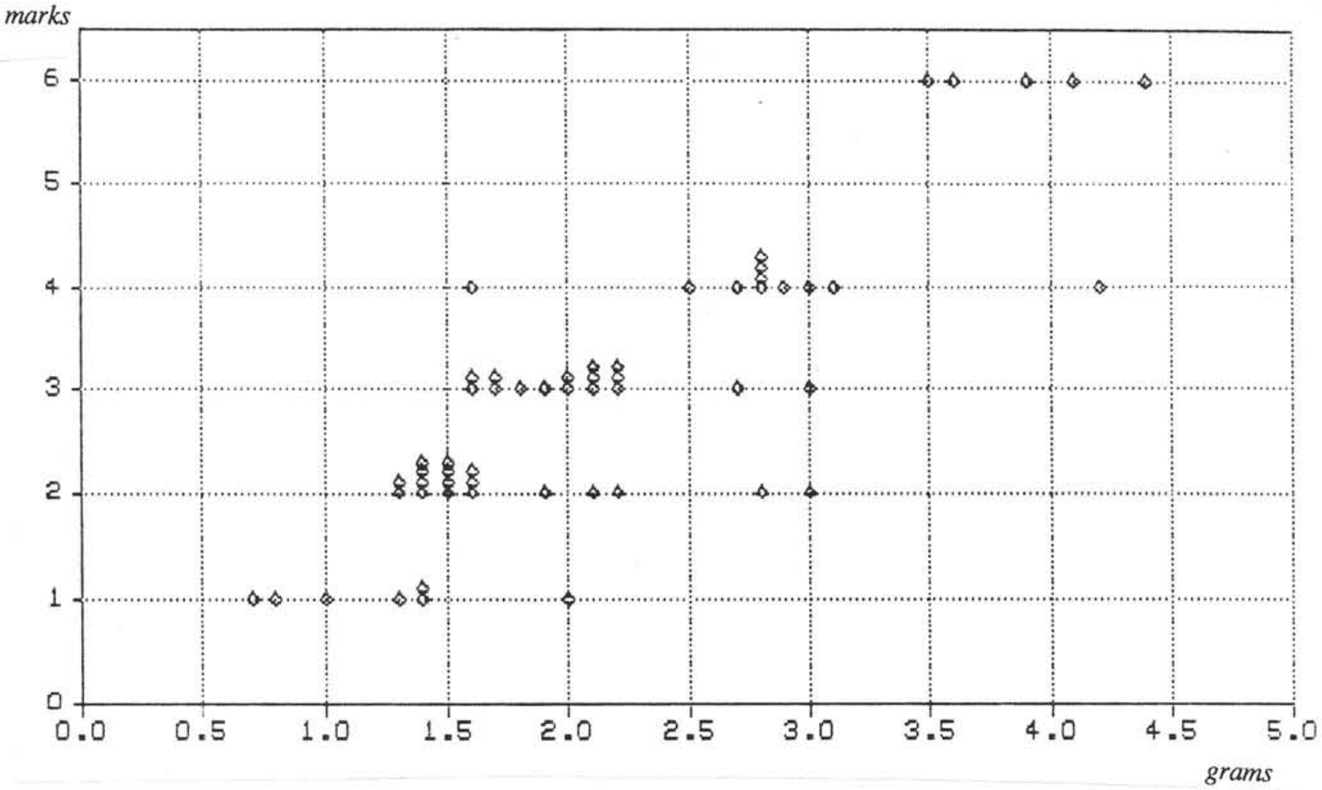

Fig 1. The cubooctaedric weights from Bandlunde. Distribution of the ring marks. Number of marks vs weight of the pieces, g

Fig 2. The small ball shaped bronze covered iron weights form Bandlunde, c. 4 - 14 g. "Before stabilization"

THE FIND FROM BANDLUNDE, GOTLAND: 150 WEIGHTS BELONGING TO AN ISLAMIC WEIGHT SYSTEM

by Erik Sperber

ABSTRACT

cf Summary

Introduction

In 1983-84, a great find of, among other things, many Viking Age weights and a very corroded balance was made in Burs parish on the farm of Häffinds Gotland. The place is situated at a bay at the Eastern shore of the island named Bandlunde-viken.

The find was made on plowing a field and many of the weights were scattered over a part of the field. Part of the find was excavated indoors by Majvor Lindström who also prepared the Report. Most of the weights were localized with a metal detector, however, and recovered. At the border of the same field a hoard of 1428 Islamic coins and coin fragments, called "Stavars skatt" has been found. It was named after the mythical viking chieftain Stavar who is said to have lived here. The last coin was dated A D 957. - During the Viking Age the site was a harbour and a workshop center where trading activities also took place. The silver coin hoard and the weights need not necessarily be absolutely contemporary.

The present study concerns the weight system represented by the weights found. Earlier a laboratory study has been published on the globular weights of the find (Sperber 1986). The aim was to obtain as exact figures as possible of their original weight.

Many authors have pointed out that in an area with weak Governmental power and with technically primitive control methods, you cannot expect well defined measuring systems common to large areas. Instead, a large number of local systems will appear. In Sweden some such systems used for farm product persisted into the 19th century.

The gold and silver trade consistuted an exception. The goods were here of a high and permanent value. They could easily be transported and their value - in the form of coins - might be guaranteed by royal mints, sometimes though not always, having a high technical standard. On the other hand, forgery was possible.

There were only a fairly limited number of merchants having the experience, competence and economical capacity for large scale gold and silver trading. For them it was natural to use the weight system legally adopted in their home country or in the country dominating the trade in their part of the world. If controversies nevertheless arouse, they had to be eliminated by comparing the weight sets and by subsequent negociations.

The trade of Gotland was, at this time, largely oriented to the East. Hence, you might expect an Eastern weight system to be the dominating one. However, you cannot, a priori, exclude Western influence which from the year 980 onwards grew steadily ending up with a totaldominance in the Hansa period.

In the Islamic countries, there existed since the reign of the chalif Abd al-Malik a weight system authorized by him in 696 (v. Bergmann 1870, Herschend 1987). The unit weight was the mitqal = the weight of the coin dinar = 4.24 g. A subunit was used, the legal dirhem, weighing 0.7 mitqals = 2.97 g. The factor 0.7 was chosen to make the value of one mitqal of gold equal to the value of 20 dirhems of silver. This was also true as long as gold was 14.1 times as precious as silver. Unfortunately, the relationship changed with time and was probably anyhow the subject of negociations. Therefore, eventually another dirhem develloped, a "trade dirhem" = 2/3 mitqals. The factor 2/3 did not try to settle the price relationship between gold and silver, but it gave a simple and practical system.

The existence of two dirhem unit weights together with an unknown number of Western and Scandinavian systems made it necessary for everybody intending to trade with gold or silver to have some means of controlling the weight set of his trade partner. In principle one single known weight piece only, was needed for that purpose and it might be a borrowed one. However, we know from numerous finds that many Gotlanders owned one or more weights and that the same held true for Birka too, to judge from the grave finds from Björkö.

The market for such weights was considerable as shown by the number of weights found at Bandlunde, 158 pieces. They must largely have been for sale, at least, they do not stem from a large grave field like many of those of Birka.

In Birka only a moderate number of more or less complete sets of weights, 4 - 7 weights, have been found. Kyhlberg (1980) discusses the 11 of them in some detail. From his catalogue we can see that 96 graves contained a single weight, 33 graves contained two weights, and 11 graves 3 weights. In addition, there are a number of objects with uncertain use. If used for weighing, they certainly have been for control purposes only, like the weights that appeared singly or in pairs. Perhaps, the number of 11 graves - about one eighth of all graves with weights - is too low. A weight set was very expensive It must have been tempting to keep it or to steal it rather than to bury it with its owner. We know, however, nothing for certain about that.

The find at Bandlunde is not useful for finding out the proportion between complete weight sets and single weights to be sold. The weights have been thoroughly mixed up when the disaster struck the owner of the weights as well as later by plowing. It is evident, however, that some very complete weight sets were included into the stock. Why else should next to all multiples of a probable unit weight, 0.35 g, be represented among the globular weights between 4 and 12 g?

In the material from Birka there is a group of objects not represented at Bandlunde. It concerns the artefacts, 15 in number, of bronze or silver with supposed secondary use as control weights as well as about the same number of glass or stone pieces.

With the metal detector used at Bandlunde no glass or stone objects could be registered so none were found. More remarkable is that no silver objects were found and that the bronze objects were few. The non presence of these objects feels natural. Why should a renowned trading company like the one at Bandlunde carry provisional weights for sale?

Missing knowledge about their use makes the distinction between provisional weights and scrap metal pieces very uncertain. One piece of metal may on one day be a used and useful weight. On the next day it may have been discarded and thrown into the scrap metal box, maybe upon the initiative of some trade partner who did not find it exact enough.

Steuer (1987) has discussed the problem of intentionally damaged globular weights. One of those weights, SHM 5582 b, stems from Sojvide in the parish of Sjonhem only some 30 km from Bandlunde. It has been damaged by making a cross on one of the polar faces with a chisel or the like. The impression is that somebody intended to cancel the weight. No metal has been taken away. The present weight is 93.193 g, the density 8.48 g/ml. It is solid and consists of a copper alloy with c. 10 % Zn and c. 10 % Pb.

The explanation of the rough treatment of the weight may be its size. A 24 unit weight from Bandlunde (half a mark) should weigh 101 - 102 g. The Sojvide weight would then be about 8.5 % too light. The error may be serious enough to cause the cancelling of the weight.

Possibly, the weight is a "do it yourself" copy from a valid weight. If a clay mould has been used, the clay will have shrunk and the resulting copy will be too small. The 8.5 % of the weight missing correspond to to a linear shrinking of 2.8 %, a quite possible figure.

Another possibility is that the weight stems from a geographic area where the unit weight used was low. In Birka e.g.it seems to have been 4.0 g (Sperber 1986). If the Sojvide weight originated from there its nominal value would have been 96 g only. A weight c. 3 % low might have been acceptable there.

The cubooctaedric weights

In the Bandlunde find these 78 pieces are all made of bronze, mostly with lead as the second largest component. They weigh 0.6 - 4.2 g and represent very different degrees of corrosion. They were classed according to there density in two groups: 8.5 - 9.0 g/ml, 24 pieces, and under 8,5 g/ml, 54 pieces. A new weight would show a density around 8.7- 8.8 g/ml. Kyhlberg (1980 p.185) has shown the density to be highly correlated to the degree of corrosion for bronze objects recovered from the soil. Hence only the first density group was used for metrological purposes.

The second criterium used for the judgement of the quality of the weights was subjective examination under the stereo microscope at about 10 times magnification. The aim was to see if there were gross losses of corrosion products e.g. by flaking. The weights were sorted into four groups: 1 - excellent, 2 - good, 3 - poor and 4 - very poor. The correlation between these quality figures and the density measured prooved to be - 0.48 , a very significant figure at the sample size available. Only 12 weights, however fulfilled both the criteria.

Most of the cubooctaedric weights carry marks on there quadratic fields and some on the triangular ones too. Usually a small ring stamp with a diameter of c. 1 mm was used for the marking but sometimes two rings are combined in the stamp to give an 8 - like figure. Generally, heavy weights carry more marks than the small ones. It has often been supposed that the number of marks shows the nominal value of the specimen. The modern system used by ourselves works in that way with the difference that we use figures instead of the number of marks.

Any find including several sets of weights, mixed or separated , seems to show, however, that there is no absolute connexion between the number of marks and the nominal weight. Rather, the number of marks seems to indicate the place of each weight in its set. The sets being largely parallel but not identical, the heavy weights will as a rule, but not always, carry more marks than the small ones.

The distribution of the number of marks as a function of the weight of the items expressed in grams is illustrated in Fig. 1. One can see e.g. that a weight weighing 2.8 - 3.0 g may have 2, 3 or 4 marks on each quadrate.

Four of the objects carry a cylindrical hole from one side to the opposite one. The diameter of the hole was c. 6 mm for three of them. They may have functioned as pearls but the hole is bigger than customary. Maybe they were intended to be used with a leather string? The fourth weight had had an iron pin fitted into its hole, measuring c. 2 mm. Nowadays the iron has turned entirely into rust. The fitting of the iron pin into the bronze body could not have meant to adjust the weight. The difference in density is too small. Besides, any adjustment could have been made much easier with a file.

An alternative to the pearl hypothesis could be that the 6 mm hole constituted a solution to a practical problem. Weight pieces of 1 g and less are small and can easily be lost. If you take a 2.5 g weight and bore away 1.5 g of bronze, a much easier to handle 1.0 g weight will result.

I have chosen to treat these "pearls" as the common weights they resemble.

The small globular weights with flat polar surfaces, 4 – 12 g.

The small globular weights, 32 in number, with few exceptions are in a very poor state. Almost all of them are heavily corroded, the corrosion of some of them lies in pieces near the weight, others have lost pieces of the weight itself. Three of them could be measured with a fair degree of exactness. From them a unit weight of 4.57 g could be calculated (Sperber 1986, p. 73). This group of three was complemented with another iron/bronze weight and with an all bronze one. For the others no attempt was made to apply any corrections but the weight "when found" was used. This uncorrected weight is plotted in fig 2. Evidently groups of 1- 5 weights "gather" at regular intervals of 0.35 g. The same weights are listed in Table 1. It is seen that every multiple of 0.35 between 6 and 18 with the exception of 7 and 9 units is represented.

The four weights belonging to this class that were measured and calculated are separately listed in Table 2. They are weights number 15, 19-33, 8 and 144. Also in this table there is the all bronze weight number 256:1. This latter weight has not been subject to the devastating galvanic corrosion following the contact between the leaking bronze shell and the iron core. It therefore looks next to new. The Table shows the common subunit in this case to be 0.373 g or rather 2x0.373 g = 0.746 g. a figure c. 7 % higher than the unit weight calculated from those heavily damaged by corrosion.

Until now no good explanation has been found for this difference. There are several questions that arise and points that require further research:

- are there two or more weight systems represented in the material?

- is measuring the weights and subsequently calculating their weight a useful method for these small bronze covered iron weights?

- have the bronze surfaces been cleaned well enough before the measurements?

- has the thickness of the bronze surface corrosion layer been misjudged when measuring and calculating?

- have the weights been manufactured in a manner that makes the small weights more vulnerable to corrosion than the bigger ones?

The large ball shaped weights 14 – 163 g.

The large weights from 14 g and upwards are listed in Table 3. Endeavour to fit these weights into a weight system failed regardless if the weight "when found" or "after stabilization" was tried. The measurement and calculation of the volume of the 12 best weights turned out to give useful results pointing to a unit weight 4.19 - 4.23 g (Sperber 1986).

The problems met with may be illustrated by weight number 166. When found it weighed 39.56 g. After stabilization 37.95 g remained. The original weight according to the best information available today, the figure obtained after measuring and calculation, was 42.98 g. The weight was most probably intended to be a 10-unit one with a nominal weight of 42.4 g in the Islamic system. The errors turn out to -7 %, -12 % and +1 %. Evidently only the last figure can be accepted in a serious study. - Weight number 166 is only one example, others could be given.

Taking all the posssible errors in account, the unit weight obtained, 4.19 or 4.23 g, is quite compatible with the Islamic mitqal, 4.24 g.

Objects similar to weights

A total of 17 objects that cannot with certainty be classed as weights are contained in the Bandlunde find. Most of them seem to be in a fairly good shape in spite of their long stay in the soil.

9 objects have a density over 10 g/ml which indicates that they are made of rather pure lead. Two others are of a lead/tin alloy, density 7,09 and 7.67 g/ml respectively. The remaining 5 pieces are of copper or bronze.

Probably most of these objects have sometimes been used for weighing, especially the leaden ones that are formed like coins or flat cylinders. They weigh 1 - 5 g i.e. within the range of the cubooctaedric weights. The leaden specimens either carry no marks or marks that are difficult to observe. This speaks against their use for weighing. Such small weights are difficult to distinguish from each others. Some special features like the different number of marks of the cubooctaeders would be expected in the leaden pieces too.

Steuer (1984) like most other authors accepts the leaden pieces as weights but considers them to be inferior substitutes or copies in a cheap material of the expensive bronze weights.

In any case these leaden pieces will certainly have filled the need for cheap aids in weighing much better than the number of glass objects, broken brooches, pearls and many other things mentioned as probable provisional weights.

As a rule, a good portion of criticism should be applied before classing any object as a weight piece. The mere coincidence of its weight with a known standard weight is not sufficient. It should be remembered that a weight set is characterized in the first place by the relationship between the different weight pieces and only secondly by its identity with a known weight system.

Features indicating the use of an artefact as a weight may also be the presence of different marks or number of marks on the object.

If no certain indications for an artefact to be a weight exist, one has better to try to imagine other probable uses for it!

In spite of the Bandlunde find being very large, it is very homogenous. The weights probably stem from a single manufacturer who may also have been the owner of the collection as well as the seller. If several persons were involved there was most probably some companionship between them. Apart from manufacturing and selling the weights, the aquisition of scrap metal was important. Probably the companions cooperated here too.

The amount of metal needed for the Bandelunde find is not large, between 500 and 1000 g. For such a production even small scrap metal pieces might be considered. The large variation of the lead/zinc/tin contents between the various weights suggests the use of small ingots of different composition depending on the raw materials at hand.

In all, scrap metal pieces are to be expected in the find. We actually found a piece of nearly pure copper, number 151, weight 10 g, density 8.72 g/ml. Further candidates are the already mentioned number 74, weight 3.3 g and maybe 364:2. They may have been used as weights but they do not fit very well in the cubooctaedric weight line. Their composition is similar to that of soft solder and they may have been intended for production or repair of animal-head brooches. They may also simply have been scrap metal pieces. A piece of brass cut from an arm bracelet, number 176, weight 4.3 g, density 5.75 g/ml and number 196:11 the head of a bronze pin evidently included into the collection after the pin had been broken, are almost certainly scrap metal pieces.
The needle head itself is cubooctaedric with a little knob.

To conclude, the two leaden objects, number 11, a half cylinder, weight 12 g, density 10,0 g/ml and 364:1 a somewhat flattened leaden ball, 16.5 g, density 11.2 g/ml may have been scrap metal pieces too. Their weight is, however, not far from 3 and 4 mitqal units resp. In addition, the objects 364:1, :2 and :3 were found close to each other. They may constitute a weight set.

Factors affecting to the accuracy of the weights

In the preceeding article (Sperber 1986) the author discussed in some detail the fate of the bronze covered weights in the soil during the centuries. The galvanic properties of copper and iron made it possible, to some extent, to foresee what was going to happen. The iron protected the bronze galvaniccally in such a way that the original bronze surface in many cases could be approximated. The many cubooctaedric weights do not have this protection of adjacent iron that will be sacrificed in favour of the bronze. The corrosion will therefore be free to attack the entire weight. These small weights were manufactured with less percentage accuracy than the big ones. Available merchant balances had a limited sensitivity, usually 0.2 to 0,3 g for a deviation of the pointer of 1 mm. As there is no reason to believe the weights to be more exact than the balances, errors of the very common 1.4 g size up to 10 or 15 % might be expected even for new, uncorroded weights.

If copper or one of its alloys like bronze is left in contact with air and humidity, it will corrode forming various oxides and in addition some more complicated compounds such as verdigris. The alloy metals other than copper will form similar compounds. These metals will in some cases give corrosion products more soluble in the ground water than the copper compounds. The corrosion products formed from a weight unit of a metal will contain in addition to the copper atoms (atom weight 64), oxygen (atom weight 16) and often hydrogen (atom weight 1) and carbon (atom weight 12) in various proportions. Their total weight therefore always be higher than the weight of the copper they contain. If the brown cuprous oxide Cu_2O is formed the resulting increase in weight will be 12.5 % if the green verdigris is formed the increase is very uncertain but may be as much as 70 to 80 %. Similar figures are obtained for iron, zinc and tin. The figures for lead are lower due to the very high atom weight of lead (atom weight 207).

Equally important for the discussion is that all corrosion products formed have a much lower density than the metals they were formed from. Table 2 gives you some examples.

Stoichiometry is a manner to calculate the atomic composition of a well defined chemical compound. Unfortunately, corrosion products are never well defined. Therefore the table can only give you figures for hypothetical situations. The figures of the table can only show you the directions of changes occuring in weight and volume during corrosion.

Two common reaction products behave differently from the other compounds of corrosion.

First we have the initial compounds formed when iron is attacked, the divalent iron compounds. They are mostly quite soluble in the ground water and may migrate long distances. When they react further with oxygen, rust is formed which settles upon nearby surfaces. The rust formed may contaminate other bronze objects with hard to remove pecks and change their weight, in many cases making them unfit for metrological purposes.

Second, zinc, too, may migrate in the form of divalent ions. It may thus be lost from a corroding surface to an unproportionally high degree. Zinc corrosion also dissolves rather easily in EDTA- solutions inflicting losses during the stabilization work too.

Thus: A CORRODING OBJECT ALWAYS GAINS IN WEIGHT IN THE FIRST STEP OF THE CORROSION. LATER THE CORROSION FORMED MAY BE LOST TO THE SURROUNDINGS EITHER BY DISSOLUTION OR BY MECHANICAL DAMAGE.

Evidently, the stabilization work may involve losses unless one works very cautiously. If it is tried to restore the look of the once new object by polishing its bronze surfaces, the losses of corrosion products may amount to 100 %.

A hypothetical example may be given: Imagine a copper cube, density 8.9, weighing 2.00 g. Suppose 5 % of its metal be transformed into cupric oxide, density 6.4. (Cupric oxide is often not the main corrosion product but its properties may be used as an average between the cuprous oxide and verdigris, though a very crude one.)

If no corrosion products are lost, the cube will after corrosion weigh 2.02 g (increase: +1 %).Its volume has increased too (+3 %). Its overall density will be only 8.74 (-2 %).

Further, suppose that one third of the corrosion the thickness of which is around 0.1 mm is remowed by dissolution or otherwise. Its overall weight will now be 1.98 g involving a loss from the origine of -1 %. and its overall density 8.79 (-1.3 %).

If all corrosion is removed, the weight will be 1.90 g and the density will be back at 8.9 g/ml. Both weight and volume will have lost 5 %.

The example shows that, with this moderate degree of corrosion, if not more than one third of the corrosion layer is lost, the original weight will be retained within about 1 %.

This knowledge will be very useful when selecting the best weight pieces from your find. Your aim should be to ascertain that your specimen has a density not more than 0.1 to 0.2 g/ml less than the original one which is about 8.7-8.8 g/ml for bronze.

You will also have to make sure that there is still a largely untouched layer of corrosion on the surfaces. Even if you are not lucky enough to find such a weight, you may use one with maybe 0.5 g/ml loss in density if the corrosion layer is still there. Its use may then involve an error of not more than 3 - 5 %.

The worst damage may be done by careless stabilization work. One has to work very cautiously in order not to damage the remaining corrosion layer by dissolving or brushing.

The stabilization consists of repeated washing in EDTA-solutions of different pH, followed by brushing and repeated washing in distilled water until no chloride ions can be detected in the wash water. The weight is then thoroughly dried. It is adviceable to postpone the final coating of the specimen by varnish till after the density has been measured and other analyses have been carried out.

A detailed report of the stabilization work which was led by prof. Birgit Arrhenius will be published separately by her.

Many of the weights were analyzed by x-ray spectroscopy. As the weights were not freed from corrosion before analysis, the figures obtained refer to the surface exposed, i.e. that of the corrosion. The analyses must be judged as merely qualitative because of the soft ware used. The background of the spectra e.g. was subtracted manually instead of applying the complicated corrections possible by computer calculations. On collecting the spectra the electron ray was allowed to sweep a small area of the specimen. No attempt was made to select any special kind of corrosion or any special part of the weights for the analysis.

The figures of analysis are listed in the catalogue.

Typically some kind of lead bronze was used for the production of the weights and lead was found in most of the weights. One or two percent of zinc was often found in the specimens high in copper. This is thought to depend upon an error of analysis.

The zinc maximum used for the analysis is situated between two copper maximums and is difficult to free from the influence of the copper. Apart from this, the method of analysis is believed to give a true but somewhat crude picture of the alloy present in the weights measured.

The fact that the weight of an artefact coincides with some unit weight doesn't prove it to be a weight. Other criteria must be met with too:

- it can be shown to belong to a class of artefacts considered to be weights.

- some preferably simple relationship can be found to other objects found with it.

Not until you have found good evidence of the above types, you are entitled to speak of weights or weight sets. Subsequently you may try to establish a common unit weight, which, in turn, can be proved to belong to a system already known, maybe from ancient documents.

We have a good knowledge of the types of artefacts usually used as weights among the swedish iron, bronze and maybe lead objects. Many investigators have shown that the cubooctaedric bronze pieces as well as the bronze clad iron balls are indeed weights. For them the first task will be to establish the weight relationships in an statistically acceptable way. The random errors may often be large due to the presence of seriously damaged objects. You may, of course, disregard from such objects and concentrate on the very best ones. The important point is then how to choose your criteria. The above discussion suggests that the combination of density estimations with visual examination will offer some progress. Both are reasonably objective.

It should be stressed that introduction of the actual weight of the specimens as a part of the selection cannot be accepted.

Most recent investigators have realised that they have to be very critical when they select their material.

The most critical author is Steuer (1973) who actually discarded all weights of each size with the exception of one only, the very best one.

The great number of weights present in the Bandlunde find allows us to select more than one weight of each size, namely the ones classed as excellent after examination under the microscope which have also a density of 8.5 - 9 g/ml.

12 cubooctaedric weights out of a total of 78 fullfilled these conditions. They are listed in Table 3. The subunit for the weights was preliminaryly found to be around 0.35 g which figure was later corrected to 0.362 g for the weights "when found" and 0.352 g for the weights "after stabilization". The loss in treatment was thus - 2.8 %.

It is not selfevident which of these figures reflects best the state of the weights 1000 years ago.

The weightsystem in Bandlunde and elsewere

There is a considerable litterature regarding the weight systems during the time in question in Sweden and its neighbouring countries. In many cases, however, the criticism of the scources, the weights,leaves a lot to be desired.

The random errors of weights that have spent a thousand years in the soil are necessarily large and would have to be coped with by using large samples - which are not available. What can be done is evidently to rely upon the biggest finds. At present the finds of Birka and of Bandlunde as well as some preliminary figures from the Paviken find (Lundström 1981) are available to the author.

At the time in question there existed both Western and Eastern weight systems and a borderline between them may well have run across Scandinavia.

As to the Eastern system Herschend (1987) has analyzed the contemporary system of the Islamic countries. He gives a frame into which we have to try to fit our finds.

The Islamic weight system as described by Herschend derives from a weight reform issued in the year 696 by the Chalif Abd al-Malik. The unit weight is the mitqal = 4.24 g. Below, there was the legal dirhem defined as 0.7 mitqals = 2.97 g with its fractions.- The Russian solotnik 4.28 g is very similar to the mitqal. They may have been identical. Later a somewhat smaller dirhem of 2/3 mitqal = 2.83 g was in use.

In the material from Bandlunde we found among the small weights a unit of 0.352 or 0.362 g depending on the treatment of the weight before the weighing. Eight times this unit brings us to 2.82 or 2.90 g, that is to the dirhem. Twelve times will give 4.22 or 4.34 g. If we try the dirhem/mitqal proportion 0.7, we obtain for the mitqal 4.02 or 4.14 g.

KNOWING THAT THE MITQAL WAS 4.24 g IT IS EVIDENT THAT THE BEST FIT IS OBTAINED BY USING THE WEIGHT OF THE STABILIZED CUBOOCTAEDRIC OBJECTS AND BY ACCEPTING THE DIRHEM EQUIVALENT 1 DIRHEM = 2/3 MITQAL BUT ALSO THAT THE DIRHEM = 0.7 MITQAL = 2.97 g CANNOT BE RULED OUT WITH CERTAINTY. True, we may still have underestimated the systematic errors that may have develloped during the centuries in the earth the above conclusion seems as safe as could reasonably be hoped for.

The problem of the cubooctaedric weights having been solved, the picture of the small ball-shaped weights 4 - 13 g still remains very obscure. One would like to believe them to belong to same system too. Alas, the solution which gave a good fitting of the cubooctaedric weights into the Islamic system doesn't work equally well here.

Of course, rust has ruined many of these weights. In most cases it was deemed impossible to restore them well enough to obtain reliable estimates of the original weight. If the weight "when found" is used for the calculations a dirhem unit weight of 2.80 g is obtained, i.e. very close to the "practical dirhem" 2.83 g.

The five best weights of this class could, however be measured and their weight calculated. They are listed in Table 2. The result points towards the "legal dirhem" of 2.98 g. This dirhem was not found elswhere in the material.

At present, it seems, no certain conclusions regarding these weights can be drawn.

The measuring of the big ball shaped weights 13 - 160 g was accounted for by the author (1986). One could select 12 weights from a total of 34 available that were measured and calculated. 11 of these belonged to a system having a unit weight 4.19 - 4.23 g. (The twelfth gave a lower unit 4.03 g). The agreement with the mitqal is striking.

The finds from Birka and Hedeby

It is interesting to compare the weights from Bandlunde with those from other finds.

From Birka we have about as many weights as from Bandlunde. They have largely been recovered by sifting the soil which tends to leave the smallest objects underrepresented. Further, the weights stem from a whole period that lasted for some two centuries. The interesting question if there was a change in the weight system during this time is by no means settled and they cannot be settled until you have defined the weight systems accurately enough.

Generally speaking, the Birka cubooctaeders are more corroded than those from Bandlunde, which makes it more difficult to sort the weights according to size. Especially, the small cubooctaeders 1 - 2.5 g are not easily sorted in groups. They are evenly distributed over this region. From 2.8 to 4.2 g there are 6 weights available from the tables of Kyhlberg. They belong to his corrosion classes 1, 2 or 3 and have a density 8.5 - 9 g/ml. They seem to belong to a system where the unit weight "when found" is 2.86 g. This unit may well be a 2/3 mitqal dirhem.

The big ball shaped weights from Birka are shown by the author to have a common unit weight of 3.99 - 4.03 g, which can hardly have been identical with the 4.24 g mitqal.

Steuer (1973) published a study of the cubooctaeders from Hedeby. He examined the weights visually and choose the best one to represent its size. His results are included into Table 5.

Table 5 shows that the figures from all four of the sites are very similar to each others indeed. There is one exception only, the 4.0 g unit weights from Birka. This unit may be explained by the ladder theory of Herschend (1987). According to this theory, mitqals 5 % lighter and heavier than the original of 4.24 g existed. The Birka mitqal may be one of them but it may also have belonged to another system, perhaps Western. Less probable, it was part of a local system.

Supposing that the ball shaped weights were primarily used for silver trade, the low unit would mean that silver was 5 % more expensive in Birka than in Bandlunde.

It is sometimes supposed that the balances and small weights were to a large extent used for the weighing of gold. To me this doesn't seem probable regarding the multitude of weights and balances found. In the Vikingage gold is generally considered a fairly rare material. It seems much more probable that the balances were used for the control of silver coins and pieces. We know that a lot of toil was taken to control the silver objects by "hacking". We also know that the coins varied a lot in weight, which also called for control.

Islamic silver coins weighed about 3 g, the most common Western ones about 1.5 g.

The large number of weight of 1.4 g and of 2.8 g would thus be useful for the control of the coins.

On the symmetrical two armed balances both pans may be used for weights as well as for goods. For such balances weight sets where the ratio between two successive weight sizes is 3 are the cheapest. If you own e.g. the weights 1 - 3 - 9 - 27 - 81 units you can weigh anything between 1 unit and 121 units to the nearest unit weight using the five weights only. The Vikings were probably aware of that, as shown by the many pieces 1.4 - 4.2 - 12.7 and c.38 g found. The characteristic ratio of this series is 3.

It is clear, however, that some people preferred the set 1 - 2 - 3 - 4 - and so on. Perhaps, their training in adding and subtracting was not good enough? - Another explanation would be that a set with "all" weights made an impression of professionalism on the trade partner.

If the aim of the weighing was to control a few coins collected on one pan, only, the absence of fractional weight would be embarrasing. In the Bandlunde find only four of the pieces are smaller than 1.4 g. The metal detector would have revealed more of the small pieces if they had been there. We know that several of the slightly bigger 1.4 pieces were detected.

The explanation could be that people got rather tired of the small weights and their deplorable habit of disappearing. Instead, differential weighing would work. You put a 1.75 g or a 2.1 g weight on the one pan and 1.4 g on the other. The net will be 0.35 g or 0.7 g and the problem is solved.

Steuer (1984) points out that there must have been special circumstances that made it possible to maintain the apparently high standard of weights, balances and weighing during the Viking age in Scandinavia despite the probable lack of Governmental control. The explanation is supposed to be that the corpus of internationally active merchants exercized an effective control.

This may well be the case, but the Bandlunde find of weights belonging to the Islamic system suggests that there might have existed a real and competent weight control exercised by the powerful Islamic government. Bagdad, however, was far away from Gotland and so the immediate control of the weights was left to the trade partners themselves. Everybody wanting to take part in the silver trade had to acquire his own means of control if necessary by borrowing them. The man who owned a balance and weights, however, had anadvantage, he had plenty of opportunity of learning how to use them. He who hadn't had to compensate for his lack of knowledge by being very cautious and suspicious. The goods of trade very frequently bear witness of this cautiousness, the silver coins and pieces having been hacked with a knife, often several times. The coins were bent and marks were cut in their surface. Thus the interior of the coins was laid open for inspection. Evidently people knew that a coin could be forged not only by manufacturing it of lead but also by using low standard alloys of silver and by making it low in weight.

Evidently it was a matter of great importance to the Gotlander to ascertain that the silver he purchased - maybe for his hoard - was of good quality. Generally, he was very successful; forged coins are very rare in the Gotlandic hoards.

Summary

In 1983-1984, a big find of, among other things, 158 weights and a balance was made on the East coast of the island of Gotland on the farm Häffinds, Burs parish. The site was near the shore, which here forms a bay called Bandlundeviken. The place has evidently been a workshop area and a trading center in the Viking age. A big hoard of silver coins has earlier been found here. The weights have now been cleaned and stabilised.

From their shape and appearance they could be assorted into different classes:

- cubooctaedric pieces weighing from 0.7 to 4.5 grams, mostly manufactured from lead bronze.

- globular weights with two flattened polar areas, made of iron and clad with a thin sheet of lead bronze. They weighed from c. 4 - c. 160 g.

- leaden weights, mostly flattend spheres and coin shaped pieces.

- a few pieces of copper and some of lead and tin. They may have been used for weighing but they may also have been scrap metal pieces intended for the manufacturing of new weights.

- a collapsible balance.

For the analysis of the weight system mainly the very best objects were used. The equality of the cubooctaedric weights was judged by examination under the microscope and also by measuring their density. Twelve of the 78 weights were visually judged as "excellent" and, in addition, had a density of 8.5 - 9.0 g. They were shown to derive from a common unit weight of 2.92 g "when found" or 2.82 g "after stabilisation", both with a standard deviation of + 0.07 g and a standard error of the average + 0.025 g. The nominal weight of the Islamic trade weight the dirhem (2.83 g) is defined as two thirds of the mitqal weight that equals a dinar (= 4.24 grams) in the contemporary Islamic weight system.

The small bronze clad iron weights c. 4 - 13 g were generally in a very poor shape. The best ones, the volume of which could be measured and their weight calculated, 5 in number, seemed to belong to a system with a unit weight of 4.5 g whereas those badly corroded pointed to a unit weight about 4.2 g. The right figure cannot be established at present. The majority of the weights are simply not good enough. Some of the biggest ball shaped bronze clad weights were very corroded too. However, 12 of them were good enough to be measured and their weight calculated. Their polar faces were still intact and in place. Further, one or more "meridians" could be found where the original bronze surface was still virtually uncorroded and fit for measurements. These weights belonged to a system deriving from a unity weight of 4.19 or possibly 4.23 g. The Islamic mitqal was 4.24 g.

THUS, THE BANDLUNDE WEIGHT SYSTEM WAS IN ALL PROBABILITY IDENTICAL WITH THE ISLAMIC ONE WHERE THE MITQAL WEIGHED 4.24 g AND ITS SUBUNIT, THE "TRADE DIRHEM" WEIGHED 2/3 MITQAL OR 2.83 g. THE SAME SYSTEM WAS USED, AT LEAST FOR THE WEIGHTS UNDER 4.24 g INBIRKA, HEDEBY AND PAVIKEN.

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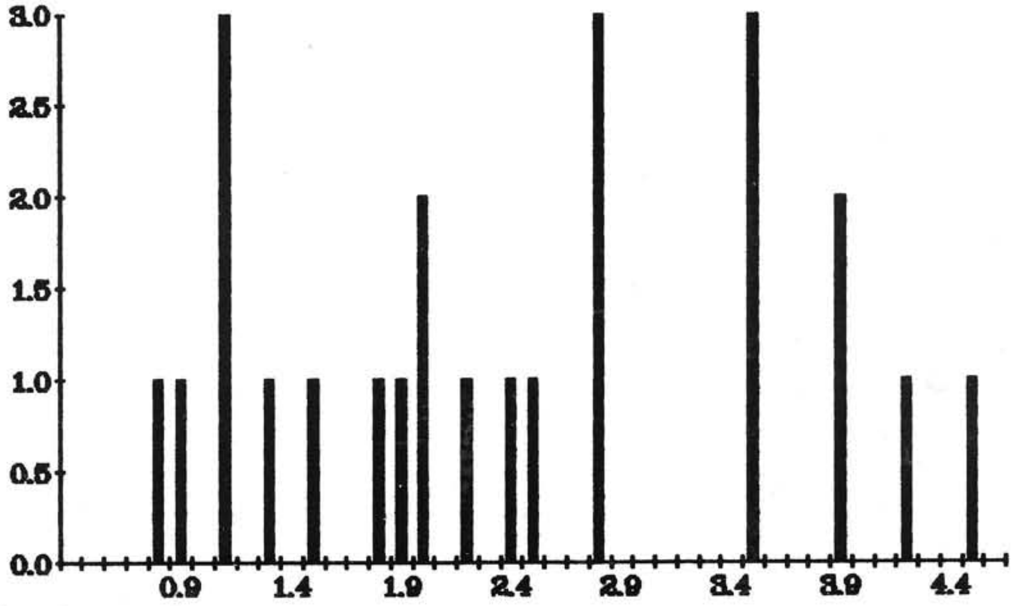
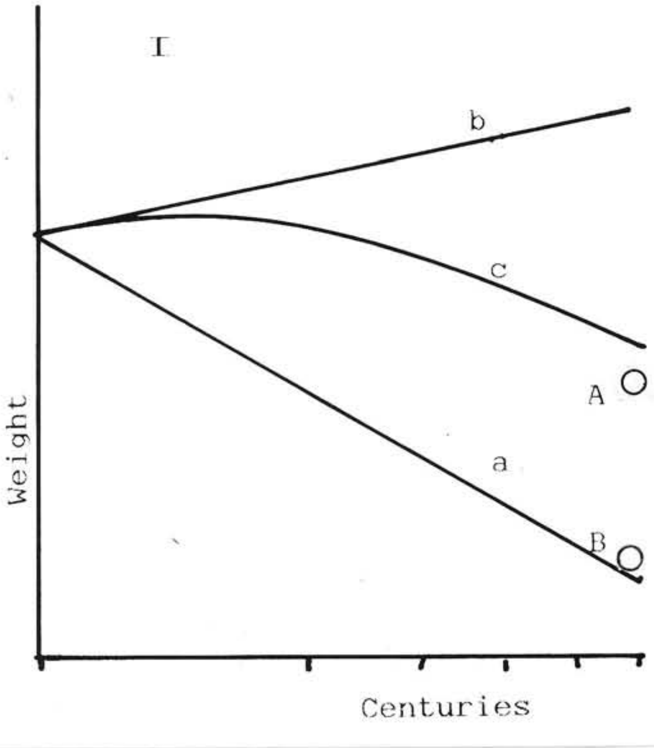


Fig 3. Cubooctaedric weights from Birka. Kyhlberg's data. "Before stabilization". State of corrosion 1, 2 or 3 acc. to Kyhlberg



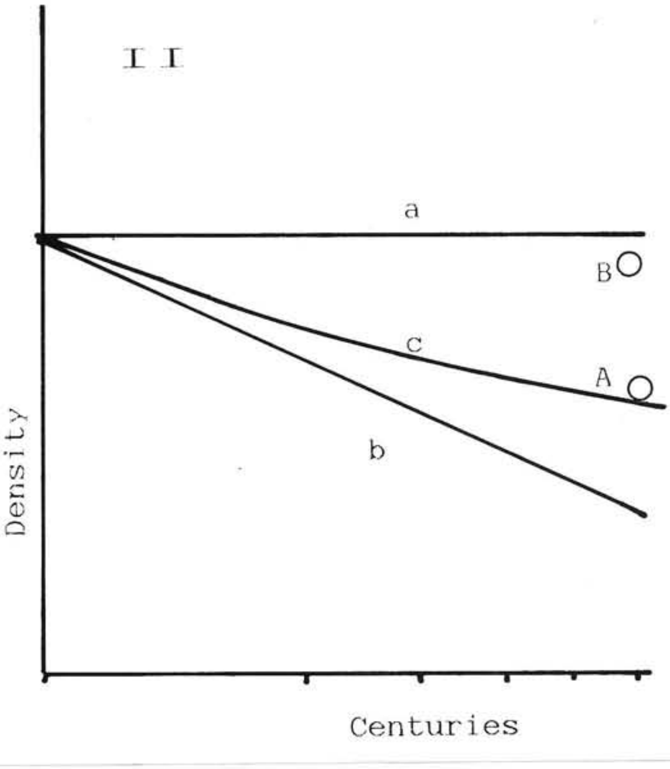


Fig 4. Result of the corrosion of a copper object in the soil. (The picture is qualitative only)

I. Weight of object vs. time (decades or centuries).
a Weight of remaining metal.
b Weight of object including corrosion products adhering to it if no losses occurred to the surroundings.
c Like b , but some corrosion products are continually being lost to the surroundings.

II. Density of the object vs. time.
a Density of the remaining metal.
b Density of object including corrosion products adhering to itif no losses occurred to the
c Like b, but but some corrosion products are continually lost.

Table 1
Ball shaped weights from Bandlunde.
Weight 4 - 13 g. Weight "when found". Provisional unit 0.70 g.

Number of units	Number of weights	Average weight	Unit weight found
6	3	4.437	0.740
8	1	5.754	0.719
10	2	6.871	0.687
11	4	7.691	0.700
12	6	8.227	0.686
13	3	8.926	0.687
14	1	9.617	0.686
15	2	10.437	0.696
16	2	11.227	0.702
17	5	11.976	0.704
18	3	12.704	0.706
		Average	0.699

Table 2

Ball shaped weights from Bandlunde.
Weight 4 - 13 g. Weights "after stabilization".
Weights measured and their weight calculated acc. to Sperber (1986)

Weight number	Number of units	Weight calculated	Unit weight found
15	6	4.60	0.767
256:1	10	7.447 (weighed)	0.745
19-33	18	12.59	0.699
8	18	13.70	0.761
144	18	13.61	0.756
		Average	0.746 ± 0.012

Table 3

Cubooctaedric weights from Bandlunde, density 8.5 -9, classed as "excellent", weighed "when found" and "after stabilization". Provisional unit weight 0.35 g.

Number of weight	Number of unit weights	Weight "when found"	Weight "after stab."	Unit weight found "when found"	Unit weight found "after stab"
18	3	1.077	1.070	0.359	0.357
1	4	1.412	1.358	0.353	0.340
348:10	4	1.449	1.391	0.362	0.348
142	5	1.731	1.664	0.346	0.333
348:7	5	1.821	1.763	0.364	0.347
294:6	6	2.294	2.184	0.382	0.364
209:1	6	2.257	2.206	0.376	0.367
72	8	2.869	2.784	0.359	0.356
348:3	8	2.872	2.805	0.359	0.351
132:1	8	3.020	2.962	0.378	0.370
174	10	-	3.076	-	0.358
348:2	12	4.124	4.033	0.344	0.336
			Average	0.362 g	0.354 g

Standard error of observation ± 0.012 g, of average ± 0.004 g.

Table 4

Increase of weight and volume of metals on corrosion.
The figures are the result of calculation and intended to express the magnitude of changes to be expected only.

Compound	Formula	Density g/ml	Increase in weight %	Increase in volume %
Iron	Fe	7.9	-	-
Rust	FeOOH	3.4	+ 60	+ 270
Copper	Cu	8.9	-	-
Cuprous oxide	Cu_2O	6.0	+ 13	+ 70
Cupric oxide	CuO	6.4	+ 25	+ 75
Verdigris	$CuCO_3$, $Cu(OH)_2$	4.4	+ 80	+ 270
Lead	Pb	11.3	-	-
Lead white	$2PbCO_3$, $Pb(OH)_2$	6.1	+25	+ 130

Table 5

Comparision between weight systems of Nordic sites. Cubooctaedric weights.

	Nominal weight, parts of a dirhem 2/4	3/4	4/4	5/4	6/4
Bandlunde, "when found", g	1.43**	2.27***	2.92***	-	4.13*
Bandlunde, "after stabil.", g	1.38**	2.20***	2.85***	3.56*	4.03*
Birka, "when found", g (Kyhlberg's data)	-	2.10***	2.81***	3.51**	4.23*
Hedeby (Steuer's data), g	1.45*	2.17*	2.86*	3.53*	-
Paviken, "after stabil." g	1.50*	2.12*	2.83*	3.64*	-
Dirhem (= 0.7 mitqal), g	1.48	2.23	2.97	3.71	-
Dirhem (= 2/3 mitqal), g	1.41	2.12	2.83	3.53	4.24

* Only 1 weight of this size available. ** Average of 2 weights of this size.
*** Average of 3 weights of this size .

The weights from Paviken were more corroded than the other weights. Hence, they are less reliable. The Paviken find included two ball shaped bronze clad iron weights that could be measured and calculated. Their calculated weight was 4.75 and 4.98 g. 7/4ths of a "2.83 g dirhem" would be 4.95 g.

THE CUBOOCTAEDRIC WEIGHTS FROM BANDLUNDE (GOTLAND, BURS, HAFFINDS)

1. Density 8.5 - 9.0 g/ml.

Find number	Material Cu	Sn	Zn	Pb	Density	Weight before	after	Marks	Colour	Surface	State	
18	85	4	6	5	8.77	1.077	1.070	none, drilled	brown	smooth	exc.	
256:7					8.73	1.333	1.318	2 p. frame,+1 p. 5-6 pcs	brown	rough	good	
1	86	-	11	3	8.66	1.412	1.358	none, drilled	90 bronze,10 rust	smooth+rough	exc.	
348:11	55	-	1	34	8.60	1.432	1.395	2 p.2-4 pcs.1 p.8 pcs	10 brown,90 green	mealy+smooth	good	
348:10	93	2	1	4	8.79	1.449	1.391	illegible	brown, rust	rough	exc.	
132:8					8.75	1.544	1.475	2p. frame,1 pc. rest illeg.	90 brown, 10 green	rough	good	
294:8	96	-	3	1	8.59	1.614	1.488	none, nearly illeg.	brown, rust	mealy	good	
156:9	68	-	4	28	8.87	-	1.588	3 p. 3? pcs,nearly illeg.	50 brown 50 green	rough	good	
294:7	88	2	7	3	8.59	1.652	1.634	3 p. 1? pc.,nearly illeg.	brown	smooth	good	pitted
142	87	1	9	2	8.70	1.731	1.664	2 p. 1 pc., 3 p. 3 pcs + 1 p. 5-6 pcs.nearly ill.	brown	smooth	exc.	
348:7	97	-	2	1	8.63	1.821	1.763	3 p. 6 pcs,nearly illeg.	80 bronze,20 black	rough	exc.	
132:4	98	-	1	1	8.56	1.962	1.945	2 p. frame, 6 st.near.ill.	50 brown,50 bluegr.	rough+smooth	good	
207:1	90	8	1	1	8.68	2.054	2.005	1 o. 3-4 pcs,nearly illeg.	brown	mealy	good	
208:1	45	-	3	52	8.68	2.102	2.008	2 p. 5 pcs	50 brown,50whitish	mealy	good	
294:6					8.96	2.294	2.184	3 p, 6 pcs +1 p. 1-2 pcs	80 brown,20 green	smooth+rough	exc.	
209:1	76	-	2	22	8.77	2.257	2.206	3 p. 4 pcs 2 p. 2 pcs	green	smooth	exc.	
72	90	-	9	1	8.73	2.869	2.784	4 p. 6 pcs	brown (brass)	smooth	exc.	
348:3	82	-	8	9	8.61	2.872	2.805	4 p. 6 pcs	brown	mealy	exc.	
3	94	-	3	3	8.71	2.984	2.919	4 p. 3 pcs 3 p. 2? pcs	90 brown,10 black	smooth	good	pitted
132:1	62	4	2	32	8.77	3.020	2.962	2 8. 3 pcs rest illegible	brown	mealy	exc.	
17					8.62		3.032	3 p. 3-6? pcs, rusty	90 bronze,10 rust	smooth	good	
146	73	1	3	23	8.70		3.188	4 p. 6 pcs	brown		good	
174	76	-	2	22	8.51		3.576	6 p. frame 6 pcs+1 p.8 pcs	90 brown,10 green	mealy	exc.	
348:2	68	-	2	30	8.76	4.124	4.033	6 p. frame 6 pcs	brown	mealy	exc.	

THE CUBOOCTAEDRIC WEIGHTS FROM BANDLUNDE
2. Density under 8.50 g/ml

Find number	Material Cu	Sn	Zn	Pb	Density	Weight before	after	Marks	Colour	Surface	State
196:15	31	-	2	66	8.26	0.709	0.693	1 p. 6 pcs	50 brown,50 whitish	rough	good
348:13	32	16	2	50	6.42	0.837	0.799	1 p. 6 pcs + 1 p. 1 pc.	50 brown,50 green	mealy	exc.
196:14					8.31	1.077	1.071	1 p. frame 6 pcs	green	mealy	good
348:9	48	-	2	50	8.12	1.456	1.262	1 p. 1 pc. rest illeg.	70 brown,30 green	mealy+smooth	good
196:13					7.79	1.374	1.343	1 p. 6 pcs + 1 p. 1 pc.	brown	rough	rough
196:12					8.50	1.383	1.361	2 p. frame 5-6 st.pcs	40 brown,60 green	smooth	good
204:1					7.74	1.426	1.369	1 o. 4 pcs drilled	50 brown,50 green	rough	good
2					8,42	1.404	1.378	2 p. frame 6 pcs	green	rough	exc.
348:12	39	17	8	36	8.47	1.416	1.395	2 p. frame 2-6 pcs	10 brown,90 green	rough	good
256:6	76	5	3	15	8.07	1.473	1.430	4 p. 1-2 pcs 2 p. 2pcs.	70 brown,30 green	rough+smooth	good
201:3	87		3	10	8.31	1.514	1.431	1 8. frame 6 pcs	80 brown,20 green	rough	exc.
294:9	28		2	70	8.15	1.569	1.478	3 p. 4 pcs rest illeg.	80 brown,20 green	rough+smooth	good
294:10					8.47	1.551	1.481	2 p. 1 pc? + 1 p. 1 st.	50 brown,50 green	rough	good
119					7.42		1.488	illegible, rust covered	brown, rusty	rough	poor
NF180d	56	42	3	-	7.21	1.559	1.513	2 p. 6 pcs	80 brown,20 green	rough+smooth	good
348:8					8.13	1.599	1.517	2 p. 6 pcs	50 brown,50 green	rough	exc.
196:10					7.97	1.566	1.530	illegible	20 brown,80 green	rough+smooth	good
132:7	59	3	6	32	7.56	1.618	1.546	2 p. frame 1 pc.rest ill.	brown	rough	poor
196:9					7.89	1.653	1.639	2 p.1-3 pcs rest illeg.	50 brown,50 green	rough	good
132:6					8.31	1.681	1.645	2 p. 6 pcs	90 brown,10 green	smooth+mealy	exc.
196:8					8.14	1.680	1.651	none	70 brown,30 green	rough+smooth	good
256:5					8.45	1.720	1.655	3 p. 5-6 st.	20 brown,80 green	mealy+rough	good
211:1					8.28	1.768	1.756	3 p.frame 5-6 pcs+1 p.4-6	60 brown,40 green	mealy	good
132:5					8.39	1.891	1.824	3 p. 1 pc. rest illegible	30 brown,70 green	rough	poor
205:1	67	-	3	30	7.35	1.955	1.855	illegible	80 brown,20 green	very rough	poor
248:5					5.69	1.912	1.864	2 p. 2 pcs rest illegible	20 brown, rusty	smooth+rough	very poor
5					5.28	2.201	1.951	3 p. 3 pcs nearly illeg.	green	rough	good
196:6	53	18	2	25	8.17	2.107	2.001	3 p. frame 6 pcs	green	rough	good
196:7	19	19	3	59	7.98	2.099	2.053	3 p. 6 pcs	50 brown,50 green	rough+smooth	exc.
348:6	71	16	4	15	7.87	2.161	2.062	illegible, thick rust			poor
203:3					6.74	2.150	2.077	3 p. 5 pcs rest illegible	50 brown,50 black	mealy+smooth	good
196:5	75	-	2	23	8.27	2.185	2.176	3 p. frame 6 pcs	50 brown,50 green	rough	exc.
196:4					8.39	2.225	2.192	illegible	green	rough	poor
132:3					6.89	2.287	2.195	4 p.frame 6 pcs+1 p.8 pcs	brown	mealy	exc.
210:5					7.73		2.385	none	50 brown,50 green	mealy+smooth	good
210:4					8.11	2.535	2.482	illegible	green	mealy	good
348:5	94	-	2	4	7.92	2.573	2.489	none	80 brown,20 green	rough+smooth	good
210:3					8.26	2.552	2.490	4 p. 5-6 pcs+ 2 p. 2 pcs	30 brown,70 green	mealy	good
348:4	89	-	3	9	8.38	2.758	2.539	3 p. 2? pcs nearly illeg.	80 brown,20 green	rough+smooth	good
248:7					6.17		2.572	illegible, thick rust			very poor
201:2	62	8	6	24	7.89	2.808	2.665	4 p.frame 1 pc+1 p.6-8 pc.	50 brown,50 green	smooth	good
132:2					8.40	2.760	2.696	4 p. 5-6 pcs. 3 p. 1 pc?	90 brown,10 white	mealy	exc.
203:2	50	10	-	40	7.81	2.907	2.698	none? frame 6 pcs.	90 brown,10 green	rough+mealy	poor
108:1					8.34	2.836	2.732	2 p. 2 pcs. nearly illeg.	50 brown,50 green	mealy+smooth	exc.
56					7.62	2.950	2.813	4 p. frame 6 pcs.	brown	smooth	exc.
43					7.60	3.066	3.032	? p. 1-2 pcs.	60 green,40 black	mealy+smooth	good
59					6.84		3.162	illegible, thick rust			poor
210:2					6.07	3.451	3.313	illegible, thick rust			very poor
334:9					6.25	3.392	3.335	illegible, thick rust			very poor
206:1					8.29	3.774	3.667	6 p.frame6 pcs.+1p.8 pcs.	20 brown,80 green	rough+smooth	good
60					6.53		3.951	6 p.frame1 pc.rest.illeg.	20 brown,80 rus	smooth+	good
196:2	73	1	1	24	8.46	4.215	4.180	4 p. 2 pcs. o 2 pcs. 5 p. 2 pcs. + 3 p. 8 pcs. 2 pcs. +3 p. 8 pcs.	brown	mealy	exc.
4					8.30	4.467	4.446	9 p. 1 pc.8 p. 1 pc. 5 p. 1 pc.	50 brown,50 green	rough	good

p ring mark, diam. c. 1 mm. o ring mark, diam. c 1.5 mm.
8 double ring mark, diam. c. 1 mm.
Letters before the + refer to the squares, letters following the + refer to the triangles of the weights.

THE BALL SHAPED WEIHGTS FROM BANDELUNDE (GOTLAND, BURS, HÄFFINDS)

Find number	Weight before	Weight after	Material	Measured/calculated weight	
15	4.279		bronze-iron	4.60	
334:8	4.488		bronze-iron		
334:7	4.545		bronze-iron		
128	5.754		bronze-iron		
294:4	6.815		bronze-iron		
249:2	6.927	8.532	bronze-iron		
256:1	7.447	7.359	pure bronze		dens. 8.73
294:3	7.590		bronze-iron		
9	7.841		bronze-iron		
348:1	7.886		bronze-iron		
196:1	8.024		bronze-iron		
131	8.035		bronze-iron		
19	8.235		bronze-iron		
334:6	8.311		bronze-iron		
201:1	8.334		bronze-iron		
93	8.423		bronze-iron		
203:1	8.806		bronze-iron		
210:1	8.833	8.645	bronze-iron		
334:5	9.138		bronze-iron		
26	9.617		bronze-iron		
46-50	10:288		bronze-iron		
248:2	10.566	10.446	bronze-iron		
334:3	11.087		bronze-iron		
19-33	11.366		bronze-iron	12.59	
294:2	11.701		bronze-iron		
248:1	11.855	11.684	bronze-iron		
23	11.964	10.646	bronze-iron		
8	12.178	11.899	bronze-iron	13.70	
11	12.180	11.277	bronze-iron		
144	12.482		bronze-iron	13.61	
334:2	12.774		bronze-iron		
155	12.857		bronze-iron		
109	13.557		bronze-iron		
NF180c	13.620		bronze-iron		
22	14.877		bronze-iron		
10	15.918	14.793	bronze-iron		
57	16.154		bronze-iron		
202:1	17.248	19.927	bronze-iron		
117	20.183		bronze-iron	16.65	
13	21.197	21.618	bronze-iron		
NF281c	22.115		bronze-iron		
12	23.370		bronze-iron		
NF180b	24.614		bronze-iron		
14		25.099	bronze-iron		
16		27.150	bronze-iron		
NF281b	29.600		bronze-iron		
153	30.78	32.493	bronze-iron	33.98	
294:1	30.821		bronze-iron		
NF180a	32.320		bronze-iron	34.63	
249:1	33.594		bronze-iron		
80	34.685		bronze-iron		
334:1	36.613		bronze-iron		
129	37.012		bronze-iron		
21	38.00		bronze-iron	40.30	
166	38.556	37.947	bronze-iron	42.98	
148	39.348		bronze-iron		
25	57.722		bronze-iron	57.59	
40		73.60	bronze-iron	76.68	
NF281a	90.58		bronze-iron		
20	95.55	96.91	bronze-iron		
24	142.13	143.73	bronze-iron	144.2	
108		162.79	bronze-iron	150.6	

VARIOUS WEIGHTS AND SIMILAR ARTEFACTS FROM BANDLUNDE (GOTLAND, BURS, HÄFFINDS)

Find number	Form	Material Cu	Sn	Zn	Pb	Density	Weight before	Weight after	Marks
196:11	cubooct		bronze			5.41	1.515	1.490	pin head
104	cylinder	18	35	6	11	7.0	1.526	1.474	none
203:4	coin form		bronze			6.66	1.674	1.567	3 p. on both sides
108:2	coin form		lead			10.7	1.886	1.640	none
294:5	cube, no corners		lead			10.5	2.954	2.839	none
91	cylinder		lead			10.48		3.123	
364:3	cylinder		lead		99	10.8	3.304	3.201	
74	coin form	1	74	-	24	7.09	3.344	3.280	soft solder?
95	cylinder		lead			10.5		4.096	o 1 side
176	1/2 cyl.	76	21	3	1	5.75		4.275	
213	cube		lead		100	10.83	4.411	4.314	
364:2	ball form	1	52	-	47	7.67	4.856	4.727	soft solder?
135	low rect.		lead			10.8		7.318	
151	irregular	98	-	2	-	8.72	9.900	9.496	scrap copper?
15			bronze			8.72		9.5	
11	1/2 cyl.		lead			10.0	12.18	10.15	