BALANCES AND WEIGHTS IN VIKING AGE SWEDEN

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ABSTRACT

The Viking Age balances found in Sweden form a very homogenous group. Typically they have a sensitivity of 1 mm deflexion of the tip of the pointer for 0.2-0.4g overload at low loads. At loads around 2*50 or 2*100g, some 2 per cent will cause this deflexion. To obtain the optimum information from the many weights found, it is very important that only the very best weights are selected for your study. The small, 0.7-4.5 gram, cubo-octaedric weights found at Bandlunde and Paviken, Gotland, Birka, Upland and Hedeby, Germany, belong to the same system. It is probably based upon the weight dirhem = 2.83g although the canonical dirhem = 2.97gcannot be entirely excluded. The bronze clad iron weights were estimated indirectly by measuring and calculating their volume which was then converted into the weight. The Bandlunde weights belong to a system probably based upon the *mitqal* sanctioned by the chalif Abd al Malik in Bagdad AD 696. Their unit is c 4.25g. The Birka unit was only 4.0g. Some solid bronze weights derive from a unit=3.0g. It is an impossible task to map all the different weighing systems used during the Medieval Age simply because administration in most areas was weak and did not own the technical facilities needed for a rigid control of weights and balances. For one type of trade, only, one may expect international weighing systems, the trade with precious metals. The high and persistent value of the goods made the weighing meaningful. A piece of silver kept its weight even if it was carried to another market. In Scandinavia there have been found more than one hundred balances and several hundred weight pieces from the Viking age, mainly from the tenth and eleventh century. They are remarkably uniform and several authors have studied them and tried to attribute them to the various weight system prevailing in Europe and the near East. The problem is, however that these systems are rather similar and that the exact nominal weight of the often severely corroded pieces is difficult and frequently impossible to establish. The accuracy to be expected in the weighing system has been another source of confusion, sometimes errors of ten per cent have been accepted as probable and normal, in other cases the unit weight estimated is given with 4 or 5 decimals. The inexactness of the balances and of the weights contribute equally to the errors of the weighing and of the weighing system.

The balances

The balances found are remarkably uniform in construction and appearance. They may have been produced by a few workshops, only, though none of these has yet been found. It is quite possible to calculate the sensitivity of a two armed balance from its dimensions. Sensitivity is defined as the overweight on one pan that causes a predetermined deflexion (eg 1 mm) of a pointer or the like (compare eg the German industrial standard DIN 8120). - In this place, it should be stressed that friction has very little to do with the sensitivity of a balance, as long as it doesn't influence its general usefulness (the balance "sticks").

There are, above all, three parameters that determine the sensitivity of the Viking age type balance and of any two- armed balance: the size and weight of the beam, the load, including the weight of the pans, and the small distance between the support point of the beam and the center of gravity of the beam (cf fig 1). These parameters can be measured and then sensitivity calculated. Furthermore, a few ancient balances are still in working order and can be used to corroborate the figures obtained (Sperber 1988).

It was found that a sensitivity of 0.2-0.4g for 1 mm deflexion of the pointer was common at low loads (0-10g or a few coins).

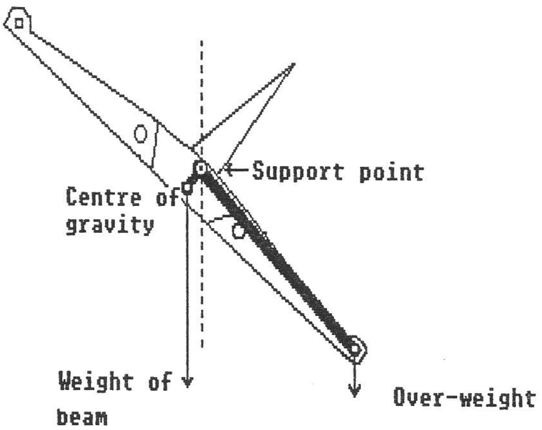

Fig 1. Equilibrium of balance beam.

The weight pieces

Several types of weight pieces have been found, the most common being the cubo-octaedric ones, the ball-shaped ones with flat poles and the mostly coin-shaped leaden weights. They behave slightly differently when corroding in the moist soil so they are treated separately.

The single weights found are all more or less corroded. Some look almost like new whereas others may consist almost entirely of corrosion products giving no reliable information regarding their original weight.

It is of utmost importance that only the best pieces are used when trying to reestablish the original standard unit system.

To include poor weights into your analysis will introduce unnecessary errors and jeopardize your results. It is especially serious that both random and systematical errors will be introduced.

How does corrosion affect different weights ?

On trying to foresee what may happen under the influence of moist, oxygen-containing soil one has to look upon the composition of the weights rather than upon their form.

Most of the weights found consist of a lead bronze containing, in addition to copper, large amounts of lead, some zinc and a little tin. Such a material is excellent for casting and it is also rather resistant to corrosion. The layer of oxides formed in the soil is mostly brownish and contains various amounts of different oxides of the metals used in the weight. The corroded sample initially looks very like the original one because of the thin-ness and uniformity of the oxide layer. It has, how-ever, a small tendency to flake off at the corners and edges. The density of the layer is usually around 6 g/ml. (The new bronze seems to have a density around 8.7 g/ml). Sometimes,the weights are green from verdigris when water and carbon dioxide have been plentiful in the soil. The verdigris has very different properties from the cupric oxide. It dissolves easily in EDTA-solutions and will be lost during preparation. Remember: the loss of verdigris is a loss of weight material that cannot be recovered!

The formation of the brown corrosion layer will not necessarily change the weight of the find very much. The oxidation of the metal will increase its weight but the slow dissolution of the layer into the ground water will diminish it. The exact sum of the two procedures cannot be calculated, it may, however, well be near zero.

An example: Imagine a copper cube, density 8.9 g/ml, weight 4.00g,having the edges c 7.7mm.

Suppose that 5 per cent of the copper (=0.20g) is transformed into 0.25gcupric oxide. The oxide layer will be around 0.10mm, the weight 4.05g (=+ 1.25%). The corrosion layer will probably loose some material to the surroundings, suppose half of its weight (=0.13g).The overall weight will then be 3.92g(=-2%). Thus, if not more than half the oxide layer is lost, the cube will have retained its original weight within 2%.

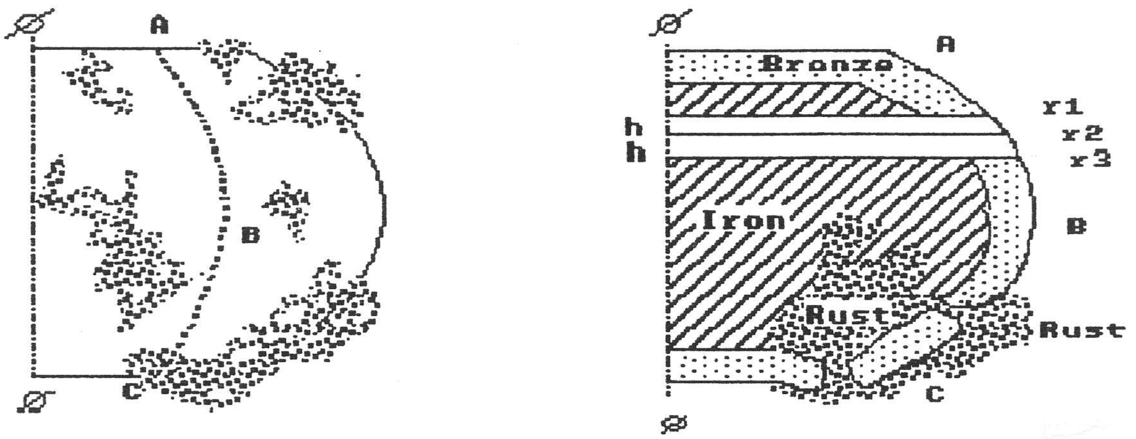

Fig 2. Ball-shaped, bronze clad iron weight. Left, exterior view with rust patches. Right, interior view. Weight cut along A-B-C meridian.(∅-A-B-C-∅) Meridian free of rust patches. Suited for measurements. (r_1 r_2 r_3) Radii of points at the weight surface. (h) thickness of slice whose volume is to be calculated.

Losses of oxide can be judged by visual examination. Evidently all weights where more than 5-10% of the metal has been transformed into corrosion and, in addition, substantial amounts of the oxide have been lost by dissolution, flaking, mechanical damage or excessive treatment with EDTA or the like are not suited for our purposes. They should not be included into the study but for special reasons.

The bronze clad iron weights to some extent behave like the solid bronze weights but because of their iron core they are more vulnerable. They corrode in a typical way which makes weighing of the specimens a rather meaningless procedure: There are always pores in the bronze shell. In the soil, these pores will allow the ground water to enter the interior of weight where it will react with the iron. The close contact between the bronze and the iron will promote the electrolytical transfer of iron into ferrous ions which will partly diffuse out of the pores, meet with oxygen and form rust. The rust settles upon the bronze surfaces of the weight and upon other surfaces in the neighbourhood. It will also trap particles from the soil. Some of the ferrous ions may migrate a long way until they meet oxygen. They may even turn up as bog ore in a nearby bog or lake. The ferrous ions left inside the shell will form rust and fill up the interior cavities of the weight. Rust has a very low density and correspondingly a high volume. If, for some reason, it is locked up in the interior, it may cause boils and cracks at the bronze surface. Some weights found have even burst into two or more pieces.

As a result, it will be impossible to estimate the original weight of such a piece by weighing. You can never know for certain the amount of iron that has been oxidised (and gained considerably in weight) or the amount of reaction products lost to the surroundings.

The galvanic contact between the iron core and the bronze shell has thus destroyed the iron and the iron compounds formed as a source of information. Fortunately by sacrificing itself, the iron has largely saved the bronze shell from chemical attacks. Weights that have not yet been deformed, often have their shell still left in its original form and position. The ball-shaped weights are mostly next to perfect rotation bodies and their volume can be calculated from their dimensions using Simpson's formula and Guldin's rules, which can be found in any text-book of mathematics. The parameters necessary to measure are illustrated in figure 2. The size of the weight is estimated by adding the volumes of the slices determined by the measured dimensions h and r. They have to be measured to the next few hundreds of a mm.

From the volume calculated, the original weight can be obtained. The density of the iron core, according to Hütte, is around 7.8 g/ml, that of the bronze shell is more uncertain. By weighing good ancient solid bronze specimens, an approximate value, 8.7-8.8 g/ml, has been found. Figure 3 shows what happened when the best 10 out of 30 weights were selected, measured and calculated according this method. The module of the system, in this case about 4.25g, shows up very clearly, indeed.

Whereas bronze weights and bronze covered weights form very homogenous groups that may well stem from a few workshops, leaden weights do not. Casting of lead is easy and probably some of the

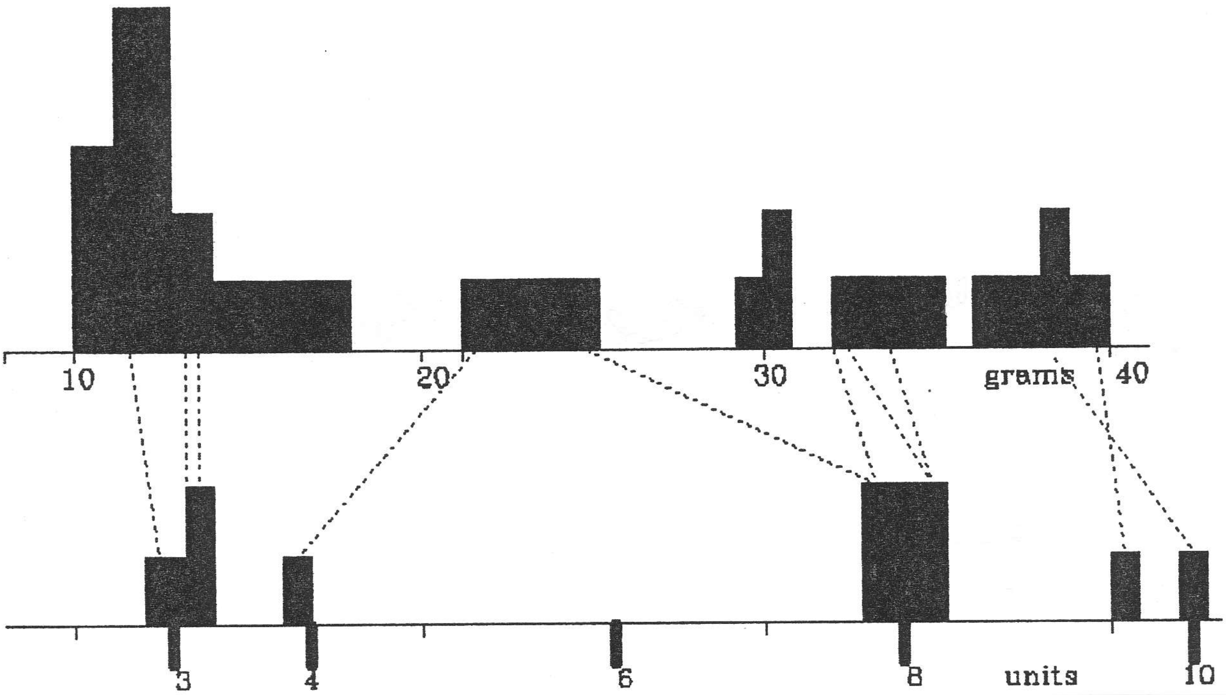

Fig 3. Ball-shaped, bronze covered iron weights. 10-45 grams. Bandlunde. Upper row: weights when found, c 30 pcs. Lower row: the 10 best weights selected, measured and calculated. Standard unit weight observed= c 4.25 grams.

weights found have been manufactured by local blacksmiths not having the proper means for the control of the weights. Until a better method has been found, the present weight of good looking lead specimens may be accepted as a useful approximation of the original weight. In any case, severe losses through migration of lead ions seem less probable than those of zinc, iron or copper.

How to disclose and estimate a standard weight unit from a set of weights found

Several methods for estimating the standard weight unit from a find of weights have been used in the past. The success achieved depends upon the accuracy of the weights in question but also to a very large extent upon the "common sense methods" and upon the statistical or mathematical methods used or in some cases misused. The least square exemplifies a method that may give misleading results. Analyzing the weights, you had better select sets where the heaviest weight is not more than about ten times the lightest one. If you extend your analysis further, you will soon reach a point where your figures are not accurate enough for the analysis.

Holm's method (Holm 1987) has been specially developed for sets of figures deriving from a common module, like a set of weights from a standard weight unit. It is based upon the fact that the "error" of an assumed weight returns to zero at regular intervals as the weight unit increases. The same is true for a sinus curve. The method can be used to trace possible modules. The calculating and plotting of the result may be carried out by a computer.

The finds of Bandlunde, Birka and Paviken and to some extent Hedeby provided the present author with a fairly great material of data from well preserved cubo-octaedric weights made of lead bronze. It was soon evident that they represented the same weight system founded upon a standard weight around 2.9 grams, probably 2/3 or maybe 7/10 of the islamic mitqal = 4.245g (Sperber 1989).

The minima found (fig 4) for the Birka material were 0.19, 0.35 and 0.705g and for the Bandlunde weights 0.36, 0.40 and 0.71g. Assuming that the 2/3 mitqal = one dirhem = 2.83g was in use, these figures correspond to 1/16 (=0.18g), 1/8 (=0.36g) and 1/4 (=0.715g) of a 2.83g dirhem. The 0.40g minimum of Birka could not be explained. It corresponds to 1/7 of 2.83g a rather odd unit, should it belong to the same system.

The minima found strongly confirm the hypothesis that all of the small cubooctaedric weights fit into the islamic system.

As mentioned, a bronze clad iron weight should be

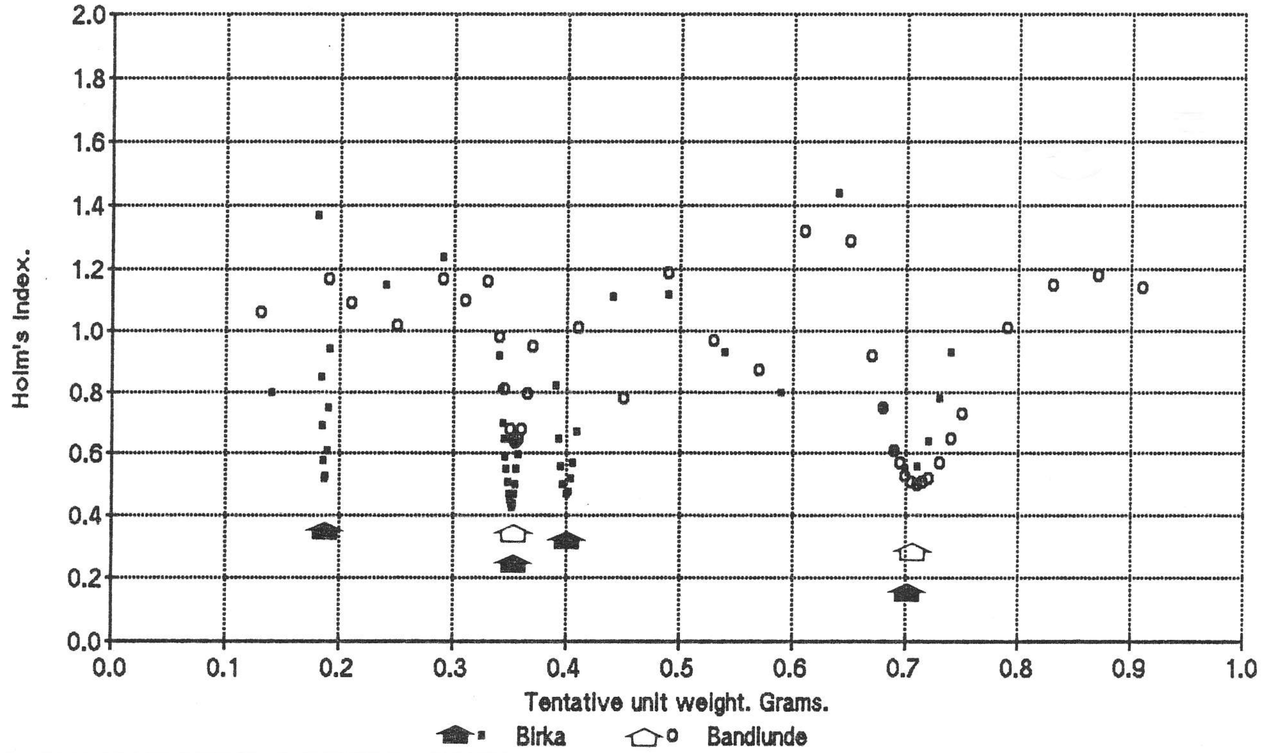

Fig 4. Cubo-octaeders less than 4.5 grams from Birka and Bandlunde.

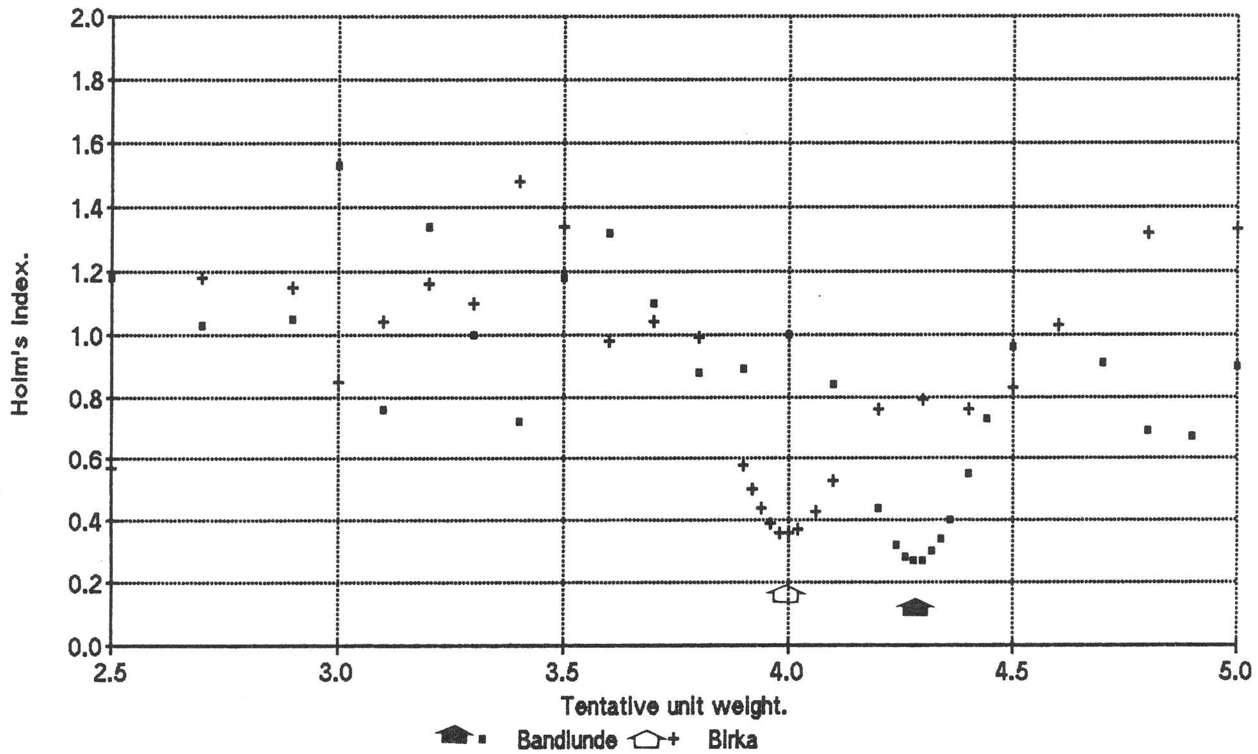

Fig 5. Ball-shaped weights. Fe+Cu. 4-45 grams from Birka and Bandlunde.

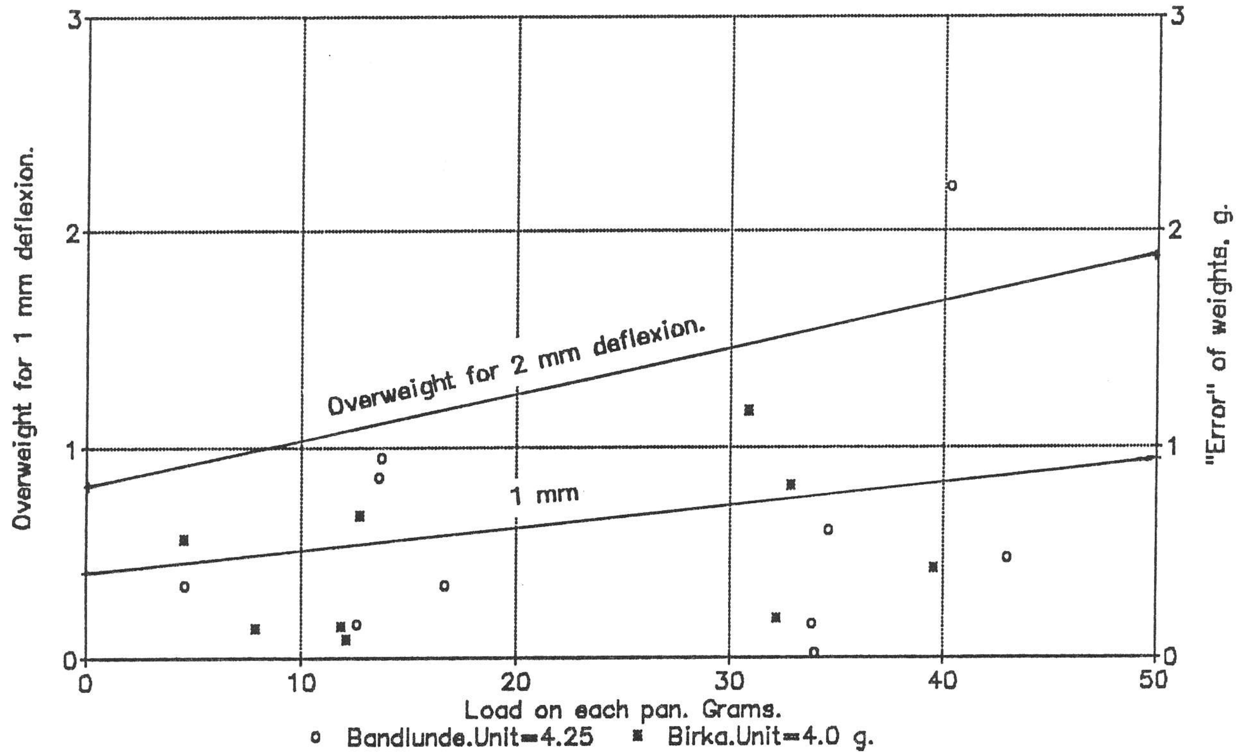

Fig 6. Sensitivity of the Vårdinge balance vs errors of Bandlunde and Birka weights.

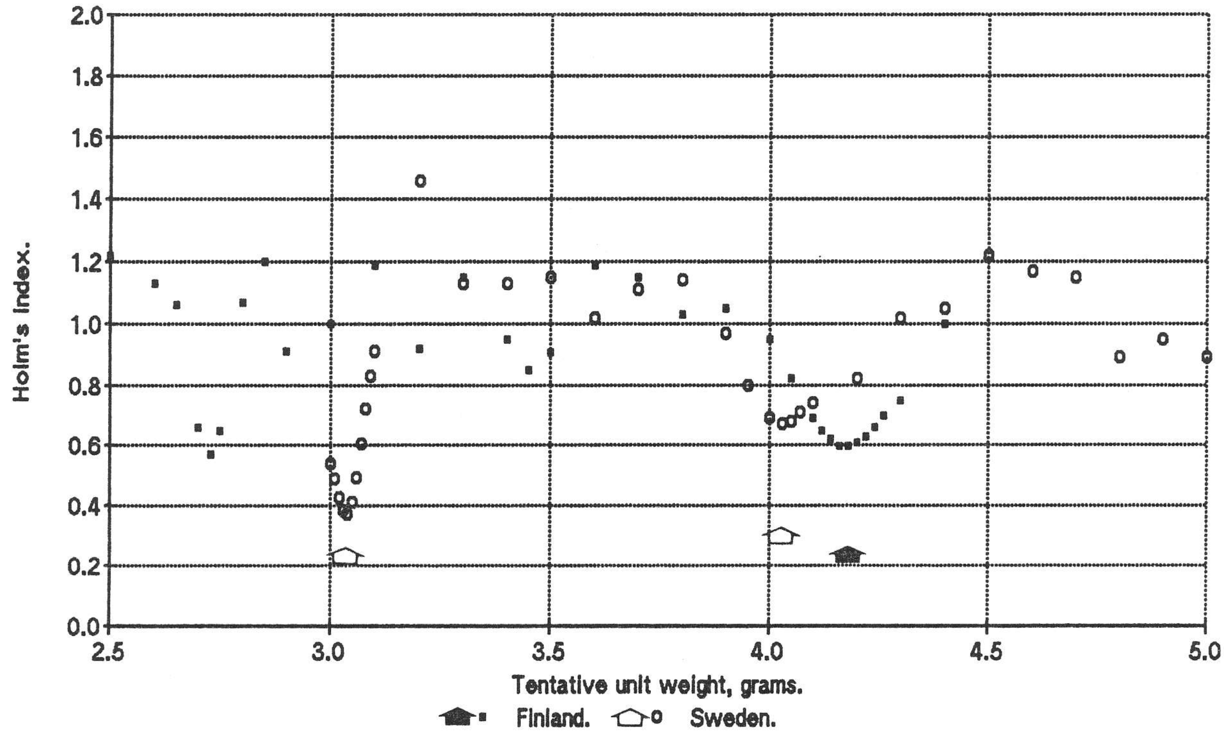

Fig 7. Ball-shaped weights of solid bronze. 4-45 grams from Finland and Sweden.

estimated by measuring and calculation rather than by weighing. In the literature, no such measurements are available, the only useful figures for such weights deriving from this laboratory. They concern most of the rather few sets found in Sweden. Again, only the best weights can be used, the majority of them coming from Birka and Bandlunde. The important find of Sturkö, eg, contained 14 weights, among them 10 bronze clad iron weights. Only 4 of these could be measured with the accuracy needed. 23 ball-shaped weights from Bandlunde and from Birka were submitted to the analysis acc to Holm (fig 5). You can see that the Birka curve indicates a module of 4.00 grams whereas the module of the Bandlunde is 4.28 grams. The existence of the two minima is statistically significant to the 5% level or better.

Using these modules, the errors of each single weight found can be calculated as well as the deflexion of the pointer of a typical Viking age balance, the Vårdinge balance, when the weight is compared with a "true" weight of the same size. The result is plotted in figure 6. If 1.5-2 mm deflexion of the balance pointer was accepted by the merchants, 22 out of the 23 weight pieces of the study would be good, even after a thousand years in the soil.

The figures 4.0g and 4.28g corroborate old estimations of the units of Birka and Bandlunde.

There are a number of weights, mostly from late finds which consist of solid lead bronze without an iron core. They are often in a remarkably good shape and their weight has probably not changed very much during their stay in the soil.

Holm's index for weights of this type found in Finland and in Sweden is shown in figure 7. The results are astonishing: the Finnish and Swedish weights show a low significance tendency to gather around 4.2 grams and 4.0 grams respectively. More important is perhaps the significant minimum for the Swedish weights at 3.1g. The same unit weight appears in the late finds of Kv Guldet, Sigtuna, and Unna Saiva, Gellivare, Lappland especially if the few cubo-octaedric weight of these finds are included into the analysis (such mixing of different types of weights was generally avoided in this study). Some of the figures arrived at are shown in table 1.

The system of methods described is largely a mechanical one. It tries to take into consideration the variation and errors of the balances and the weights as well as to some of the complicated processes occurring in the soil. If you are lucky you may end up with a set of figures giving valuable hints to the solution of the problem of the Viking age weight unit. In some cases, however, it may mislead you. In particular, Holm's index is not fit to deal with mixed systems having more than one module. Of course, if there turn up too many 13-unit weight pieces in your set, you had better be suspicious and look for a different solution to your problem. Maybe, you just overlooked it.

Table 1. Probable unit weights of some sites. Ball-shaped, bronze clad iron weights, 4-45 gram.

Site	Number of weights found	Unit weight	Holm's index
Bandlunde	11	4.27	0.40**
Birka	9	4.0	0.36**
		3.3	0.52*
Kv guldet Sigtuna	7	3.1	0.47*
Valbo, Gä.	5	4.0	0.07**
Sturkö, Bl.	4	4.1	0.20*
Valsgärde Up.	4	4.1	0.33

References

Holm, S. 1987 Statistical methods for module problems. *Tor 21*. Uppsala.

Sperber, E. 1988 The find from Bandlunde, Gotland: 150 weights belonging to an islamic weight system *Laborativ Arkeologi 3*. p.64.

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A very complete list of earlier references is found in:

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