements by Pfeiffer, ANET^2 437a, and the latter does rather beg the question), but was reprieved. Counter-judgments can be cited also, for example the Sumerian myth of Inanna's descent to the underworld describes how she eventually reaches the judgment area (ANET^2 55b): "The Anunnaki, the seven judges, pronounced judgment before Ereshkigal. They fastened (their) eyes upon her, the eyes of death". It may be significant however, for the development of Mesopotamian eschatology, that the judgment is missing from the later Akkadian version (ANET^2 108a).

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324. Roux Ancient Iraq (1964) 124-8 is a useful introduction to the Semitic problem, also E.T.Ryder in PCB^2 §52b.

325. After contact in the third dynasty and following, Egypt established positive control from the time of Thutmose III (1505-1447 BC) and held it till the end of the Amarna period, c.1350, when the Hittites took over, especially in North Syria. After them the Assyrians, Babylonians, Persians, and finally, after 332 and briefly, the Greeks.

326. Roux Ancient Iraq 226-9 with bibliography on the Aramaeans in n.12 p.387. The extent to which they carried overland internal trade (as mentioned in Ezekiel 26f) cannot be assessed: see B.H.Warmington Carthage (Penguin 1964) 21.

327. The problem of the origins of the Philistines is still debated: D.Harden The Phoenicians (1962); Gray PCB^{2} §89 b-c; R.A.S.Macalister The Philistines (Schweich Lectures, 1913) but this last is now rather out of date.

328. The script, but not its language, is similar to that of the earlier Hittites; Ura seems to have been central to the development of the group, and Carchemish a major city: Roux Ancient Iraq 223-5; Gurney Hittites^{3} (1961) 39-46; Boardman Greeks Overseas (Penguin, 1964) 80f.

329. Although several biblical commentators are attracted to the equation (as Gray PCB^{2} § 42 d), the Habiru are not to be confused with the later Hebrews. They were true Palestinian guerrillas: Roux Ancient Iraq 197 with n.22 on p.383 for bibliography.

330. As it stands in Genesis 11.13; 12.5-10; 13.1-4,18 the route taken by Abram from "Ur of the Chaldees" to Hebron is telescoped at its start and somewhat circuitous thereafter. Although the usual view is that he came from Ur in Sumer c.1850 BC to Hebron (Roux Ancient Iraq 196, 221), it has been suggested that Ur is in fact Ura, an unidentified North-Syrian town close to Ugarit but under Hittite control at the time of the documents of PRU IV that frequently mention the "merchants of Ura" trading through Ugarit: C.H.Gordon "Abraham and the merchants of Ura" JNES 17 (1958) 28-31. It would indeed be easy for a confusion to have arisen between the well-known Ur and this obscure, but well-placed, Ura. On the date of the Exodus see below n.428.

331. IX.1.(5). The Elephantine colony of Hebrews is considered apart also in an Addendum to this section on the Hebrews.

332. The problem is whether the Old Kingdom text (Dyn III) recording the arrival of ships from Gebal laden with cedars implies that Byblos (which retained this name in the later second millenium) was already occupied by the later Canaanites. Harden The Phoenicians 21,44-5 is inclined to think so; Warmington Carthage 17 is not.

333. Apart from their city name of course. This may be the simple explanation for the term "Sidonians" in Homer (Iliad 6.290; Od.4.84) although it causes some confusion when applied to known kings of Tyre (Ethibaal of I Kings 16.31, the father of Jezebel; or Hiram in the Cyprus bronze bowl inscription of 741 BC: see Harden The Phoenicians 53-4) before the ascendency of Sidon began after Tyre's destruction by Nebuchadnezzar in 574 BC. Again, the matter does not seem settled. Harden op.cit. 21-2 refers to the Akkadian form Kinahu or Kinanu of the Amarna letters, to general Hebrew references Canaanites, and, at the other end of the period, to Mark 7.26, Matthew 15.22 and to St.Augustine of the fourth century AD who said that local Africans would regard themselves as "Chanani". Warmington Carthage 16-17 thinks that the Greek Phoenicians were properly a branch of those Canaanites who called themselves "Sidonians".

334. R.B.Revere "'No Man's Coast': Ports of Trade in the Eastern Mediterranean" in Polanyi (ed) Trade and Market (1957) pp.38-63.

335. On the absence of markets (ἀγοραι) in the Near East, see K.Polanyi "Marketless Trading in Hammurabi's Time" in Trade and Market pp.12-26. I do not mean to imply that the Canaanite cities were more than depôts however.

336. The Ugaritic evidence is briefly reviewed by C.F.A.Schaeffer The Cuneiform texts of Ras Shamra - Ugarit (Schweich lectures, 1939); the economic documents are published by J.Nougayrol in vols.III and IV of Le Palais Royal d'Ugarit (1955, 1956), to which they will be referred as PRU III and PRU IV, and also in various volumes of Ugaritica. The other Canaanite cities are less conveniently published. The Amarna letters afford the most immediate literary starting point (note EA 270,271,292,297 in ANET^2, translated by Gezer). Otherwise it is necessary to consult individual city excavation reports.

337. The division made by clerks at the Palace of Ugarit would appear to be between foreign documents, local village accounts, metropolitan matters, and public (Ugaritic) decrees (Nougayrol PRU III Introd.).

338. PRU IV.17.146. This penalty of 3 minas (silver) for the murder of a merchant can be seen exacted in PRU IV.17.158 (180 shekels to the mina).

339. To be inferred from PRU IV.17.229, a verdict by Ḫattušilis III on merchants murdered by people in the Ugaritic town of Apsuna; the amount per merchant cannot however be deduced. Compare the Hittite Law Code I.5 for a similar ruling (discussed above in IX.1.(2)).

340. PRU IV.17.130, an order of Ḫattušilis III in reply to complaints from Niqmepa, King of Ugarit.

341. PRU IV.17.341, a Carchemish decree in response to Ugaritic complaints about secret trading.

342. PRU IV.17.424C with 397B.

343. Mašanda, the caravan owner, was claimed to owe the 4000 shekels (represented by the 400 donkeys) to an unspecified Talimmu: PRU IV. 17.346.

344. Provision of lapis-lazuli for the Hittite court (PRU IV.17.383, 17.422; but with evidence of a personal approach, see also above n.92); provision of two juniper trees according to the specification of the King of Carchemish (PRU IV.17.385).

345. Regulation of the tribute to be paid to the Hittites; the extent of the political area controlled by Ugarit; correspondence associated with the divorce of Ammistamru comprises a sizeable part of PRU IV.

346. RA xxxi pp.125-136 (ANET^2 487 a).

347. Above nn.340-1.

348. PRU III.31.

349. Ugaritica 5 (1968) pp.251-7 with p.324. Discussed further below.

350. Found in lexicon variants for the Sumerian "cost": Schaeffer (as in n.336 above) p.40.

351. Thus PRU III.15.63, a letter between two individuals not apparently connected with the court. Abiramu has received delivery of goods from merchants (tamkâri) and asks Silabanu to take 45 (shekels) silver from two people and give it to Rišpaya to pay the merchants (or pay them directly himself). Abiramu encloses some precious stone with the letter to Silabanu, and wants him to "give their weight in silver". Again, Ugaritica 5 (1968) 13 [RS.17.465], Rašapabu takes orders for wool; and PRU III.15.108, an order to transfer money, and to buy and deliver bronze.

352. I am indeed doubtful about alternative payments at all apart from the gold of certain penalties (the exceptional PRU III.16.139), or the gold and wool as well as tunics and silver in the Hittite tribute (PRU IV.17.227 etc). The distribution of oil and wine (Ugaritica 5 (1968) 99 [RS.20.425]) to palace officials would appear a largesse; similarly that of two jars of wine to the Chiefs of Ura (Ibid.100 [RS.20.04]). PRU III.16.257 ff are palace accounts.

353. See Nougayrol PRU III Index I (pp.223 and 228) for collection of passages under these headings.

354. Nougayrol PRU III p.32 "ce qui frappe surtout dans les transactions c'est l'abondance de la monnaie..."

355. Wool in PRU III.11.732 and 15.43 (though always with the same number of "tunics" as 100 shekels, as on the Hittite treaties: PRU IV.17.227 etc); flax in PRU III.16.110, 16.359C; copper in PRU III.16.110, 16.359C.

356. The best example is the trousseau of Queen Ahatmilku in PRU III.16.146 and 161. The gold objects are weighed as 762, 216, 628, 80, 40, and 1070 shekels; the bronze (not so carefully) as 2900, 3T, 2T1500, 1T, 1T600, 1000, 1200, 900, 600, 500, 600, 600, 170, 260, 2T1600. Also PRU III.16.239, where bronze is weighed as 200 and 200 shekels.

357. PRU III.15.63 (cited above in n.351). The precious stones were not to be balanced directly against silver; Abiramu would have recorded the weights of the stones as a precaution. Compare ABL 292, cited above in IX.1.(3) as no.(15) of the first list of texts illustrating the extensive use of weighing in Mesopotamia.

358. Ugaritica 5 (1968) 251-7, 324 (Nougayrol).

359. The certain figure is the 3000-shekel talant, deduced from a wool account tablet: F.Thureau Dangin "Un comptoir de laine pourpre à Ugarit d'après une tablette de Ras Shamra" Syria 15 (1934) 137-146. From this Schaeffer (above n.336) p.27 and Nougayrol PRU III p.223 have deduced a mina of 50 shekels, comparing Exodus 38.25-26. As will be shown below in IX.1.(5) when this passage is discussed, 50 minas of 60 shekels each would give the same total (cf.Scott PCB^2 §35 a). Without further confirmation, the question is best left open.

360. Nougayrol PRU III 223 for the 9gm shekel of Ugarit. If the weights are Babylonian however, it would be better to express the limits in terms of the Babylonian 8.4gm shekel: $\frac{1}{3}$grain is unaltered, but the upper limit (60T) becomes 1814.4 kg. The conclusion however is no different.

361. Limits of 0.15-0.2gm seem established: see above n.275 and Appendix B.

362. Nougayrol's comment that $22\frac{1}{2}$ grains on the Ugaritic standard are approximately 1 gramme is irrelevant. The Ugaritic system, deduced from the number of shekels to the talant, is as yet not sufficiently clear for conclusions on the number of grains to the shekel (see n. 359 above).

363. There is ample evidence of similar aids for the international commercial organisation in Ugarit, including of course the lexica that have proved so invaluable in the decipherment of documents. The present Europaean Parliament will recognise the problem, as seven languages appear to have been in use in Ugarit: Schaeffer (as above n.336) pp.38-39.

364. RS.11.772---"heavy shekels" (line 19). The Hittite version is PRU IV.17.227--- (Suppiluliumaš, 1380-1340 BC), and the"heavy shekels" would appear to mean Hittite shekels. Nougayrol, PRU IV p.39, explains the variation by suggesting a Hittite mina of 40 shekels. On the alternative view that it, like the Mesopotamian, had 60 shekels, a heavier shekel and mina would have to be suggested. In principle I should favour this approach, as there is no reason to assume as a starting point that a standard weight (be it mina, shekel, or talant) applied throughout the Near East. Gurney The Hittites[3] p.84, holds to a 60-shekel Hittite mina, and concludes that the shekel was lighter than the Babylonian of 8.4gm (using the evidence of a much later Carchemish mina); instead however it should be heavier than the Ugaritic of 9gm (as the present text clearly shows). See above with n.81.

365. See above in IX.1.(3); the wine-seller of the Code of Hammurabi ch. 108, penalised for selling wine for silver "by the heavy weight", can hardly be using an improper standard as the correct standard is not indicated.

366. Note that no such inferences apply to the Hittite weights, as these need be no more than those laid down by Suppiluliumaš' administration.

367. Schaeffer (above n.336) p.27.

368. Found in a hoard,in a house in Chantier B, dated by a bronze axe-head to the fourteenth century BC: Schaeffer "Nouveaux monuments pondéraux" Syria 18 (1937) 147-151. The weight, 469gm, lies between the Egyptian and Babylonian minai of 437 and 504gm respectively; the unit implied, of 23.50gm, corresponds to no readily identifiable weight.

369. Fourteenth-thirteenth century BC Level in the street: Schaeffer (as in n.368) 149-150 and Pl.xxiv. The six weights are: 2.05, 3.05, 9.05, 18.70, 91.55gm, and a further weight (in the shape of a human head) could also belong to the series at 190gm. The weights represent $\frac{1}{4}$-, $\frac{1}{3}$-, 1-, 2-, ?- (70gm), 10-, and 20- the Ugarit shekel of 9.05.

370. The 70gm weight is rather far from the 72gm-plus multiple for 8 shekels on the 9.05gm Ugaritic base; it is also an otherwise unattested multiple. Alternatively, and preferably, it could represent 3 times the 23.50gm unit implied by the reclining bull weight (above and n.368).

371. It is however difficult to be precise with the weights, all from different contexts, described by Schaeffer.

372. Whether for personal accounting or for calculating amounts and proportions of materials to be used in a given piece of work.

373. Schaeffer The Cuneiform Texts (above n.336) wrote passim on the cosmopolitan society of Ugarit, the Minoan-Mycenaean element of which was especially related to the metalworking and jewellery-making activities in the city. The Mycenaean "colony" (hardly more formal than the settlement there alongside other peoples of certain Mycenaeans: Boardman Greeks Overseas p.58) is well-attested from the pottery found there; for the Egyptian presence see the reclining bull weight; lexica and other documentary evidence indicate most strongly the Mesopotamian residents.

374. Ships are described by type and by capacity (Schaeffer, as in n.336, p.39). The Hittite Queen, Puduḫepa, was involved in a case concerning the collision of a boat of a man of Ugarit with a quay elsewhere in Hittite territory (? Cyprus: PRU IV.17.133). Forty ships loaded with cedar from Gebal (Byblos) reached Egypt during the third dynasty (Harden The Phoenicians p.44).

375. There is no indication that Canaanite cities traded directly overseas with Mycenaean peoples before the collapse of the Minoan-Mycenaean thalassocracies and the administrative centres that supported them (Harden The Phoenicians pp.157-8). Actual presence of Mycenaeans in Ugarit seems certain (above n.373), but some orientals may also have set up workshops ~~abroad~~ in parts of the Minoan-Mycenaean world.

376. For a general survey of Ugaritic literature see Schaeffer The Cuneiform texts of Ras Shamra - Ugarit (1939) ch.III and IV; C.H.Gordon Ugaritic Literature (1949) and Ugaritic Manual (1955); and more recently texts have been published in Ugaritica 5 (1968). A translation of the major mythical texts by H.L.Ginsberg appears in ANET^2 129-155 from which my quotations are taken. The literary style of the Canaanite letters to Egypt identifies them as a further source: ANET^2 483ff (referred to as EA for Tell El Amarna).

377. Without doubt the most popular parallels for Ugaritic literature have been sought in the Old Testament, beginning with the unlikely identification of a certain Adm, who had a beautiful Eastern garden, as the Adam of Genesis (Schaeffer, above n.376, is cautious pp.76-7; Albright PCB^2 49a and Gray 88c-f). On the Keret legend most are sceptical: G.S.Kirk The Songs of Homer (1962) 106-7; but Schaeffer, op.cit. p.76, predictably prefers a biblical parallel in the invasion of the Negeb by the Terachites.

378. Ugaritica 5 (1968) no.163 line 16: "qui va avec un homme de métier, va en sécurité" (Nougayrol p.284).

379. Harden The Phoenicians 122f makes considerable use of the Ugaritic material in this context.

380. The arrangements whereby the deceased was to be assured of a supply of drinking water are particularly elaborate: Schaeffer (above n.376) 49-53.

381. Poem of Baal and Anath (ANET^2 132a) eII AB (i) 31; also 28-9: "he'd melt silver by the thousands (of shekels); gold he'd melt by the myriads".

382. Id.(v) 77-8 (ANET^2 133b).

383. EA 292, 297 (Gezer: Akkadian); see ANET^2 490a.

384. See above in IX.1.(3) The lamentation of the fall of Ur (ANET^2 455a, line 244).

385. KRT A.(i) lines 28-9; see ANET^2 143a.

386. I suppose that glass shekel weights would be an alternative, but would these be though of as proper "shekels" ? and what evidence is there of such weights at Ugarit ? Hittite zapzagaia, even if they may be glass weights (see above IX.1.(2)), are patently not called "shekels".

387. KRT A.(iv) lines 205-6; see ANET^2 145a. Two translations are offered: "her double I'll give in silver, and her treble in gold" or "two parts (ie. thirds) of her I'll give in silver, and the third in gold". Whereas the former might be feasible by the direct weighing of Hurriya against the metal (twice, then three times), the fact that gold was more precious than silver makes it virtually certain in my opinion that more silver than gold was offered, and that therefore the latter interpretation (two thirds silver, one third gold) is correct. This without doubt implies the independent weighing (measurement) of Hurriya and then subdivision of the figure obtained into three. Compare the comparable passage ABL 292 r.6 and 9 (above no.(15) in the first series of passages listed in IX.1.(3)); and see n.238 above.

388. This lack of much literary allusion to the practice of weighing may be directly related to the highly technical (and therefore somewhat prosaic) nature of Canaanite weighing. I should prefer however not to have to explain the silence; see also below n.421.

389. Subsequent iron-age occupation of the area (for example the Greeks at Al Mina) was on a different site. Ugarit was wide open to attack from both land and sea, its position in considerable contrast with Tyre to the south or with Antioch some way inland.

390. See Revere as cited above in n.334.

391. For example the Hebrews now reappear upon the scene (the Exodus being dated c.1250 BC - see n.428 below) and begin to establish their territorial claims.

392. Above n.333.

393. The detailed cause of Phoenician overseas expansion is relatively obscure, but most historians have agreed on one or two of these factors as fairly central. I do not mean to exclude trade as a contributory factor (compare Warmington Carthage ch.I).

394. Or were now able to expand trade to the west. The bronze-age prosperity of the cities however was hardly an incentive to sail far afield before it was necessary.

395. Elected magistrates now filled the functions of the earlier hereditary kings, and an oligarchic council appears. Wealth, which in these cities would be from trading, was the main qualification. The detailed organisation is obscured by lack of direct evidence and by the confusing (as varying) terminology of foreign writers. Possibly for some time the hereditary kings persisted as did Hiram of Tyre. See Harden The Phoenicians 78-9; Warmington Carthage 144ff and 154ff.

396. The political positions of Tyre, Sidon, and Carthage (founded from Tyre: Warmington Carthage 21-2) are the bset-attested indications of inter-city relations. Initially independent, Tyre seems to have been strong enough by 741 to include Sidon (Harden The Phoenicians 53); yet with the collapse of Tyre to Nebuchadnezzar in c.574 BC, Sidon took the lead until Tyre again recovered. Sidon profited from Tyre's misfortunes also in 332 when Alexander besieged Tyre (Arrian Anab.II.15.6). Such struggles account perhaps for the occasional variant "Sidonians" for Phoenicians in both Hebrew sources and in Homer (above n.333). Nevertheless in trade there is no such specification of city of origin: the Greeks speak of the "Phoenicians" (as they sold purple-dye). Nothing suggests that the political rivalry of the cities ever manifested itself in trade rivalry. This important point applies equally to the Greek cities with which the Phoenician have so much in common - a fact which Alexander the Great recognised (see Philoxenos and Koiranos in Arrian Anab.III.6.4 and E.Badian "Alexander the Great and the Greeks of Asia" Ancient Society and Institutions (Studies to Ehrenberg) (1966) pp.37-69).

397. Harden The Phoenicians ch.VIII esp.119-123; G.Rawlinson History of Phoenicia (1889) 384ff.

398. Exceptions being the appearance of cremation, temporary and never widespread, around the twelfth century BC for example (Harden The Phoenicians 105; Warmington Carthage 162).

399. Broadly: Harden p.122; Warmington p.155.

400. The question of whether objects carried, for example from the Greek mainland to the west, were carried by Greeks or by Phoenicians is extremely delicate. The patterns and manner of trade must be reconstructed, and this study of Greek weighing is in part aimed at the latter as a result of the former: see Preface.

401. Ezekiel 26-27 describes the fall of Tyre to Nebuchadnezzar (c.574BC) and laments the extent of Tyrian commercial power along with that of Sidon, Arvad, Byblos (Gebal) and other Phoenician cities. Despite the emphasis on sea trade, which went south-east via the Red Sea (II Chron. 8.17) as well as to the west, there is mention also of Egypt (27.7), of Mesopotamia (at this stage Persia, 27.10, but note also Asshur, 27.23), of Syria (27.16), of Damascus (27.17), and of the now-divided kingdoms of Israel and Judah (27.17).

402. II Samuel 5.11; I Chron. 14.1: cedars and workmen to David. The commercial nature of the transactions is made clear by Solomon's arrangements: I Kings 5.1-11, paying Hiram 20,000 measures of wheat and 20 measures of pure oil per annum for wood and the hire of servants for the temple contract. See also the expedition to Ophir by the Red Sea: II Chron. 8.17; I Kings 9.26-8, 10.22.

403. That Yahweh should not find fault with the Tyrian use of the balance is a bad argument from silence; yet it is noteworthy that the normal Hebrew complaints about false weights and measures, and about unjust balances (references will be discussed in IX.1.(5) following), are never brought against the traders of Tyre.

404. Ezekiel 27.10 and 23, and see above in IX.1.(3).

405. Hdt. III.91.1. This silver was weighed, according to Herodotus (III.89.2), by Babylonian weights.

406. I do not want to include here the coins on the"Phoenician standard" issued by Carthage under the hellenistic empire of Ptolemy; the reasons for the weight may be similar to those which led Carthage earlier in the fifth century to coin on Greek standards; the most likely interpretation for these may be convenience of interchange during trade. Tyre's coinage began in the mid fifth century BC and other cities followed suit; the coins are claimed to be struck on the native "Phoenician standard" with the exception of those of Aradus, which used a"Persian standard"(Harden The Phoenicians 166-7).

407. Considerable attention has been paid to these parallel inscriptions as the extant Punic literature is so scarce; ANET^2 502-3 gives both documents, the silver weights are: "5 silver [pieces]", "1 shekel of silver and 2 zr", "three quarters of silver and 2 zr". The only unrestored reference to meat is a supplementary payment of "meat weighing one hundred and fifty". The single mention of shekels is perhaps sufficient to indicate the value of the other units. The detailed accounts are only in the Marseille version: see also Harden The Phoenicians 105; Rawlinson History of Phoenicia 397ff.

408. For example Ezek. 27.3: "O thou that art situate at the entry of the sea, which art a merchant of the people for many isles". Compare Ezek. 26.17f, and 27 passim; Isaiah 23.1ff. "Howl ye ships of Tarshish...".

409. Above, esp.n.394.

410. Weight systems, and moreso standards, require the support of an administration. The Minoan-Mycenaean palace-culture represented such an administration (as also the great centralised courts of the Near East), and probably the only contacts made by the bronze-age near-eastern traders were with this palace administration. Upon its collapse neither trade contact nor weight system would remain. See further below IX.1.(6) on the Greek Bronze Age, and further IX.2 on the question of transmission.

411. Except that is for the purposes of the Phoenician traders themselves (their accounting and record-keeping that would be necessary to calculate profit). I am indeed assuming that the Phoenicians retained their earlier weight systems etc for internal use.

412. See above ch.II.2 on coinage, and V.1.

413. Gold is commonplace; for hides see the Nippur temple accounts (above no.(9) in the first list of passages in IX.1.(3)): BE.14.

414. Hdt. IV.196. Note that in contrast to the Greek opinion of the Phoenicians as cheats (Homer, Herodotus I.1, and [Arist].Mech. § 1), Herodotus is forced to comment of this trade with the Africans: ἀδικέειν δὲ οὐδετέρους (196.3).

415. Harden The Phoenicians 165 n.169 cites references to Müller Geog. Graec.Minores 1.15ff. Unguents, glass (?), pottery, and a fourth unidentified material were exchanged for Ethiopian skins, tusks, and wine.

416. Warmington Carthage p.38 "The primitive nature of Phoenician commerce, its reliance on barter, became fixed, as neither the barbarians of the west nor the peoples of the Levant adopted coinage for some time to come"; and as perhaps also Harden The Phoenicians p.166 "The age-old nature of their commercial traditions and their frequent contacts with more primitive peoples made them...proficient in the use of barter". Both writers recognise implicitly that it was the people with whom the Phoenicians traded, Greeks included, who possessed primitive mechanisms of trade.

417. [Arist].Mech.1.849b34ff; and see further Appendices A and B.

418. Carthage first coined (in silver) on Greek standards and closely imitating Greek coinage in the west; the subsequent gold coinage of the city was on an eastern (non-Greek) standard that should be assumed to be a weight standard the city had retained. See further n.406 above.

419. Stealing of persons, usually young women: Homer Od.14.288-9, 15.415ff; Hdt. I.1-3. Contrast the legitimate, but unhelpfully described, carriage of a Sidonian bowl by Phoenician traders: Homer Iliad 23. 741ff.

420. Hdt. I.1-3.

421. The silence of the Phoenician evidence is not surprising. Warmington Carthage 162 infers a shadowy afterlife from the miserable grave goods of Carthage; and Harden The Phoenicians 82ff peoples this afterlife with a certain amount of Ugaritic mythology. This is surely a fair procedure. But there is no judgment, no reference to the criminal use of the balance, nor any symbolical application of the balance itself. Even other outside sources are silent: see above n.403.

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422. The greater part of the Old Testament reached its present form in the late fourth century or even later. Amos and Hosea are possibly eighth-century, and Jeremiah was composed soon after the prophet himself in the seventh century, where also can be put Deuteronomy and the historical books Joshua, Judges, Samuel, Kings. Sixth-century composition has been shown for Ezekiel, Deutro-Isaiah, Lamentations, ? Obadiah; all of which post-date the destruction of Jerusalem in 586 BC. Despite their late composition, it is clear that a great deal of very early tradition was sustantially preserved as a result in part of the poetic structure of the compositions, and in part derived from earlier written accounts; thus, the twelfth-century Song of Deborah (referred to in Jg.5) and the Book of the Wars of the Lord (Num.21.14f). See discussion by Rowley in Peake's Commentary on the Bible (new edition, 1962) [henceforth PCB^2] §§ 68-72, and introductions to individual books in the same Commentary. The relationship between the Old Testament and the literature of Ugarit has already been mentioned: see above n.377.

423. Other written evidence relating to the Hebrews includes, from Palestine, the Lachish Ostraka (relating to a military predicament in 589-588 BC) and the Samaria Ostraka (giving barley measures and wine jars from Jerusalem 786-746 BC). These texts are translated by Albright in ANET^2 320-2. The Aramaic Papyri of the fifth-century Jewish mercenary colony at Elephantine in Egypt are documents that bear both upon Persian administration and on certain aspects of Hebrew life; because of their peculiar position, I have separated the evidence of these papyri for consideration in an Additional Note at the end of this section on the Hebrews.

424. Gen.23.16. Scott, PCB^2 35a, comments "The commercial shekel is specified...in order to distinguish it from the lighter shekel of the sanctuary" (see below n.434). Quality is thought to have been the point by E.W.Heaton Everyday life in Old Testament times (1956) p.190. The New English Bible translators favour the former: "four hundred shekels of the standard recognised by the merchants".

425. So varied were the weights and systems in operation there: IX.1.(4).

426. C.E.Wright Biblical archaeology (1957) ch.VII.

427. Whether they came from "Ur of Chaldees" (as Gen.11.31 and the general consensus of Old Testament scholars) or from Ura, close to Ugarit (as suggested by Gordon: see n.330 above). As the text properly reads "Ur of the land of the Chaldees" (Albright PCB^2 48e), a town at one time under Mesopotamian control becomes possible. I incline to Gordon's interpretation.

428. Wright (above n.426). A mid thirteenth-century date for the Exodus, with the Hebrews arriving in Palestine towards the end of the century, seems the most generally accepted solution: thus Albright PCB^2 49-50; and May PCB^2 91.

429. 1 Sam.13.19-22 shows how much on the edge of the iron age were the early Hebrew monarchies: see further below n.439 on this passage.

430. References above in n.402; see also Gray PCB^2 88a-b. Contact was closest under David and Solomon, but it appears that Ahab (King of Israel 869-850 BC) was able to marry the daughter of the King of Sidon - Jezebel: 1 Kings 16.31. Nor was Solomon above such contact: 1 Kings 11.1.

431. Certainly the most significant part as regards temple administration etc was moved away. According to Jeremiah a total of 4600 were deported in several stages (Jer. 52.28-30); few of these probably returned after Cyrus took Babylon and issued his edict (Haggai).

432. Direct control of governors and other officials: Rehum in Ezra 4.9 and Nehemiah himself Neh.5.14 ("from the time that I was appointed to be their governor in the land of Judah, from the 20th year even unto the two and thirtieth year of Artaxerxes the king"). Special Persian interest in stabilisation of temple administration: Ezra as a Persian official (see Browne PCB^2 102a, 325d-e; Ezra 7.12 "the scribe of the law of the God of heaven"). Tribute: Herodotus lists Judah in the fifth satrapy (Hdt.III.91.1). Nor is there much reason to doubt that Persian civil law applied in Palestine any less than in the much more distant Jewish colony of Elephantine: see Additional Note following IX.1.(5).

433. See bibliographies of Scott PCB^2 p.41 and Hultsch GRM^2 456-74 (and n.1 on p.457). The most concise and recent account I have found is Scott PCB^2 §§ 34-37.

434. PCB^2 35a-b. Scott infers a different system from the sanctuary one on the grounds that the "sacred" shekel had only 20 gerahs as opposed to the normal Babylonian of 24 gerahs. There is however no evidence of 24-gerah shekels in Hebrew literature anywhere; there is no reason to suppose that the commercial unit was Babylonian while the "sacred shekel" not, for there is no good reason for assuming a common commercial standard in the first place. The only evidence Scott mentions for this is Gen.23.16; but patriarchal trading arrangements are hardly evidence for the later period; secondly, in Gen.33.19 Hebrew q^{e}sîtâh are paid (again for land) by Jacob, and are clearly different units; and thirdly, no standard can be deduced from the Genesis passages. Scott's remarks in PCB^2 35c (end) do not fit his text.

435. See Additional Note following.

436. Sennacherib's account (ANET^2 288a) gives 30T gold and 800T silver, the latter figure varying from the biblical 300T. Hultsch makes considerable use of the only partial correspongion to develop his view of varying gold and silver standards (GRM^2 465 n.7). Scott PCB^2 makes no mention of the discrepancy.

437. Surprisingly Scott PCB^2 34a; Heaton Everyday Life in OT times p.190; D.Diringer "Early Hebrew weights found at Lachish" PEQ (1942) 82-103.

438. Note the reverse occurring in the "three pound of gold" (1 Kings 10.17; Heb. mâneh) and "three hundred shekels of gold" (2 Chron.9.16) of Solomon's shields. It is not clear whether the temple tax itself has changed, or the system of measurement, from Exod.38.26 ($\frac{1}{2}$-shekel) to Neh.10.32 ($\frac{1}{3}$-shekel).

439. "Thirds" occur twice in the Old Testament: Neh.10.32 ($\frac{1}{3}$-shekel temple tax) and 1 Sam.13.21 (a corrupt passage giving charges for implements, best rendered by the New English Bible "The charge was two-thirds of a shekel for plough-shares and mattocks, and one-third of a shekel for sharpening the axes and setting the goads"). The charges in 1 Sam. were levied by the Philistines, and so are perhaps less relevant here than the temple tax in Neh. On multiples of shekels see esp. Ezek.45.12 and further below n.446.

440. Hultsch GRM^2 460-3 concludes that it was a Hebrew weight corresponding to 50 shekels and being of similar order as the Babylonian mina. Scott PCB^2 36b notes its similarity to the Septuagint "lamb" and suggests that it represented the value of a sheep in silver. The Hittites have a comparable equivalence in their Law Code II.179 (see above IX.1.(2)).

441. Inferred from the Persian context and the fact that silver and not gold (darics: see next note) are mentioned: Scott PCB^2 36c.

442. The Hebrew possibly distinguishes the two: thus dark^{e}môwn (S.1871) in Ezra 2.69 whereas ʾădarkôn (S.150) appears in 1 Chron.29.7, 8.27.

443. Tribute to Assyria: 2 Kings 18.4.

444. See above discussion of this question in the context of ancient Greece: chs.III (Conclusions), IV-V.

445. 20-gerah shekel of the sanctuary is repeated elsewhere in the temple ritual: for example, Levit.27.25.

446. The Hebrew reads 20 plus 25 plus 15 (total 60) shekels, which the New English Bible corrects to 10 plus 25 plus 15 (totalling 50). For equally theoretical reasons Hultsch GRM^2 467-8 altered the constituents of this mina to read 20 plus 15 plus 10 plus 5 (again totalling 50); the reason for the division of the mina in this way by Ezekiel is not however clear.

447. See above n.359.

448. The practical relevance of weight system and temple standard is pursued further below.

449. I quote from the more familiar Authorised Version while noting the few variant readings or improved translations that exist where they are material. My Hebrew is taken from the lexicon in J.Strong The Exhaustive Concordance to the Bible (1894), thus (S.---). While every effort has been made to pursue Hebrew rather than English idiom, my lists illustrate the range of references to weighing rather than covering every occurrence.

450. Levit.19.36; Job 6.2, 31.6; Psalm. 62.9; Prov.11.1, 16.11 (but see below), 20.23; Isaiah 40.12 (see below), 40.15; Jer.32.10; Ezek. 5.1, 45.10; Hosea 12.7; Amos 8.5; Micah 6.11. The variant qâneh (S.7070), derived from the root meaning "erect" and probably indicating the straight beam of a balance, occurs in Isaiah 46.6. Either "beam" or whole "balance" has been suggested for peleç (S.6425), the only other word used in parallel with mô'zên, as in Isaiah 40.12 ("weighed the mountains in scales [peleç] and the hills in a balance [mô'zên]") or Prov.16.11 (Heb.literally: "mô'zên and just peleç are Yahweh's"). See further below n.479 and discussion of the last passage; also G.W.Wade Commentary on Isaiah (1911) p.254 and the New English Bible on Prov.16.11.

451. From * zibana (CAD sv. zibānītu and see above n.228).

452. A separately-standed balance can be inferred from the divorce procedure laid down in Mibtahiah's third marriage agreement (c.440BC) "She shall sit by the balance and weigh out to [As]hor a sum of 7 shekels..." (Elephantine: ANET² 223a; Cowley Aramaic papyri of the fifth century BC (1923) 15.23-4; and see Additional Note following). Egypt generally preferred the standed balance types: see above n.8.

453. Megiddo Tomb 912B (dated towards 1200 BC) contained four pans (bronze, c.10cm diameter, flat with raised lips; but no details of suspension-holes are available) along with some wood fragments and chains, which the excavators associated with the balances. Tomb 39 (EI I: 1200-1000 BC) had a single bronze pan of similar size to the others but fragmentary (the "elliptical" pan can be ignored). See Megiddo Tombs (1938) plates 125.6-9, 127.6 and 167.3n.

454. Three bone disks of this description were found in excavation levels at Megiddo: in Strata V (1050-1000 BC: Megiddo II (1948) plate 203.2) diameter 10cm and three clear holes in the tabs; in Strata III (780-650 BC: Megiddo I plate 98.2); and in Strata I (600-350 BC: Megiddo I plate 98.1). The Byblos examples are clearly similar, though they have four tabs and no holes: Byblos II plate 202 nos.9740 and 9960.

455. Deut.25.13-15. Micah 6.11 also.

456. But not where criticism is being made of merchants cheating by the use of weights slightly over- or under the supposed standard or accepted constant as in Deut.25.13-15 "Thou shalt not have in thy bag divers weights, a great and a small".

457. Refgrences to the "shekel of the sanctuary" are collected by Hultsch GRM² 460 n.1. Note especially Ezek.45.12 (which has already been mentioned above). Levites were charged with the control of "all manner of measure and size" [NEB "weights and measures"] (1 Chron. 23.29).

458. And again the shekel was this unit: "he weighed the hair of his head at two hundred shekels after the king's weight". Serious doubts have however been cast on what this shekel was, for a year's growth of hair ("for it was at every year's end that he polled it") cannot really weigh more than a maximum of 234gm. Where Hultsch (GRM² 463 n.5) seeks a solution in terms of variant gold weights, I would rather suspect the figure of 200 shekels. This would imply an inordinate number of weighings (and practical weighing must be

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by the fact that the king's "weight" here is rendered by ʾeben ("stone") rather than mishqâl (notional "weight", as in 2 Sam.21.16 etc); and so 10 weighings (of 20 gerahs each) might be what the text conceals. Certainly hair would be measured in silver weights and not gold (as Hultsch would suppose): cf. the Egyptian practice described by Hdt.II.65.4 from which Absalom's offerings are surely derived (it recurs also in Ezek.5.1, but with no weights given).

That the "King's weight" should therefore be a "shekel" as the sanctuary weight is called, makes it possible that these two were virtually the same object; before the building of the Temple, the monarchy would solely be responsible for such administrative duties as were subsequently handed to the Levites (n.457 above); even in the later period the two powers, civil and religious, accounted together: "the king's scribe and the high priest came up, and they put up in bags, and told [literally "weighed"] the money [lit. "silver"] that was found in the house of the Lord" (2 Kings 12.10 under Jehoash, King of Israel 802-786 BC). Royal control of weights has been inferred from Prov.16.11, but I feel this to be unlikely: see further below on accounting and weighing booty etc.

459. Indeed [Arist.] Mech. 853b25ff describes a bismar in such detail that one must presume actual examples were known to the writer. Aristophanes even earlier suggested a fixed-weight balance (Pax 1240-9), but this was in comedy, and no real popularity was attained for the single-pan balance until the Roman steelyard. See above in ch.I.2.(1). Biblical passages referring to the use of a deceitful balance (see below) might apply to the steelyard in theory but were written well before its introduction; deceitful weights (especially as clearly physical weights: ʾeben "stone") have no place at all in such balances. Toy's statement that the biblical balance was a steelyard (Commentary on Proverbs (1899) p.324) can be ignored.

460. For a further supporting argument from the use here of the Hebrew verb mishqâl see below with n.510. The New English Bible translates Ezek.5.2 "Then take scales and divide the hair into three".

461. W.M.Flinders-Petrie has suggested (in Hasting's Dictionary of the Bible vol.I (1898) sv. balance p.234b) that the Hebrews brought the practice of account-weighing with them out of Egypt. In Palestine they possibly lost the ability to weigh precisely (contrast David's vagueness in 1 Chron.22.14 with the detailed, historically earlier, inventories of Exod.38.24-9 and Numb.7.13) until it was brought back from Babylon (where Ezek.45.12 was written). On the other hand, the use of the balance is well-attested for the patriarchs and was established in Canaanite bronze-age trading practice (above IX.1.(4)) well before the Hebrews went to Egypt (itself, even on Glanville's hypothesis, now using the balance in everyday commerce: see above IX.1.(1)). The emphasis on weighing for accounting purposes in the Old Testament springs more from the subject-matter and the literary tradition than that this use was necessarily basic to the Hebrew culture as a whole.

462. See n.458 above.

463. The "talant of lead" in Zech.5.7 can perhaps be included in this section as the point of the story is that the woman representing wickedness is concealed in a receptacle (the ephah measure) - the weight of the lid is entirely gratuitous. However the Hebrew word for talant (kikkâr S.3603) also means simply "a round circle", and this might be all that is meant (thus NEB "a round slab of lead").

464. Above n.458 and (for Greek possible parallels) ch.VII.2.(14).

465. Hebrew mânâh (S.4487) "weigh out", with the same root as mânêh (S.4488) "mina" and "weight" (notional).

466. The silver weighed out is partly also for the payment of the craftsmen. See n.471 below.

467. The Lex Talionis appears in its crudest form ("eye for eye, tooth for tooth...") only in respect of body-injuries and damages to property (Exod.21.23-5; Deut.19.21); there is considerable evidence of modifications on this model in other fields (temple asylum; payment in other animals where one has been killed etc): see Burrows PCB^{2} 109.

468. Compare Code of Hammurabi §§250-2 where the same figure is given (the Babylonians at least operated with a 60-shekel mina, and the text reads ½-mina here; in Eshnunna.54 however the fine is two-thirds of a mina of silver). This raises the question of whether these formulations are survivals from bronze-age legal traditions. They are extremely inconsistent however: for example the causing of a miscarriage in Exod.21.22 is left open to the judges whereas in the Code of Hammurabi §§ 209-214 a whole scale of penalties is worked out (10 shekels, 5, or 2). That the Hebrew should resort to the Lex Talionis so readily in Exod.21.23-5 should the mother also die (contrast Code of Hammurabi §§212 and 214, but not 210) might indicate inferior administration in practice - although the notorious lack of correlation between the provisions of the Babylonian Code and actual practice cautions any firm conclusions on this point (see above in IX.1.(3)).

469. The tribute Solomon received (1 Kings 10.14-22) is here inventoried, not prescribed: his actual assessments were in kind (1 Kings 4.7ff).

470. Examples of barter nevertheless do not abound. In Hosea 3.2 the silver price is made up by a measured amount of barley, and so can hardly count here. Job includes the possibility of barter in his search for wisdom - "and the exchange of it shall not be for jewels of fine gold" (Job 28.17). The same word, t^{e}mûwrâh (S.8545), recurs in Gen.47.17 where bread is bartered for horses; in this case however silver was not available - 47.15-17 "and when money [lit. "silver"] failed in the land of Egypt...". Like the Greek "ἔμπορος", the Hebrew words for merchants refer to their travelling rather than to their methods of trading (see below n.495).

471. Though gold-smith is not specified in the Hebrew (tsâraph S.6884, from the root "to fuse" of metal), the inference that silver is his hire is supported by the way gold is provided without limit (AV: "lavished out of the bag") while the silver, though a cheaper metal, is cautiously weighed out. In Judges 17.4 the silver goes straight into the images being made.

472. The significance of this sum may be no more than its convenient division by three if it is picked up again in the metaphor of Zech. 13.9 (which is more than likely in view of Ackroyd's translation of 11.13 as "casting it into the smelter in the Temple foundry" PCB^2 571g; the New English Bible however retains "treasury"). Zechariah remarks on the price paid as being high ("a goodly price that I was prised at by them"), contrast the Mesopotamian metaphor indicating that, at least for Ur, 30 shekels was a miserable figure (The lamentation of the fall of Ur, ANET^2 455ff at line 244).

473. The alternative, that the merchants were selling silver, which perhaps could be inferred from "that we may buy the poor for silver", makes nonesense. If their weights were too heavy, they would lose, yet their profit is clearly implied.

474. Rowley PCB^2 69b; Hyatt PCB^2 541a,e: "the earliest of those OT prophets whose utterances are preserved...about 750BC... The visions in Chs.7-9, reported in the first person, have the best claim to have been written, or dictated, by Amos himself".

475. On this reading see above n.446.

476. See above n.458.

477. This suggestion was made by Toy Commentary on Proverbs (1899) p.324. The word mishpât (S.4941) denotes formal decree (see below n.482) and is unique in a weighing context here.

478. Toy op.cit. p.325; the idea of justice is deleted by the translators of the New English Bible also.

479. Strong (above n.449) in his lexicon note on peleç (S.6425) relates it to pâlaç (S.6424) "to roll flat, prepare a road, revolve i.e. weigh mentally, ponder". Certainly no relation to physical weighing is contained in the use of this verb in Psalm 58.2 (AV: "Ye weigh the violence of your hands in the earth"; NEB: "survey the violence that you have done on earth") or Isaiah 26.7, where the road-building idea is clearest (AV: "Thou, most upright, dost weigh the path of the just"; NEB: "Thou markest out the right way for the upright"). Whatever its derivation however, the parallelism with môʾzên and the "weights of the bag (ʾeben) in the second half of Prov.16.11, make virtually certain the meaning of a physical balance for peleç also. If the metaphor of mental weighing is common to both Hebrew and English, this is a point of further interest, not a counter-argument.

480. Job 30.20 "I cry unto thee and thou dost not hear me: I stand up and thou regardest me not". These passages of Job will be discussed further below; the inference I have made here about Job's insistence on correct weighing is obscured by the New English Bible translation

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of 31.6, which requires tsedeq (justice) as a noun and makes Job ask to be weighed "in the scales of justice". This rendering however, which reduces to little more than a plea to be judged, cannot be supported by any general note on the scales of justice as being a particular metaphor. The rendering of the Hebrew (literally "scales of justice") as "just scales" is indicated beyond doubt in Levit. 19.35-6.

481. See above in IX.1.(3).

482. As already noted, Job's "even" balance means a "just" balance (see n.480). It does not refer to the angle of the beam. Another Hebrew word applied to the balance is the problematic misphât (S.4941), a noun meaning "justice, formally decreed", that is used with peleç in Prov.16.11 (above n.477). This does not however lead to any useful inferences.

483. The New English Bible rendering of Amos 8.5, "tilting the scales fraudulently", is but one way of reproducing in this context the verb ʿâvath (S.5791). Elsewhere it occurs as the opposite of "straight" (Eccles.1.15 "that which is crooked cannot be made straight"), and might allow the idea of a curved beam in the balances of Amos 8.5. However a more general sense of injustice or destruction is involved where it occurs in Job 19.6 and Lament.3.36. The weighted balance beam is shown to have been a possible means of cheating by [Arist.] Mech.849b34 (purple-dye sellers); on which see Appendix A. Despite the New English Bible gloss of "pointer" on Prov.16.11, there is no indication that the Hebrews retained the Egyptian concern for this part of the weighing apparatus (see above in IX.1.(1); I know of no Hebrew word for this part of the machine; the "plumbline" of Amos 7.7ff is a builder's instrument).

484. Above IX.1.(3). Deut.25.13ff is very much clearer in this respect than Prov.20.10 where "divers weights" is a rendering of the Hebrew "a stone and a stone".

485. Hebrew shâlêm (S.8003); as this word is used in a number of passages concerning human morality, I am not prepared to insist on the inference from its root "to complete" that weights of these passages are necessarily "made up to specified standard weight". Its opposite, mirmâh (S.4820) "false, deceitful", does not encourage the inference.

486. Amos 8.5-6 describes a situation almost identical to that of the Mesopotamian wine-seller of the Code of Hammurabi ch.108: see above in detail in IX.1.(3). As was argued there, the "great shekel", meaning that it was heavier than the norm, implies the relevance for the trade in question of a weight (and measure) standard norm. If this standard was no more than the norm of established practice, then departure from it would amount to changing the price rather than deceit, which is what is in fact being penalised. The standard must be one laid down by authority. For the wine-seller this was by the Palace bureaucracy (and special reasons perhaps applied to her trade for it to be thus singled out in the Law Code: above nn.298

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and 303), but for the Hebrews the authority was the Temple Law, and both this law and the range of trading involved (in general, apart from the specific example of the Amos passage) would appear to include all Hebrews, without special relevance to any particular class or profession.

487. As for practical purposes the extension of the idea of weight standards into commercial practice makes little effect on the experience of weighing most Hebrews had, the question is perhaps also a little academic. If however it is felt that the idea of a weight standard itself represents a significantly different attitude to weighing from that whereby each person's weight must be suspected or accepted for what it is in its own right, then there is no clear evidence that the Hebrews felt this. The line of argument that indicated it must therefore be wrong, and the most likely point at which to fault it lies in the inference from the words in Hebrew for "just weight". Thus "perfect", "completed", and "formally decreed" could be restricted to the Temple context or to individual usage and even Amos' shekel-weight removed from its status as an absolute standard to a weight these same traders might actually use. "Shekel" is in fact a word closely comparable to the Greek "stater" - a fixed, but not necessarily absolutely or universally fixed, weight; the word has the same root as the Hebrew verb "to weigh" in cases where measurement by weight is mentioned or implied: Heb. shâqal (S.8254) Numb.7.85; Job 6.2 etc. As the Amos passage is so closely related to the Code of Hammurabi ch.108 (n.486), and as the practical implications seem so slight (given the absence of effective administrative control), I am inclined to prefer to leave the inferences as they are in my text.

488. In Deut.25.13-16 both inconsistency ("divers weights...a great and a small") and inaccuracy ("perfect and just weight") are set together. Elsewhere the expressions are, as has been seen, mainly indeterminate: "just", "deceitful", "false"... (weights and balances).

489. That the Levites were in charge only of the Temple weights and measures does not imply that these Temple standards were not used elsewhere. It would be indeed most surprising if they were not, given the Temple-oriented nature of Hebrew life.

490. As the King's weight was probably the same as the Temple shekel (see above nn.434 and 458), this is the only attested official weight.

491. Hosea 12.7-8. Ephraim had made himself a fortune, no doubt related in part to his fraudulent use of the balance.

492. As is shown by the large number of occasions on which false weights are condemned and by Job's own (entirely gratuitous) mistrust.

493. See above in IX.1.(3). The Hymn to Šamaš and the Šurpu ritual both refer explicitly to merchants giving and taking false weights and measures.

494. Isaiah 23; Ezek.26-8; Amos 1.9.

495. The most common Hebrew words for traders are çachar (S.5503) and râkal (S.7402), both of which also mean "to travel around": cf.the Greek word "ἔμπορος" and references to other near-eastern merchants in n.470 above ; even the mistranslated K^{e}naᶜanîy (S.3669-7) or "Canaanite" of Isaiah 23.8; Job 41.6; Hosea 12.7 and Zeph.1.11, is probably, in the Hebrew context, also a"trader", just as was Ephraim in Hosea 12.7.

496. See also the examples listed above of silver penalties, tribute and prices.

497. Above under passages illustrating accounting.

498. See above n.463.

499. Above nn.458 and 464.

500. All Temple matters concerning weights and measures were delegated, as already noted, to the Levites (1 Chron.23.29), covering therefore temple accounts, building, taxes, and the administration of its law. The civil authorities might have controlled penalties applying to civil crimes (as Exod.21.32; Deut.22.29, if these are not properly iron-age), and representatives of foreign kings were no doubt responsible for the collection of Israel's tribute (cf. 2 Kings 15.20). On the agents of Solomon's trading ventures see "the king's merchants" of 1 Kings 10.29 (Mauchline PCB^{2} 295g suggests this was a royal monopoly), but I am not prepared to suppose royal control of commercial weights and measures on the evidence of Prov.16.11 as already argued above. A different situation applied in Elephantine where there was no local king, and "royal weight" most probably refers to that upheld by the King of Persia (see Additional Note following).

501. Ezek.4.10, 16 (meat); Deut.25.14 (measures in the house).

502. Gen.23.16; Isaiah 46.6; Jer.32.9-10; Zech.11.12. That the practice is thus well-attested in the later periods of post-exilic Isaiah and of the possibly fourth-century Zechariah (Ackroyd PCB^{2} 569a-e on the problematic dating of the collection of sayings that comprise Zech.9-14) makes the problem of whether Gen.23.16 is bronze- or iron-age somewhat academic (see Hooke PCB^{2} 143d, 160d). Consistency exists from the late seventh-century Jeremiah to Zechariah of the probable fourth century BC. See further on dating n.422 above.

503. 2 Kings 7.1. Even if the purchase of food for silver described at 2 Kings 6.25 was occasioned by famine, one can reasonably infer from the unpalatable nature of that food that Elisha's vision included a return to normal food-availability as well as to normal commercial practice.

504. Amos 8.5-6 (see above).

505. Job 28.15. For further confirmation that the weighing of silver is involved see n.512 below. Note however that gold is simply to be exchanged.

506. Abram carried gold and silver, also cattle (Gen.13.2); Solomon's trading brought in great quantities of gold and silver (1 Kings 10.11-29). On the other hand the supply of these metals to both Canaan and Egypt ran out on one occasion (Gen.47.15) and this circumstance forced the people to barter (Gen.47.17).

507. See above in IX.1.(3) and (2). The only Hebrew Law Code equivalent is Levit.27.16, although Scott has suggested that the obscure silver q^{e}sîtâh was the equivalent of the value of a sheep (above n.440, and see also n.434).

508. 1 Kings 10.27. Silver was not even scarce in besieged Samaria (2 Kings 6.25); Micah or his mother are said to have owned, as private individuals, 1100 shekels of silver (Judges 17.2); the Temple accounts and building funds show no lack of resources (both 1 Chron.29 and Ezra 2).

509. That the servant was Saul's is immaterial as Saul was as yet no more than the son of a small-time Benjamite farmer (1 Sam.9.21).

510. As in "the weights of gold that came to Solomon" 1 Kings 10.14 and passim. It also occurs interestingly in Ezek.5.1, confirming the independent argument that measurement must have been used to divide the hair into three parts (as argued above).

511. Also 2 Sam.14.26, 21.16; Ezra 8.25, 26, 33 (and note in v.34 "and all the weight was written at that time").

512. Also Job 28.15 "neither shall silver be weighed for the price thereof" (on which see above), 31.6 (an important passage also, to be discussed below); Isaiah 40.12 "weighed the mountains in scales" (see below again); possibly also Jer.32.9 "weighed him the money, even seventeen shekels of silver" if the action can be separated from the amount weighed out (as also 32.10).

513. The New English Bible translates Job 28.25 "He...measured out the waters in proportion". Strong (above n.449) notes on tâkan "Fig. to arrange, equalise through the idea of levelling". On Daniel 5.27 see following. The only other verb translated "weigh" is palaç and on this see above n.479.

514. As will be apparent, but must be admitted here, the limitations imposed on this survey by a lack of knowledge of Hebrew are most considerable as concerns the deduction of Hebrew metaphor from behind the various modern attempts at rendering the Old Testament in English idiom (for this has necessarily been my starting point). Strong's lexicographical section (above n.449) remains the major source for my inferences here, although considerably supplemented by commentaries on the passages involved.

515. Ch.VI is in many ways central to this whole thesis.

516. I quote the Authorised Version; the New English Bible is virtually the same. On the date see PCB^{2} 71d.

517. On the date see PCB^2 72g: post-exilic, and probably fourth-century. The point of the "even balance" I take to be no more than an exhortation to accuracy; I am not at all happy with the New English Bible rendering "scales of justice" in that this might give rise to the unwarranted inference that for the Hebrews scales symbolised justice (see above n.480 - if they did why did this neurosis exist about their deceitful use !). The same translators have also rearranged the verses at the start of ch.31, but this does not affect the arguments used here.

518. On the date see PCB^2 72f. In its present form the book is post-exilic, but much of it dates back to earlier periods. The New English Bible renders the passage "but the Lord fixes a standard for the spirit of man". This is, I believe, to impose an English metaphor (and a theological notion) on the Hebrew tâkan, which should mean no more than simply to weigh. Although the idea of a standard of judging weight/worth is found in Daniel 5.27 (above in text), it is surely anachronistic for this passage of Proverbs.

There is a further passage that might be added to these three; as its interpretation is rather problematic however I have decided to restrict it to these notes. In the pre-exilic Prayer of Hannah (on its date see PCB^2 69a) of 1 Sam.2.3 the Authorised Version reads:

> "Talk no more exceeding proudly...for the Lord is a god of knowledge, and by him actions are weighed"

The verb used is tâkan, as in Prov.16.2, and the general context of judgment is brought out by v.10 "The Lord shall judge the ends of the earth" as also by the general equalisation described in the intervening verses (for example, v.8 "He raiseth the poor out of the dust ...to set them among princes"). On these grounds the passage falls precisely into the category being considered in my text. The New English Bible however changes the metaphor entirely, reading:

> "For the Lord is a god of all knowledge;
> he governs all that men do"

According to this interpretation, the metaphor is one of total control; the weighing is therefore the careful weighing out of measured amounts (despite NEB, weighing must come into the interpretation of the passage in view of the Hebrew). It is true that this can be made to fit the general context of Hannah's prayer, which might imply no more than a totally contrived world-order, with Yahweh the operator. I cannot however help feeling that however optimistic she was being, Hannah nevertheless supposed there to be justice in Yahweh's actions; and for this reason I should like to retain the passage alongside Daniel 5.27, Job 31.6, Prov.16.2, rather than consign it to the list of other passages involving the weighing metaphor to be considered in what follows.

519. There is no question of Job's admitted faults being outweighed by his virtues in 31.6, nor is his lot dependent upon another's. The element of competition in Christian versions of St.Michael's judgment is probably an iconographic rather than a theological muddle (see further below in IX.2.(2)).

520. See n.518 (latter part); this "standard" is entirely supplied by the translators.

521. Above ch.VI.3.(1) sv.Zeus but esp. (3).

522. The most frequent wish of Job is simply to be able to plead his case before Yahweh, and the metaphor used is invariably that of the court-room: cf. Job 9.19-24, 13.18, 19.7, 23.3-10, and also 9.2-3, 13.3 and 16.21. The alternative, of forcing god "by strength" to change his attitude, is not seriously supported: 9.19. There remains Job's seeking to escape by death: 6.8-10, 14.13. Nowhere is it implied that the weighing of 31.6 is a necessary procedure: it is presented in a section (31.5-40) that bears some similarity to the Mesopotamian Šurpu ritual incantations or even to the Hittite Kantusilis' prayer (see above in IX.1.(3) and (2); the texts are translated in E.Reiner Šurpu; a collection of Sumerian and Akkadian incantations (1958) and ANET pp.400-401 [Kantusilis]), and is constructed of a series of conditionals, the majority of which are sins to be denied by the speaker. 31.6 should be taken closely with 31.5, of which it is the apodosis: "If I have walked with vanity, or if my foot hath hasted to deceit; let me be weighed..."; compare the concluding 31.38-40: "If my land cry against me,... if I have eaten the fruits thereof without money or have caused the owners thereof to lose their life; let thistles grow instead of wheat, and cockle instead of barley". The rearranged verses of the New English Bible simply resultin a different protasis to 31.6 (namely 31.1); my argument on structure is not affected.

523. Despite the nationalistic basis to their religion, the Hebrew outlook on life was originally close to the Mesopotamian. "Before I go whence I shall not return, even to the land of darkness and the shadow of death" Job 10.21 is a virtual translation of Kurnugia, the Mesopotamian "land of no return" (see IX.1.(3) and passages cited under 5.Judgment of the dead and the afterlife). The significance of life most assuredly lay for the Hebrews in life itself, as afterwards all are as nothing, both high and low (2 Sam.1.19-27; Job 14.1-10, 21.17-26; Isaiah 14.9-11). All the affairs of life were believed to be in the power of the single god Yahweh, whose constant interventionism was believed to account for reversals in human affairs, both good and bad. Not always was a motive recognised, but such cases as are explained by the Old Testament writers indicate a considerable variety and development in the type of reasons given: jealousy about his divine honours (Exod.12.12; Isaiah 19 and 21.9), nemesis consequent on hybris (1 Sam.2.1-10; Deut.32.39; Psalm 75.7 and compare the words of The Magnificat in Luke 1.52). This last, as the voabulary used suggests, would approach close to the Greek model; but the purpose for intervention on such occasions was seen by the Hebrews rather as Yahweh's upholding of the Sinai Covenant - it applied to other mighty rulers (that stood in their way), but not to themselves. The Sinai Covenant was probably the main reason for divine action given by the Hebrews. The legalistic aspect of justice it involved (cf.Deut.7.9) was broadened to less national and more ordinary matters: disputes between individuals as Gen.31.53 (Jacob and Laban), cf. also Gen.16.5 (Sarai and Abram); Exod.18.16 (Moses and the Israelites); 1 Sam.24.12-15 (David and Saul); or the more general Psalm 43.1. As the vindication of Israel and its firm establishment in Palestine delayed, the problem of the individual suffering of innocents was more carefully analysed (as Job); from this was evolved a part for the idea of morality in judgment, this last being continued beyond death into an afterlife that might be expected now to offer some consolation for obviously unfair treatment in life. Daniel, especially ch.7,

523 contd.

is important in this development after Job had opened up the problem. This is perhaps best seen in the equation of the living with the righteous in Psalm 69.28 "Let them be blotted out of the book of the living and not be written with the righteous"; contrast Job 21.17-26 and note therefore the presumptiveness, only lightly veiled, in his call for accurate assessment of his merits in 31.6; clearer is 21.22 "Shall any teach god knowledge ?". For a general discussion of Hebrew eschatology see further S.G.F.Brandon The judgment of the dead (1967) 56-75.

524. Exod.32.32-33 "Whosoever hath sinned against me, him will I blot out of my book" also Psalm 69.28 cited in the last note. Like Daniel's "found wanting", the phrase refers to execution rather than to simple evaluation.

525. See below IX.2.(2); references in Brandon (as cited n.523 above) pp. 118-126.

526. See above n.518 (latter part).

527. The version in the New English Bible is not materially different, although it suggests an interpretation closer to the legalistic model of the "scales of justice" of 31.6; in fact no comparison of the two passages is possible: "O that the grounds for my resentment might be weighed, and my misfortunes set with them in the scales ! For they would outweigh the sands of the sea".

528. The sense is brought out more explicitly in the New English Bible: "Stone is a burden and sand a dead weight, but to be vexed by a fool is more burdensome than either".

529. The verb "counted" here is the Hebrew châshab (S.2803), and is properly a mental operation; the simile "as the dust of the balance" is the interesting part of this passage. The New English Bible adds, without reference to source, the idea of weighing "no more than moisture on the scales".

530. Alexandrine Greek: ὅτι ὡς ῥοπὴ ἐκ πλοστιγγων ἕλος ὁ κοσμος ἐναντιον σου. This is a distinctly non-classical use of ῥοπὴ : see above ch.VI.5.(3).

531. The Authorised Version is inadequate: "Surely men of low degree are vanity and men of high degree are a lie: to be laid in the balances they are altogether lighter than vanity". The social implications of "high degree" were excised in the Revised Version "in the balances they will go up".

532. I am not sure whether the idea is that no weight is small enough to avoid their going up ("they can only rise" of the NEB does not imply they necessarily do rise), or that even with no weights they will go up (whence the inference that they are lighter than air). If the latter, then the Revised Version is to be preferred to the NEB. My argument is unaffected however.

533. Certain other passages might have been included in this survey were it not for the difficulty of separating Hebrew from English metaphor. Particularly intractable are references to mental weighing or pondering, where the Hebrew pâlac appears certainly related to

533 contd.

in view of its noun peleg (see above n.479): thus in Prov.16.11; Isaiah 40.12, possibly 26.7; Psalm 58.2. None of these passage affect materially the conclusions I have been able to reach. The Elephantine papyri (considered separately in an Additional Note for their evidence of weighing practice) are relatively prosaic and contain little of relevance to this section. Perhaps of note here however is the expression of large amounts as "worth as much as a thousand talants" (Cowley 30.28, 31.27 and possibly the fragmentary 50.9: see n.452 above for references): this simply emphasises the extent to which amounts of silver were weighed and recorded by this community.

534. Psalm 62.9 mentions only rising. General ideas of rising and falling are more often than not expressed in the Old Testament in terms of birth and death; the original image is presumably agricultural if not properly eschatological: thus 1 Sam.2.6-7. Little can be deduced from the Hebrew words for light and heavy.

535. Implied by the accounting metaphors and by Job's recourse to the balance to prove his case.

536. The small dust of Isaiah 40.15, that is presumably ignored.

537. Inadvertently revealed in Job's "even balance".

538. Above n.423.

539. A.Cowley Aramaic papyri of the fifth century BC (1923) p.xvii, and see Mibtahiah's marriage contract to an Egyptian (Cowley 15).

540. Many of the documents do not even concern Jews (Cowley notes on 24, 26, 73). Parts of Ezra and Daniel are written in Aramaic, but the major part of the Old Testament is in Hebrew (PCB^2 52a).

541. Cowley (n.539 above) gives both translation and commentary; some documents are also translated by Ginsberg and appear in ANET^2.

542. Cowley pp.xxx-xxxi.

543. The silver purity formula "2R per K" is however slightly rarer than "2R per 10".

544. Cowley's interpretation of the formulae is on p.xxxi; he is followed by Ginsberg ANET^2 222b n.3.

545. Thus Cowley on no.28.10-11, where the unique "standard silver" appears.

546. It is to be presumed that this meant weighing out the valuation amounts and not the actual bronze as this last is not listed by weight of bronze.

547. Apart from the dubious 3 talant inheritance of the fragmentary Cowley 83.29. The wood weighing 1 talant and 10 minai is unique also in being the only example of wood weighed in the whole of the evidence I have considered (Near East and ancient Greece) in anything other than whole talants. It is interesting that the weights are Egyptian.

548. See lists below in n.568.

549. Aristotle HA 551a14 and later writers. A.J.Evans "'The Ring of Nestor': a glimpse into the Minoan after-world" JHS 45 (1925) 1-75; C.Picard Les religions préhelléniques (1948) p.290; M.P.Nilsson The Minoan Mycenaean religion and its survival in Greek religion (2nd. ed. 1950) 34-6, 46; and more rationally E.Wüst RE sv. Psychostasie [XXXIII.2] 1446.

550. The Hagia Triadha Sarcopagus, for example, has generated speculation about transport to the "other world": S.G.F.Brandon The judgment of the dead (1967) p.77 and 217 n.8; E.T.Vermeule "Painted Mycenaean Larnakes" JHS 85 (1965) 123-148; J.T.Hooker "Homer and Late Minoan Crete" JHS 89 (1969) 60-71 on pp.63-4. Homer's twittering ghosts are surely more bat- than butterfly-like. On comparison with Egypt, see H.Schlieman Mykenai (1878) 228f against A.W.Persson New Tombs at Dendra near Midea (1942) p.73.

551. This appears to be the present situation at least; further finds may reveal more. See above IX.1.(2); at least the Hittites treated the balance symbolically in a funerary context. The problem is common ancestry or bronze-age contact, and I should favour the former approach, which is also rather less committing: see n.163 above and further in IX.2 below.

552. This is important, as it is problematic. Balances might symbolically be used in ritual during life (cf.Hittites); after death the only near-eastern use attested is the Egyptian, yet the deceased did not, for the Egyptians, require his own pair of scales - they were provided by Osiris, Thoth etc. It is in fact far from easy to find a near-eastern parallel for the balances found in graves of the Greek bronze age: see further below n.591.

553. The most humble tombs appear to be Mavro-Spelio (that of a craftsman, E.J.Forsdyke "The Mavro-Spelio Cemetery at Knossos" BSA 28 (1926-7) 253, 288-9) and Mycenae Tomb 529 (where even identification of balance pans is not certain: see Catling in n.568 below).

554. See discussion above ch.VII.1.(2).

555. This doubt is my own; one reason for suspicion is that the balance in question is too small to have weighed the 81 lb.10 oz. copper ingot found with it: see Catling Cypriot bronze-work in the Mycen. World (1964) pp.278-281.

556. See Forsdyke in n.553 above.

557. No weights, that is, of local manufacture. The agate duckweight, found in a royal tomb at Dendra, may indicate that outside weights were used, though it seems to me more likely that such objects were kept for their artistic rather than metrological value (the latter would hardly be practical): for evidence see A.W.Persson The Royal Tombs at Dendra near Midea (1931) 41, 58. A more feasible weight was found in the Enkomi Trésor de bronzes no.9 (Catling, above n. 555, on p.263 no.1: bronze with lead adjustment, weight 266gm).

558. Most conveniently C.T.Seltman Athens: its history and coinage before the Persian Invasion (1924) ch.I (diluted in GC but with no radical change); see also A.J.Evans "Minoan weights and mediums of currency, from Crete, Mycenae and Cyprus" Cor.Num. (1906) 336-67; J.Sundwall "Minoische Beiträge I - 1. Gewichts- und Wertangaben in Knossos und Pylos" Minos 3 (1954) 107-110; M.Ventris and J.Chadwick Documents in Mycenaean Greek (1956) pp.56-8. Many more ingots have been found since Seltman first wrote, but the popular interpretation lingers on: for example W.Culican The First Merchant Venturers (1966) pp. 61-2. It is not altogether unfair to recall Seltman's earlier position (1924; p.4 with figs.3 and 4 of the ingot in question): "A glance at the illustration...shows that this Mycenaean ingot, like the others, is cast in the shape of an ox-hide, dried and stretched. The obverse roughly represents a hairy hide, the reverse the raw inside of a skin with its edges curling inward. Neck and tail are not shown because for practical purposes they are not needed..." The resemblance is possible, even to the extent of later appellation as ox-hides, but Plut.Thes.25 (Seltman's starting point) is slender evidence for this. Decisive against the identification of these ingots as weights however are their variance in weight, their lack of marking (possible foundry-marks occur on some but by no means all ingots, and are clearly not weight-value marks), their heaviness and lack of comparable smaller weights in series, and, mainly, their quite sufficient role as metal ingots.

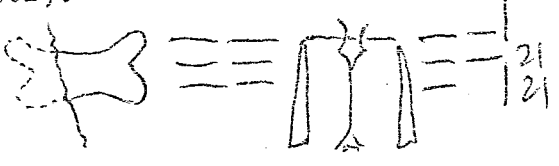
559. For example, the thirteenth-century wreck of a Cypriot ship off Cape Gelidonya (S.Turkey) with thirty "ox-hide" ingots, scrap metal (or, depending to a certain extent on overall interpretation, a number of weapons and agricultural tools), and a set of Egyptian weights (AA 77 (1962) 358).

560. Again an example, the locus classicus, tablet Ca 730 (see below n.563); such inventory tablets imply in their turn the practice of storing the ingots.

561. Seltman Athens: its history and coinage ch.I and Greek coins^2 pp.7-8.

562. The absolute weight is about a reasonable man's load; the shape suitable for its being carried on the shoulders (as on Egyptian reliefs) and, with the corners, easily handled; flatness for convenient storage, but more likely dictated by the process of manufacture (flat, open sand moulds) and the need for re-use (as thin, easily melted).

563. Tablet Ca 730 (which is reproduced here from Evans, as cited above in n.558, fig.14 p.361):



Taking the balance sign as a weight (see further below on Linear B weight systems), the tablet could read "6 ingots weighing 52(? talants) 2 (? minai)". The relationship between metalworking and units of weight has been discussed for Greece above ch.VII.1.(2); the possibility of the weight of an ingot, or of a series of ingots, leading subsequently to the establishment of a weight standard should certainly be allowed.

564. Thus most unidentifiable metal objects tend to be treated, however tentatively, as weights: for example the metal rings from the late twelfth-century Enkomi hoard, Trésor de bronzes nos.29-31, 32-34, by C.F.A.Schaeffer Enkomi-Alasia (1952) 43-44; and the lead disks from a Vaphio Chamber Tomb, see Chr.Tsountas Ἀρχ-Ἐφ (1889) 156ff.. Both Catling Cypriot bronze-work 231.n.6 and Tsountas op.cit. are sceptical about these being weights; but see further studies by Sundwall (for example as cited above in n.558).

565. Since A.J.Evans Scripta Minoa II p.21 (on the balance sign), can be noted E.L.Bennett Jr. "Fractional quantities in Minoan bookkeeping" AJA 54 (1950) 204-22; Ventris and Chadwick Documents 53-56; and L.R.Palmer The interpretation of Mycenaean Greek texts (1963) pp.11-17.

566. Documents p.56.

567. Persson (as cited above n.550) pp.73-4 argued  to be a representation of a hand-held balance on its side (originating, that is, from ). A problem here however is that balances in Linear B, as opposed to Linear A, are always shown standed (see below n.571). Other possibly related signs in Linear B stray far from phonetic compatibility:  na;  di;  a.

568. The evidence is listed by Catling Cypriot bronze-work in the Mycenaean world (1964) pp.185ff (outside Cyprus) and 162f (in Cyprus). To which add: the gold balances from Mycenae Shaft Grave III - H.Schlieman Mykenai (1878) 228f; Persson New Tombs at Dendra near Midea (1942) p.73; A.J.Evans Palace of Minos III.151 and JHS 45 (1925) 59-61; also two bronze disks from a Mycenaean tholos tomb at Kasarina (Argolis) AAA ii (1969) 4.

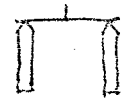
569. If it is meant to be balanced on the finger compare perhaps the Carchemish relief (in the Louvre) reproduced by B.Kisch Scales and weights: a historical outline (1965) fig.3.

570. A bronze "bar" is noted in association with two Pylos balance pans, but no details are given as to whether it can be a balance beam: Blegen and Rawson Palace of Nestor I.15. Two bronze "hooks", shaped  , from a Vaphio tholos tomb could be part of the balances (pans) found there: Tsountas (as in n.564 above). A possible balance handle (or pointer ?) was associated with a square-section beam at Mavro-Spelio: Forsdyke BSA 28 (1926-7) 253, 288-9. Finally, Persson New Tombs at Dendra (1942) 72-4 interpreted a T-shaped gold plate (4.5cm by 3.5cm) as once covering a wooden projection (handle or pointer ?) from the cross-beam of a balance.

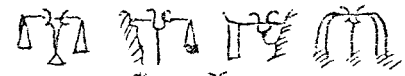
571. Representations in script may in certain cases have been simplified in publications; even these however indicate the following variations of balances.

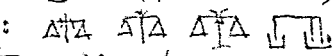
Linear A - Evans Scripta Minoa II.53:  , II.21: 

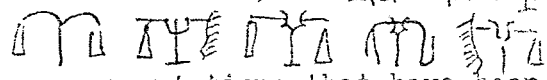
- Sundwall Der Ursprung der Kretischen Schrift (1920): 

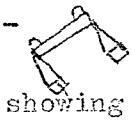
- Bennett Fractional quantities (1950): 

571 contd.

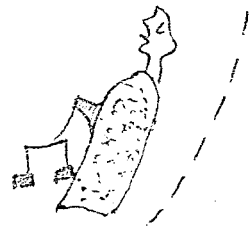
Linear B - Evans SM II drawings of nos.730-3: 

,, printed in Tables I,IV: 

- Bennett (1950): 

I am discounting two further representations that have been thought to be of balances: first the Minoan sealing of a bull with, across its belly at an angle, the sign -  (Evans SM I 43 fig.20.a.1; and SM II 21);

and secondly the Enkomi crater, showing a man standing before a chariot and holding in his hand an object consisting of two solid squares suspended from a cross-piece -



This latter scene is discussed profusely in literature about early Greek religion: M.P.Nilsson Archiv.fŭr Religionswissensch. 33 p.90f; E.Wüst ibid. 36 p.167f; Evans Palace of Minos IV (2) 659 n.2 fig. 646; A.B.Cook Zeus III (2) 1150; Picard Rel.préhell. (above n.549) p.290; Persson New Tombs at Dendra (1942) p.73.

In both these latter cases a balance can be ruled out by the fact that the pans are shown as sold squares rather than flat lines, hemispheres, or even disks (as if seen from above, in truly geometric fashion). Whether the shared association with animals might support the alternative interpretation of some sort of fetter, blinker, or stirrup, it is not necessary to establish here.

572. The graves show hand-held balances, the representations attest to the standed type; neither context, in Linear B, yields the other type.

573. See ch.IX n.8 above.

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574. ANET^{2} 407b (R.1,5ff).

575. 1 Kings 7.47; 1 Chron.22.14 (Solomon and David); Numb.7.14 (10-shekel gold spoon). Petrie suggested that the Israelites, on emerging from Egypt, temporarily lost their ability to weigh (above n.461), but how then was this gold and silver weighed ?

576. Hittite Law Code II.179, 186; Gurney The Hittites^{3} 84-5 (tables); ANET^{2} 196a.

577. Hosea 3.2: 15 "pieces" (shekels) of silver and 1½ homers of barley.

578. For example, Glanville (above n.7) pp.23-25.

579. The weights are to be distinguished from silver carried and from weighed silver pieces: Gen.42.35 with 43.21 (lump); Hosea 3.2 (weighed pieces); Gen.23.16 and Micah 6.11 (lump and bag of weights).

580. Of the so-called Beqa-standard; only weights of this standard were marked with  , the Egyptian hieroglyph for gold (Skinner Weights and measures (1967) 28-32). I have not however seen in metrological work on weight standards in Egypt any comment on, or discussion of, the closeness of the hieroglyphs for gold and silver. Gardiner, Egyptian Grammar[2] p.504, Signs S.12-14, gives the following:

gold  fine gold  silver 

581. Hittite Law Code II.127, 170 (silver); II.181 (copper); II.157 (bronze); II.182 (cloth). Translation ANET[2] 194-6.

582. And still is in modern idiom - a pint of milk, pot of honey, cup of tea, spoon of sugar, glass of wine. The Greeks illustrated this well: thus "charcoal measures" and "wood weights" in the third-century Delian inscription SIG[3] 975 (Pleket no.10).

583. This is not repetition as it is possible that all measures (weight included) might be in units associated with only particular commodities. This is not only not improbable, but is in fact close to what I have shown (in chs.III-V above) to have been Greek practice. For the point made here however, it is sufficient to quote one example from each of the relevant cultures. Thus the Egyptian deben is used for the weight of copper (letters of Hekanekht of Dyn XI, see above n.25) or of bronze and silver (Dyn XIX lawsuit, ANET[2] 216). The Hittite mina has already been associated with silver, copper, bronze and cloth (Law Code, n.575 above). Similarly the Mesopotamian mina is used for copper and silver (Eshnunna.1,42; ANET[2] 161-3) or for gold (Nuzi, an Akkadian sale or adoption; ANET[2] 219b no.(1)). The Hebrew shekel is used of silver (Numb.7.13), of gold (1 Kings 10.14), of brass (1 Sam.17.5), of iron (1 Sam.17.7), and of hair (2 Sam.14.26).

584. Such as Daniel 5.27 (above IX.1.(5)), or the story of Senosiris son of Satmi (above IX.1.(1)).

585. See above VII.1.(1); [Arist.] Mech.1.849b34ff; and further in Appendices A and B.

586. ANET[2] 409 (c.B.1, 155ff); dated towards 2000 BC.

587. Aesch. Choeph. 61-5.

588. Especially Kantusilis' prayer (above IX.1.(2); ANET[2] 400-1) but other ritual also involves the balance.

589. W.G.Skinner Weights and measures (1967) p.11 comments on the high accuracy of the Indus weight series, which stretched from 0.86gm to 10.97kgm even before the seventeenth century BC. See also in K. de B. Codrington "The origins of coinage" Bull.Inst.Arch.Univ. Lond.4 (1964) 1-24.

590. See above n.64 with my apprehension in n.551.

591. I am deliberately overstating the case here. The only certain vocabulary argument is that the same concept was used both in Linear B and in later Greek for the balance and for one of the weights used on it. It is by no means an established fact that the Linear B word was talanton, or even related. Similarly the earliest Greek balance, from Lefkandi (ch.I.1.(1) no.1), is also the only one yet known. Its broken condition and context (the fill of a tomb) might compare with the breaking of a balance in the Hittite funerary cult (see above in IX.1.(2)). However, as already noted above n.552, the fact that the Mycenaeans put balances in their graves must be distinguished (and perhaps the distinction is critical) from funerary ritual outside graves (as the Hittite).

592. See the concluding section of IX.1.(4).

593. Esp. VII.1.(1) and VII.3 Conclusions.

594. Contrast the status of the near-eastern merchant, albeit more often than not acting on behalf of his king in the evidence that has survived: above nn.86-96, 219-21, 272, passim in IX.1.(4), nn.410 and 500.

595. Ar.Nub.144 (Socrates asking how many of its own feet a flea might jump) has been seen by Dover (ed. Clouds ad loc) as a reference to the newly fashionable experimental studies of the period that used measurement; not very much later Meton presented the Athenians with a revised calendar (being honoured with a statue even if his measurements were not adopted); a later passage in Plato's Republic even claims that measurement and calculation are the better part of man, able to rescue him from complete sujectivity (Rep.X 602c-603a: even if all weighing is a matter of showing what is "heavier"602d8). See ch.VI.1.

596. Thus the advance, if really made, of Plato Timaeaus is quashed by Aristotle De Caelo. See ch.VI.2.

597. Such as the bismar developed by meat-sellers; [Arist.] Mech. 20. 853b25 ff. Above ch.I.2.(1) and ch.VII.1.(1).

598. Such as insisted upon the recognition of a commercial weight standard in the late second century: leading to IG II^2 1013.

599. Alexander the Great and the Near East; on the other side Rome, for example the Treaty of Apamea (see Appendix E: Additional Note).