The weights found at the Viking Age site of Paviken, a metrological study

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The excavation in 1967—73 of the Viking age site Paviken by Per Lundström revealed a multitude of activities in commerce and crafts. Among the thousands of finds were 40 weights of bronze or lead. The analysis of the weights has shown that they presumably belonged to the system of *mitqals* and *dirhems* legalized in A. D. 696/97 by the Chalif Abd-alMalik. The same system was presumably in use also at Bandlunde on the Gotlandish East coast as well as in Birka and Hedeby.

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On the West Coast of Gotland near the small community of Västergarn, the remains of a Viking age working and trading area have been partly excavated by Per Lundström of The National Maritime Museum in Stockholm. His book *De kommo vida...* gives a broad, partly detailed account of the finds.

The numerous artefacts recovered, included 40 weights belonging to the types often found on Viking age sites. There are mainly three such types:

1. Ball shaped weights of iron with flat polar faces, clad with a 0.5—1 mm thick layer of bronze. Sometimes they consist of solid bronze. They usually weigh between 4 g and 200 g. In Paviken, seven such weights were found.

2. Cubo-octaedric weights of bronze, usually lead bronze, sometimes, however, tin bronze or brass. These weights were probably cast in a mould. If necessary, their weight was adjusted to the right value with the help of a file. They weigh up to 4.2 g. Only very few heavier pieces have been found. If there is a low weight limit, it was probably set by the sensitivity of the commercial balances then in use.

In Sweden the balances commonly used typically had a sensitivity of 0.1—0.2 g at small loads and about 2 % at high loads, say 100 g or so. At Paviken 16 weights of this type were found. (The term cubo-octaedric is to be preferred, being a geometrically exact description of the weight form. The word polyedric which is commonly used merely refers to a body with many surfaces.)

3. Leaden weights of many different shapes and sizes. The small ones, some below 1 g are often shallow cylinders, "coin shaped". Sometimes they have a centre hole. Some have pits in their surfaces to make them recognizable by their user. Whereas weights with a bronze surface are usually decorated the leaden weights are not. Probably the leaden weights were the less accurate also when new.

Forty weights of high quality would suffice to establish and prove a weight system. Unfortunately, however, the Paviken weights are rather severely corroded so the present work had to concentrate on their assignment to an existing weight system, in this case the Islamic system of the Chalif Abd-alMalik, or proof that they do not fit.

Such work has to start with a critical examination of the material, combined with some knowledge of what may have happened to the items during the 1000 years in the soil. The best weights, only, should be allowed to influence the judgement and poor specimens must not disturb the conclusions.

As regards the much larger and far better preserved find from Bandlunde, only 12 out of

the 78 cubo-octaeders passed the two examination steps and were used for the defining of the weight system to which they belonged. For the Paviken find the limits had to be set much lower. Finally, seven out of 16 weights could be accepted as useful for the defining of the weight system.

The bronze covered iron weights

There are seven weights in this category. Two of them, numbers 23 and 18, did not, however, resemble the others. They are small ball segments, weighing only 1.23 and 1.82 g. The inside iron has turned into rust, which has greatly expanded and laid the interior of the weights wide open. In their present state they can give very little information regarding the weight system.

Two other weights with illegible registration numbers, weighing 4.67 and 4.35 g, are relatively well preserved. Their volumes could be measured and their original weight calculated to 4.99 and 4.75 g respectively. If they were intended to represent the same size, their average weight was 4.87 g. In the Islamic system there are few probable sizes among which to choose. Seven quarters of a 2.83 g *dirhem* may be the best candidate =4.95 g.

Weight number 22 is an iron weight without a bronze cover. At present it is only a lump of rust yielding no exact information. Its present weight is 22.98 g, roughly corresponding to a 6 *mitqal* weight of about 25 g.

The last ball shaped weight is in a reasonably good condition. Its registration number could not be read. It now weighs 31.79 g. Its volume could be measured along three ''meridians'' and its weight calculated to 33.32 g. Assuming it to be an 8-*mitqal* weight, a value of the *mitqal* can be calculated =4.17 g in reasonable agreement with the commonly accepted value, 4.245 g.

The cubo-octaedric weights

The cubo-octaedric weights are all of bronze, often lead bronze, sometimes tin bronze or brass. In the Paviken find no determinations of the chemical composition were carried out.

The density, however, was estimated by weighing the pieces in benzyl alcohol, density 1.046 g/ml. The weights were first freed from protective varnish by washing in acetone. Afterwards the varnish layer was restored.

The original density of the bronze weights is believed to have been 8.7–8.8 whereas all possible corrosion products have a much lower density, often around 6 g/ml or even less. A low density of a weight recovered from the soil therefore indicates that a thick corrosion layer is adhering to it. If the corrosion layer is removed, the original metal density will be restored but the weight has suffered irreparable damage. This result will be the same regardless of whether the corrosion is removed mechanically, by dissolution into the ground water, during the stabilization procedure, or otherwise.

The present state of the corrosion will therefore have to be controlled by visual examination, preferably under a low power stereo microscope (e.g. 5–10 times magnification).

All of the Paviken cubo-octaeders show a fairly low density (8.31 g/ml at most) indicating that nowadays even the best weights contain some 15 % of their weight of corrosion products, the corresponding figure for the worst specimens being around 50 %. In comparison, in the Bandlunde find 24 out of 78 cubo-octaeders had a density of 8.5–9.0 g/ml, indicating that no more than some 10 % of the weight consisted of corrosion products.

Notwithstanding, seven out of the 16 Paviken cubo-octaeders were classed as excellent. (This word may not have exactly the same meaning in Paviken as in Bandlunde). They are listed in Table 1. The figures of Table 1 are consistent with a weight of a *dirhem* of 2.91 g which is slightly higher than the expected value 2.83 g (2/3 *mitqal*) or slightly lower than the expected value 2.97 g (0.7 *mitqal*).

The leaden weights

As was pointed out, leaden weights cannot be expected to have been manufactured with the same high precision as the bronze weights. The mere absence of decorations indicates that the workman did not care to make the weights better or more expensive than was necessary.

At least two different alloys have been used when manufacturing leaden weights as re-

Table 1. "Excellent" cubo-octaedric bronze weights from Paviken. Stabilized. Weight in grams. — "Utmärkta" kubooktaedriska vikter från Paviken. Konserverade. Vikt i gram.

Nr.	Weight	Size *dirhems*	Weight calcul.*	Difference *	**
26	2.649	7/8 (?)	2.48	+0.169	+0.101
27	2.565	7/8	2.48	+0.089	+0.017
40	2.537	7/8	2.48	+0.061	—0.011
39	2.123	3/4	2.12	+0.001	—0.061
?	1.815	5/8	1.77	+0.046	—0.005
35	1.748	5/8	1.77	—0.021	—0.072
31	1.498	1/2	1.42	+0.083	+0.042
Average				+0.06 ±0.042	

* *Dirhems* of 2.83 g (2/3 of a *mitqal*) were tentatively used.
** *Dirhems* of 2.91 g (average of these weights) were tentatively used.

Table 2 A. Leaden weights under 4.25 g. — Blyvikter under 4.25 gram.

Nr.	Weight found	Size *dirhems*	calcul.*	Weight diff.	calcul.**	diff.
5	3.436	5/4	3.54	—0.10	3.71	—0.27
7	3.244	9/8	3.18	+0.06	3.34	—0.10
12	2.834	1	2.83	0.00	2.97	—0.14
15	2.574	7/8	2.48	+0.10	2.60	—0.03
14	2.226	3/4	2.12	+0.11	2.23	0.00
11	1.480	1/2	1.42	+0.06	1.48	0.00
8	1.259	1/2	1.42	—0.17	1.48	—0.22
Average				+0.01 ±0.04		—0.11

* Based upon a *dirhem* weight of 2.83 g.
** Based upon a *dirhem* weight of 2.97 g.

Table 2 B. Leaden weights over 4 g. Density 9 g/ml. — Blyvikter över 4 gram. Täthet 9 g/ml.

Nr.	Weight found	Size *mitqals*	Weight* calcul.	Difference grams	%
1	103.25	24	101.76	+1.49	+1.4
2	102.81	24	101.76	+1.11	+1.1
3	51.4**	12	50.88	+0.52	+1.0
9	8.496	2	8.48	+0.02	+0.2
4	6.396	1.5	6.36	+0.04	+0.6
10***	5.828	1.33 ?	5.65	+0.18	+3.1
		(1.43 ?	6.06	—0.23	—4.0)
Average				+0.56	+1.2
				(+0.49)	±0.4

* Based upon a *mitqal* weight of 4.245 g.
** The calculated weight of a large patch of rust adhering to the weight has been deducted = 1.0 g.
*** The weight was probably intended to represent 2 *dirhems* i.e. 1.33 or 1.43 *mitqals*.

vealed by their density. Pure lead has a density of 11.4 g/ml while the density of tin is 7.3 or lower (there are other allotropic modifications of tin with lower densities).

To ensure that the group of leaden weights remains as homogeneous as possible, I have chosen to consider only the weights with high density. The main reason is that a low density found may depend upon the presence either of tin or of large amounts of corrosion products. Lead corrosion products show a low density similar to that of e.g. copper corrosion.

In addition, the alloy between lead and tin, soft solder, was in common use for the repairing of the multitude of brooches and other bronze objects characterizing the Viking age society. Generally it is not possible to recognize the intended use of a lead-tin alloy specimen unless it has a characteristic form.

The corrosion products of lead are as a rule whitish. They are very often discoloured by iron compounds or copper compounds which make them slightly brownish or bluish. They tend to be fairly tough and do not easily flake as do many copper products. Corroded lead objects retain their original form rather well.

Thus, there are reasons to treat the pieces of high density separately. The limit for "high density" was — of course arbitrarily — set at 10 g/ml.

Using these criteria the following artefacts were classed as weights: The pieces 1, 2, 3, 5, 7, 10, 12 and 15 because of their high density. The pieces 7, 8, 11, 14 and 15 because of their form.

In addition, Lundström already identified artefacts numbers 1, 2 and 3 as probable weights of the sizes 1/2, 1/2 and 1/4 marks which corresponds to 24, 24 or 12 *mitqals* in the Islamic weight system of Abd-alMalik. All these weights are listed in Tables 2 A and 2 B. The weights below 4.25 g in Table 2 A fit well into the system based upon the 2.83 g *dirhem*.

The weights listed in the Table 2 B give an independent value for the *mitqal* = 4.30 g, a figure about 1 % higher than the usually accepted 4.245 g, showing that losses of lead have been low at Paviken. It also corroborates the general belief that lead has a very low tendency to migrate with the ground water as distinct from copper, zinc and especially iron which readily

leach, mainly in the form of divalent ions.

Unfortunately, the series of weights does not pass Holm's test (Herschend 1987) which would exclude them from being a random series of figures.

were identical although all figures of the table may not be statistically significant.

There were two possible *dirhem* unit weights, differing by only 5 %.The complex systematical errors arising from the long sojourn in the soil

Table 3. Comparison between the weight systems in some Nordic sites. — Jämförelse mellan viktsystemen i nordiska handelsplatser

	Nominal weight, parts of a *dirhem*				
	$^2/_4$	$^3/_4$	$^4/_4$	$^5/_4$	$^6/_4$
Bandlunde, before stab.	1.43**	2.27**	2.92***	—	4.13*
Bandlunde, after stab.	1.38**	2.20**	2.85***	3.56*	4.03*
Birka, before stab. (Kyhlberg's data)	—	2.10***	2.81***	3.51**	4.23*
Hedeby,(Steuer's data)	1.45*	2.17*	2.86*	3.53*	—
Paviken,bronze weights after stab.	1.50*	2.12*	2.83*	3.64*	—
Paviken,leaden weights	1.37**	2.26*	2.83*	—	
Dirhem (= 0.7 *mitqal*)	1.48	2.23	2.97	3.71	
Dirhem (=2/3 *mitqal*) 1.42	2.12	2.83	3.53	4.24	

* Only one weight of this size available.
** Average of two weights of this size.
*** Average of three weights of this size.
All weights are expressed in grams.

Tables 2 A and 2 B give us an independent possibility of comparing a Gotlandish *dirhem* with a Gotlandish *mitqal*. The comparison is unusually free from objections. We are able to compare two sets of weights from the same material which have been close to each other in the soil, be it for a very long period.

We find that a *dirhem* of Paviken weighs 0.66 *mitqals* or nearly exactly 2/3 of a *mitqal*. Expressed in modern units, the *dirhem* weighs 2.83 g if the *mitqal* is set at 4.245 g.

Comparison between finds of weight sets from important sites in Scandinavia

The weights from Paviken should be compared with other important finds of weights in Scandinavia.

Such finds from Birka and from Hedeby have been evaluated by Kyhlberg and by Steuer. In addition the large find from Bandlunde has been critically examined by the present author. Some main results are compiled in Table 3.

There seems to be no reasonable doubt that the local weight systems of these important sites makes it difficult to decide which one was used in Viking age Scandinavia. The find of Paviken, however, speaks in favour of the light *dirhem*, the one of 2.83 g. It was used with the *mitqal* of 2.245 g.

References

Lundström, P. 1981. *De kommo vida... Vikingars hamn vid Paviken på Gotland.* Statens Sjöhist. Museum rapportserie 22. Stockholm.

Kyhlberg, O. 1980. Vikt och värde. *Stockholm studies in archaeology.* Stockholm.

Herschend, F. 1987. Metrological problems. *Tor 21.* Pages 182 and 220. Uppsala.

Sperber, E. 1988. The Find from Bandlunde, Gotland... *Laborativ arkeologi 3.* Pages 65 ff. Stockholm.

Steuer, H. 1973. Das archäeologische Fundmaterial II. *Berichte über die Ausgrabungen in Haithabu 6.* Pages 9 ff. Neumünster.

The weights from Paviken, list

1. The bronze clad iron weights. — De bronsklädda järnvikterna.

Number	Diam.	Height	Weight found	Weight calcul.
?	21.26	14.9	31.79	33.93, 34, 32.58 Av. = 33.3
21	**		22.98	
22	*		12.98	
?	11.28	7.96	4.67	4.98, 5.00 Av. = 4.99
?	10.99	7.81	4.35	4.74, 4.75 Av. = 4.75
18	**		1.82	
23	8.67	4.27	1.23	

* Rectangular, no bronze cover.
** Not measurable.

2. The cubo-octaedric weights. — De kubooktaedriska vikterna.

Number	Weight	Density	Marks	Colour	State
24	3.615	7.48	6 p, frame, 6 pcs frame, 8 pcs	gr, br	poor
37	3.355	7.51	3 p, 3–4 pcs, 1 p, 1 pc	bl, gl	good
25	3.648	8.22	6 p, frame, 6 pcs	bl, br	good
28	2.832	8.27	4 p, 6 pcs	bl, rd	good
27	2.565	7.91	4 p, frame, 6 pcs	br, bl	exc.
40	2.537	8.08	3 p, 6 pcs	br	exc.
39	2.123	8.03	3 p, frame, 6 pcs	bl, gl	exc.
30	1.637	7.93	2 p, frame, 6 pcs	br, gl	good
38	2.319	7.73	3 p, 1 pc, rest illegible	gr	poor
29 ?	2.407	7.96	3 p, ? pcs rest illegible	bl, br	poor
26	2.649	8.31	4 p, 6 pcs	bl	exc.
?	2.44	7.45	4 p? frame? near illegible	gr	poor
35	1.748	8.12	3 p, frame, 6 pcs	bl, gl	exc.
31	1.498	7.91	2 p, 6 pcs	gr, bl	exc.
?	1.815	not est.	3 p, frame, ? pcs	bl	exc.
?	1.831	not est.	3 p, ? pcs	bl	poor

p = ring mark in square; gr = green; br = brown; bl = black; rd = brick red; gl = glossy.

3. Leaden weights. — Blyvikter.

Number	Weight	Diam	Height	Densuity
1	103.253	29–30	14	11.21
2	102.806	30	15–17	10.84
3	52.396	24–26	10–11	10.14
4	6.396	13	6	9.52
5	3.436	11	4	10.48
7	3.244	12**	3.5	10.19
8	1.259	8*	3	9.17
9	8.496	14.5	7	9.14
10	5.828	11.5	7	10.75
11	1.48	12*	3	6.81
12	2.834	11	3	10.81
13	1.996	10	4	9.26
14	2.263	11	3	9.56
15	2.574	10 × 7.5***	4	10.71
41	8.397	13	7.5	9.88
43	5.258	16.5	6	6.05
6 (?)	0.526	9	2	6.32

* A 2 mm hole in the centre of the weight.
** A 2.5 mm hole in the centre of the weight.
*** The surface is rectangular.

Sammanfattning

Vid studiet av arkeologiska fynd som kan identifieras som vikter men som skadats under vistelsen i jord m. m. är det viktigt att såvitt möjligt finna metoder att objektivt utvälja de bästa vikterna som kan förväntas ge de tillförlitligaste upplysningarna om det viktsystem de tillhör. För vikter av bly eller kopparlegering ger bestämning av densiteten god ledning tillsammans med visuell granskning av föremålen under stereomikroskopet för att fastställa om delar av korrosionen förlorats eller eljest avlägsnats.

För vikterna från Paviken kunde konstateras att bronsföremålen farit illa i jorden medan blyföremålen klarat sig bra. 20 till 50 % av bronsföremålens nuvarande vikt torde bestå av korrosionsprodukter.

Av bronsvikterna kunde de 7 bästa av de 16 kubooktaedriska vikterna visas tillhöra det viktsystem som kalifen Abd-alMalik fastlade år 696/97. Detsamma gäller de 13 bästa av de 17 vikterna av bly .

Undersökningen visar att ett arabiskt viktsystem användes under långa tider i Paviken. Enhetsvikten var en *mitqal* à 4.245 gram. De kubooktaedriska vikterna tillhörde med stor sannolikhet enhetsvikten *dirhem* som var 2.83 gram eller två tredjedels *mitqal*.

Kubooktaedriska vikter funna vid Bandlunde på Gotland samt i Birka och i Hedeby har visats tillhöra samma viktsystem, *dirhem* à 2.83 gram även om en dirhemvikt av 2.97 gram =0.7 *mitqal* inte helt kan uteslutas.