

Some remarks on the cognitive impact of metallurgical development in promoting numerical and metrological abstraction in Europe

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ABSTRACT – *If we accept the thesis that advanced metrological systems existed in Bronze Age societies, described and analysed as weight standards by many authors, we should also consider its simple consequence; these weight standards were the successors of earlier and rather simpler systems of value that developed within Eneolithic societies. Dealing with the issue of early metallurgy in Europe, some authors have traced patterns and proliferation cycles of copper for this period that allow us to see that the introduction of metal to the main regions in Europe was the subject of growth, spread, and changing social perspectives rather than a crisis in metal production and hiatus. This is the point, I think, at which we can embed one source of Bronze Age weight standards on the one hand, and earlier simpler methods of measuring copper, on the other.*

IZVLEČEK – *Če pristanemo na trditev, da so v bronasti dobi že obstajali napredni merski sistemi, ki so jih mnogi avtorji opisali in analizirali skozi standardizirane utežne mere, potem moramo pristati tudi na izpeljavo trditve: ti utežni sistemi so se razvili iz preprostejših merskih sistemov, ki so nastali v eneolitskih skupnostih. Mnogi avtorji so ob preučevanju zgodnje metalurgije v Evropi prepoznali vzorce razvoja rabe bakra, ki kažejo, da je bila uvedba kovin v Evropi bolj kot krizi in prekinitvi proizvodnje podvržena rasti, razširjanju in družbenim spremembam. To je tudi točka, kjer lahko po mojem mnenju povežemo izvor bronastodobnih utežnih standardov na eni strani in zgodnjih preprostih metod tehtanja bakra na drugi strani.*

KEY WORDS – *Eneolithic measure concepts; copper; Bronze Age weight standards; linear measures; cognitive development; Central Europe*

The beginnings of metal production

Conceptualisations of the development of early metallurgy in Europe have been strongly influenced by processual and Marxist-oriented ideas intended to expose technology and society in mutual relations. This approach can be traced back to the work of Vere G. Childe (1944), who at the time was influenced by Marxism (Trigger 1989.254–263), and Theodore A. Wertime (1964). Christian Strahm (1994.5–7) sketched some significant points of this process. In the 6th millennium BC there is slight evidence of copper processing in south-eastern Europe, limited mainly to small cold-forged copper ornaments which had no

significant impact on the economy or society. This phase he described as preliminary. Already at the beginning of the 5th millennium BC, intense development of copper production in the Kodžadermen-Gumelnitsa-Karanovo VI cultural complex occurs, whereby massive copper implements such as adzes, axes and chisels become a conspicuous element of local culture (Todorova 1981). In the Vinča culture, however, copper ores might have been utilised from the earliest phases in the last centuries of the 6th millennium BC (Borić 2009.238). Macroscopic, microstructural and compositional analyses have revealed a

particular preference for black and green copper minerals by prehistoric communities inhabiting Balkan settlements between 6200 and 4400 BC (*Radivojević 2015.333*). But still the most prominent example of this development is provided by the Varna culture cemeteries in Bulgaria (*Lichardus 1991; Ivanov 1991; Lichter 2001*).

Technologically speaking, copper production at the time was still in the experimental stage (*cf. Klassen 2001.235*). It is important to note that early techniques of copper processing are in almost every respect identical to lithic and flint processing technologies. Budziszewski performed a comparison of the two technological paths. He wrote that both metallurgy as well as macrolithic technology from good quality sources were practiced on a similar socio-economic basis. The person who received a copper product did not have to know how it was made, as his role was only to participate in the exchange. A similar process occurred with macrolithic blades and axes. On the one hand, there was specialised production in separate settlements that generated prestigious flint goods, and on the other home production based on local traditions and resources, which focused mainly on makeshift production and altering tools by means of primitive techniques. This was clearly separated from specialist activity, which always had a cross-regional, and often cross-cultural, distribution (*Budziszewski 2006.275*). Casting techniques were used to produce tools and ornaments only rarely, with plastic working (forging, bending, cutting) playing the main role (*Sherratt 1997*). New techniques lending copper processing the true character of metallurgy appear only in later stages. We can thus say that the detachment of the new technology from the older Neolithic production traditions and contexts was a gradual process, and that this technology progressed to becoming a new cultural, social and economic quality only after the passage of a certain time.

The new technology eventually spread to other parts of Europe. It reached the Black Sea steppes; an important metallurgical centre developed in Hungary (Carpathian Basin), initially linked to the Tiszapolgar culture and later to the Bodrogkeresztur culture. This centre turned out the same forms and employed the same production techniques as the Balkan centres (*Mohen 1990; Lichardus 1991; 1991a; Strahm 1994; Sherratt 1997*). Others emerged almost simultaneously with the one in the Carpathian Basin: in the Balaton culture in Transdanubia and further to the west. Intensive copper production is in evidence

in the eastern Alpine regions at the beginning of 4th millennium BC or even earlier where the local cultures used a characteristic copper and arsenic alloy displaying metallurgical properties superior to that of pure copper (*Bartelheim et al. 2002; Höppner et al. 2005*). A typical representative of this tradition is the Mondsee culture, which produced massive quantities of copper artefacts in a variety of forms and left behind copious traces of production that indicate beyond any doubt that copper was intensively processed by these people (*Ottaway 1982*). The mutual contacts between these centres were continuous and probably lasted several centuries (*Ottaway 1981*).

After a period of intensive development of metallurgy in the Carpathian-Balkan centres, some break in metal production is observed, which is interpreted by Strahm as a collapse in copper production due to the exhaustion of easily accessible ore deposits and to problems in switching to sulphide ores (*Strahm 1994*). Versions of this interpretation have been also formulated by Sherratt and Shennan (*Sherratt 1993; Shennan 1993*), who describe the character of early metallurgy as 'boom and bust', which caused cycles of production, exchange and the search for new and more advanced techniques of mining and smelting in the 'bust' phase. However, no such hiatus in metallurgical production is observed in central Germany in the period from 3500 to 2700 BC (*Müller 2001*). This region abounds in rich easily accessible deposits of copper and tin ores, and researchers agree that the communities inhabiting the area continued to develop traditional technologies originally developed more than a thousand years earlier (*Bartelheim, Niederschlag 1998*). Müller (*2001.Fig. 254*) sees also cycles in copper production, but he highlights the steadily growing presence of copper artefacts in central Germany as evidence of this, noting the two-fold increase in their numbers at the turn of the 4th and 3rd millennia BC. This author also believes that a fully developed copper technology already existed at the time, raising socio-economic complexity to new levels (*Müller 2001.414–416*). The communities inhabiting central Germany in those days had long been exposed to intensive exchanges of ideas, establishing close and long-lasting cultural relationships discernible in archaeological materials in culturally mixed assemblages such as those from Walternienburg, Bernburg and Schönfeld (*Müller 2001*).

Anticipating what follows below, it is important to add that central Germany gradually evidenced deve-

lopment of Bronze Age societies and constituted one of the earliest and strongest centres of bronze production in Europe. In this context, we should also place the finding from Kelsterbach (near Frankfurt), where a corded ware amphora containing a copper hoard were found. The vessel, besides a large amount of metal artefacts, yielded a collection of copper beads which revealed a clear metrological structure based on a concept of weight (Behn 1938; Witter 1941; Dzbyński 2008a). The beads were produced by the very simple technique of pouring small quantities of molten metal into previously drilled holes with sticks inserted in their middle. This earliest appearance of this kind of material in Europe together with clear indications that also corded ware vessels in central Germany were produced according to certain metrological rules (Dzbyński 2004) makes a thought-provoking contribution to the problem discussed in this paper.

The existence of a hiatus in other regions has been also questioned by Timothy Taylor (1999). He takes a new look, focusing particularly on the nature of the evidence of a hiatus, dealing with the question: how did copper become bronze? Focusing on Lewis Binford's middle-range theory (1983) and the concept of site formation processes from Michael B. Shiffer (1976), he tries to elaborate a mix of both approaches to propose a new understanding of metal proliferation in Europe. By analysing approximations of copper production in Europe presented by various authors, he concludes that a vast amount of metal is missing from the archaeological record. Stating that answers to this discrepancy will not be found without theorising some mechanisms whereby metal was moved into and out of potentially preserving contexts, he explicitly cites three general phenomena (mechanisms) that should be taken into consideration: (1) legitimate recycling, (2) illegitimate cycling and (3) skeumorphism.

Legitimate cycling refers to when most of the metal was never deposited in the archaeological record, but recycled and reused in a continuous chain reaching deep into later periods. This mechanism is accepted by most scholars. Its weakness, however, is that while it is clear that metal was in circulation, it is not as clear whether this was directional trade or some other form of exchange and reworking.

Illegitimate cycling is just as important, but not widely acknowledged. It covers such behaviour as theft, booty-taking, discovery and appropriation of the hoards of others and grave robbing (Taylor 1999.

25–28). Grave robbing is the most recognisable activity in the archaeological record, appearing as an organised mass phenomenon (Jankuhn 1978). Taylor cites the example of the early Bronze Age cemetery of Gemeinlebarn, where only 15 of 258 graves had not been robbed in antiquity (Neugebauer 1991). Concerning the Eneolithic period, he notes that the relatively frequent evidence of disarticulated skeletons in Eneolithic cemeteries from the Carpatho-Balkan and steppe regions, although direct evidence of theft may seem slight is suggestive.

In the light of illegitimate cycling, it may be suggested that metal artefacts in the Eneolithic were initially seen as symbolically powerful grave goods; they had magical and transformative qualities and they rapidly became a liability (Taylor 1999). As metal came to play an ever greater economic role, so greater social control was placed on it, because metal could be more easily accumulated than other objects (Chapman 2000.128–130). Depositing metal in graves carried certain risks. Therefore, for Taylor it is clear that theft was seen as desecration by the relatives of the deceased, even if that was not the primary intention of the thieves. “*It is thus entirely consistent that, after an early and enthusiastic inception, metal should suddenly become more elusive in the archaeological record. Not only was it being dug out from cemeteries as the highest quality, pre-smelted, raw material, but communities were taking the decision to remove it themselves, either before burial or between the initial and final funerary rites*” (Taylor 1999.27). Finally he proposes viewing the transition from the Eneolithic to the Bronze Age, solely because of grave robbing, as one reason for the development of a characteristic type of grave which can be termed ‘a defended burial’, of which the first were tumuli in Hungary and in Yamnaya societies on the steppe. Once the burial contexts were made more secure, writes Taylor, metal was again more frequently placed in them. However, Kristian Kristiansen came to a similar conclusion about the Bronze Age (Kristiansen 1991).

In summarising the two mechanisms of metal cycling, it can be said that “*whether legitimately cycled above-ground, through curation, inheritance, and prestige exchange, or illegitimately liberated from below-ground funerary contexts and hoards, the lateral cycling of artefacts is probably the principal reason that only 0.01–0.1% of the copper produced in the Eneolithic has been archaeologically recovered*” (Taylor 1999.28).

Skeuomorphism has been described in the context of the emulation of metal forms in flint production. From the Bronze Age, highly elaborate flint products in the form of metal knives and even swords are widely known (Zich 2004). The same has been suggested for the earlier flint blades and axes from the Eneolithic. Thus Janusz Budziszewski points out that the establishment of macrolithic industries was linked to the development of early metallurgy, as the manufacture and organisation of the distribution of macroliths was the same as that used for copper products (Budziszewski 2006, and above in this text). This phenomenon has been recognised in Scandinavia, as well as France, a region where another distinct hiatus has been observed: Carpathian copper reaches Scandinavia early and then vanishes from the archaeological record until the first bronzes appear (Klassen 2001; Taylor 1999). The question for Taylor is whether copper was ‘swamped out’ by the development of local flint exchange economies or simply not archeologically perceived. It is worth noting, however, that skeuomorphism in pottery is one of the most striking features of ceramic production in Europe between 3500 and 3000 BC.

It is hard to imagine that such widespread skeuomorphism means that metal objects were totally absent from those societies. Taylor (1999) argues that it is rather evidence of direct metal activity. After his analyses, Taylor (1999:28) concludes that “*the relative absence of metal is rather a sign of its developing worth and its growing association with*”. This is not to posit a crisis or hiatus as many researchers do. “*Metal use developed within communities in an embedded way, not as a secular, economic add-on ...*” writes Taylor (1999:30). For him, it was a process of evaluation which can be described as follows: “*Copper was soft; yet, for all that, it changed everything, allowing a multitude of tasks to be accomplished in a different manner; even a soft-edged axe might have its uses. It is the first truly cyclable artefactual product, which could be unmade and remade at will virtually ad infinitum without any necessary loss of basic material value. I believe that it is to be expected that there will be dramatic shifts in the depositional pattern of such a revolutionary material through time, and especially during the period of its inception. Such shifts would be underscored by the fact that the new material was also ‘good for thinking’. It was not treated in a dis-embedded, secular manner: the act of making it and the remains of making it were as significant as the product itself. Even slag was treasured*” (Taylor 1999:29).

Later metal: the Bronze Age

A confirmation that metal was ‘good for thinking’ as formulated by Taylor is very clearly visible in the Bronze Age when complex societies with strong economic pressure on metal emerged (Kristiansen 1987; Sherratt 1993; 1994; Harding 2000; Pare 2000). Metal was without doubt a central focus of Bronze Age societies. Kristiansen discerns a distinctly hierarchical social system already in the early stages of the Bronze Age, with rival chiefs vying for access to prestige goods in the form of specific bronze objects. In conditions of excessive consumption of prestige goods, the best strategy for retaining one’s position is to gain control of important branches of the economy and routes of exchange of exclusive objects produced by specialists. Accordingly, competing chiefs must have employed some forms of force and perhaps also controlled the production of selected commodities (Kristiansen 1987; Knapp 1999). From then onwards, an increasing amount of control and administration occurs, with the use of rationalised communicative mechanisms that had already evolved in large measure in the preceding period. What we have at the stage we are considering here is in fact an initial form of the state (Kristiansen 1991).

In this kind of social system, we can expect to see an integration of rationalised communicative actions involving the use of advanced measures of value, profit and loss calculations, *etc.*, into power relation structures (Kristiansen 1987; Primas 1997). Therefore, an inalienable element of Bronze Age culture became the knowledge not only of how to produce metal in great quantities and numerous forms, but how to measure it within complex systems of exchange that emerged in this period (Pare 2000). Researchers seeking weight standards and related phenomena in the European Bronze Age made a valuable contribution by showing that this was a widespread, protracted and crucial process characteristic of rationalisation and the development of civilisation.

Bronze Age weight standards

Majolie Lenerz-de Wilde (1995; 2002) performed detailed analyses of numerous bronze finds showing that highly rationalised communicative and exchange systems did exist in the European Bronze Age. She analyzed the weights of ring bars (ger. *Ringbarren*) from Central Europe and suggested that a highly abstract concept of weight/mass of the bronze raw material had to be involved in their making, so that we may speak of the standardisation of weight (Fig. 1). The standardisation of ring bar weights,

however, varied over time and from region to region. Moreover, the chronological evolution consists of the emergence of increasingly lighter weight standards. A consequence of this process appears to have been the severe fragmentation of bronze objects, mainly sickles, which thus assumed pre-monetary functions in the Middle and Late Bronze Age (*Sommerfeld 1994; Primas 1986*).

Let us assume that the form of the ring bar was quite new in Central Europe. Similar artefacts were discovered in a hoard in Byblos dated to between 2130 and 2040 BC, prompting some researchers to interpret the oldest ring bars in Europe as evidence of imports from the Levant (*Schäffer 1949*). Eventually it transpired, however, that many of the European ring bars are in fact older than the Levantine ones, which this suggested that any transfers of this form would have to have been in the opposite direction (*Lenerz-de Wilde 1995:300*). It has also been pointed out, however, that very similar objects made from copper were previously present in the Baden culture in Austria (*Ottaway 1982:293*). Despite a hiatus between the early copper form and the later bronze bars, Lenerz-de Wilde admits the possibility that this suggests the continuous presence of a ring ornament form. This hypothesis is additionally supported by the fact that the bronze ring bars first appeared precisely in Austria.

Ring bars, however, are not the only artefact standardised according to weight. Neugebauer (2002) describes in detail hoards that feature bronze caul-

drons whose weights were 'adapted to fit' the weight of ring bars. The hoards from Ragelsdorf and Unteradlberg thus illustrate the next metrological leap marked by heavy necklaces (ger. *Ösenhalsreifen*) weighing twice as much as the ring bars.

In light of the above, many researchers see it as probable that the miniature bars served as money equivalents already in the final stages of the Early Bronze Age. Some hoards from that period provide evidence of their intentional fragmentation. This practice gains great momentum in the Middle Bronze Period, from which we have scores of hoards in which fragmented bronze objects (the vast majority of which are sickles) are a regular feature. However, as Margarita Primas (1986) believes, they were not fragmented in order to make pieces of some standard weight. In her opinion, the fragmented sickles recovered from many settlements and hoards were also not the result of accidental occurrences or material prepared for re-melting. She notes that foreign forms recovered at sites far removed from where they were produced are broken up into small pieces. Primas (1986:40) believes that sickles were fragmented intentionally, but with little attention paid to the weights of the individual pieces which circulated as an early form of currency.

This turning point is especially stressed by Christoph Sommerfeld (1994; 2004). In the Urnfield period (from c. 1200 BC onwards) we observe a radical change in the composition of bronze hoards, with bars and axe-heads being replaced entirely with sickles. Researchers are fairly confident that the fragmentation of these implements was intentional. The fragments remained in circulation for long periods, as suggested by their signs of wear (*Pare 1999:444*). Sommerfeld agrees with Primas that the fragmentation had nothing to do with technological considerations, but completely disagrees as to the interpretation of this practice. While Primas believes that the bronze objects were broken up more or less haphazardly, Sommerfeld is of the opinion that the broken-off fragments were intended to meet a specific weight standard (*Sommerfeld 199:57; 2004; Primas 1986:40*).

Some Middle and Late Bronze Age graves in Central Europe also contained objects interpreted as balance weights that were probably compatible with the Late Bronze Age system in the Aegean (*Pare 1999:491; Petruso 1992*). Aegean balance weights, which were usually lead plates, represented a basic weight unit of 61g. The bigger weight units in this system were

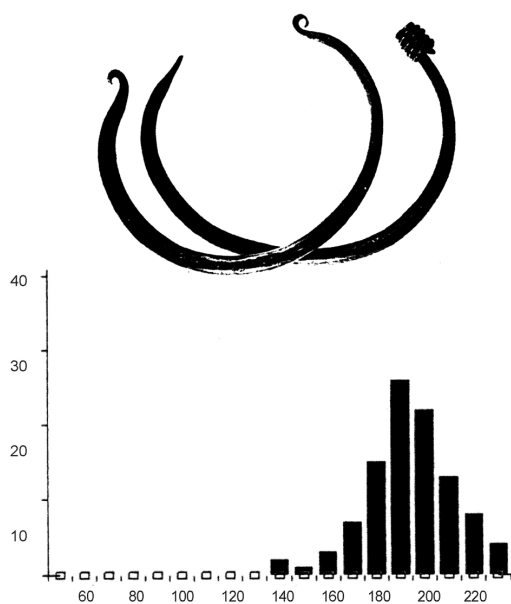


Fig. 1. Weight analysis of ring bars from southern Germany (after Lenerz-de Wilde 1995).

the mina (488g) and the talent (29kg), both known in antiquity. The 61g unit is thus one-eighth of the mina. Most of the balance weights recovered from graves dating to the Middle and Late Bronze Age were probably derived from the Aegean system or, rather, were compatible with. The best evidence of this compatibility comes from the weights from Gondelsheim (Pare 1999.436).

Most balance weights from Central Europe are dated to the Late Bronze Age, while those analysed by Petruso are some 200 years older (Petruso 1992). However, there is no straightforward link between the European weights and their Aegean predecessors, if only because of the typological differences between the two. The most popular Aegean balance weights were flat, circular discs made from lead or stone, whereas their Central European equivalents are made from bronze and usually in the form of rectangular bars (Petruso 1999; Rahmstorf 2010). Pare concludes from this that the shape of the latter is the result of an original development process in Central Europe; parallels are not common in the East Mediterranean (Pare 1999.492). This is a significant observation, in that it emphasises the role of the European communication area, in which, as I also tried to demonstrate (Dzbyński 2008), specifically directed rationalisation processes were active since the Neolithic.

Pare wonders here about the kind of social context that would require precise measurements with balance weights that were practiced at the time in Europe. He notes that this phenomenon, as well as the existence of complex and diverse metrological systems, were also technological achievements which, in theory, could have found diverse applications in, for example, exchange systems, administration, ancient medicine and metallurgy. Exploring this issue, Pare mentions analyses of social aspects of ancient metrology in Europe and points out that weight measurement implements were rare in graves throughout the ancient world. Equipment of this kind was deposited in graves in only a handful of periods and in a limited territory. It is important to note here that in all periods and in all territories which provided archaeological evidence of such practices, it is likely that this evidence is linked to a special form of economy which we may call the 'Weighed Currency' economy. This kind of economy flourishes most on the peripheries of Iron Age economies with minted coins, in areas lacking strong rulers who could lend credibility to the currency, and where value had to be measured according to individual-

ly devised scales (Pare 1999.511). The origin of a system of this kind is also obvious to Mats Malmer. The Bronze Age economy in Greece relied on exchange and trade, and trade is difficult without rational measurement solutions such as weight systems. Solutions of this kind are part of the intellectual achievements of societies engaged in intensive communication and exchanges of ideas. Malmer therefore expects to see Bronze Age weight measurement systems in territories as far apart as Greece, Central Europe and Scandinavia. It is quite obvious that the picture painted by Malmer clearly refers to a common cognitive frame of reference which prevailed over almost half of Europe (Malmer 1999; Peroni 1998).

What about copper?

The phenomenon of Bronze Age weight standards as described above points to the fact that they obviously present some element of why they were 'good for thinking' in the course of developing the value of metal as suggested by Taylor. But Taylor states that already copper was 'good for thinking' (Taylor 1999.29)!

The Bronze Age systems of measures are systems for conceptualising weight. They are highly abstract, as weight is an abstract measure. It is worth considering how the notion of weight could have come about in the first place. Colin Renfrew in his studies says that weight must first have been apprehended through physical experience. "*It could only be experienced and apprehended in the first place by the physical action of holding a heavy object in the hand and perceiving that it was heavy, more so than other similar objects. If you have a symbolic relationship, the stone weight has to relate to some property that exists out there in the real world*". Renfrew (2004; 2007.120–129) refers here to the known findings of the Harappa Culture, where stone balance weights were found. In a sense, these stone clubs, he writes, serving, as weights are symbolic of themselves: weight as a symbol of weight.

Similar evidence is found in Europe, at the latest from the Middle Bronze Age onwards, where stone weights and balance weighing are recorded in archaeological studies (Pare 1999; 2000; Rahmstorf 2010). They were probably partly adopted from the eastern Mediterranean, but already in the early Bronze Age there is enough evidence of weight standards being used, so that we can follow a certain evolution of complexity of this process (Lenerz-de Wilde 1995; 2002; Rahmstorf 2010). We do not

know how the earlier weight standards were measured without using balance weights. Lorenz Rahmstorf speculates in this way that many simple weights have probably not yet been identified in Europe (Rahmstorf 2010.98); or perhaps they were rather symbols of themselves and not weighed properly in early phases?

To me, the question of how such systems came about in the light of the undeniable assertion that both copper and bronze were 'good for thinking' seems far more important. It is quite important to stress that, in fact, what Taylor proposes is not an isolated voice in publications (Pernicka et al. 1997; Shenan 1993; Staaf 1996). It is important, however, to shed light on the characteristic vocabulary that is used to describe metallurgical development. So Björn M. Staaf (1996), for example, in studying copper axes from Central Europe, traced one pattern that appears persistently. The introduction of metal in the main regions of manufacturing copper in Europe was subject to growth and dissemination. In the first stage, it affected the Balkan-Carpathian region and, subsequently, central and west Europe. What Staaf (1996.152) basically suggests is that by the end of the Eneolithic period, certain norms of perception and specific activity towards metal were being formed, which he called "a general common understanding of metallurgy", something close to the formation of a 'new mind' in the cultural discourse.

The context of weight systems is a good starting point for our considerations, although my aim is to go a bit deeper into prehistory. As Renfrew states, weight systems can be seen to have developed independently in different societies along different trajectories of development. In many cases, they emerged in quite complex societies, sometimes in state societies, and are not usually found earlier in the trajectory of development (Renfrew 2007.125). This seems to be the evidence of Europe, where weight systems emerged in complex Bronze Age societies, but not earlier. In her study, Lenerz-de Wilde (1995) analysed some copper artefacts from the Eneolithic period (primarily axes) coming to the conclusion that they were not perceived through their weight, as was the case of numerous later bronze objects. This fact gave her the opportunity to reject the hypothesis about their metrological structure. Is weight, we may surely ask, the only way to measure?

Before moving on to the next section, let me recall Renfrew's statement. He concludes that weight has to be perceived as a physical reality in the hands

and arms, not only in the brain within the skull, before it can be conceptualised and measured. The mind works through the body. He refers to a theoretical branch of archaeology that is covered by such themes as material engagement, extended mind, incorporated mind *etc.*, rooted in the philosophy of Martin Heidegger and Maurice Merleau-Ponty (Heidegger 1962; Merleau-Ponty 1945; Malafouris 2013; Lakoff, Johnson 1980). If this is true, can we define other measures that are perceived even in a more embodied fashion?

Other ways to measure

Actually, we do not have any single reason to claim that metal was perceived and measured from the very beginning only by weight. Although weight is the best way to measure metal, there can be other ways to perceive it – for example as a linear measure. Remember that a linear measure is also conceptualised in the way described by Renfrew: as a physical entity experienced by people. However, it can be not symbolic of themselves what makes them less abstract. A linear measure should refer to other things, for which the best option is reference to human body (Lakoff, Núñez 2000). Moreover, a linear measure has the advantage over weight that it can be used in the more primitive circumstances that are supposed for early copper processing phases (Strahm 1994). Last, but not least, a linear measure is also 'good for thinking', as it is rational enough, although less abstract than weight. Let us take a look at some indications of this method of measuring metal in the Eneolithic.

Let us begin with Baden materials, where we find the copper rings mentioned by Lenerz-de Wilde as being a model of later bronze bars that served as weight standards. Lenerz-de Wilde emphasises the typological resemblance of these two ring forms. Earlier examples from the Baden culture are made of copper wire and are very simple in form. There is a hiatus of hundreds of years between them and the later bronze rings, which was probably also, why Lenerz-de Wilde did not analyse them in terms of weight. In my opinion, it would have been unjustified as it would regard any copper artefact from the Eneolithic period, because they were not yet conceived in this way. Let us look at some examples.

Some Baden copper rings (Fig. 2A) were placed in graves in the following manner: as a complete ring and a half (Menke 1982; Sachße 2010.Taf. 86). Unfortunately, graves with copper rings in the Baden

culture are rare, but there are other examples. Similar artefacts and finds are known from the Alps, where they are called Ösenhalsband. A juxtaposition of some exemplars from different places shows that they can be reduced to a segment or to a length which was divided into a half and a quarter (Löffler 2010, *Taf.* 23). They date to the end of the 4th millennium and belong together with the Baden copper rings of the same period (Fig. 2B).

Copper beads from the Cortaillod culture which were manufactured according to the same method as the above-mentioned artefacts are dated slightly earlier (Fig. 2C). Several sites in Switzerland and Alsace that yielded this type of bead, although the best known are Seeberg, Burgaschisse-Sud, Colmar, and Gerolfingen (Sangmeister, Strahm 1974; Ottaway, Strahm 1975; Ottaway 1982; Löffler 2010; Lefranc et al. 2012). The beads were made from a copper rod which was divided into specific fragments (Ottaway, Strahm 1975). The rod has undergone plastic forming, resulting in the final small bars, which then were knotted to form a bead. Some fragments of the rod

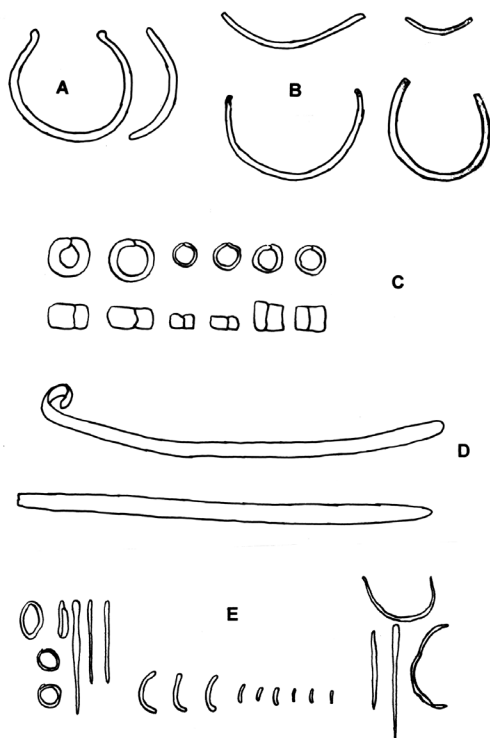


Fig. 2. Examples of artefacts that could be perceived according to a linear measure in the Eneolithic period (after various authors): 2A – copper rings of the Baden culture; 2B – examples of necklaces from the Alpine region dated to the end of 4th millennium; 2C – copper beads of Cortaillod culture; 2D – examples of the sheet and wire industries of the later Eneolithic in the Alps; 2E – objects made from copper wire of the Epi-Corded Ware communities.

had to be subsequently stretched to twice or four times their original length to produce an appropriate amount and value of beads. In other words, the production of such items was an example of the appropriate manipulation of a metal rod and application of simple rules of mathematical proportion (Dzbyński 2013).

The best known example of these beads comes from Seeberg, Burgäschisee-Süd (Sangmeister, Strahm 1974). They emphasise two important observations concerning these objects. Firstly, the specific number of beads on both strings reflected a simple mathematical proportion. Secondly, they clearly differ in weight in such a way that there are twice as many lighter than heavier beads, which can be viewed as a form of separation of the beads' values on the strings. We should not be disturbed by the fact that it is their weight that was studied and analysed. The weight of the beads has been used only to clearly indicate that a mathematical calculation lies behind their production (Dzbyński 2014). Obviously, they were reworked by their maker and folded in order to be ready for transport, so that a *chaîne opératoire* applied in their making is no more clearly visible. This issue has already been alluded to above. In a later study, it was proposed that the beads be treated as special purpose currency, as they actually present an early form of copper ingots (Ottaway, Strahm 1975).

Clear evidence as to how these beads/ingots were perceived has come from Colmar (Alsace), during rescue excavation research, where an Eneolithic burial with the type of copper beads with a characteristic feature of Cortaillod society was found (Lefranc et al. 2012). Three necklaces were placed around the skeleton of an adult man placed in an atypical prone position. One necklace with 25 beads was found near the feet of the deceased. A second consisting only of light pieces was found at his waist. The third group, of four medium heavy beads, was discovered under the skeleton (Fig. 3). This localisation of the three groups suggests that the beads were on strings similar to those from Seeberg and attached to the deceased in some way or simply placed around him. They were not attached at random however; each size category was intentionally placed around the man's body (Dzbyński 2013).

Moreover, as Philippe Lefranc, the researcher of the Colmar site, noticed, both necklaces in Seeberg and in Colmar comprise quite similar amounts of metal, which is about 400g (Lefranc et al. 2012). This

weight is quite typical, more or less of course, for an average, non-broken copper axe from this period in the Alpine region (*Lefranc et al. 2012. 713*). Taking the notion as well as the fact that copper axes are the most popular copper artefact within European Eneolithic/Copper Age, we are confronted with a situation where a copper axe could have been ‘counted’ quite precisely, although it could not yet have been weighed. In other words: this possible ‘counting procedure’ was still based on a linear measure, not on the concept of weight.

There are not only beads, however, that should be taken into consideration in future research to make the claim presented more credible or to re-examine them. One characteristic feature of the sheet and wire industries of the later Copper Age are artefacts that actually fit very well to the thesis presented. They were deliberately made to be extended, long and thin (*Endrizzi, Marzanico 1997; Fig. 2D*). Last, but not least, there is much to suggest that on the peripheries of the Bronze Age world, similar mechanisms of measure that could survive longer as objects made from copper sheet and wire continued to be used by Epi-Corded Ware communities (*Machnik 1984; Baczynska 1994*). We could make here formal comparisons with the earlier mentioned artefacts (*Fig. 2D*). Actually, many artefacts of the sheet-and-wire industry formally resemble the Cortaillod culture beads in their differentiation.

The beads from Seeberg and Colmar as well as other objects described in this paragraph seem to present an early stage of measuring and counting of metal, so that we can say that we are dealing with tangible evidence of an ongoing discourse on the value of metal in the Eneolithic society. One could admit that this stage was very strange. Metal was not yet weighed, but measured according to a linear measure, according to the measuring stick idea (*Lakoff, Núñez 2000*). Dividing a rod of metal into a particular number of small bars by means of linear proportions was the only method of producing the given categories of beads, since the weighing of metal is not evidenced until the Bronze Age (*Lernerz-de Wilde 1995; Pare 1999. 477; Rahmstorf 2010*); and not only

this: the beads also shed light on macrolithic flint industries that are viewed as examples of skeuomorphism by some researchers because copper and flint were conceptualised on the same socio-technical level (*Taylor 1999; Budziszewski 2006; Dzbyński 2008; 2011*). This kind of processing is partly rooted in the Stone Age, not the Metal Age, which agrees with conclusions of other researchers (*Strahm 1994; Krause 2000. 225–241*). Manipulations of certain copper objects before the introduction of weight standards as well as on the peripheries of the civilised world could have been performed on the same cognitive plane for a long time.

Summary

To make the thesis presented in this article more clear we should ask: how is it possible that advanced systems of valuing metal through weight appeared so suddenly at the beginning of the Bronze Age

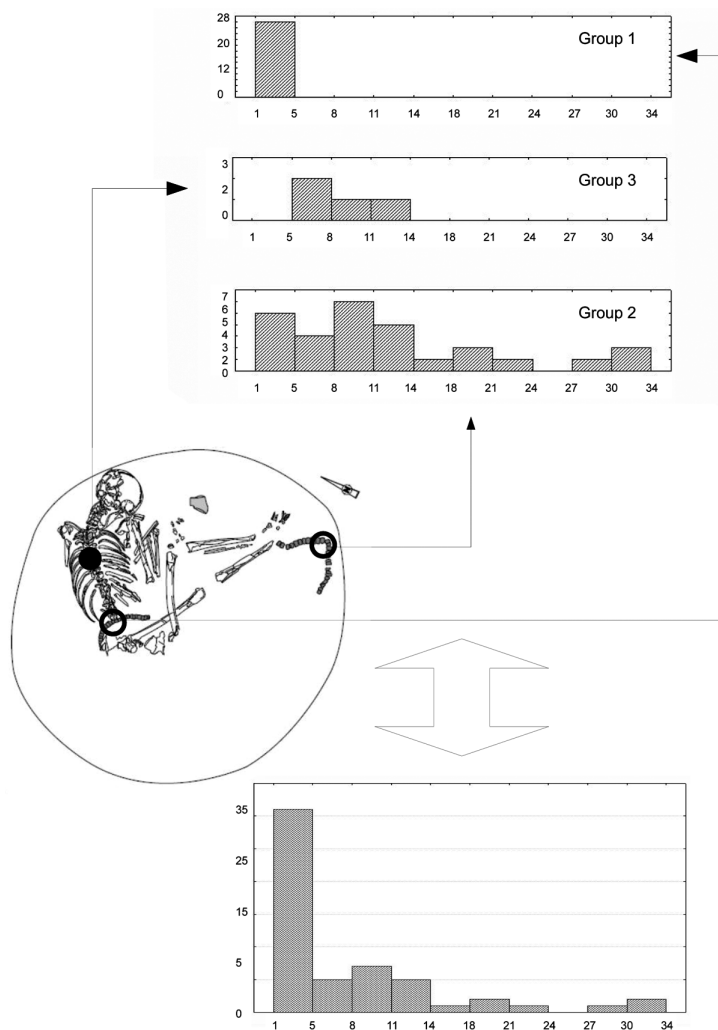


Fig. 3. The placement and analysis of copper beads in Colmar. Certain values have been attached to particular parts of the body (after Dzbyński 2013).

period without evidence of external influences? In the case of diffusion, we would expect similar forms of relevant artefacts, but there are no such examples; the opposite is the case. The relevant artefacts (weights and balance weights) differ in form from their adjacent counterparts, but conform in substance (*Petruso 1992; Pare 1999; Rahmstorf 2010*). Let me make this question more vivid and imagine that we are art historians who have just discovered the sculptures of Polykleitos and are delighted with the human figure, a dynamic counterbalance between the relaxed and flexed body parts and between the directions in which the parts move. After making this conclusion, we decide to end our research, saying that it was the pure ingenuity of human mind that created these sculptures out of nothing at the very beginning of art history. We know today that it would be nonsense to say such things.

Let me turn back to the problem highlighted by Taylor in seeking to fill the hiatus in metallurgical production in Europe by different cycling mechanisms. His efforts are supported by Staaf, who also suggested that by the end of the Eneolithic, some new norms for perceiving metal appeared, which he called 'a general common understanding of metallurgy', something close to forming a 'new mind' in the cultural discourse. So we can finally ask: what is this 'general understanding of metallurgy', this 'new mind' as formulated by Staaf? And, finally, what does it mean that metal was 'good for thinking' in the context of its developing value, as Taylor states? Were stone artefacts not good enough for thinking? In order to answer this question clearly, I will add only one word to refine this statement: the metal was good for thinking in measures. It was good for thinking in measures and numbers because metal actually must be perceived only this way if it has to be used more rationally within growing social complexity (in exchange, in tool production *etc.*). At the beginning, however as several materials from the Eneolithic suggest, metal could have been perceived with a less abstract linear measure, not by weight, and conceptualised in a more concrete manner.

Therefore, in the core of a general common understanding of metallurgy, of this new mind, there were the first European measures, early metrological systems, rational systems of value, no matter precisely what we call them now. We have to assume, however, that these metrological systems of the Eneolithic could have been very different from the later complex and abstract weight systems of the Bronze Age. Nevertheless, having to deal with the latter logical-

ly requires an assumption that there were concepts of number in use earlier than in the Bronze Age, and above all that a numerical scale was in use which gave the right perspective to measuring. The scale, which is in fact linear, as we should expect, comes from the Eneolithic or even earlier. In my opinion, this goes much further. It was a cultural and cognitive achievement of those societies that manufactured both silex and metal tools within the growing social complexity of the period (*Dzbyński 2013*). The cycling mechanisms proposed by different authors can only support the emergence of early concepts of measure, as there was a strong tendency to deal more efficiently and economically with desired material in exchange. Additionally, skeuomorphism created a continuous connection between flint artefacts and metal, as they were permanently compared according to their value. As I have written elsewhere, flint artefacts, mainly macroliths and axes, were a sort of alter ego of metal at a time when metal was preparing society for its complete acceptance, with which many economic, ideological, cognitive and other consequences were connected, and at a time when both technologies were continued as part of the same complex of words, metaphors and concepts (*Dzbyński 2011; 2013; Fig. 4*). Therefore, measurement became the basic landmark element in the communication process, which corresponded on the plane of the metaphorical network, along with such features as specialised production centres, copper, precious resource extraction from the ground, value, prestige, *etc.*

I suggest that Bronze Age societies were cognitively prepared to adopt abstract weight measures because earlier societies also used counting and measuring, although without abstract numbers and with limited arithmetic, as shown by the example of Near Eastern recording systems and ethnological research (*Barrow 1999; Schmandt-Besserat 1992; Ifrah 1985; Saxe 1982*). Before the development of the abstract concept of weight, which is the most adequate description of metal value in complex social relations, and which did not fully occur until the Bronze Age, more specific assessment mechanisms were in use which we see as markers of the fragmentation of copper objects, as well as the forming of copper into bars or ingots according to a linear measure, as in the case of Cortaillod beads, copper rings, copper wire *etc.* However, we would have great difficulty in establishing those units of measurement. We should rather assume that they had not yet been detached from the concrete, which several virtually different measures discovered in Europe seem to sug-

gest (Thom 1967; Rasch 1987; Nikolov 1991; Rotländer 1999; Karlovsky, Pavuk 2002). Their dissimilarities probably result from the fact that they were anthropogenic measures taken on the spot. They had a strong connection with the body, perhaps with many bodies or with different body parts which were a reference for different areas of myth and ritual (Dzbyński 2013). Another possibility is that some artefacts were perceived as a reference unit of themselves, which is suggested in the correspondence between Cortaillod beads and the copper axe. This assumption is very interesting in the context of Strahm's (1994:19) studies, where he noticed that within the individual workshops there may have been a need to produce uniform axes, pointing to the handful of recorded wooden axe models in the Alps.

The examples and interpretations mentioned above make us aware that the process of reaching some truths, which are obvious from our perspective, took place in a time and space of which we still know little. We may surely assume, however, that mathematics did not appear spontaneously in the heads of our ancestors and was not introduced to them from the outside, but was a long-lasting process, which continues to this day. At this point, we have discussed only a part of this process, the very early part. The evidence presented confirms the generally accepted hypothesis that the process of forming mathematical ideas went from the concrete to the abstract. As to Europe, this was also a process of transforming a linear measure, a measuring stick, into an abstract number which belonged to a new vocabulary, describing the metal's weight (Dzbyński 2013). According to Renfrew (2004), weight is a material-



Fig. 4. The macrolithic blade was both a requisite of prestige as well as a mental image of the metal bar (after Dzbyński 2013).

symbolic fact. It does not develop as an embodiment or materialisation of earlier mental concepts, but through the development of the concept-construct itself in connection to experience of the material world. This process took place on a human communication level in interaction with material culture development in prehistory.

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