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A BRONZE STEELYARD WITH AN ACORN-SHAPED COUNTERWEIGHT FROM THE PAPHOS AGORA

Abstract: *Steelyards were commonly used by sellers at agorae and fora during the Roman and Byzantine periods. They are based on the principle of the lever, mentioned by Aristotle and probably well-known even earlier. One steelyard made of bronze has been found, together with an acorn-shaped counterweight, at the agora of Nea Paphos during an excavation conducted by the Department of Classical Archaeology, Institute of Archaeology, Jagiellonian University. Also preserved were fragments of chain and two hooks that were used to hang the weighted objects, as well as fragment of a third hook. The device represents the Pompeian type of steelyard and can be dated by analogy to other examples from the 1st century AD. The Paphos balance may be evidence of the use of a local island weighting system based on an operating unit other than the Roman pound (libra).*

Keywords: *Steelyard; acorn-shaped counterweight; Cypriot pound; Paphian pound; weighing systems*

Introduction

In 2011 an archaeological expedition from the Jagiellonian University in Krakow (JU) joined numerous archaeological missions operating in the ancient city of Nea Paphos on Cyprus. The excavation works are being carried out by the Department of Classical Archaeology of the JU Institute

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of Archaeology within Paphos Agora Project and directed by Professor Ewdoksia Papuci-Władyka.[1] The main objective of the mission is to examine the agora of the ancient city, verify the time of its existence, restore the functioning of its public space, and particularly to determine whether the Roman agora had been preceded by a Hellenistic one hidden underneath it (see Papuci-Władyka *et al.* forthcoming).

The first season of the research work has already resulted in great findings, not only in the form of numerous architectural remains, but also many portable, sometimes very valuable, objects. The latter include a small bronze balance discovered in July 2011, belonging to the type known as a Roman balance or a steelyard.[2] The balance along with an acorn-shaped weight (Pl. 1: 1) was discovered within context 103 of Room 2 in Trench II, which from the east adhered to the *crepidoma* of the east portico of the agora (Papuci-Władyka and Machowski 2016). It is noteworthy that in 2012 a rectangular lead weight was found in Room 3 (adjacent to Room 2 from the south), which contained an inscription mentioning *agoranomos* Seleukos, the son of Ioulios Bathylos (Papuci-Władyka and Machowski 2016).[3] This fact may be proof of the existence of an agora in the researched site. The ceramic material from the mentioned context 103 was very abundant with prevailing Early Roman pottery and few contamination of earlier and later periods. On extraction, both the balance and the acorn-shaped weight were in very good condition, and were both moved to the Paphos District Museum and labelled with the following inventory numbers: PAP/FR 3/2011 (steelyard) and PAP/FR 5/2011 (weight). The maintenance work performed by Associate Professor M. Biborski made it possible to acquire much more information, previously concealed under a layer of corrosion and contamination.

[1] The project is financed by the Narodowe Centrum Nauki (NCN – National Science Centre, Poland) grant OPUS NCN 2011/01/B/HS3/01282 (years 2011–2014) and MAESTRO NCN 2014/14/A/HS 3/00283 (years 2015–2019).

[2] M. Wacławik conducts the larger project on *Weighing systems in the Mediterranean in the Roman and Early Byzantine Periods* financed by NCN grant PRELUDIUM 2014/15/N/HS3/0136.

[3] This weight will be published by A. Twardecki from the Warsaw National Museum (Twardecki forthcoming).

Description of the steelyard from Paphos Agora

The steelyard from Nea Paphos consists of: 1. an arm with two hooks, 2. fragments of a chain and a third hook, 3. an acorn-shaped weight (Pls. 1: 2, 2: 1).

1. The bronze arm of the balance is quadrate in section. The total length of the entire device is 15.8cm and its total weight 66.3g. The arm is divided into two parts: the longer one is 12cm long, 0.72cm wide and is terminated with a spherical knob. The other part of the arm is flattened at the length of 3.8cm and thereby expanded by 0.848cm. It is terminated with an annular opening whose outer and inner diameters are 1.77cm and 0.7cm, respectively. The larger opening adheres to another smaller opening with diameters of 1.3cm and 0.6cm, respectively. It also adheres to an annular aperture through which the hook hanger is threaded. On the other side of the arm, in the place where the second opening terminates, there is a third opening with diameters of 1.4cm and 0.7cm to which another hook was attached. At present, its mounting is damaged to the extent that it is impossible to attach the hook to the arm of the steelyard without prior reconstruction work. Where the quadrate part of the arm meets the flattened part of the arm, there is a rim made of wire entwined around the arm, and on which the weight was probably suspended. The quadrate part of the arm has engraved markings of two scales, both read from left to right. The order of grooves on the first scale referred it to the opening that was located further on the arm and on which the weighed goods were suspended. This scale was used for weighing lighter loads. The other scale, located on the other side of the arm and connected to the opening more proximal to the end, was used to determine the weight of heavier goods (see calculations below). The smaller hook (5.2cm long) is made of a single piece of quadrate wire, flattened and bent into a suitable shape. On the mounting site, it is only wrapped into a loop and otherwise left in its original shape. The other hook (7.3cm long) is of a slightly different construction. It is made of a more defined original wire that is quadrate in cross-section and the curve of its arc is notably bent and not smooth, as the first hook is. Nothing certain can be said about the mounting of the hook. Most likely the tip passing through the rim was wrapped around the base of the hook, as evidenced by coils of wire running around it spirally. On the other hand, it cannot be ruled out that they could have been merely a decorative element and not an essential part of the construction.

2. In the immediate vicinity of the steelyard arm, fragments of a chain (approx. 16cm long) and a hook which was used to suspend weighted

objects and originally situated at the end of the chain have been found. Due to the fragmentary nature of the finding it is not possible to reconstruct its original length, but by analogy (see below), it seems that two chains came out of the handle and were finished with hooks on which the weighted goods were hung. The weave of the chain resembles a doubled loop-in-loop chain (Higgins 1980, 17). The hook (4.9cm long) crowning the entire chain was made of a piece of quadrate wire, bent in the shape of letter U. In the place of its mounting to the chain, there is a ring on which fragments of the chain are preserved.

3. The weight has a height of 6.919cm, its maximum diameter is 3.853cm, and it weighs 405.5g. It has the shape of an acorn with a cup-shaped cupule.[4] On top, there is a rectangular-shaped handle with a circular opening used to suspend the weight. The cupule is decorated with ten horizontal grooves. The pericarp is oval-shaped and at the bottom it has a plastic ring that separates it from the lower narrower section which survived only in fragments (at the height of 5mm). The analogies discussed below indicate that this part ended in a point – remains of style.

History of the steelyard

In the Roman world, a pair of scales was called a *trutina* and the term referred to both the pan scale – *libra*, and the steelyard – *statera*. Pan scales were invented much earlier than the steelyard and were widely used in Egypt, Greece and later in Rome (Yates 1875). According to Isidore of Seville (*Etym.* 16.25.6) the steelyard was invented in Campania, and to be distinguished from other scales it was called *trutina campana*. Consistent with this remark, there have been numerous findings of such balances among the ruins of Herculaneum and Pompeii (Michon 1918, 125). The steelyard is often simply referred to as the Roman balance. Because of this, most researchers (e.g. Zahn 1913, 3; Richter 1924, 70; Karydas 1998, 45[5]) consider it to be a Roman invention. However, as claimed by N. Karydas (1998, 45), the very operational mechanism of the steelyard based on the principle of the bilateral lever (counterweight) was already known in the Hellenistic period, if not before, and information about it can be found in Aristotle's *Mechanics* (853b.25). It is interesting that over a century ago R. Zahn (1913, 4) pointed out the far-eastern origin of the idea of a steelyard,

[4] More about the symbolism of this type of weight see Wacławik 2015.

[5] We are deeply indebted to Dr. E. Raptou for drawing our attention to this article and other help.

citing wooden beams mentioned by Bols-Reymond, the length of which corresponded to the height of a man. Under Babylonian and Achaemenid influences, the idea could have then reached the Greeks of southern Italy, and from there, the Romans. This route can be confirmed by findings from the mentioned period, the purpose of which has not yet been fully identified. One of these findings is a bronze rod from the period of Lars found in the company of a few female figurines, from work in Dur-Samsu-iluna (Smith 1938, 139). One ending of the rod is rectangular and has a groove; the other is adorned with a ram's head. The entire length of the rod has a number of grooves that could have served as a measuring scale, with figurines found nearby acting as weights (Smith 1938, 140). Similar ram-like rods have been ascribed to the Achaemenid times, including a 49.5cm-long iron rod whose one end fits the figurine of a sitting ram. A bronze hook attached to its arm may have served to suspend the device itself, or weighed products (Burnett and Curtis 1973, 135 n. 44). Later, as the Persian Empire expanded, the idea of the steelyard could have reached the Greek merchants unhindered, and from them, the Romans. Unfortunately, there is no evidence of such a route in the archaeological material. Examples of scales that appeared after the Achaemenid period include only those dated back to the period around the turn of the era – so there is a continuity gap that stretches over about five centuries. There is a quite likely valid – though still unproven – hypothesis about the discovery of the steelyard in Europe as early as Hellenistic times, regardless of its eastern predecessors.

Principles of the operation of the steelyard

The Roman balance is based on the very simple principle of bilateral leverage (counterweight) that was described in antiquity, among others, by Aristotle in his aforementioned work and by Vitruvius (*De arch.* 10.3.4). Its straight-beam is divided into two arms of unequal length which flank the suspension point, called the *fulcrum*. On the shorter arm, which ends with an opening, weighed items were attached to the chain. The second, longer arm had marked scales, and a weight was attached to it that acted as a counterweight to the load being weighed. The mounting of the counterweight was movable, allowing it to slide along the arm. This solution made it possible to find a point where the balance was in equilibrium. Next, on the basis of the conversion of the equation EP=DW,[6] it was possible to read

[6] E = the weight of the counterweight, P = the distance between the weight and the axis, D = the distance from the axis of the weighted object, W = the weight of the object.

the mass of the weighed object from the scale. The mass of the weighed object can be calculated according to the equation W=EP/D. In practice, it is much simpler, because the scale engraved on the arm reflects the result which can be read once the weight has been correctly positioned (Tarbell 1909, 139; Zahn 1913, 5; Richter 1915, 445; *BM Guide* 1920, 161; Hill 1952, 51; Karydas 1998, 44; Wacławik 2016a, 118 and Pl. 1). The second hook, which constitutes the other axis of gravity, correlates to the other scale etched on the arm. By shifting the center of gravity, objects whose mass went beyond the first scale could be weighed without additional complications, such as changes in the mass of the counterweight (weight) or other modifications (Hill 1952, 52).

As mentioned above, the balance found has two scales that use the Latin measuring system. On the first scale, which is related to a further located mounting hole, the engraved characters indicate the following: vertical lines for units; punched S (from Latin *semis*) for half units; and V (where the arms have no tangent point) for fives. Each value is additionally marked by a short cut on the arm that ranges from one to seven and a half operating units. Values higher than five are indicated only by a single vertical line, probably due to lack of sufficient space. The other scale, related to the mounting hole proximal to the end, has all the indications mentioned above except for S. However, it has X for the value of ten, doubled for its multiplicity. Subsequent weight indicators are marked only by short cuts on the arm of the balance (due to the lack of space), and more rounded values are indicated by X and V for easier reading. This scale was used to read the mass of loads weighing between eight and 28 operating units. It was therefore an excellent continuation of the first scale, which is relatively rare among known balances. Indeed, in most cases the scales either overlap in certain sections, or bypass some fragments of the weighing sequence. The fact that the scales perfectly complement each other in the Paphos balance results from the appropriate location of the openings on the arm and is proof of the high precision and accuracy of the craftsman who made the device.

Analogies and chronology

Many steelyards are known to be stored in museums and collections. Unfortunately, a considerable number of them have never been described. They are usually mentioned in excavation reports, information about purchases made by museums or in exhibition catalogues, where relatively

little space is devoted to individual artefacts (Wacławik 2015, 257). There are relatively many steelyards like the one found by our expedition, i.e. ones with two scales and two hooks for hanging weighed goods (Michon 1918, 1227–1228, n. 1) and they were once just as popular as one-scale balances. According to the typology proposed by Franken (1993, 77), the steelyard found under the Paphos Agora Project should be classified as a Pompeian type and dated to the 1st century AD. Especially close analogies are those devices that have counterweight in the shape of an acorn, as one discovered in Pompeii (Quaranta 1832, fig. 2; = Overbeck 1884, 439; = (?) Michon 1918, fig. 4476 [= here Pl. 2: 2]; Richardson 1988, 27; Corti 2001, 185; *Museo Archeologico Nazionale* 2014) and another one from the British Museum collection (inv. no. GR 1858,1226.887)[7]. The last object, which was donated by Sir William Temple, is on display at the museum exhibition where it is described as Roman and dating back to the 1st century AD. Its shape is almost identical to the Nea Paphos Agora exemplar, with the location of the mounting holes the same as in our steelyard. The only difference is that it has a slightly larger knob at the end of the arm. The British Museum weight is also shaped like an acorn and there are ten grooves on the cupule. The undamaged ending and a well-preserved mounting of the weight to the balance allow for better understanding of the function and appearance of the artefact discovered during the Krakow excavations, as well as its various details, for example the ways of hanging the chains. The British Museum steelyard, though available to a wide range of visitors, unfortunately has not yet been the subject of any publications.

Interestingly, the Paphos Agora steelyard seems to be the first device of the Pompeian type discovered in the eastern part of the Mediterranean.[8] Most of the findings are known from Italy (Franken 1993, fig. 5) but it is probably the result of the state of research. Another, presumably Pompeian type steelyard (which is hard to establish because of the state of preservation) found in this region, is stored in the Studium Biblicum Franciscanum Jerusalem Archaeological Museum (Wacławik 2016b).

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[7] We are deeply indebted to Dr. Thomas Kiely and Dr. Alex Truscott from the British Museum for their help and assistance.

[8] In this context the lack of a publication on a steelyard purchased by the Cyprus Museum in Nicosia in 1957 (Megaw 1957, 50) is particularly discernible; there is also a 'handle and tongue of a balance' in the same museum (cf. Myres and Ohnefalsch-Richter 1899, 182, B.5, no. 3695), but this object is undated.

Ratio Operandi

It would be difficult to understand the ancient weighing system without understanding how the mass of one pound (*libra* = lb), which is the module for the operation of the balance, converts to grams. An object weighing one pound causes the levelling of the arm of the steelyard while the counterbalance (weight) is set at a distance indicated by the scale as I. Using the above-mentioned equation we can calculate the mass of weight E. Substituting appropriate values into the equation,[9] we obtain the result of 283.85g for the module of the Paphos steelyard (Wacławik 2016a, 119). However, the Roman pound was heavier and weighed – as is commonly believed – 327.45g (Michon 1918, 1231 n. 15). With the passage of time, during the late Roman and Byzantine periods, the pound became lighter (Karydas 1998, 44–45). A value close to the value obtained in our calculations (285g) was to be found in a very light Byzantine pound mentioned by Ballance *et al*. (1989, 134). It cannot be ruled out that the value we calculated should be increased to 285g due to a small loss of the tip of the counterweight coating, and because numbers were rounded off in the calculations. In light of our study the following question arises: what weight system was used in Cyprus in the early Roman period? Perhaps it was a local system different from those used in other parts of the empire, as was suggested by Qedar (2001, 24), who speculates that in the newly conquered territories of the East other local systems could have been used alongside the state system of measurement. If this is proved in future research, we would speak of a 'Cypriot' or 'Paphian' pound.

Conclusions

To sum up all the above, it can be concluded that the Paphos steelyard represents a very common type of simple Roman balance known in Latin as *statera* or *trutina campana* and widespread from the 1st century AD to the late Roman and Byzantine times. It represents the Pompeian type in Franken's classification. It is a small balance with two scales, two hooks for hanging the loads and an acorn-shaped weight. It was used for weighing goods of up to 28 pounds (approx. 8kg) using an operating unit of about

[9] In this calculation the weight of the fragments of the chain and hooks has not been taken into consideration, because the steelyards were calibrated in such way that their components did not influence the weighing mechanism.

285g. Based on strict analogies with Pompeian type steelyards, it can be dated back to the 1st century AD.

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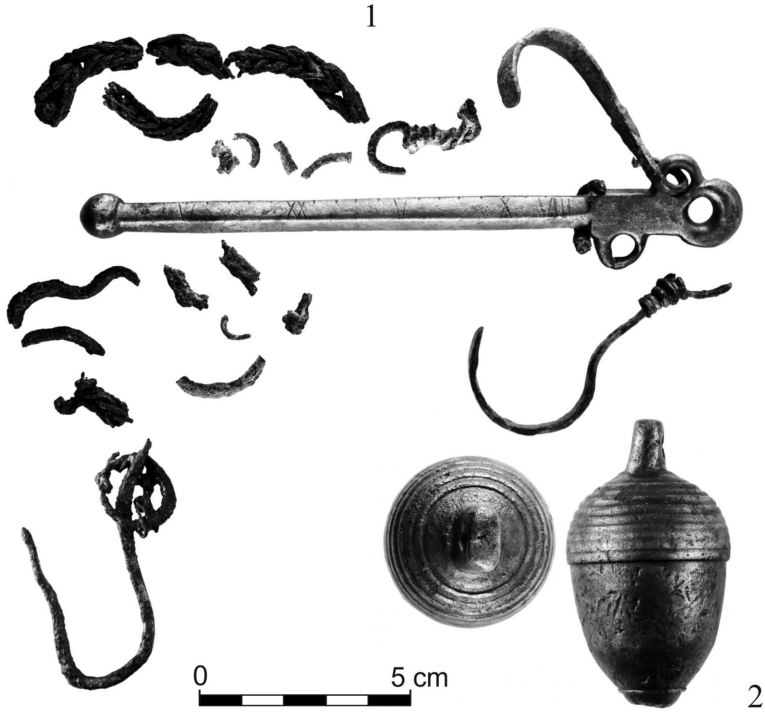

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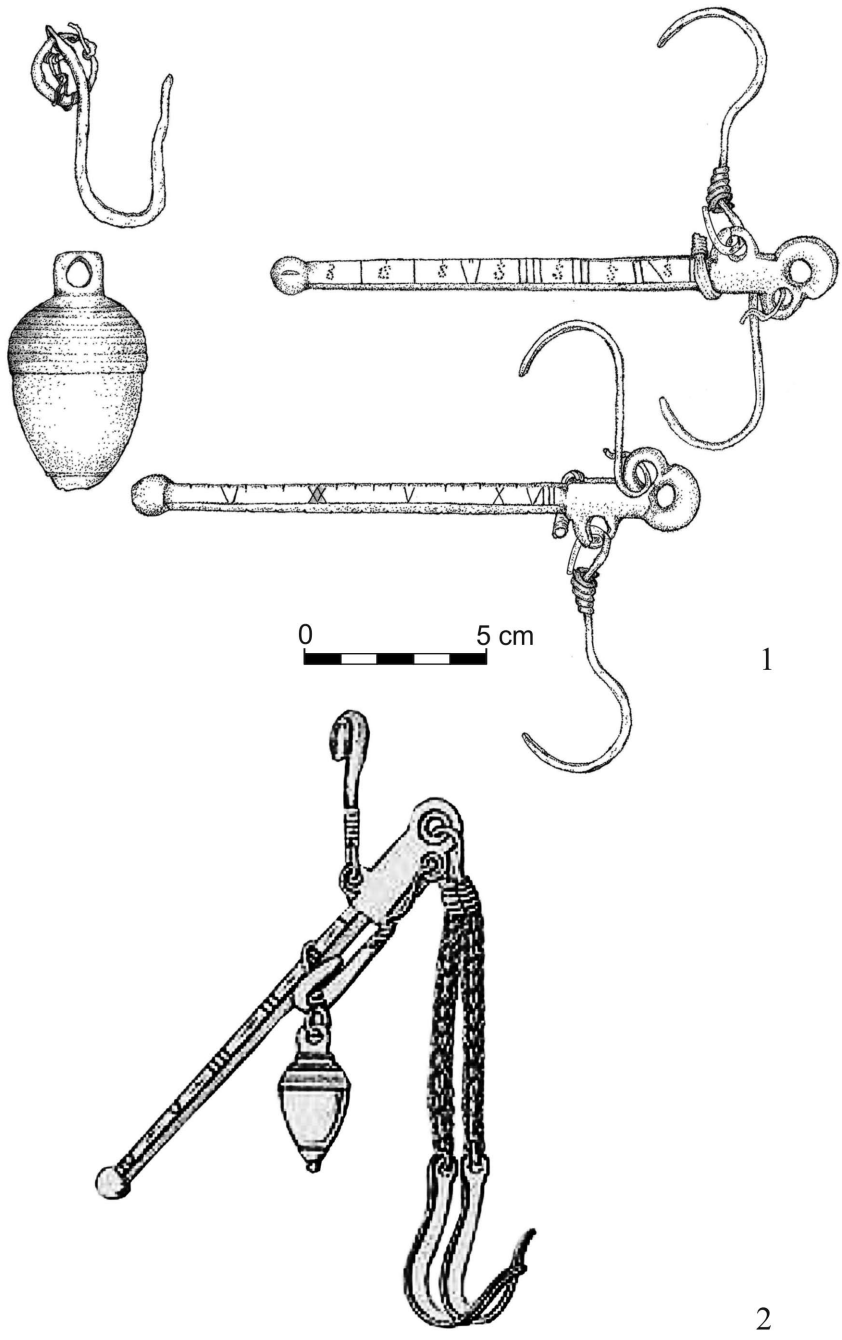
Pl. 1. 1 – Steelyard and weight *in situ*. Photo by W. Machowski;
2 – Steelyard and acorn-shaped weight after the conservation process. Photo by M. Iwan



Pl. 2. 1 – Steelyard and weight. Drawing by M. Droste, digitization and reconstruction of one of the suspending hooks attachments by U. Socha; 2 – Steelyard from Pompeii. Based on the drawing from Michon 1918, fig. 4476, digitization by U. Socha