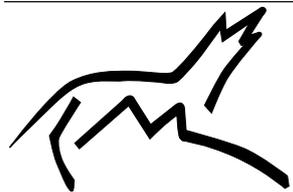


Revista
d'Arqueologia
de Ponent



n° 35 2025

**Measurement systems
and quantification in antiquity**

*Sistemes de mesurar
i quantificar a l'antiguitat*

Edited by Mònica Bouso

Tolle numerum omnibus rebus et omnia pereunt
Take from all things their number and all shall perish
— Saint Isidore of Seville, *Etymologies* III, 4

Introduction

The idea for this dossier arose during a research stay at the Archaeological Research Unit of the University of Cyprus in 2022 following conversations with Enrico De Benedictis, a PhD candidate specialising in the weight system of Cyprus. These exchanges highlighted the enormous problems and shortcomings surrounding the study of measurement systems and quantification in antiquity. This is, in fact, an area of study that is fundamental to understanding many aspects of the lives of communities of the past.

Quantification has played an essential role in countless aspects of the human experience. It is

unthinkable to consider the most basic aspects of everyday life, such as predicting the quantity of seeds required to sow a field, measuring the field itself, or arranging a meeting, without wondering how it was done. These systems need to be codified and agreed upon not only in order to function effectively within a community, but also between communities from different regions.

However, although this topic has been the object of study for almost two centuries, the positive impact it bears on our understanding of ancient societies is often overlooked. We believe that this situation also stems from methodolog-

ical issues of the discipline. In fact, the identification of material culture serving to quantify time, length, surface area, weight, etc., is often problematic. It is time to overcome this state by adopting a truly interdisciplinary perspective.

And, while archaeology as an interdisciplinary field whose research requires the collaboration of multiple specialists (geologists, physicists, chemists, philologists, etc.), the specific area of measurements and quantification without this interdisciplinary approach simply could not be carried out. This is because the team must also include archaeologists (who analyse the elements of both material culture artefacts and iconographic remains), epigraphists and philologists (who are proficient in the writing techniques and languages of different geographical areas), and also mathematicians, astronomers, and physicists.

These specialists are capable of understanding where lead the figures that appear in the texts, what measures and systems lie behind lists and elements of material culture, what artefacts whose identification and function may not be obvious at first glance (such as water clocks, i.e., ceramic containers with perforations), as well as their lack of preservation due to their perishable materials. The idea is not new that if you do not know what you are looking for, or do not use the right techniques to identify it, you will not find it. There exists a variety of examples of this, one of the most striking being the recovery of countless micro-remains from excavated sediments simply by sifting, or collecting pebbles in places far from rivers.

In other words, we must not only study what the texts say and their implications, but also question what traces of material culture may accompany these operations, their contexts, their functions, etc. It is particularly urgent to focus directly on the material remains. In this regard, De Benedictis also drew my attention to the usual lack of information about the weight of objects that could have served as weights in the online databases of many museums around the world. This type of research can also, why not, resort to experimental archaeology to test whether such reconstructions are feasible (what materials are needed, how to work them, how they function, etc.).

It is surprising to note that the essential collaboration of all these specialists occurs only on rare occasions, and that this field of study has only recently begun to receive more attention, as evidenced by the volumes edited by Chemla and Michel 2020, Chemla *et al.* 2022, and Chambon and Otto 2023.

These reflections led to the conception of this dossier that was initially a very ambitious pro-

ject integrating articles highlighting systems for measuring time, length, volume, capacity, and weight centred on a specific period, the end of the Bronze Age, in three interconnected geographical areas (Eastern Mediterranean, Near East and Egypt). Ultimately, although it did maintain the temporal scope, it was not possible to achieve this objective as the dossier only includes one contribution on each of these systems (i.e., time, length, volume, capacity, and weight). Although it would have been ideal to have delved into all these systems from the standpoint of the same place and period, we consider the results to be optimal as they not only offer a coherent approach to these aspects, but point out future lines of work.

I would like to take this opportunity to express my sincere gratitude and appreciation to the specialists who accepted and submitted excellent contributions to this dossier, as well as to the reviewers for their invaluable collaboration and comments that have improved the overall results.

The dossier opens with the article 'Thebes versus Hattusha: two different ways of understanding time at the end of the Bronze Age' by Juan Antonio Belmonte (researcher at the Canary Islands Institute of Astrophysics and professor at the University of La Laguna). It compares two different systems of measuring time used by two of the major powers of the Late Bronze Age: the Hittites and the Egyptians. Although these states were part of the so-called 'Club of Great Powers', and maintained close diplomatic relations and commercial contacts, each retained its own way of measuring time.

The following article, 'Measuring length in ancient Egypt', is also set in New Kingdom Egypt, a period that boasts an extraordinary archaeological, iconographic, and textual record, making it an inexhaustible source of information. In this sense, Egypt is not only exceptional due to its environment that has allowed the preservation of artefacts of perishable materials that have not survived elsewhere, but also serves as a reference and inspiration for other contexts. Annette Imhausen (professor at Goethe University Frankfurt), through an approach to all possible records with absolute authority, provides a kaleidoscopic and exhaustive overview of the systems of calculating length in Egypt's Late Bronze Age.

The next contribution entitled 'Mesures de la terre et des briques dans les activités de construction en Mésopotamie ancienne à l'âge du Bronze' by Martin Sauvage (researcher at the French National Centre for Scientific Research) takes us to Mesopotamia. This item addresses

the complex study of textual data and archaeological remains, not only regarding the measurements of mud bricks used in construction, but also other relevant aspects such as the division of labour.

This is followed by ‘Filling the gaps: methodological issues in capacity research of Late Bronze Age Maritime Transport Containers’ by Cydrisse Cateloy (post-doctoral researcher at ARU, University of Cyprus). This methodological study delves into calculating the capacity of ceramics used for transport. Its importance does not need to be emphasised given its crucial implications regarding aspects of the transport and exchange of products, etc.

The dossier closes with an article by Enrico De Benedictis (PhD candidate at the University of Cyprus) entitled: ‘Is it a weight? Methodological challenges in metrological research. A study case of the Late Bronze Age site of Apliki-Karamallos (Cyprus)’. This contribution, primarily methodological in nature, begins with a first-hand analysis of a set of artefacts to demonstrate whether or not they could be weights. It demonstrates how a rigorous treatment of the archaeological record is the first step in achieving consistent results.

In short, we hope to have fulfilled one of the main motivations behind this dossier, which is to highlight the importance of this field of study and encourage genuine interdisciplinary research in order to gain the most holistic understanding possible of a fundamental part of the activities of communities of the past, as they are for those of today, notably measuring time and trade.

We therefore hope that this modest but illustrative dossier represents a first step in this direction.

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Tolle numerum omnibus rebus et omnia pereunt
Treu a totes les coses el seu número i totes moriran
— Sant Isidor de Sevilla, *Etymologies* III, 4

Introducció

La idea d’aquest dossier va sorgir durant una estança de recerca en el *Archaeological Research Unit* de la Universitat de Xipre en 2022 després de diverses converses amb Enrico De Benedictis, doctorant especialitzat en el sistema de pesos a Xipre. Aquestes converses van posar sobre la taula les enormes problemàtiques i mancances que envolten l’estudi dels sistemes de mesures i quantificació, en general, en l’antiguitat. Un àrea d’estudi que precisament és fonamental per entendre múltiples aspectes de la vida de les comunitats del passat. La quantificació va escenificar un paper essencial en innumerables aspectes de l’experiència humana. Sense dubte resulta impensable entendre els aspectes més bàsics de la vida quotidiana, com preveure quantes llavors són necessàries per plantar un camp, les mesures d’aquest camp o concertar el moment d’una trobada sense preguntar-se com es feia. Uns sistemes que a més de ser codificats necessiten ser consensuats per poder funcionar de manera efectiva, no només dins d’una mateixa comunitat, sinó entre comunitats de diverses regions.

Tot i així, encara que aquest tema s’ha estudiat durant quasi dos segles, l’impacte positiu que podria tenir en la nostra comprensió de les societats antigues es passa per alt amb freqüència. Creiem que aquesta situació també es deriva de qüestions metodològiques d’aquesta disciplina. De fet, sovint la identificació de la cultura material, que s’utilitzava per quantificar el temps, la longitud, les superfícies, els pesos, etc., sembla ser problemàtica. És hora de superar aquesta situació adoptant una perspectiva autènticament interdisciplinària.

I, si l’arqueologia com a disciplina que necessàriament arrossega amb ella tantes altres i, per això, la converteix en essència en un camp interdisciplinari, que requereix del treball conjunt de múltiples especialistes (geòlegs, físics, químics, filòlegs, etc.) per conduir una investigació, en allò que es refereix a l’estudi de les mesures i la quantificació, sense aquesta interdisciplinarietat, l’estudi, simplement, no es pot dur a terme. Això és així ja que no només és necessari comptar a l’equip amb arqueòlegs (que saben analitzar els elements de la cultura material, tant artefactes como restes iconogràfiques), epigrafistes i filòlegs (que dominen les tècniques d’escriptura i els idiomes de les distintes àrees geogràfiques), sinó a més: matemàtics, astrònoms i físics.

Aquests especialistes són els que són capaços d’entendre a on ens porten les xifres que apareixen en els textos, quines mesures i quins sistemes s’amaguen darrera de llistes i elements de la cultura

material, uns artefactes llur identificació i funcionalitat a simple vista pot no ser obvia (com poden ser rellotges d'aigua, i.e., contenidors ceràmics amb perforacions), així com l'absència de la seva preservació per haver estat fabricats amb materials peribles. No és nova la idea de que si no se sap que és allò que se cerca, o no s'apliquen les tècniques adequades per això, no és possible trobar-ho; tenim varietat d'exemples d'això, un dels més il·lustratius és el de rescatar del sediment que s'excava innumerables micro-restes amb només garbellar-lo, o recollir còdols en llocs allunyats de rius.

És a dir, cal estudiar no només el que diuen els textos i les seves implicacions, sinó qüestionar-se quins vestigis de la cultura material poden acompanyar aquestes operacions, el seu context, el seu funcionament, etc. Especialment resulta imperiosa la necessitat d'estudiar les restes materials directament. En aquest sentit, De Benedictis va cridar la meua atenció sobre la usual falta d'informació sobre el pes dels objectes, que podrien ser pesos, en les bases de dades en línia de molts museus arreu del món. La investigació, a més, pot, per què no, utilitzar l'arqueologia experimental per provar si aquestes reconstruccions poden ser viables (quins materials es necessiten, com es treballen, com poden funcionar, etc.).

Amb gran sorpresa s'observa com la imprescindible col·laboració de tots aquests especialistes es dona només en comptades ocasions, així com que aquest camp d'estudi està rebent una major atenció només recentment, com els volums editats per Chemla i Michel 2020, Chemla *et al.* 2022 i Chambon i Otto 2023 posen de manifest.

Aquestes reflexions varen provocar, doncs, la concepció d'aquest dossier. Un projecte que inicialment era molt ambiciós, pretenia reunir articles de tres àrees geogràfiques interconnectades en un període específic, el final de l'edat del bronze (Mediterrània Oriental, Pròxim Orient i Egipte) i tractant, en cada un d'ells, els sistemes de mesurar temps, longitud, volum, capacitat, i pes. Finalment, no ha estat possible assolir aquest objectiu i el dossier recull únicament una contribució sobre cada un d'aquests sistemes, i.e., temps, longitud, volum, capacitat i pes, però s'ha intentat mantenir l'àmbit temporal. Encara que l'haver tractat tots aquests sistemes d'un mateix lloc i època hauria estat lo ideal, considerem que el resultat ha estat òptim, ja que ofereix una coherent aproximació a aquests aspectes i, a més, s'apunten línies de treball futures.

Des d'aquestes línies vull expressar la meua més sincera gratitud i reconeixement als especialistes que van acceptar la invitació i han escrit per aquest dossier unes excel·lents contribucions, així com la inestimable col·laboració dels avaluadors que amb els seus comentaris han millorat el resultat global del dossier.

Obre el dossier l'article "Thebes versus Hattusha: two different ways of understanding time at the end of the Bronze Age" de Juan Antonio Belmonte (investigador del Instituto de Astrofísica de Canarias i professor de la Universidad de La Laguna). En ell s'ofereix la comparació entre dos diferents sistemes de mesurar el temps de dues de les principals potències del bronze recent: la hitita i l'egípcia. Unes potències que, tot i que formaven part de l'anomenat "Club dels grans poders" i van mantenir estretes relacions diplomàtiques i contactes comercials, cada una va conservar la seva pròpia manera de mesurar el temps.

El següent capítol "Measuring length in ancient Egypt" se situa també en l'Egipte del Regne Nou, període que compta con un extraordinari registre arqueològic, iconogràfic i textual, registre que el converteix en una font inesgotable d'informació. En aquest sentit, Egipte no és només excepcional, degut als beneficis del seu medi que han permès la preservació d'artefactes fabricats amb materials peribles que no s'han conservat en altres llocs, sinó que també pot servir de referent e inspiració per altres contextos. Annette Imhausen (professora de la Goethe University Frankfurt) aporta un calidoscòpic i exhaustiu recorregut pels sistemes del càlcul de la longitud en l'Egipte del bronze final, apropant-se, amb absoluta autoritat, a tots els registres possibles.

A continuació, en el següent capítol "Mesures de la terre et des briques dans les activités de construction en Mésopotamie ancienne à l'âge du Bronze", Martin Sauvage (investigador del *Centre national de la recherche scientifique* francès) ens transporta a Mesopotàmia. En aquesta contribució s'aborda el complex estudi de dades textuales i restes arqueològiques no únicament sobre les mesures dels tovots utilitzats en la construcció, sinó també altres rellevants aspectes relacionats, com la divisió del treball.

Segueix l'article "Filling the gaps: methodological issues in capacity research of Late Bronze Age Maritime Transport Containers" de Cydrisse Cateloy (investigadora post-doctoral al ARU, University of Cyprus) sobre la capacitat. En aquest cas es presenta una aproximació metodològica sobre el càlcul de la capacitat de les ceràmiques destinades al transport. No resulta necessari recalcar la importància d'aquest estudi per les seves implicacions en aspectes crucials per al transport i l'intercanvi de productes, entre d'altres.

Tanca el dossier l'article d'Enrico De Benedictis (doctorand de la University of Cyprus) titulat: "Is it a weight? Methodological challenges in metrological research. A study case of the Late Bronze Age site of Apliki-Karamallos (Cyprus)". Aquesta contribució de caràcter fonamentalment metodològic, comença des del principi, és

a dir, analitzant de primera mà un conjunt d'artefactes per demostrar si podrien ser o no pesos. Demostra com tractar amb rigor el registre arqueològic és el primer pas per obtenir resultats coherents.

En definitiva, esperem haver complert una de les principals motivacions d'aquest dossier que és posar de manifest la importància d'aquest camp d'estudi i encoratjar un autèntic estudi interdisciplinari per entendre de la manera més holística possible una part fonamental de les activitats de les comunitats del passat, com ho continuen sent per les actuals, com és mesurar el temps o comerciar.

Esperem, doncs, que aquest modest però il·lustratiu dossier sigui un primer pas en aquest camí.

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Thebes versus Hattusha: two different ways of understanding time at the end of the Bronze Age

Tebes versus Hattusha: Dues maneres diferents d'entendre el temps al final de l'edat del bronze

The multinational Hittite Empire and the powerful theocratic Ramesside monarchy of Egypt clashed along the shores of the eastern Mediterranean during the Late Bronze Age. Numerous sources shed light on how the Egyptians measured time during that period through their civil calendar. Interestingly, this calendar more or less followed the rhythm of the climatic seasons newly in this period after centuries of wandering on the seasons tapestry. However, evidence as to how the Hittites measured time is scarce and less explicit. The little data from Hattusha nonetheless suggest a lunar calendar attempting to keep pace with the seasons based on a mostly unidentified pattern which might have included an intercalary month. This study briefly summarises and confronts each of the time-keeping systems. They indeed obey to different climatic and sociological conditions. The calendar of the Hittites may have collapsed with the abandonment of Hattusha in the early 12th century BC, whereas that of Egypt survived a period of uncertainty to eventually rule the whole world through its offspring, the Julian and Gregorian calendars.

Keywords: Ancient Egypt, Hittite Empire, Late Bronze Age, calendar: civil, calendar: lunisolar, *Peret Sopdet*, Rameside star-clocks.

L'imperi multinacional hitita i la poderosa monarquia teocràtica ramèssida d'Egipte es varen enfrontar al llarg de les costes de la Mediterrània oriental durant l'edat del bronze final. Nombroses fonts donen llum sobre com els egipcis mesuraven el temps durant aquest període a través del seu calendari civil. Curiosament, aquest calendari seguia més o menys el ritme de les estacions climàtiques, una novetat en aquest període després de segles de vagar pel tapís de les estacions. No obstant, les evidències de com els hitites mesuraven el temps són escasses i menys explícites. Tot i això, les escasses dades procedents de Hattusha suggereixen un calendari lunar que intentava seguir el ritme de les estacions basant-se en un patró majoritàriament desconegut que podria haver inclòs un mes intercalari. Aquest estudi resumeix breument i compara aquests dos sistemes de mesurar el temps. De fet, aquests sistemes obeeixen a diferents condicions climàtiques i sociològiques. El calendari dels hitites pot haver desaparegut amb el col·lapse de Hattusha a principis del segle XII aC, mentre que el d'Egipte va sobreviure a un període d'incertesa per acabar dominant el món sencer a través dels seus descendents, els calendaris julià i gregorià.

Paraules clau: antic Egipte, imperi hitita, bronze final, calendari civil, calendari lunisolar, *Peret Sopdet*, rellotges d'estrelles ramèssides.

Introduction

The two great powers of the eastern Mediterranean toward the end of the Late Bronze Age (LBA) (mid-1200s BC) (see von Beckerath 1997 and Hornung *et al.* 2006 for the chronology of this period) settled on a truce after decades of conflict as their endless clashes almost exhausted their economic and human resources. Their rulers Ramesses II and Hattusili III (fig. 1) thus signed the first peace treaty reported in human history. The act was so far-reaching that a replica of it welcomes foreign delegations in the entrance hall of the United Nations building in New York (Bryce 2024). In the treaty the King of Hatti, in need of legitimation, and the powerful Pharaoh of Egypt concurred that trade and mutual support were more beneficial than a permanent state of war which only favoured their rising enemies

such as the Kingdom of Assyria. The truce was consolidated by the marriage of the eldest daughter of Hattusili and Paduhepa to Ramesses II, the latter having recently lost his beloved wife (possibly Nefertari).

These two powers differed greatly regarding several social, political, and economic aspects, as well as in their approach to time and how to design a calendar. These last points, the main focus of this essay, illustrate how contemporary neighbouring cultures can in fact differ in key features of daily life as the control of time.

Ramesside Egypt was a centralised state where the ruler played an overwhelming role in every sphere of life. After Akhenaten's attempt to place in check the power of the priests, notably those of Amon, former general Horemheb and his Ramesside successors restored order under a military dictatorship. The intention was to reinstall

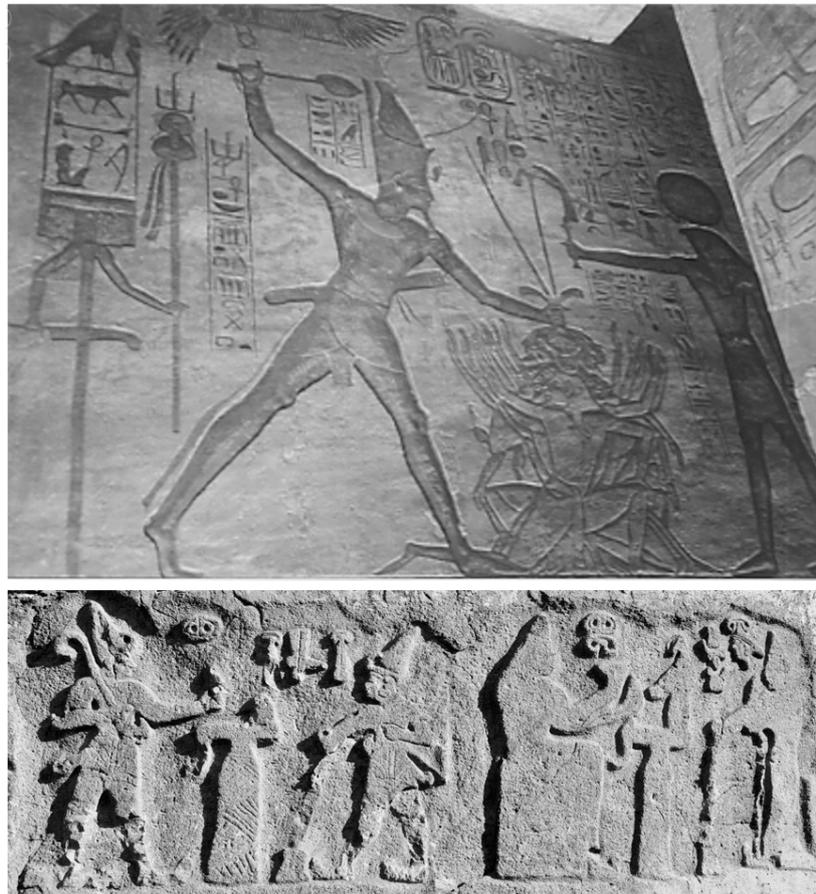


Figure 1. Two different perspectives of the two great antagonists of the Late Bronze Age. Top: King Userma'atra Ramesses (II) executing Hittite enemies after the battle of Qadesh in the freezes of the temple of Abu Simbel. (Photograph by author). Bottom: Fraktin relief in the Taurus Mountains depicting Hittite King Hattusili III (who participated in the Battle of Kadesh as a prince) making an offering to God Teshub. To the right is his wife, Queen Tawannanna Puduhepa, making an offering to Goddess Hebat. (Photograph courtesy of wikimedia-commons).

	CLASSIC SOURCES	CIVIL MONTHS	OLD NAMES	TRANSLATION	NEW NAMES	TRANSLATION
1	Thoth	I <i>3ht</i>	<i>th(j)</i>	Drunkenness	<i>dhwtyt</i>	Thoth's
2	Phaophi	II <i>3ht</i>	<i>mnht</i>	Clothing	<i>p3 n jpt</i>	That of Opet
3	Athyr	III <i>3ht</i>	<i>hwt-hr</i>	Hathor	<i>hwt-hr</i>	Hathor
4	Choiak	IV <i>3ht</i>	<i>k3-hr-k3</i>	Ka on ka	<i>k3-hr-k3</i>	Ka on ka
5	Tybi	I <i>prr</i>	<i>šf-bdt</i>	Emmer Spring	<i>t3 ʿbt</i>	The Offerings
6	Mechir	II <i>prr</i>	<i>rkh (ʿ3/wr)</i>	(Great) Burning	<i>(p3 n p3) mhyr</i>	Low Lands
7	Phamenoth	III <i>prr</i>	<i>rkh (nds)</i>	(Small) Burning	<i>p n imn-htp</i>	That of Amenhotep
8	Phasmouthi	IV <i>prr</i>	<i>rnwtt</i>	Renutet's	<i>p n rnwtt</i>	That of Renutet
9	Pachon(s)	I <i>šmw</i>	<i>hnsu</i>	Khonsu's	<i>p n hnsu</i>	That of Khonsu
10	Payni	II <i>šmw</i>	<i>hnt-hty</i>	First of ...	<i>p n int</i>	That of the Valley
11	Epiphi	III <i>šmw</i>	<i>jpt-hnt.s</i>	Her majesty Ipet	<i>jp jp</i>	(Feast of) Ipet
12	Misore	IV <i>šmw</i>	<i>wpt rnpt</i>	Year Opener	<i>wpt rnpt</i> <i>mswt rʿ hr-3hty</i>	Year Opener Birth of Re ⁶ (Hor-Akhty)
	Epagomenoi	<i>dw [5] hrwy rnpt</i>		5 upon the year		

Figure 2. Proper names of the 30-day long months of the civil calendar plus the five *epagomenoi* (upon or above the year). Besides the classic names, the old (traditional) and new proper Egyptian names are listed, together with their hypothetical translation. A series of month names changed completely in the Ramesside period to adapt to important festivals in the area of Thebes such as *Opet* (*Phaophi*) or the Feast of the Valley (*Payni*). The 12th month changed its name from *Wepet Renpet* to *Misore* at an undetermined moment in the first millennium BC. (Adapted from Belmonte and Lull 2023: Table 5.3).

Egyptian power in the Levant and in Nubia as far south as the fourth cataract (Shaw 2000). In order to control Palestine and the south of Syria, a new capital was founded at Pi-Ramesses. However, Thebes, where the kings were buried, still retained religious primacy with an unprecedented construction programme.

The Egyptian population was presumably a very coherent ethnic group in spite of comprising Nubians as well as Syrians from the petty vassal states south of the Lebanese Mountains. Even if 'Middle Egyptian' still served for monumental inscriptions, a new language, 'New Egyptian', which included determinative articles, was presumably dominant in daily life. A particularly relevant example of this was the creation, perhaps in Thebes, of a new set of names for the months of the civil calendar (fig. 2), as will be discussed below.

The Hittite Empire, on the contrary, was a multi-lingual and multi-cultural state that controlled Anatolia and northern Levant for more than three centuries. From their homeland in the Land of Hatti, and their capital in Hattusha, the Hittite rulers dominated a vast territory with varying frontiers. This 'empire' at its maximum extension in the late 13th century BC included, thanks to a network of vassal states, the vast majority of Anatolia and the north of Syria. The nucleus of the kingdom was formed by the Land of Hatti, the adjacent Upper and Lower Lands, and the neighbouring territories of Kizzuwatna and Tarhuntassa. The region was inhabited by a variety of peoples, including the Hittites, who spoke the 'Nesite' language, an Indo-European language. This was

written in cuneiform script and its name comes from the still unidentified city Nesha. However, the Hittite population of the LBA also comprised numerous groups of Luwians who spoke another Indo-European language written in Luwian hieroglyphs (fig. 1). The Hurrians, particularly in the region of Kizzuwatna, also contributed to the linguistic diversity. There are arguments that Nesite was only used for state politics and religious acts at the end of the kingdom, while Luwian was the language spoken by the vast majority of the population (Bryce 2005; Melchert 2003).

The religious practices and social customs of the Hittites comprised a complex and diverse amalgamation of traditions. The case of religion is of particular significance in this framework given that Hittite and Luwian creeds, influenced by Assyrian traditions, superseded the original substrate of ancient Hattian beliefs (see Taracha 2009 for an examination of the Hittite religion). This situation was further complicated by the influence of Hurrian beliefs on the Hittites. This may have taken place in Hattusha after the seizing of power by Tudhaliya I (c. 1400 BC) and his successors (possibly of Kizzuwatnean origin). Taracha (2009: 33) asserts that this dynasty was instrumental in the creation of the empire. It is thus not surprising that the primary sources referred to the 'Thousand Gods of Hatti'. Therefore, Hittite religion, in its strictest sense, has been described as a syncretistic system endorsed by the state (Singer 1994). The Hittite calendar thus possibly resulted from similar variegated influences.

However, before delving into the debate of how the problem of time control was confronted by these contemporary civilisations of the LBA, it is necessary to devote a few paragraphs to the ultimate reason why keeping time in a simple and coherent manner was so difficult in the past. This leads to the discussion of the problem of incommensurability.

How to face incommensurability

The need to resort to specific astronomical events in order to control time has been subjected since ancient times to one of the problems that has caused the most trouble for astronomers of all times, the notion of ‘incommensurability’. These include phenomena such as the solstices and ‘equinoxes’ (Belmonte 2021), or the rising or setting of certain stars, such as Sirius or the Pleiades. Hence, the natural duration of the most important cycles of time, the tropical year and the synodic month, appear to have been ‘invented’, so to speak, to complicate humans lives.

The lunar month or lunation is a unit of time that is very appropriate to subdivide the seasonal cycle into shorter periods. The full moon likewise must have been very decisive for people possessing no electric light. It is for this reason that the moon served for calendars of almost all cultures of the planet (Stern 2012). However, the first problem of measuring time based on the moon is that the synodic month averages 29.5306 days. The easiest solution was to alternatively define months of 29 and 30 days, not necessarily in a regular basis, leading to an average ‘month’ of nearly 29 and a half days.

This yielded a year consisting of 12 lunar months broken down into 354 days. However, this lacked 11 and a quarter days in round numbers to complete a tropical year of 365.2425 days in Antiquity. This led to the question of what to do with these days? Some cultures or religions, such as Islam, completely ignored them. Others like the earlier Babylonians or ancient Romans occasionally resort to intercalary months with solstices, and maybe equinoxes, or the rising and setting of the stars, as milestones. Others simply ignored the true lunar month and ended up developing a unit bearing the same name that had nothing to do with the phases of the moon (today’s Western culture is a case in point). Finally, certain cultures possessing an advanced mathematical knowledge developed stable systems, intercalating months in cycles of three, eight, or nineteen years to solve the incommensurability.

The simplest nearness between the lunar and solar cycles occurs every three years (fig. 3) as 37 synodic months equates to a total of 1,093 days

yielding an average of three solar ‘years’ of 364¼ days. However, this would be one day shorter than the real one. Therefore, adding an intercalary month of 30 days every three pure lunar years resulted in a reasonable means to adjust the calendar for the typical period of a human life span, which in the past equated with 30 to 40 years. However, finer adjustments were needed for longer periods of time. Hence, this cycle still resulted in a vague lunisolar calendar that required periodic reforms and adjustments.

The next moment of nearness is every 2,923 days (more or less one day) as 99 synodic months are almost equivalent to eight tropical years. The difference is slightly more than one and a half days after eight years, or approximately one month every 150 years. This cycle is called the ‘octaeteris’. This served as the base of the calendar of most Hellenic cities since its ‘discovery’ by Cleostratus in the early 5th century BC and subsequent refinements by Eudoxus of Cnidus in the middle of the 4th century BC.

However, the best possible estimate is due to that 235 synodic months corresponds with astounding accuracy to 19 tropical years, with a dif-

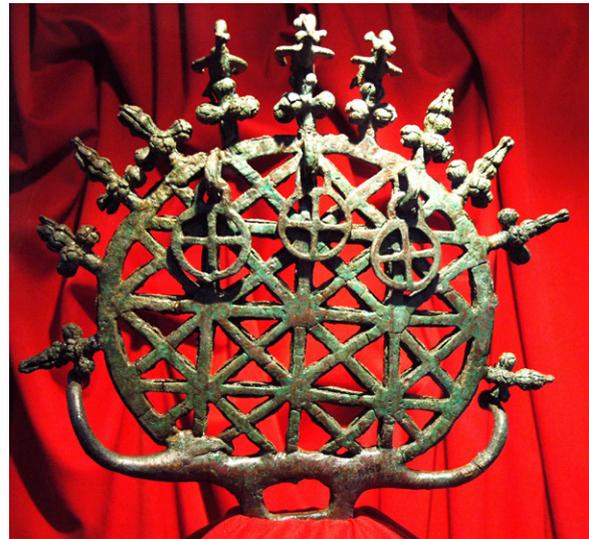


Figure 3. Bronze disc discovered in one of the pre-Hittite so-called royal tomb in Alaça Hüyük (perhaps ancient Arinna). This complex object may have a strong astronomical symbolism with the disc divided in 14 crossed sections, crowned by 12 appendices (one lost) and completed by 3 hanging ‘solar’ crossed symbols. It might schematically represent a year of 12 moons counted 3 times, the simplest way to produce a working lunisolar cycle by adding one intercalary month. This is perhaps being represented by the central disc itself. Being a singularity, there is no additional evidence supporting this hypothesis. (Photograph by author, courtesy of the Museum of Anatolian Civilizations, Ankara).

ference of only two hours and eight minutes per cycle or one day every 213 years. This exceptional coincidence is the basis of the 'Metonic cycle' (named in honour of the Athenian astronomer Meton), who presumably discovered it in 432 BC. However, it is more likely that this cycle, along with the method of intercalating the months serving to work it out, saw and earlier developed in Mesopotamia, where it was adopted as the basis of the calendar. Or perhaps not? A compelling proposal in this sense is discussed below.

It is due to these issues that astronomy was entrusted, among other facets, with the task of adjusting the calendar. It is also likely that the need to control the seasonal cycle led to the first serious attempts to identify the trajectories of the celestial bodies, specifically, the sun, moon, planets, and main stars. This was the case of Egypt and Mesopotamia, and other neighbouring regions. However, the insertion of intercalary months does not seem to have followed any established rule. It was not until the 5th century BC that a stable cycle of intercalations was developed based on the 19-year cycle that served as the basis of the official calendar of Babylon during the Seleucid Empire (and perhaps earlier). This was ultimately spread by the Jewish diaspora and from there passed on to the Christian church, where it served as the basis to calculate the dates of Easter well into the 16th century.

The problem of adequately squaring the seasonal cycle with the movements of the sun and the moon provoked King Alfonso X of Castile, to complain about the God's 'subtlety' when creating such a complex scheme. This ruler known as the 'Wise' went as far as to argue that if it had been his duty to create the Cosmos, he would have made it less complicated.

The Civil Calendar of ancient Egypt

One of the greatest mysteries remaining today, despite the spectacular advances of Egyptology since the decipherment of the hieroglyphs almost two centuries ago, is the question of the origin of ancient Egypt's 'civil' calendar which served as the basis of calendrics in the Nile Valley. Several hypotheses have been the subject of endless debate (Parker 1950; Spalinger 1994; Wells 1994; Depuydt 1997; von Bomhard 1999; Spalinger 2018). This analysis retains the hypothesis we have defended for years (Belmonte 2003) that has been recently upgraded by Belmonte and Lull (2023: 320).

This 365-day civil calendar, which can be catalogued as a solar calendar, probably dates to the outset of the Pharaonic Era, presumably during the 2nd Dynasty, when there is the first evidence of the Cult of the Sun-God Ra (Krauss 2011). It

was fully developed during the Old Kingdom as it served to govern the offerings in the cemetery of Saqqara. This is evidenced by papyri dating to the reign of Userkaf that cite events that took place at the end of the 4th Dynasty under the rule of Menkaura.

This revolutionary calendar consisted of twelve months of 30 days each, divided into three decades totaling 360 days. To these were added the 'Five upon the Year' (fig. 2), five additional days called *epagomenoi* in Hellenistic sources. These were dedicated, at least since the New Kingdom (as it was thought they rhymed with their moment of birth), to five of the greatest ancient Egyptian deities: Osiris, Isis, Seth, Nephthys, and Horus the Elder. These five days, which upped the total to 365, stood apart (hence the name) and were not taken into consideration within the general computation of the year.

The months, in turn, were grouped into three 'seasons' of four months (fig. 4), known since the earliest documents as Inundation (*Akhet*), Going Forth (*Peret*), and Drought (*Shemu*, perhaps literally meaning 'water in the ponds'). The last two were at times in Hellenic texts termed as winter and summer. These designations, with season and an ordinal number from I to IV, were common throughout the Pharaonic period. In fact, they are the only cases that appear to be standard among the monumental hieroglyphic inscriptions.

However, the months in Greek and Aramaic papyri from the Hellenistic period and in later Coptic texts are not named in this way but referred to by a series of standard proper names. These include the names of certain divinities. Figure 2 lists the names in later sources (and Coptic) and the old and new names of the months as reported in Pharaonic registers. It is compelling that these have been preserved in spoken Arabic in Egypt and are still used by the Coptic Church to establish the corresponding Christian festivals.

These names, which can be traced back to the original Egyptian language, have been the subject of great controversy. Almost all of these names have been found in lists of festivals, where they may correspond to proper names of months, and in hieratic inscriptions, written mostly on ostraca and papyri dated to the LBA. These have been mostly discovered at Deir el Medina, the village of the workmen who built the royal tombs at Thebes. The fundamental discrepancy is the name of the twelfth month, *Misore*, which clearly relates to the Egyptian *mswt-ra* ('birth of Ra'). However, this name does not appear in that form in the inscriptions as it was most often replaced by *Wepet Rempet* (i.e., 'the one that opens the year'). Of interest is also the use in I *Akhet* 1, the First of Tehy among the older names, and the First of



Figure 4. Relief depicting the three seasons of the Egyptian calendar (*Akhet*, *Peret* and *Shemu*) originally based on the Nile cycle. The scene decorates a door-jamb at the gate of the Tomb of Mereruka (Vizier of King Teti, 6th Dynasty) in Saqqara. The 'Five upon the Year' are absent from the scene. (Photograph by author).

Thoth among the new versions of the Egyptian New Year festival (fig. 2).

The civil months depicted in the friezes of the Hellenistic Temple of Horus at Edfu appear associated with a series of proper names that only minimally align with those discussed above. These other names do appear on other occasions in hieroglyphic inscriptions, such as that of the Tomb of Senenmut (where the last month is nonetheless *Wepet Renpet*). These probably are the original names of the months of the civil calendar (Spalinger 2018; Belmonte and Lull 2023: 335). However, worth noting is the suggestion by Depuydt (1997) that this was somehow related to a parallel lunar calendar, an argument not espoused by Belmonte (2003).

One of the peculiarities of the 365-day calendar is precisely its length. The duration of the tropical year being about a quarter of a day longer implies that all cyclical events, including those of astronomical nature, are delayed by one day every four years (fig. 5). Among these singular events was the heliacal rising of the star Sirius (*Sothis* in Hellenic sources) called *Peret Sopdet*, a key festival of the annual calendar since it was supposed to be the harbinger of the flooding of the Nile. It was indeed a vital climatic phenomenon of social and economic significance throughout Pharaonic history (fig. 6). A delay of one day every four years meant that the timing of *Peret Sopdet* rotated throughout the civil calendar over a period of 1,460 years, known as a Sothic Cycle. The actual period is shorter, about 1,453 years, due to the

star's proper motion. According to Krauss (1985), the civil calendar was designed from its inception with this in mind, meaning that *Peret Sopdet* would be delayed one day every four years. However, there is hardly any evidence backing this in ancient sources.

It has often been assumed since first proposed by Parker (1950), but never absolutely proven, that *Peret Sopdet* equated with *Wepet Renpet* at the dawn of Egyptian civilisation when the civil calendar was created. This latter was the beginning of the civil calendar on the first day of the first month of the Inundation (I *Akhet* 1), when this and the beginning of the actual Flooding must have nearly coincided in time.

However, there is no trace of *Peret Sopdet* prior to the Middle Kingdom (see Krauss *in press* vs. Habitch *et al.* 2015). It is for this reason that Belmonte (2003) defended that the coincidence between the observation of the solar zenith-pass, during the summer solstice at Elephantine, with the arrival of the true flooding, was a better milestone to mark the origin of the civil calendar in the Protodynastic period. The timing of the *Wepet Renpet* subsequently began to wander through the climatic seasons (approximately one day ahead every four years) completing a cycle in about 1507 years. This period is slightly longer than, albeit similar in scale, the Sothic cycle (fig. 5).

This delay certainly did not go unnoticed. However, the point is that it was not considered sufficiently relevant to alter the normal course of things and merit modifications to the calendar. It

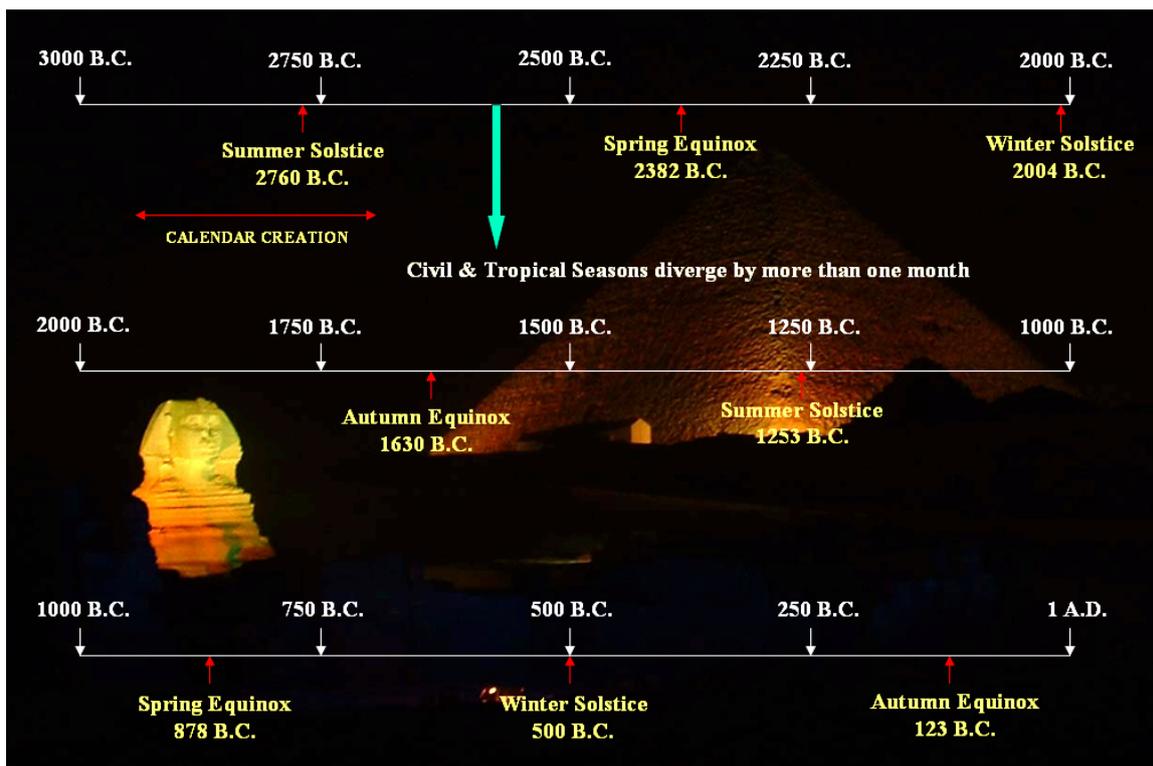


Figure 5. The New Year Festival (*Wepet Renpet*) of the Egyptian civil calendar as a wandering date on the season tapestry versus time, circling in c. 1507 tropical years. It is noteworthy that the civil and climatic seasons were in phase again c. 1250 BC during the reign of Ramesses II, for the first time after the creation of the calendar in a period centred in c. 2760 BC. This will not repeat until the Roman era. (Schema by author).



Figure 6. The Nile Flooding covering the fields of Egypt to the desert limits in the late 19th Century. This event marked the beginning of the economic year in ancient Egypt. It also precisely signalled the beginning of the civil calendar, with the first day of the first month of the Inundation (I *Akhet* 1), only when the calendar was created just before the era of the pyramids, and, fifteen centuries later, during the Ramesside period. (Adapted from an original old image by Lehnert and Landrock).

represented a time-keeping system whose great regularity from the economic, fiscal, administrative, and social standpoints rendered it so powerful that it apparently remained unchanged for more than 2,500 years.

Ptolemy III during the Hellenistic period unsuccessfully attempted to reform it in 238 BC by adding a sixth epagomenal day every four years (fig. 7). This reform known as the Decree of Canopus was only imposed under Caesar Augustus once Egypt had lost its independence (the Alexandrian calendar, which is still used by the Coptic church). In any case, the civil calendar continued in use in parallel to the new calendar. It was applied by the astronomer Claudius Ptolemy in all his calculations and 'endured' until the Renaissance, as Copernicus based his measurements on it.

This circumstance rendered it possible to determine when Thoth 1 coincided with the helia-

cal rising of Sirius, already in Roman times. This took place according to Censorinus in his *Die Natali Liber* in 139 AD under Emperor Antoninus Pius.

This information served as a milestone rendering it possible to establish the Egyptian chronology with relative accuracy. This is possible because the Egyptians referenced (albeit rarely) the date of the heliacal rising of Sirius in the civil calendar (fig. 7). Therefore, it is sufficient to calculate retrospectively, from the initial date provided by Censorinus, in order to know, in theory, with a small margin of error, on what Gregorian (or Julian) proleptic date such a notation was made. There exist several Sothic dates (Belmonte and Lull 2023: 365). One appears in the Decree of Canopus itself, which fits perfectly with the chronology established by alternative methods. Those of truly useful nature correspond to earlier dates that were registered, if it were not for the fact that

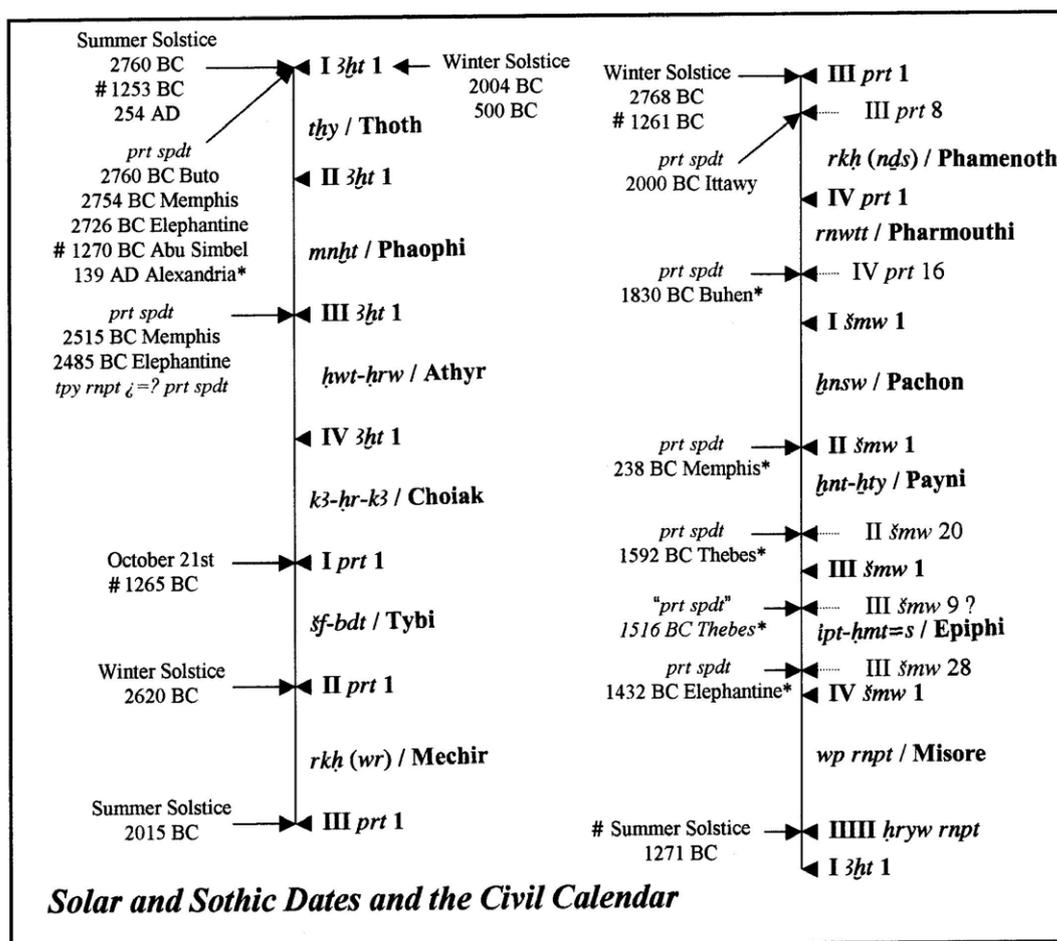


Figure 7. Solar milestones and *Peret Sopdet* dates as a function of chronological time and the civil calendar. The symbol # indicates key moments of the reign of Ramesses II. These include summer solstice in *Wepet Renpet* (I *Akhet* 1) in 1253 BC, *Peret Sopdet* at Abu Simbel temples in I *Akhet* 1 in 1270 BC, and I *Peret* 1 (aka the *Nehebkaou* Festival) in October 21st (Gregorian proleptic date) in 1265 BC, fulfilling the main alignment of the great temple of Abu Simbel (fig. 17). (Schema by author).

they are not always as accurate as one would expect or desire.

Another critical controversy regarding Egyptian calendrics is the role of religious festivals in society and, above all, their correct placement within the timeframe in the civil calendar. Numerous festival calendars are known from the Old Kingdom to the Graeco-Roman period. Two are notable for their length, number of festivals, and corresponding offerings (El Sabban 2000). On the one hand, there is The 'Million-Year' Temple of Ramesses III at Medinet Habu, which coincided with the collapse of LBA societies of the Levant. On the other hand, there is that of Dendera which is much later. Most calendars from the middle of the New Kingdom onwards, including certain from earlier times, mark festivals that relate to dates in the civil calendar. There is thus little doubt that the civil calendar from the 14th or 13th centuries BC onwards (if not even earlier) controlled much of the country's religious life.

Important singularities are the most relevant moments of the lunar phases (conjunction, first crescent, full moon, and the two quarters). These were always significant to Egyptian religion (unfortunately, there is not enough evidence to determine if they were also relevant to civil society). The civil dates of these lunation days varied from

year to year due to the very structure of the calendar. It was later discovered that 25 calendar years fairly accurately covered a period of 309 synodic months, a notion gleaned from Papyrus Carlsberg 9 dating from Roman times. Therefore, the civil calendar was also a powerful tool serving to predict lunar dates. However, it remains unknown whether the cycle was already recognised and used in earlier moments of Egyptian history, notably during the Ramesside Period. In any case, the moon played a significant role in the Egyptian worldview (fig. 8).

There is nonetheless a hypothesis explaining why the civil calendar gained such a key role in every profane and religious aspect of life. This is based on the fact that the heliacal rising of Sirius in the decades around the turn of the 14th to the 13th centuries BC, depending on the latitude, again coincided with I *Akhet* (fig. 9). A similar circumstance presumably occurred for the actual climatic seasons which again appear, after 15 centuries of wandering, to have matched those of the civil calendar. This means that the Flooding once again took place during *Akhet* (Inundation) and the lower levels of the Nile coincided with *Shemu* (aka Drought). This took place during the reign of Ramesses II (fig. 7) suggesting that the population at the time, including the king himself, must

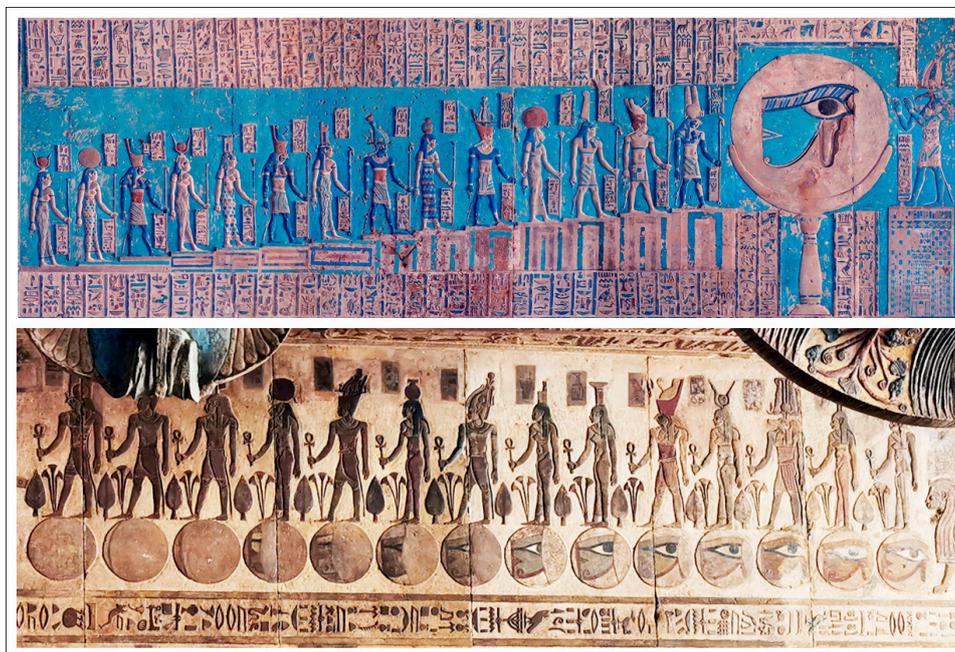


Figure 8. The ancient Egyptians tracked control of the lunar days of a lunation. These days received proper names (Belmonte and Lull 2023: Table 5.4), but also were related to certain deities who enter or depart from the moon at certain lunar days during the waxing and waning phases. This aspect is illustrated in the astronomical ceilings of the hypostyle halls of Hathor (up) and Khnum (down) temples at Dendera and Esna, respectively. The deities and dates are almost, but not exactly, identical, with local peculiarities. (Diagram by the author; lower image courtesy of Artiom Gizum).



Figure 9. The column to the right of the month of IV *Shemu* in the astronomical ceiling of the Ramesseum at the Western Bank of the Nile at Thebes reads: ‘may you bright as Isis-*Sopdet* in the sky in the morning of *Wepet Renpet*’. This indicates that at a period during the reign of Ramesses II, *Peret Sopdet* was in coincidence with the season wandering first day of the civil calendar or *Wepet Renpet*. (Photograph by author).

have felt that the logical order of time once again were in accord with the organisation of the cosmos and that they were living in an epoch blessed by the gods.

The same obviously does not apply to the earlier periods. An example is the existence in the Old Kingdom of two *Wagy* Feasts, the most important associated with Osiris. One was fixed within the civil calendar (I *Akhet* 18), while the commemoration of the other fluctuated over time. The latter was perhaps determined by the first full moon, or another important moment in the lunar cycle, after the outset of the actual Flooding (Spalinger 1994). This was delayed during the late Old Kingdom by several months to the beginning of the season of the Inundation (*Akhet*) and by half a year during the Middle Kingdom. Subsequently, only the former, the civil *Wagy*, endured, and during the New Kingdom, notably during the Rames-

side Period, the 365-day civil calendar reigned in solitude.

However, there is no doubt that the Egyptian religion was affected by the persistence of a series of festivals linked to various relevant phases of the moon, notably the ‘Beautiful Festival of the Valley’, or *p n int*, the origin of the month *Payni* (fig. 2). These are likewise key to establishing chronological issues. Moreover, certain stellar deity festivals such as *Peret Sopdet* also prevailed. Although governed by the moon cycles or the stars, they also remained firmly within the framework of the civil calendar. Their timeframes functioned similarly to how the current Gregorian calendar includes celebrations such as Easter or the Pentecost (or even profane festivals such as Carnival) calculated by phases of the moon.

Another theme worthy of mention is that of the Egyptian systems of night-time measurement, the star-clocks (Neugebauer and Parker 1960-69; Leitz 1995; Belmonte and Lull 2023: 113). Three types have been identified: diagonal decanal clocks; the ‘Fundamentals of the Courses of the Stars’ (von Lieven 2007) formerly known as the Cosmology of Nut; and the Ramesside transit stellar clocks. The first saw use during the First Intermediate Period and the Middle Kingdom. The last two, probably used during the New Kingdom, have been unearthed in tombs and cenotaphs of the Ramesside period (see fig. 10 for examples in paintings from the transition of the LBA to the Iron Age).

The diagonal decanal clocks, the oldest of the three, have been identified on the lids of certain coffins of officials and priests from the First Intermediate Period and the Middle Kingdom. Although dated to the late third millennium BC, they may be earlier. Based on the civil calendar, their name comes from the assignment of a special star or asterism to each decade of the calendar, hence the term ‘decan’. The second type, the ‘Fundamentals’ model, appears to be an evolved version of the decanal. It came into use when the former ceased to be functional around 1800 BC due to the precession of the equinoxes. Examples of this type are associated with the representation of the sky Goddess Nut on the ceilings of the funerary chamber of Ramses IV in the Valley of the Kings (fig. 10) and on the cenotaph of Seti I in Abydos. Hence, this is the name by which they were known in earlier times: the Cosmology of Nut.

Depictions of Ramesside star-clocks, the last of the three, have been found on the ceilings of the Tombs of Ramesses VI, Ramesses VII, and Ramesses IX (fig. 10) in the Valley of the Kings (hence their name). They seem to reflect an entirely new system developed to measure night-time hours at the beginning of the New Kingdom

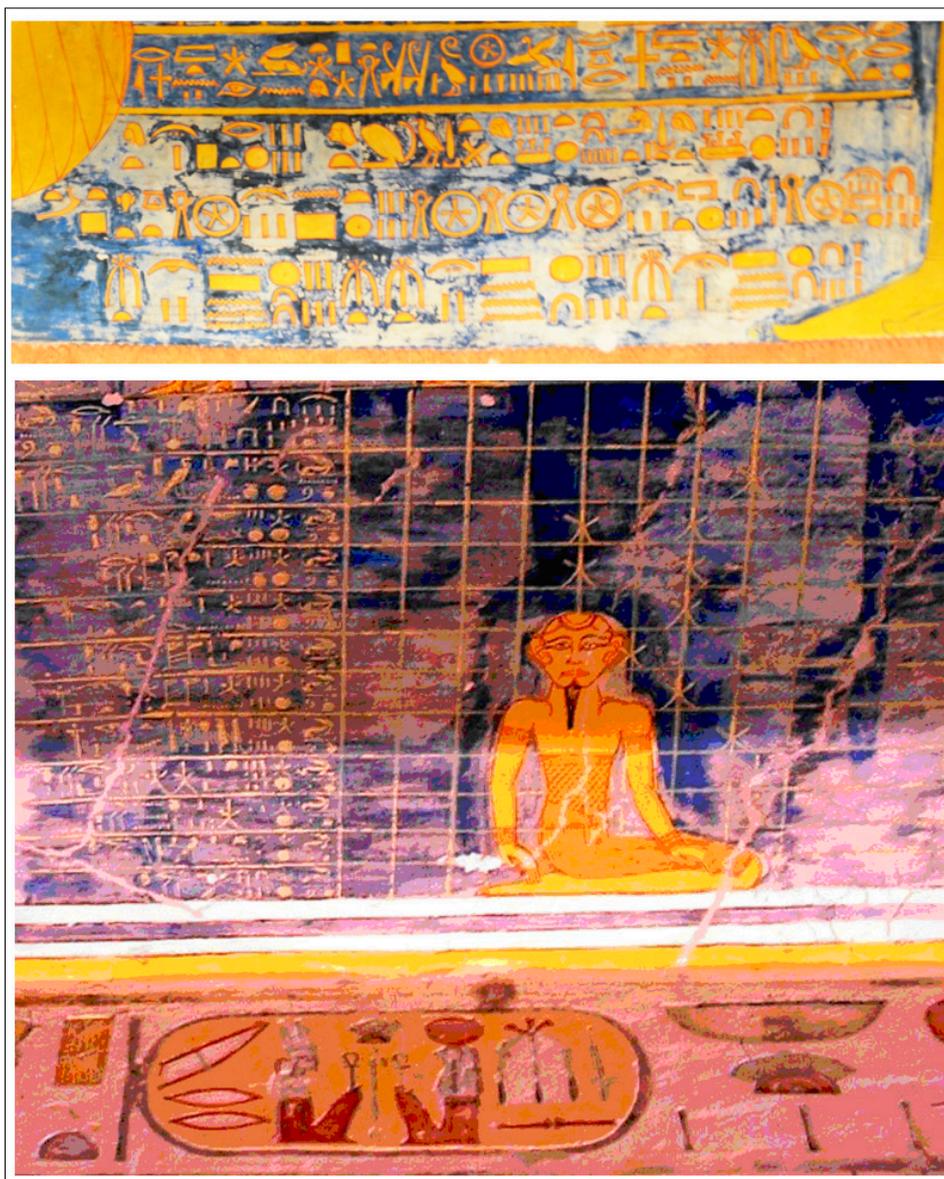


Figure 10. Stellar clocks of the Ramesside period in the Valley of the Kings: a fragment of the Fundamentals of the Course of the Stars as part of the Cosmology of Nut in the astronomical ceiling of the tomb of Ramesses IV (KV2) (top). A complete fortnight list of the 12 stars marking the hours of the night in the ceiling of the tomb of Ramesses IX (KV6) (bottom). (Photographs by the author).

based on an entirely different set of stars (with a few exceptions) from that of the decanal clocks (Belmonte and Lull 2023: 132). Although their precise means of operation is the subject of much debate, it is assumed that they were used in temples by 'horologists' (i.e., hour-priests) to calculate the hours of the night (Belmonte and Lull 2023: 57). This was perhaps essential to properly establish the beginning of the cult schedule at dawn. However, star-clocks may also have served for more prosaic purposes in civilian life.

All form part of the funerary equipment, either in the coffins of high dignitaries or in the

so-called astronomical ceilings of the New Kingdom pharaohs, meaning they must also have been laden with a strong religious symbolism. This is perhaps due to that they served as indicators of cycles of time, repeated over and over again, or possibly were meant to assist the deceased cope with the difficulties of the night-time journey to the afterlife.

Egyptian star-clocks ultimately stem from two systems of structuring time that have survived to our days. The first, universally serving both the profane and sacred, is the division of the day into 24 hours. The second is the division of the

twelve zodiacal signs into 36 houses or decans, each bearing its symbolic peculiarity. This can be attributed to a modern way of structuring sacred time as astrology is without a doubt a modern form of religious belief.

Therefore, it is possible to argue, as a preliminary conclusion, that the current way of measuring time owes two of its fundamental pillars to the Egyptians: the 365-day 'solar' year (filtered by Roman and Christian tradition), and the division of the day into 24 hours. It is noteworthy, however, that these aspects were never adopted by Egypt's contemporary Hittite State.

Sacred time in the Land of Hatti: Hittite festivals, calendars, and cycles

The ancient Middle East is characterised by a plethora of cultic calendars, and dozens of local variants (Cohen 1993; Stern 2012), which can prove challenging to even the most dedicated scholar. This assertion is indeed valid for Hittite Anatolia, where the fragmentary and, at times, contradictory nature of the written records impedes a precise identification of their calendar.

This even includes its well-documented period of the Hittite Empire (14th and 13th centuries BC) preceding its collapse in about 1190 BC. Although a challenging task, the variety of sources nonetheless offers enough information that can be arranged in a more or less logical pattern.

The celebration of festivals dedicated to specific deities at their proper time was essential to the ancient Hittites in maintaining the order of the universe (Taggar-Cohen 2006: 117). Each temple was staffed by priests of different categories performing a variety of duties. Certain were entrusted with special missions such as carrying out the celebration of festivals in a timely manner. Along this line are records signalling that the 'SANGA-priest of the Sun-Goddess of the Earth' regularly slept 'under the stars' in the temple courtyard (Taggar-Cohen 2006: 181). It is possible that one of his night-time duties was to observe the sky so as to determine the timing of offerings and festivals to the deities (fig. 11). Possibly pertinent in this regard is the reference to the Pleiades associated with rituals observed during the *Purulli* festival given that this prominent asterism has globally served as a seasonal and temporal indicator. However, it is noteworthy that there is



Figure 11. Relief of King PUGNUS-meli of Melid (present day Malatya) making an offering to the greatest deities of the Hittite pantheon. These include the Moon and Sun-gods (top), the Storm-god, and Goddess Shausga (Venus, bottom). It is noteworthy that the celestial deities are represented with wings either through personification or, in the case of the Sun-god, as a winged-disc. This neo-Hittite relief follows imperial traditions as depicted in fig 16. (Photos by author, courtesy of the Museum of Anatolian Civilizations, Ankara).

nothing analogous to the ubiquitous star-clocks of Pharaonic Egypt among the epigraphic evidence of the Hittite world.

Lists of festivals from both the Old Hittite Kingdom and Hittite Empire have been discovered in Hattusha and in minor sacred villages of the Land of Hatti. As in the case of numerous other historical and contemporary cultures, sacred time was governed by a yearly seasonal cycle. Although longer periods were also possible, as will be discussed in more detail below, they were undoubtedly connected to agricultural activities. In this sense, the pivotal periods of the agricultural year in Central Anatolia were autumn (September to November) and spring (mid-March to mid-June). These respectively align with sowing and reaping which correlate to the moments of two of the most important Hittite feasts: the *nuntarriyashas* and the AN.TAH.SUM.

The AN.TAH.SUM (Güterbock 1960; Houwink ten Cate 1986) was named after a flower (often identified as a crocus or a fennel) that formed part of the rituals. It was a significant festival which lasted approximately 38 days (perhaps occasionally longer or shorter). This was a time when the king and the queen (i.e., Labarna and Tawananna; see fig. 1) travelled between the city of Hattusha and other minor cult centres such as Zippalanda or Arinna (fig. 12) in the company of other high-ranking priests and priestesses. Although its precise timing remains unknown, it could have been fixed by the first lunation af-

ter the 'spring equinox'. Another less likely option is that it took place during the period of invisibility of the Pleiades, between the cluster's heliacal setting and rising (González-García and Belmonte 2011).

The final form of this festival was defined by Hattusili III (c. 1267-1237 BC) (fig. 1), a contemporary of Ramesses II (1279-1213 BC). This took place following its presumed inauguration by King Suppiluliuma I (c. 1344-1322 BC), which was preceded by the religious reform imposed by Hattusili's father, Mursili II (c. 1321-1295 BC). The feast was dedicated to the supreme deities of the land, the Sun-Goddess of Arinna and the Storm-God of Hatti, later assimilated with the Hurrian deities Hebat and Teshub (fig. 1). It comprised a number of peculiarities, notably that the activities commemorated on its 11th day symbolically convey the 'old year' to the *hešta*-house of Hattusha (a sacred feature linked to the cult of the ancestors) (van de Hout 2002). This aspect is potentially very significant for the interests of this study.

It is clear that the Hittites resorted to a lunar-based time-keeping system due to the existence of the 'festival of the month'. However, there is little certainty as to the precise organisational structure of this calendar, and the method by which it was synchronised with the lunar year and the cycle of the seasons (governed by the tropical year). It is noteworthy, as state above, that the duration of a pure lunar year (354 days) differs from



Figure 12. Reliefs forming part of the monumental Sphinx Gate in the archaeological site of Alaça Hüyük (perhaps ancient Arinna), depicting a Hittite King performing a ritual. The rite is carried out in front of a cult statue of a bull, perhaps representing the Storm-god of Hatti. This was one of the cities visited by the royals in a pilgrimage during the main Hittite festivals during the empire. (Photograph by author).

the average solar year made up of 365 days. This discrepancy of eleven days is significant in the context of the AN.TAH.SUM festival, as its 11th day may carry a particular significance within the framework of a suitable working lunisolar cycle. This issue will be revisited below in the conclusion of this section.

The other memorable festival, the *nuntarriyashas* (Houwink ten Cate 1988: 167), shared numerous parallels with that of the ‘crocus’. Translated as the ‘festival of haste’, it is thought to have lasted for at least 40 days and was celebrated on the occasion of the king’s return from the battlefield before the onset of winter. There is evidence, at least during the Late Imperial Period, suggesting that another key festival, the KI.LAM (Singer 1983), was celebrated as part of the main one. However, this festival was celebrated independently during the Old Hittite period and was the most important commemoration honouring the tutelary divinities of the Land of Hatti. In spite of this, its precise timeframe remains uncertain.

One of the most significant Hittite festivals was the *Purulli*, originally celebrated in the sacred city of Nerik. This city fell to the northern enemies for nearly a century until its recovery by Hattusili III during the reign of his brother Muwatalli. This explains why it was subsequently moved to Hattusha, where it was celebrated near or even as part of the AN.TAH.SUM which was held ‘when the land prospers and thrives’, as ancient text remark (Hoffner Jr. 1998: 11). Kellerman (1981) advanced the idea that the *Purulli* was the inaugural

pre-Indo-European Hattic New Year festival observed in the winter months, and that it was subsequently transferred to the spring following the reforms implemented by Mursili II. By changing it to this moment it would have marked the transition of the new year from one season to another. However, this remains ambiguous.

The situation is further complicated by the words of an oracle that stated that ‘this year His Majesty proposes to winter in Hattusha. He will celebrate the customary festivals, the festival of the year, the thunder festival in Hattusha...’ (Taggar-Cohen 2006: 302). This ‘festival of the year’ (EZEN-*witassiya*) was celebrated in winter and apparently marked the moment normally chosen to enthrone the king.

Another challenge is whether the ‘Festival of the Year’ corresponds to the ‘Winter Festival’ observed in honour of the Sun-Goddess of Arinna in Hattusha (Taracha 2009: 29; Popko 2003). This leads to the question whether it, or eventually both of them, were connected to the winter solstice.

Winter solstice alignments were not rare in Hattusha (fig. 13) and could relate to this phenomenon (González-García and Belmonte 2011). In this sense, the sources also cite the *hahratar*, the festival of the harvest that, considering the annual cycle of central Anatolia, was celebrated in summer, perhaps in relation to the summer solstice (fig. 14), or somewhat later. Hence solstices and ‘equinoxes’ (whatever the nature of the latter, Belmonte 2021) could have acted as



Figure 13. Cyclopean false-domed aedicule in the *Südbug* of Hattusha oriented to winter solstice sunrise. Although the actual meaning of the building is unknown, its orientation suggests it played a religious or calendric role, as other similar monument in the vicinity. (Photograph courtesy of Eberhard Zangger).



Figure 14. Sunset at summer solstice on a distant hill (perhaps Mount Tudhaliya), aligned with the foundations of what was once the monumental gate of the rock sanctuary of Yazilikaya, in the vicinity of Hattusha, perhaps the most important sacred precinct of the Late Hittite Empire. (Photograph by author).

milestones or harbingers within an operative lunisolar cycle.

This leads to the discussion regarding the intrinsic nature of the Hittite festival calendar. There is evidence of a cycle of thirteen regular festivals in the cult of the divine couple formed by Teshub and Hebat of Halab at Hattusha. The couple were Hurrian divinities of the city of Halap, modern Aleppo in northern Syria. Thoroughly assimilated by the Hittites, the two were, as argued above, identified with the Hittite supreme deities, the Storm-God of Hatti and the Sun-Goddess of Arinna as evidenced by the reliefs both of Hall A at Yazilikaya and Fraktin (fig. 1). These festivals were celebrated in Hattusha on a monthly basis. A thirteenth festival is recorded as having taking place when an additional intercalary lunar month was required to align with the lunar and seasonal cycles. Consequently, one can conclude with a high degree of certitude that the Hittites possessed a form of lunisolar cycle potentially subjected to meticulous scrutiny. This particular

context recalls the words of Hattushili's son, King Tudhaliya IV, who stated: 'I shall never omit the festivals again, nor shall I interchange them and celebrate them at the right time'.

The question is thus how did the Hittites adjust the cycles of the sun and the moon (fig. 15). There is scattered evidence that certain festivals, both major and minor, were not celebrated on a regular yearly basis but at larger intervals of time. Some have suggested that the local festivals were celebrated biennially. There is also some evidence maintaining that certain large festivals (or parts of them, such as the ceremonies on the 11th day of the AN.TAH.SUM) were commemorated every six years. Finally, there are grounds to believe that the festival of the god Telipinu in the city of Hanchana was celebrated every nine years, eight if an inclusive way of counting is considered (see Taracha 2009: 70 and 136 for a general discussion on these intriguing options).

As noted above, provided it is calibrated through independent solar or stellar observations, a minimum span of three years is required for the operation of a viable simple lunisolar cycle (fig. 3). Furthermore, six and nine are both multiples of this period. Hence, the aim of this analysis is to ascertain whether the ceremonies of the AN.TAH.SUM on the 11th day were connected to the coupling of the monthly and yearly cycles, a possibility that should be taken into account. This information is paramount and relevant to archaeoastronomical analyses of Hittite landscapes and architecture.

Zangger and Gautschy (2019), inspired by similar Egyptian evidence (fig. 8), recently proposed that the reliefs of Hall A of Yazilikaya (c. 1240 BC) were actually a systematic, symbolic, perhaps even functional, representation of a far more elaborate lunisolar cycle (fig. 16). This was founded either on the octaeteris (when following a simplified scheme) or possibly even the 19-year Metonic cycle, which would require accepting a series of hypotheses and reconstructions of certain parts of the reliefs that were damaged in Antiquity. The absence of evidence on the intercalary month required for such a diagram to be operative undermines this proposal. However, if this were true means that the eight or 19-year lunisolar cycle was known in Anatolia centuries earlier than expected, perhaps through Hurrian influence, and, certainly, much earlier than the cycle applied in Athens by astronomer Meton. This opens an intriguing prospect that the Hittites or their heirs (the Luwian speaking kingdoms of the Iron Age) could have transmitted this astronomical knowledge to the Hellenic world, either from their bases in Anatolia, Kizzuwatna, or in the Northern Levant.



Figure 15. Rock relief of the twelve Gods of the Underworld in Hall B of the sacred precinct of Yazilikaya, possibly the cenotaph or even the place of deposition of the ashes of King Tudhaliya IV, Hattushili's son and successor. Belmonte (1999) had speculated that the relief could also represent the twelve months of a lunar year with the scimitars in form of a lunar crescent. An equivalent series at the end of the row of male deities of Hall A of the sanctuary has been interpreted in similar manner by Zangger and Gautschy (2019; see fig. 16). (Photograph by author).

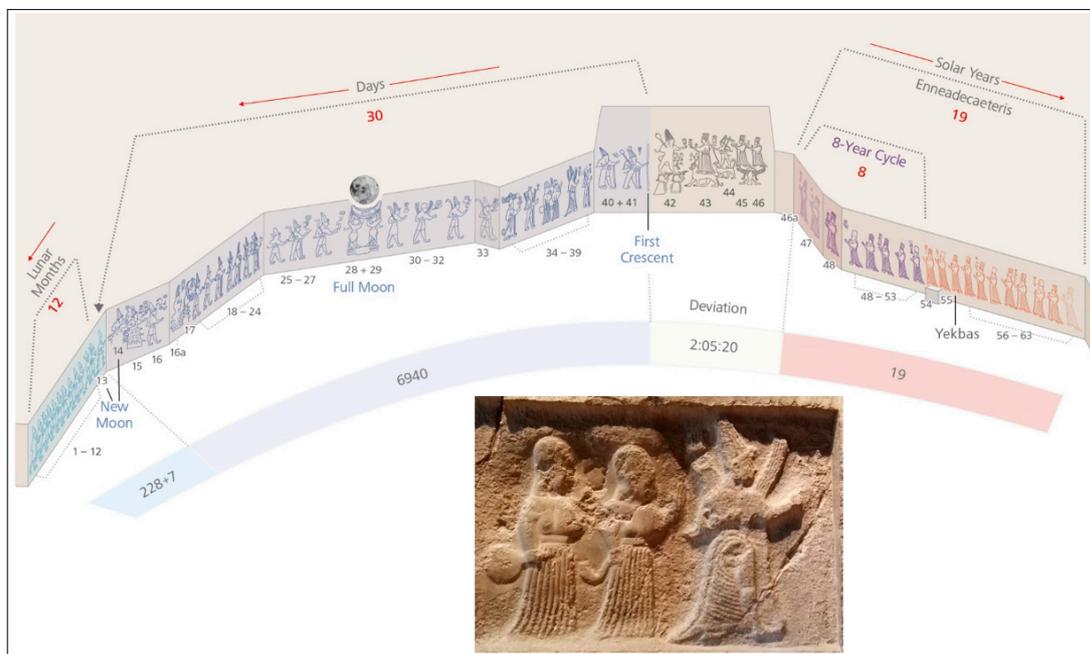


Figure 16. Schema of the rock-carved reliefs in Hall A of Yazilikaaya, illustrating the central panel, and the two rows of male and female deities, to the left and right respectively. Inspired by similar Egyptian representations (fig. 8), Zangger and Gautschy (2019) have proposed that this elaborate series of reliefs might represent a lunisolar calendar. The days of the lunation could be represented by the row of male deities, the months by the 12 Gods of the Underworld, and the years by the row of female deities, representing either an eight or 19-year cycle. The insert represents Goddess Shaushga (Hittite Ishtar) and her attendants. It is of interest that they are integrated within the male deities and supposedly representing days three to five of the lunation. (Diagram by author, adapted by courtesy from Zangger and Gautschy (2019), bottom photograph insert by author).

Conclusions

Two great powers, the Hittite Empire and the New Kingdom Egyptian Monarchy, reigned supreme and controlled the coastline of the Levant during the Late Bronze Age. This state of affairs soon collapsed as the Hittite Kingdom by the outset of the 12th century BC had vanished and Egypt was reduced to a mere regional power for several centuries. This decline continued even if the two powers in the mid-13th century had signed a truce to preserve the status quo for an 'eternity'.

The Egyptian civilisation was a very old and attained a centralised state with a level of power during the Ramesside period that had hardly been seen before, since the time of the great pyramid builders. One of the extraordinary features reinforcing the state was its civil calendar (Belmonte and Lull 2023: 307), a time-keeping system with 15 centuries of history at that moment. Despite being a 'wandering' solar calendar devoid of leap years, it perfectly served the needs of a society subject to the flooding of the Nile. While Ramesses occupied the throne, the seasons of the civil calendar (Inundation, Going Forth, Drought) were again in line with the actual behaviour of the Nile several centuries after implementation of the calendar. This is a remarkable fact that did not pass unnoticed among his contemporaries (fig. 17).

Not only were important lunar festivals such as the 'Beautiful Feast of the Valley', the *Opet*, and the Ptah Feasts, as well as other stellar festivals such as *Peret Sopdet* (fig. 9), perfectly timed within the civil calendar. Apart from certain minor doubts, they served to support the chronology of the Amarna and Ramesside Periods (see e.g., Gautschy 2014; Krauss 2015; 2016; Belmonte 2022; Belmonte and Lull 2023: 505; *in press*). This was even the case when contemporary Egyptian historical sources were tendentious and hide relevant information (fig. 18).

Two of the best sources which cast light on how ancient Egyptians resorted to the stars to measure time also date from this period: the earliest version of the 'Fundamentals of the Courses of the Stars' and the Ramesside star-charts (fig. 10) (Belmonte and Lull 2023: 2013). They are behind the current way of dividing the day into 24 hours. Therefore, there is ample evidence to interpret the way ancient Egyptians understood sacred and profane time, and used it to their own benefit.

On the contrary, there is scant evidence on how the Hittites viewed sacred time, and the little that does exist suggests it differed greatly from that of Egypt. The Sun is thought to have been paramount (fig. 11), and at least two of the most significant Hittite deities are said to possess solar traits. It is therefore logical that solar features be reflected in their calendar and in the celebration

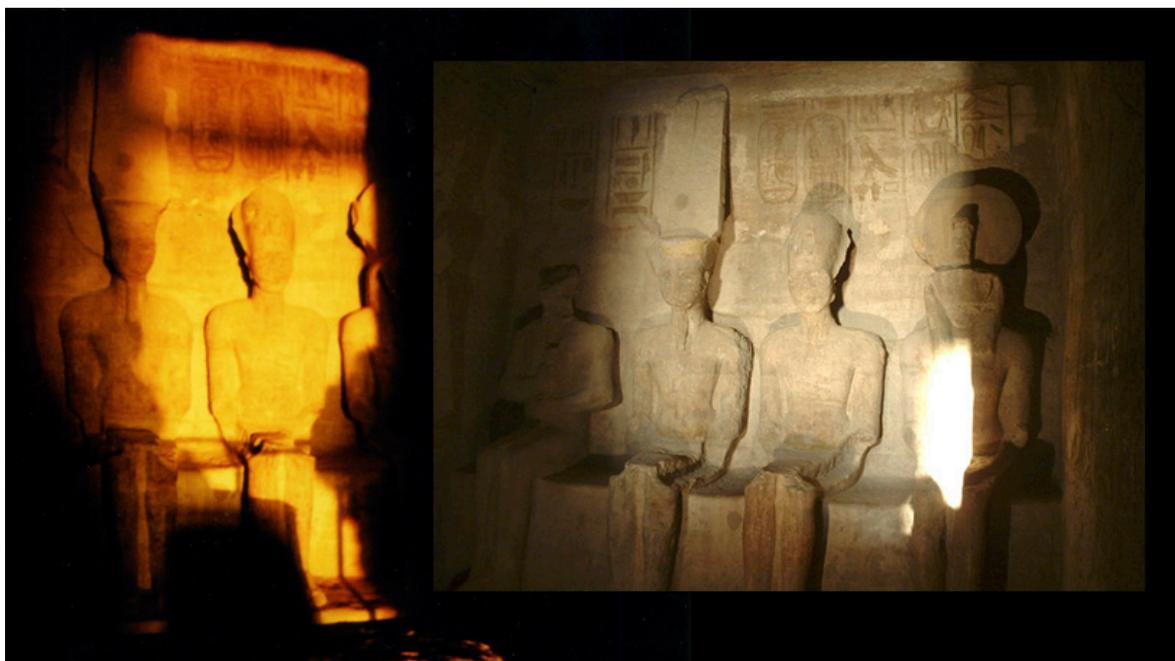


Figure 17. In Abu Simbel great temple, at sunrise during the first day of the seasons of *Peret* and *Shemu* close to 1265 BC (respectively, c. October 21 and February 20 in the Gregorian proleptic calendar), the rays of the Aten illuminate the statues of the solar triad formed by Amon-Ra, King Ramesses II and Ra-Horakhty. Underworld God Ptah always remains in darkness. The last rays of sun illuminate an erased papyrus in the hands of Ra-Horakhty. (Photos by author).



Figure 18. The end of the 18th and the beginning of the 19th Dynasties in the Ancestors List of the temple of Sethy I in Abydos. In an effort to control time and the historical discourse, the first Ramesside kings attempted to obliterate the memory of five pharaohs linked to the Amarna period (Akhenaten, Semenkhkare, Neferneferuaten, Tutankhamen and Ay). The relief directly jumps from Amenhotep III to Horemheb. Obviously, and fortunately, they failed. (Photograph by author).

of certain festivals. The 12-13 festivals dedicated to the cult of the divine couple (Teshub and Hebat) celebrated on a monthly basis suggests the presence among the Hittite time-keeping system of an intercalary month and the option of a working lunisolar cycle.

This assertion is substantiated by the celebration of local festivals taking place at intervals of three, six, or nine (eight) years. It has been posited that a minimum of three years is required for workable simple lunisolar cycle to operate (fig. 3), with six and nine being multiples of this fundamental periodicity. Determining the existence and timing of these festivals could indeed be achieved by resorting to astronomical observations (González-García and Belmonte 2011) (figs. 13-14).

In this respect, it is worth considering whether the ceremonies on the 11th day of AN.TAH.SUM were connected to a coupling of the monthly and yearly cycles, a hypothesis that requires further testing. The paucity of Hittite records renders apparent the need of future rigorous research in the discipline of cultural astronomy.

Therefore, the Double Land of the Pharaohs and the Land of Hatti, after years of enmity, reversed their relationship and developed tight bonds of friendship. Each shared worship of powerful solar deities. The rulers of Egypt were considered the Son of Ra, the Sun-God, and, in the case of the Hittites, avatars of the sun himself. The empires influenced each other, notably in military practices, and even the means of writing. It is indeed possible that Luwian glyphs were inspired by their Egyptian counterparts.

Yet, in spite of sharing many features, the time-keeping systems of the Egyptians and Hittites differed completely. Egypt possessed a long standing, solar-inspired civil calendar while that of the Hittites was lunisolar, probably based on

local tradition and perhaps influenced by the Hurrian model (hence bearing Mesopotamian astronomical aspects). Ultimately, the Egyptian calendar survived to modern times whereas that of the Hittites has been lost in the fog of history. This is the fate of two empires possessing dissimilar but complementary worldviews throughout one of the most fascinating periods of Antiquity.

Acknowledgements

Most of the information in this paper stems from two decades of research in the framework of the 'Orientatio ad Sidera' (OAS) projects. Interaction with César González-García was fundamental to the study of the archaeoastronomy and calendar of the Hittite world. Discussions with Jose Lull on the nature of the Egyptian time-keeping systems were likewise pivotal. The current OAS VI project is funded by the State Research Agency (AEI) of the Spanish Ministry of Science, Innovation and Universities (MICIU), and grants from the European Regional Development Fund (ERDF) (AYA2024 PID2023-147635NB-C21/PID2023-147635NB-C22). We also would like to recognise Eberhard Zangger and Rita Gauatschy for compelling discussions and for use of their graphic material.

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Data de recepció: 05/05/2025
Data d'acceptació: 25/07/2025

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Measuring length in ancient Egypt

El mesurament de la longitud a l'antic Egipte

Units of length measurement were a key element of ancient Egyptian mathematics and are necessarily an integral part of its historiography. The first part of this article provides an overview of research on Egyptian length measurements from the earliest contributions by Isaac Newton to recent studies of the 21st century. The second part presents examples of how length measurements were used in ancient Egypt and their contexts up to the end of the New Kingdom.

Keywords: metrology, mathematics, cubit, length measurements, historiography of mathematics.

Les unitats de mesura de longitud van ser un element clau de les matemàtiques de l'antic Egipte i són necessàriament una part integral de la seva historiografia. La primera part d'aquest article ofereix una visió general de la investigació sobre les mesures de longitud egípcies, des de les primeres contribucions d'Isaac Newton fins als estudis recents del segle XXI. La segona part presenta exemples de com es feien servir les mesures de longitud a l'antic Egipte i els seus contextos fins al final del Regne Nou.

Paraules clau: metrologia, matemàtiques, cúbit, mesures de longitud, historiografia de les matemàtiques.

Introduction

Ancient Egyptian metrology, like all ancient metrology, is a complex subject. Its study is burdened by several methodological issues that have been recognized over time. Despite its importance to other fields of study, such as mathematics, administration, and trade to name the most obvious, the study of metrology has a reputation for being difficult and dull. Consequently, in depth-studies of individual areas of this field (e.g. measures of length, volume, area, or weight) are rare. A recent comprehensive study of capacity measures was presented by Tanja Pommerening (Pommerening 2005). A brief overview of ancient Egyptian weights and measures can be found in (Pommerening 2013).

Two questions regularly arise regarding Egyptian measures of length: First, how many units of measurement were used, and what were their specific lengths? Second, what do we know about the main Egyptian length unit, the cubit? How does evidence from various contexts, such as architectural and religious contexts, affect our knowledge of it? Both questions have prompted monographs and articles. Still, essential issues related to them have not yet been fully addressed, leading to unresolved arguments that will be detailed in the first part of this study. For a concise summary of our current knowledge of length units and the relevant issues, as well as their current state of discussion, see the appendix on the system of length measures by Tanja Pommerening (Pommerening 2005: 271–277). Obviously, this article-length study cannot answer the questions raised above. Instead, the focus of this contribution is on the various uses and contexts of ancient Egyptian length measurements. To accomplish this, the various attestations of length measures in different types of texts will be used, which may be supplemented (if available) by depictions and archaeological sources. For a sociological view of metrology, see the contribution by Hector Vera (Vera 2015). Additionally, while there will be occasional references to later material, this contribution focuses on material up to the end of the New Kingdom. For Demotic length measures, see the works by Vleeming, Yasuoka, and Ziegler (Vleeming 1985; Yasuoka 2016 [article in Japanese]; and Ziegler 2007).

A Brief and Sketchy Historiography of Egyptian Measurements of Lengths

The cubit (mh)

In 1865, Richard Lepsius (1810-1884) published his monograph on the Egyptian cubit and

its subdivisions (Lepsius 1865). In this monograph, Lepsius states that the length of the Egyptian cubit was approximately 52.5 cm based on extant cubit rods (votive cubits). This measurement could be confirmed in some instances by measuring buildings that were assumed to have been planned using multiples of cubits (Lepsius 1865: 1–13; on the complexity involved in applying mathematical analysis to archaeological remains cf. Rossi 2004, on Lepsius' work on metrology cf. Reineke 1988). However, Lepsius was not the first scholar to tackle this issue. Since the early 17th century, the question of the unit of Egyptian length measurements and their actual dimensions has been discussed in literature, originating from measuring the pyramids at Giza.¹

An early, unpublished contribution by Isaac Newton (1643-1727), which is now accessible thanks to the Newton Project, refers to measurements of the pyramids taken by John Greaves (1602-1652).² In 1737, ten years after Newton's death, the results of his work to establish the length of the Egyptian cubit ('ancient cubit of Memphis') were published, which determined the cubit to be 52.79 cm (see Sarton 1936: 6 to the accuracy of the result obtained from various wrong premises):

From the Pyramids of Ægypt accurately measured by Mr. John Greaves, I collect the length of the ancient Cubit of Memphis in this manner. The side of the first Pyramid was 693 English feet. It is very probable, that at first the measure of it was determined by some round number of Ægyptian Cubits. Ibn Abd Alhokm, quoted by Mr. Greaves, tells us, that the measure of each side was an 100 Royal Cubits of the ancient times. But it is probable, that the Ægyptians learn'd, from the Orgyæ of the Greeks, their measure of four Cubits of Memphis, and gave it the name of the Royal Cubit. Thus the side of the Pyramid will be 400 simple Cubits, or four Arouræ; and the Cubit of Memphis will be equal to 1 732/1000 of the *English Foot*. (Newton 1737: 408-409)

In the 18th and early 19th centuries several European researchers took additional measurements of the remains of ancient Egyptian monumental buildings, particularly the pyramids at Giza. Their publications often speculate about the length of an Egyptian cubit, based on the assumption that monumental buildings were planned with integer values (in cubits) for their measurements, as Newton had also assumed. Two publications resulted from the French expedition under Napoleon: in 1809, Pierre-Simon Girard (1765-1836) published his estimate that the Egyptian cubit was 527 mm, based on his examination of the nilometer at Elephantine (Girard 1809: 7). Edmé François Jomard (1777-1862) contributed a section on the metrological systems to the

publication of the expedition (Jomard 1809). In 1817, Jomard published another monograph on a similar topic (Jomard 1817). Based on his measurements of the Great Pyramid of Giza, Jomard estimated the Egyptian cubit to be 0.462 meters:

En effet, la 500.^e partie de 230,902 m est 0,462 m. Or la coudée Egyptienne usuelle, comme nous le verrons bientôt, a une longueur de 0,462 m; c'est cette mesure et le pied qui en est formé, qui ont présidé à la construction de toute la pyramide. (Jomard 1817: 24)

According to Jomard, this coincides with the statement of Herodotus (5th cent. BC) that the cubit is one-four hundredth of a stadium:

Maintenant la valeur de la coudée est facile à déduire: Hérodote et tous les auteurs, sans exception, nous apprennent que la coudée Égyptienne étoit la 400.^e partie du stade. Si l'on divise donc 184,722 m par 400, on a 0,462 m. (Jomard 1817: 26-27)

In addition to measuring buildings, Jomard measured statues and depictions of people in reliefs (Jomard 1817: 71ff.). In 1822, he was the first to describe a cubit rod found in Memphis by the Italian diplomat and antiquities looter Bernardino Drovetti (1776–1852) (Jomard 1822). Jomard measured it at 0.520 meters (Jomard 1822: 6; cf. Böckh 1838: 223: “Zuerst beschrieb sie Jomard, Étalon métrique trouvé a Memphis, jedoch mit einem später von ihm berichtigten Irrthum über ihre Länge.”).

After visiting Egypt for the first time in 1835, English army officer Richard William Howard Vyse (1784-1853) began working at the site of the pyramids of Giza in 1836. He was joined by engineer John Shae Perring (1813-1869) in 1837 (for a summary of his works cf. Lehner 1997: 50-53). Vyse published the results of their work in three volumes entitled *Operations Carried on at the Pyramids of Gizeh in 1837* (Vyse 1840) Perring published another three volumes entitled *The Pyramids of Gizeh* from 1839 to 1842. The first volume of Vyse's publication includes detailed measurements of the pyramids and their parts in English units of measurement (feet and inches), e.g.: ‘Their dimensions are as follows: — King's Chamber, thirty-four feet three inches, by seventeen feet one inch;’ (Vyse 1837, Vol. 1: 206).

The second volume discusses claims by Herodotus about the Egyptian pyramids and directs readers to a 17th century work by Edward Bernard (1638-1697) about ancient weights and measures:

‘Thus the Pyramids are of one hundred fathoms; and the one hundred fathoms make up a stade of six hundred feet - the fathom containing six feet and four cubits; the foot containing four palms, and the cubit six.’ with note 5: ‘The reader is referred to Ber-

nard's work upon ancient weights and measures; where it will be seen that there were several sorts of cubits -the black, the royal, & c.’ (Vyse 1837, Vol. 2: 184, appendix citing Herodotus; ‘Bernard's work’ mentioned in the quote refers to Edward Bernard, *De mensuris et ponderibus antiquis* (1688))

The Scottish astronomer Charles Piazzi Smyth (1819-1900) took further measurements of the Cheops pyramid, which resulted in three volumes titled *Of Life and Work at the Great Pyramid*, published in 1867. Smyth was interested not only in metrological issues but also in proving that prophecies and mystical information were hidden in the dimensions of the pyramid. Smyth's dedication from 1867 points to these aims:

‘... with discoveries in the Great Pyramid, both possessing crucial importance for that primeval monument's metrological theory, and bringing to clearer light things long since dimly alluded to in Holy Writ’ (Smyth 1867: v)

The field of historical metrology gained prominence with August Böckh (1785-1867), a German classical philologist whose general work on ancient weights and measures included Egypt (Böckh 1838, Section XIII is entitled: ‘Die Ägyptischen Längen- und Körpermaße. Arabische Ellen’ (Egyptian Length- and Bodymeasures. Arabic Cubits)). In his contribution, Böckh provided an overview of the various measures, their origins, and how they became interconnected due to economic and political developments in the Mediterranean region. To determine the length of the Egyptian cubit, he used the six cubit rods available to him that were found in tombs (Böckh 1838: 223–227). Based on the examples he examined, he calculated their average length to be 524.587 mm (Böckh 1838: 227). These cubit rods include a distinction between a royal cubit of seven palms and a small cubit of six palms. Additionally, he used the markings at the nilometer in Elephantine to determine the length of the Egyptian (royal) cubit to be 527 mm (Böckh 1838: 228).

Friedrich Hultsch (1833-1906), a German classical philologist and early historian of mathematics, also contributed to historical metrology. His monograph, *Griechische und römische Metrologie* (Greek and Roman Metrology), first published in 1862, and again with a substantially expanded second edition in 1882, includes a section on Egyptian measures in its supplement (Hultsch 1862: 279–285; 1882: 349–380). Hultsch indicates the length of the Egyptian (royal) cubit as 525–527 mm, based on the results obtained by August Böckh (Hultsch 1862: 279; footnote 4 on that page). Additionally, he mentions a smaller cubit measuring 462–463 mm that was used in certain buildings:

Dieselbe (i.e. the royal cubit) liegt als Maß vielen ägyptischen Bauwerken zu Grunde; andere dagegen sind nach einer kürzeren Elle von 462 bis 463 Millim., welche nur 24 Daktylen enthielt, erbaut worden. (Hultsch 1862: 279-280)

The first publication from the Egyptological perspective was the aforementioned monograph on the Egyptian cubit by Richard Lepsius (Lepsius 1865). Lepsius begins with a critical assessment of earlier researchers' assumptions that the dimensions of ancient Egyptian monumental buildings, especially pyramids, were intended to have integer cubit values:

Nun braucht man aber nur eine Reihe anderer Pyramiden, deren Grundseiten nachgemessen werden konnten, zu vergleiche, um zu sehen, daß unmöglich alle dies verschiedenen Maße, wenn man auch der Ungenauigkeit der Nachmessungen viel Spielraum gewährt, auf bestimmte runde Zahlenverhältnisse zurückgeführt werden können. (Lepsius 1865: 3)

By examining measurements taken from rooms and sarcophagi, Lepsius (1865: 5-7) reaches similar conclusions. However, according to Lepsius, further evidence that is more straightforward to use in determining the length of the cubit can be found in preserved markings on buildings:

In einem Grabe bei den Pyramiden von Gizeh, südlich von dem Grabe no. 95 waren die Wände noch leer, doch für Darstellungen schon vorbereitet. An der Hinterwand der Kammer gegen Westen war der schadhafte Fels mit schönbehauenen Blöcken mäßiger Größe ausgesetzt. Auf der glatten Felswand daneben und zum Theil auf der Mauer laufen zwei rothe horizontale Striche hin, welche von einer großen vertikalen Linie durchschnitten werden. Links von dieser lief parallel mit ihr eine andere, von der aber jetzt nur wenig mehr zu sehen ist. Diese 4 Linien bilden in der Mitte ein Quadrat, dessen Seiten ganz gleich sind und genau 0,52 m messen. Die horizontalen Striche wurden hier von oben nach unten gezählt, wie an ihren Beischriften 1. und 2. Elle zu erkennen ist. (...) Auf der linken südlichen Felswand finden sich wieder rothe Linien, die 0,52 m von einander entfernt sind. (Lepsius 1865: 11-12)

Based on this evidence, Lepsius argues that, despite the majority of measurements taken by Jomard, the cubit measuring approximately 52 cm was used in architecture from the 4th dynasty on (Lepsius 1865: 13). He also concludes that, as is indicated by the inscriptions on votive cubits, a second, smaller cubit, must originate either from a different time or its use must have been restricted to specific areas, making it unnecessary to indicate which cubit was used (Lepsius 1865: 13). The remainder of the monograph presents his study of the votive cubits.

The publication of Lepsius was followed by two publications on the pyramid of Cheops, which

also included information on the Egyptian cubit. In 1880, William Matthew Flinders Petrie (1853-1942) published his monograph on the Great Pyramid, confirming the length of the Egyptian cubit to be $20.632 \pm .004$ inches (approximately 52,41 cm):

Probably the base of the chamber was the part most carefully adjusted and set out; and hence the original value of the cubit used can be most accurately recovered from that part. The four sides there yield a mean value of $20.632 \pm .004$, and this is certainly the best determination of the cubit that we can hope for from the Great Pyramid. (Petrie 1883: 81)

In his discussion of measurements of the Great Pyramid, Ludwig Borchardt (1863-1938) stated that the Egyptian (royal) cubit was approximately 0.525 meters:

So ergibt sich aus den Maßen der "verlassenen" Kammer in der großen Pyramide – $2 \cdot (10 + 11) E$ – eine Ellenlänge von 0,52290 m, aus denen der Grabkammer – $2 \cdot (10 + 20) E$ – eine solche von 0,52404 m. An der Pyramide des Königs Ne-user-re bei Abußir, an der eine halbe Seitenlänge scharf gemessen werden konnte – $75 E$ – ergab sich die Elle zu 0,52507 m. Diese Elle von rd. 0,525 m wurde, wie wir auf zahlreichen erhaltenen Maßstäben, allerdings aus späterer als der Pyramidenzeit, sehen, in 7 Handbreiten, also jede von rd. 0,075 m, geteilt, jede Handbreite wieder in 4 Finger, rd. 0,019 m. (Borchardt 1922: 9).

Borchardt, too, mentions the smaller cubit of ca. 0,450 m and the existence of further units (Borchardt 1922: 9).

While discussions about the length of the cubit continue (e.g. Pochan 1932), the next significant contribution to determining the length of the Egyptian cubit was made by Walter Friedrich Reineke (1936–2015), an Egyptologist who specialized in ancient Egyptian mathematics and metrology. Reineke studied the available sources for Egyptian cubits and other measurements in his works (Reineke 1963 and 2014; on Reineke cf. Popko 2021). He carried out a statistical analysis of the length of the cubit based on the method proposed by Simon R. Broadbent (Reineke 1990: 258 cites Broadbent 1955 as reference for the method used (which he sketches briefly in his article) and Rottländer 1979 for the possibility to use this method for metrological studies). The data he used originated from measurements of tombs from the first and second dynasties. The study confirmed the result of approximately 52.5 cm for the length of the (royal) cubit (Reineke 1990: 261).

However, as with capacity measures, studies of later buildings indicate that the length of the Egyptian cubit changed over time. For Graeco-Roman buildings, the length of the cubit has been established at approximately 53.2 cm (Pommerening 2005: 273, referencing Girndt 1996:

53–55; see also Cauville and Devauchelle (1984) for the length of the cubit at Edfu). Additionally, regional variations are possible and attested even in earlier times (Pommerening 2005: 273–274). Despite reaching a consensus, as indicated above, the discussion about the length of a cubit and how it can be determined continues, as illustrated by a recent dissertation and articles in journals (Hirsch 2013; Carlotti 1995a, 1995b; Waziry 2016, 2018, 2020).

Cubit rods

Since the first cubit rod was discovered, these items have been part of discussions about the length of the Egyptian cubit (cf. Jomard 1822; Girard 1824; Lepsius 1865: 14ff.; Wood 1887; Sarton 1936; Scott 1942; Scamuzzi 1961; Senigalliesi 1961; Gabra 1969; Schlott-Schwab 1981; Austin 1994; Monnet *et al.* 2016; Rosati 2017; St. John 2000; Zivie 1972, 1977a, 1977b and 1979). However, the various extant types of these cubit rods also merit their own analysis. In her dissertation, which focused on a larger unit of length measurement, the *jtrw* (cf. the following section), Adelheid Schlott Schwab also examined cubit rods. She proposed differentiating three groups of cubit rods based on the inscriptions found on them (Schlott-Schwab 1981: 53 and 58). The first group consists of cubit rods that were used

as measuring devices (Schlott-Schwab 1981: 53, references for these are provided on pages 54–55). The cubit rods of the second group have the same shape and mostly show subdivisions of the cubit into smaller units. However, they were not meant to be used by craftsmen, as can be deduced from the texts written on them and their material, which is often stone. Further texts on these cubit rods include offering formulas, titles, and names of their owners, or titles and names of a king (Schlott-Schwab 1981: 53 and 55, with references in Schlott-Schwab 1981: 55–57). Schlott-Schwab (1981: 58) designates the cubit rods of the third group as votive cubits ('Votivellen'). They are always made of stone and inscribed with texts like those of the second group, but they do not include offering formulas (Schlott-Schwab 1981: 58). Additionally, they contain inscriptions about the dimensions of Egypt, the height of the Nile, and how to measure time, as well as other texts that provide numerical data about Egypt (Schlott-Schwab 1981: 58).

One example of a cubit rod from the first group, which was recently studied (Nishimoto 2017), is that of Kha, the overseer of works from Deir el-Medina in the mid-18th Dynasty. This cubit rod has a hinge and was found with its leather holster (fig. 1). The museum website indicates its length in the folded state as 26.3 cm, which equals 52.6 cm for the complete cubit when unfolded. More ac-



Figure 1. Folding cubit rod of Kha (Turin Museo Egizio Suppl. 8391, https://collezioni.museoegizio.it/en-GB/material/S_8391/)

curate values can be found in Naoko Nishimoto's study. Nishimoto indicates the length of the cubit rod as 52.76 cm and the lengths of the palms in its subdivisions as 75 mm, 76.8 mm, 75.8 mm, 72 mm (this is the palm that is divided by the hinge), 76 mm, 76.6 mm and 75.4 mm. On the first palm subdivisions into fingers are marked as 18.0 mm, 19.0 mm, 19.0 mm and 19.0 mm. Nishimoto explains the uneven spacing of the markings of the palms as a consequence of constructing the hinge (Nishimoto 2017: 452-454).

Another example is a wooden rod with markings from Lisht that shows seven subdivisions, as well as a marking for the rod's midpoint (fig. 2). This rod is 70.5 cm long.³ It also does not have the 'usual form' of the ceremonial cubits and the folding cubit rod of Kha, but seems to be (as far as one can see from the photo) a round stick.

Subdivisions of the cubit

As one might imagine, discussions about the length of the cubit also included discussions about its subdivisions. These discussions can be found in the literature referenced above.

Ironically, the subdivisions of the (royal) cubit are detailed on those cubit rods which were not used for actual measuring purposes. According to these objects, the (royal) cubit was divided into 7 palms (*šzp*) each measuring approximately 7.5 cm. This can be seen on the cubit rod of Amenemope (fig. 3). The palm (*šzp*) was divided into 4 fingers (*ḏb'*) measuring approximately 1.875 cm. As seen in the photo of the cubit rod of Kha (fig. 1), markings are included for the fingers of the first palm, followed by markings for seven palms (without subdivisions into fingers).

In addition to palm and finger, the cubit rod of Amenemope (and other cubit rods of this type) has several other subdivisions: a small cubit (*mḥ šrj*) of 6 palms (equaling approximately 45 cm), a unit called *Remen* (*rmn*) of 5 palms (approximately 37.5 cm), a unit called *Djeser* (*ḏsr*) unit, a large span (*pḏ ʔ*) of 3.5 palms (approximately 22.5 cm), a small span (*pḏ šrj*) of 3 palms (approximately

26.25 cm), two hands of 2 palms (approximately 15 cm), a fist of 1.5 palms (approximately 11.25 cm), and a hand of five fingers (approximately 9.25 cm), as well a unit of 3 fingers (approximately 5.625 cm) and 2 fingers (approximately 3.75 cm) (all approximate values for individual units were taken from Pommerening 2005: 272).

The jtrw ('river-measure')

The *jtrw* was a unit used to measure long distances (for a historiographical survey of this unit see Priskin 2004: 57-60). However, as Adelheid Schlott-Schwab pointed out, the *jtrw* is not a fixed unit of length. Rather, it designates the distance between two resting places for a team towing a boat on the Nile — that is, the distance that could be traveled by boat in one day (Schlott-Schwab 1981: 121-122). Thus, the commonly accepted value of 10.5 km for the *jtrw* is an average based on various individual values dependent on the type of terrain (Schlott-Schwab 1981: 121; cf. also Priskin 2004 who argues for a specific length of the *jtrw* at least in later times). Schlott-Schwab cites the assessment of Jomard of a similar Egyptian measure, the *malqât*, which was still in use at the beginning of the 19th century. According to Jomard, nothing is more variable than this measure, which depends on the season, the company that one travels in, the use (or not use) of animals, and the type of animal that was used ('Or, rien n'est plus variable que cette mesure, suivant la saison, selon que l'on marche isolément ou en caravane, selon enfin que la caravane est composée de chevaux, ou d'ânes, ou de chameaux plus ou moins chargés.' Schlott-Schwab 1981: 121; on variations of travelling speed – with numerical examples – see in detail Köpp-Junk 2015: 289-302).

The discussion about the length of this unit can be traced back to publications by Jomard and Hultsch (e.g. Hultsch 1882; for a discussion of earlier studies of the *jtrw* cf. Schlott-Schwab 1981: 118-120). In 1968, the *jtrw* was studied by Adelheid Schlott-Schwab in her dissertation (published in a second edition in 1981) and a subsequent publica-



Figure 2. Rod with subdivisions into halves and seven parts (MMA 15.3.1128, <https://www.metmuseum.org/art/collection/search/557017>)



Figure 3. Cubit rod of Amenemope (Turin Museo Egizio Cat. 6347, https://collezioni.museoegizio.it/en-GB/material/Cat_6347/)

tion of 1972 (Schlott-Schwab 1972 and 1981; the latter is the publication of the extended dissertation from 1968). According to these studies, the earliest attestation for the *jtrw* originates from the First Intermediate Period and attestations continue until the Roman period (Schlott-Schwab 1981: 102-107). Schlott-Schwab concluded that the 'length' of the *jtrw*, understood as an average, was 10,5 km until the Late Period (Schlott-Schwab 1981: 135). From the Late Period on, a larger average *jtrw* of 12,6 km seems to be attested (Beinlich 1987). Using Graeco-Roman evidence Gyula Priskin discusses the relation between *jtrw*, stade and *schoinos*, and has argued for the *jtrw* being equal to 50 stades (Priskin 2004: 63).

Further units

For measuring larger distances, the unit *ht* (*n nwh*) was used, which was equal to 100 *mh*. It is attested since the Middle Kingdom and may have been measured using a rope of the same length (WB III: 341). From the New Kingdom, there are depictions of measuring the area of a field using ropes (fig. 4). Scenes depicting the measurement of fields with ropes are found in the tombs of Deserkareseneb (TT38), Khaemhat (TT57), Menna (TT69), and Amenhotep-si-se (TT75), which are all located in Gurna. Statues of scribes involved in estate and field administration (e.g., Cairo CG42128) depict them holding coiled ropes (fig. 5). Some of the depicted ropes have a ram's head at their beginning, indicating that the measurement was carried out for or on behalf of an institution of the god Amun.

For the Old Kingdom, another unit was introduced in 1981 by Miroslav Verner (Verner 1981; cf. also Roik 1993: 63): the Egyptian foot (*tb.t*), which measures approximately 8.7 cm. Apparently, the unit is derived from the width, not the length, of a foot. However, the only attested reference of this unit thus far comes from the tomb of Ptahschepes.

Following several articles on another length measurement called *nj*, Elke Roik published a monograph in 1993 entitled *Das Längenmaßsystem im Alten Ägypten* (The system of length-measurement in ancient Egypt) (Roik 1993; for a critical evaluation of this volume cf. the review Simon-Boidot 2000). However, rather than providing a survey of Egyptian length measurements, Roik aimed to argue for the devaluation of the Egyptian cubit, which was prompted by her discovery of a new unit of measurement: the *nj*, which is approximately 65 cm long. Roik was not the only researcher to work on the *nj*. Naguib Victor also tried to establish evidence connected to it (Victor 1991, cf. also Simon-Boidot 2000). As Simon-Boidot points out, the claims made by the various researchers about its length and usage are so different, that the 'Roik-*nj*' and the 'Victor-*nj*' require separate discussions (on the work of Victor see also Pommerening 2005: 275).

Despite the discussion initiated by Roik, the argument for the *nj* has not resulted in a significant change in the assessment of Egyptian length measures. Therefore, Tanja Pommerening refers to the respective entry by Helck in the *Lexikon der Ägyptologie* for a summary of the *opinio communis* concerning length measures (Pommerening



Figure 4. Depiction of measuring ropes in assessing the size of a field (Wall painting scene from the tomb of Djoserkarseneb (TT38); Archivio Museo Egizio, Album 2_030, <https://archiviofotografico.museoegizio.it/en/archive/theban-region/sheikh-abd-el-gurna/tt38-tomb-of-djeserkaraseneb/>?)



Figure 5. Statue of Amenemhet called Surero, kneeling holding rope with ram's head (CG 42128, Legrain 1906: Plate LXXVII).

2005: 271). This is summarised by Pommerening as follows: 'Die Standardlehrmeinung, die von mir befürwortet und für diese Arbeit zugrundegelegt wird, spiegelt sich im Lexikon der Ägyptologie wider. Danach bildete die Elle (*mh*) von etwa 52,5 cm – die Maßzahl wird im Folgenden noch ausführlicher diskutiert – die Grundlage der ägyptischen Längenmaße, und zwar schon seit der Frühzeit.' ('The cubit (which is approximated at 52,5 cm)

was the basis of Egyptian measures of length since the early dynastic period.') (Pommerening 2005: 271, cf. also Helck 1980: 1199-1200.)

Regardless some archeological sources and a few textual references pointing to the use of the *nbtj* measure, the dominant measuring unit from both types of sources appears to be the cubit (*mh*) (Pommerening 2005: 271-272). While Roik challenged the evaluation of archeological evidence in support of the *nbtj*, the philological evidence clearly favors the cubit (see the following section).

Despite the continuous interest in ancient Egyptian measures of lengths and the various sources available, no detailed study comparable to Tanja Pommerening's analysis of the volume measures has yet been completed. That this will not be a simple task can be seen from the historiography of length measurements so far, and most notably from the discussions of the *nbtj* measure. Such a study is urgently needed due to the importance of length measurements for a large number of ancient Egyptian sources.

(Preliminary) Survey of Philological Attestations of the Cubit and Other Units

Evidence for Egyptian length measures can be found in archeological sources by measuring the dimensions of buildings and artifacts, assuming these were planned using units or subunits of a standardized measurement system (Pommerening 2005: 271). Evidence can also be found in philological sources that mention lengths of buildings, artifacts, or appearances. Regarding the latter, it seems reasonable that the number of attesta-

tions of individual units of measurement reflects their usage. To get an idea of how often individual measurements were used, the number of attestations for each term in the *Thesaurus Lingua Aegyptia* (TLA) and the *Wörterbuch* (WB) can be used. The *Wörterbuch* used to be the academic point of reference for Egyptian words. However, it is now outdated and will eventually be replaced by the *Thesaurus Lingua Aegyptia*. Currently, however, some attestations found in the *Wörterbuch* have not yet been included in the TLA, which, in some cases, includes more attestations than the *Wörterbuch*. Therefore, both sources will be checked for each word.

The Cubit (mh)

The cubit (mh), according to *opinion communis* the most common unit of length in ancient Egypt, may – according to the *Wörterbuch* – be specified as a ‘royal cubit’ (mh nsw.t) or a ‘small cubit’ (mh šrr). The *Wörterbuch* lists the unqualified cubit (mh) as the usual occurrence (WB II: 120). The *Thesaurus Linguae Aegyptiae* does not include the specified attestations and has 300 attestations for the cubit (mh) from the Old Kingdom up to the Roman period.⁴ The attestations given in the *Wörterbuch* for the royal cubit (mh nsw.t) are Pap. Leiden 350: 3,10 (Gardiner 1905: 27) and Lepsius (1865): plate 1b, 2a, and 3c. The translation of Pap. Leiden 350: 3,10 given by Gardiner is ‘Sated (?) was the Royal Cubit, which measures blocks of stones.’ The reference(s) from Lepsius lead to three cubit rods. Plate 1b refers to the cubit rod of Amenemope now in Turin (Cat. 6347), 2a to the cubit rod of Maya now in Paris (Louvre N 1538) and 3c to a cubit rod found by Anastasi sent to Italy in 1823, which was then lost (cf. Lepsius 1865: 14-16). All attestations for the ‘small cubit’ (mh-šrr) in the *Wörterbuch* are found on these cubit rods. The subdivisions of the cubit are also found on these rods. However, the latter also occur independently. Fingers (db') and palms (šzp) are attested as early as the Old Kingdom.

As one might expect, they are used either independently when the respective length is smaller than a cubit or in combination with the cubit, if the length of the object to be measured happens to be more than a specific integer cubit value.

The ‘river-measure’ (jtrw)

The ‘river-measure’ (jtrw) is listed in the *Wörterbuch* with the meaning ‘ein größeres Wegemass’ (‘a larger measure of distance’) (WB I: 147.2). Attestations given originate from four sources, including boundary stelae from Amarna (Davies 1908: plate 28, e.g. line 19), inscriptions from the

temple of Ramses III at Medinet Habu and the Famine Stela (Barguet 1953). The *Thesaurus Linguae Aegyptiae* lists 31 attestations from the New Kingdom to the Roman period.⁵ The study of Schlott-Schwab has a list of 60 attestations from the First Intermediate Period up to the Roman period (Schlott-Schwab 1981: 102-107).

The nbj

Although the *Wörterbuch* does not have an explicit entry for a unit of measurement nbj, it has an entry of nbj indicated as ‘meaning unknown’, which is among the references given for nbj in the *Thesaurus Linguae Aegyptiae* (WB II: 244). The latter has nine occurrences of nbj, all originating from the New Kingdom (cf. also Roik 1993: 42-46). However, several of these occurrences come from the same source (three attestations from Ostrakon Senmut 73 and two attestations from Ostrakon Senmut 62).⁶ In the text of Ostrakon Senmut 62, nbj is used alongside the cubit (mh). A further reference for nbj can be found on Ostrakon Cairo CG 25501 (Hayes 1973: 21 note 87).

The foot (tb.t)

The only known attestation originates from the tomb of Ptahshepses (Verner 1981). It is neither included in the *Wörterbuch* nor in the *Thesaurus Linguae Aegyptiae*.

The schoinos (ht (n nwḥ))

The *Wörterbuch* lists ht and ht n nwḥ separately, possibly because the former is attested since the Middle Kingdom and the latter only in the New Kingdom and Graeco-Roman Period (WB III: 341.12 and WB II:223.12; cf also Peet 1923: 24: ‘In the measurement of land the unit of length was the khet (ht) of 100 cubits, the full name of which was ht nt nwḥ, or ‘reel (?) of cord,’ a measure which may well be compared with our chain’). The *Thesaurus Linguae-Aegyptiae* includes 17 references of ht⁷ and one for ht n nwḥ⁸. The references for ht are from the *Book of the Dead*, from the boundary stelae of Amarna, from the magical Papyrus Leiden I 348 and from the magical Papyrus Budapest 51.1960. In addition to these references, there are also references of ht within the mathematical Papyrus Rhind. These come from problems 49-52, all of which are about the calculation of areas. The reference for ht n nwḥ can be found in the demotic Papyrus Rylands 9 (Vittmann 1998; a further German translation of the text is provided by Hoffmann and Quack 2007: 22-54). It is used to describe the dimension(s) of a court. In the slip

archive further references of *ht n nwh* are attested (e.g. DZA 24.725.160, DZA 24.725.170, DZA 24.725.180, DZA 24.725.200, DZA 24.725.230).

Comparison of attestations of individual measures

Despite the vagaries that are inherent in ancient Egyptian sources, the number of attestations still provides an idea of the frequency of words. The cursory survey of textual attestations of the various measures confirms the *opinion communis* of the secondary literature that the cubit was the most common unit of length. The question concerning the usage of the unit of a foot (*tb.t*), which has so far only been recorded once, remains unclear.

In addition, studies of specific units of measurements, like that of the *nj* by Roik and that of the *jtrw* by Schlott-Schwab, demonstrate that currently neither the *Wörterbuch* nor the *The-saurus Linguae Aegyptiae* provide comprehensive lists of attestations. In the example of the *jtrw*, the study by Schlott-Schwab lists double the number of references in comparison with those of the *The-saurus Lingua Aegyptiae*.

Selected Examples of Philological Sources Illustrating the Use of the Cubit in Ancient Egypt

As the previous section of this article indicated, there are a variety of philological sources available for studying Egyptian length measurements. This section presents selected examples of these sources, organized by cultural context. The order of discussion is not arbitrary, but rather reflects the frequency of attestations and consequently, the relevance of length measurements in this field. While the usage of the cubit is obvious in some contexts, such as in architecture to indicate building dimensions, it is less obvious in others. Analyzing these less obvious uses may provide better insight into Egyptian measurement concepts and their meanings.

The references in the following section offer only limited insight and do not claim to provide a comprehensive overview. At best, they demonstrate the breadth of source material that deserves an in-depth study.

The length measurement ‘cubit’ was also used to measure area. Since the two uses are not always distinguishable in writing, some of the following references may refer to areas.

Context of Architecture/Building

There is probably little doubt that the context of building is, apart from the administrative context, one of the areas in which the need for a unit

to measure length arose. One of the earliest attestations comes from a sketch of a vaulted roof on an ostrakon, where the indication of length is a vital information in the construction process (Gunn 1926; for a photo of the ostrakon cf. Lightbody and Monnier 2017, fig. 4). The sketch shows a curve divided into intervals by five vertical lines that are supposedly equidistant. The height of the curve (from the ground?) is indicated by the respective lengths measured in cubits, palms and fingers is indicated (presumably for the highest point of each interval, i.e. at the left end). These lengths are 3 cubits, 3 palms, 2 fingers; 3 cubits, 2 palms, 3 fingers; 3 cubits; 2 cubits 3 palms; and 1 cubit, 3 palms and 1 finger. The horizontal distance between the lines is not indicated.

Further attestations of the cubit in architectural contexts come from the remains of buildings.⁹ The slope of a building was conceptualized by the *sqd*, which indicated the horizontal displacement, usually measured in palms and fingers, for a vertical drop of one cubit (Rossi 2004:185).¹⁰ Calculations of the *sqd* were included within the mathematical problems (e.g. Mathematical Papyrus Rhind, problems 57-60, see below). In the context of mastabas, markings used to determine the slope of walls have been found, e.g., at Mastaba 17 in Meidum (Rossi 2004: 188–192). Horizontal lines were spaced at a distance of one cubit, starting from an assumed baseline (fig. 6).

Texts detailing the size of buildings or other constructions, such as canals, often use the cubit and its subdivisions.¹¹ Similarly, the quality of building materials or elements could be indicated by dimensions in cubits (or parts thereof).¹² These kinds of descriptions often originate from autobiographies, i.e., texts found in tombs that describe the achievements of the tomb owner (see Stauder-Porchet *et al.* 2020, with references to earlier literature). They can also be found in the context of royal inscriptions.¹³ Further attestations of this kind originate from letters.¹⁴

Additionally, in the contexts of architecture and the administration of labor, the work of a construction worker could be indicated by a specific number of cubits.¹⁵ Lastly, the cubit is central to creating two-dimensional representations (see, for example: Iversen 1975; Robins 1982 and 1994; and Robins and Shute 1985).

Administrative Contexts

In administration, the cubit was also used as a basic unit of measurement for length in various contexts. It is attested on nilometers, which were used to measure the height of the inundation to determine the grain harvest dues. While the remaining nilometers are of Graeco-Roman origin,

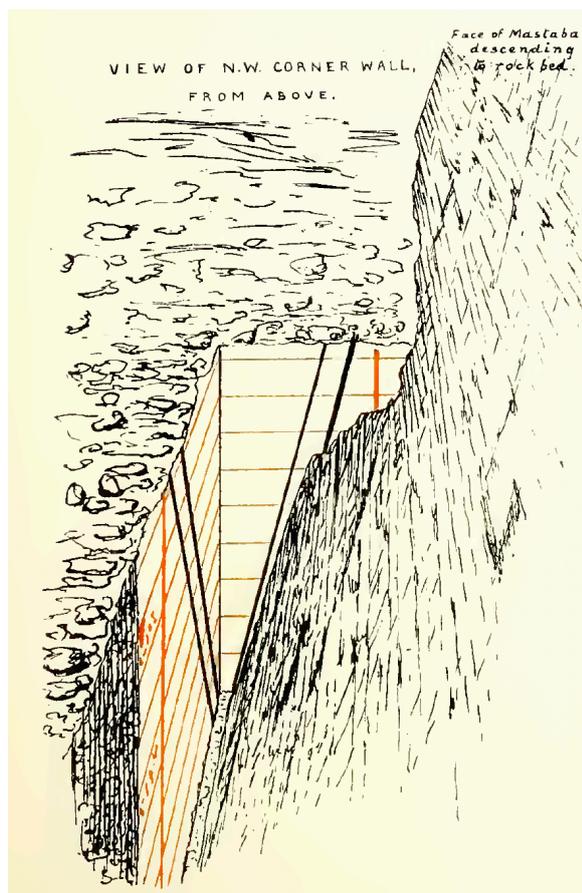


Figure 6. Mastaba 17 (Petrie 1892: plate VIII).

the practice of measuring the height of the inundation dates back to the First Dynasty (Seidlmayer 2022: 7; 2001; for an overview, see Borchardt 1906). Early records of inundation heights for successive years are found in the Royal Annals, the largest fragment of which is the Palermo Stone (Wilkinson 2000). Nilometers included a built-in scale for measuring the height of the Nile (for records of the height of the Nile see Seidlmayer 2001: 87-89). There are also later records of the height of the Nile, e.g. on the White Chapel of Sesostris I (cf. Seidlmayer 2001: 93-103) or on a stela from the 25/26th dynasty¹⁶. Information about the heights of the Nile is also included on votive cubits (cf. Schlott-Schwab 1981: 48).

The unit mh and its subdivisions are also used to quantify various goods, as for example in the description of a tribute from the Old Kingdom which is documented in the tomb of Sabni, a noble during the time of Pepi II. at the Qubbet el Hawa in Assuan: '(...) one three-cubit long elephant tusk to let it be known that I brought a seven-cubit (5^1 [+2]) long lion-skin (...)'¹⁷. In the tomb of Sechemkare (5th dynasty) at Giza, the harvest and processing of grain is depicted. There, the height of a large pile of grain is indicated as

46 cubits and 5 palms.¹⁸ The accounts of the Abusir Papyri (5th dynasty) also include goods measured in cubits.¹⁹ In the context of a ration list from the New Kingdom, mh is used to indicate the length of a piece of cloth.²⁰ Another indication of the size of a piece of cloth can be found in a letter from Deir el Medina.²¹ In these last instances, mh may also be the area measure derived from the length measure (cf. the discussion of the question if mh refers to lengths or areas in the scenes discussed in Altenmüller 1987: 19-20). As expected, the cubit, the basic unit of measurement for length, is attested in various administrative sources.

Mathematical Contexts

The Egyptian hieratic mathematical texts are closely linked to administration and include significant sections that explain metrological units and their subdivisions (for a study of hieratic mathematical problems, see Imhausen 2003). Demotic mathematical papyri also include references to the cubit. However, since this contribution focuses on earlier material, these will not be discussed. Additionally, the hieratic mathematical texts include at least some problems related to architecture in which the cubit is also attested.

Within the hieratic mathematical papyri mh is attested 14 times in nine problems and three different papyri (Rhind Mathematical Papyrus: problem 43 (2), problem 46 (1), problem 56 (2), problem 57 (2), problem 58 (3), problem 59 (1), problem 60 (1); Moscow Mathematical Papyrus: problem 3 (1); Lahun Mathematical Fragments: UC32162-01-12 (1)). In the Rhind Mathematical Papyrus, mh appears in two problems that calculate the volume of granaries (problems 43 and 46) and in all of the problems related to pyramids (problems 56-60). However, the unit mh is not found in problems that calculate areas. In these problems, the larger length measure, ht , is used instead. In all instances where mh can be found, it is used in the context of indicating numerical dimensions of the objects that are the topic of the problem. In the text of the problems of the Rhind Mathematical Papyrus, the cubit is explicitly stated as being subdivided into 7 palms: 'Concerning 1 cubit, it is 7 palms'. This introduces the subunit palm in the context of a problem about the slope (sqd) of a pyramid (Rhind Mathematical Papyrus, problem 56, cf. Imhausen 2016: 113).

Unfortunately, the occurrence of mh from the Mathematical Papyrus Moscow comes from one of the first three badly damaged problems. Problem 3 of the Mathematical Papyrus Moscow is the calculation of the mast of a ship. The length of the mast is indicated as 30 cubits – what was supposed to be calculated is not extant. Only the

end of the first instruction remains, indicating the calculation of 1/3 of 30 cubits (cf. Imhausen 2003: 309).

In the mathematical Fragment UC32162 from Lahun, *mḥ* is used in the final line of a problem about area calculations. The problem states that an area of 40 by 3 cubits should be divided into 10 smaller areas, each with a width that is 3/4 of its length. The beginning of the problem is lost, therefore *mḥ* is found only once within the text of this fragment in the statement of the result.

Contexts of Trade

Apart from evidence of measuring goods for administrative purposes, there are also depictions in the context of tombs showing the exchange of goods (see Livingstone-Thomas 2011, with references to earlier literature). These scenes are accompanied by descriptions that may indicate the conversation between buyer and seller. The Egyptian cubit is attested at least once in these descriptions, in the tomb of Nianchchnum and Chnumhotep (5th Dynasty), where it accompanies the trade of cloth.²²

Literary Contexts

Several literary works include indications of size using the Egyptian cubit. These explicit measurements may serve to emphasize impressive dimensions, as in the *Story of the Shipwrecked Sailor*. The text is extant in Papyrus Leningrad 1115 dating to the Middle Kingdom (Lichtheim 1975: 211; English translations can be found in Lichtheim 1975: 212-215 or Parkinson 1997: 89-101). The frame of the story describes the return of an official from an unsuccessful expedition by boat. His attendant attempts to cheer him up by telling him the story of a previous boat expedition on which he was shipwrecked on an island. He found the island to be plentiful in resources, and with the help of a snake-god who ruled the island, he turned disaster into success. Length measurements are indicated eight times within the papyrus. The attendant's ship is described by its length (120 cubits), width (40 cubits), and the number of sailors (120).²³ The height of the fatal wave that led to the shipwreck is indicated as 8 cubits tall.²⁴ The snake-god is described as 30 cubits long with a beard of more than 2 cubits.²⁵ When the shipwrecked sailor tells the snake-god how he came to be on his island, the dimensions of the ship and the wave are repeated.²⁶ It is interesting to compare this description with that of the return of the sailor towards the end of his tale. There, the resources that the shipwrecked sailor gets to take home with him are listed without specifying any

measuring units at all: 'Then he gave me a load of myrrh, *ḥknw*-oil, laudanum, *ḥsy*t-spice, *tišps*s-spice, perfume, eye-paint, giraffe's tails, great lumps of incense, elephant's tusks, greyhounds, long-tailed monkeys, baboons, and all kinds of precious things.' (Lichtheim 1975: 214). Thus the grandeur of the gift of the snake god is left to the readers imagination.

In the tales of Papyrus Westcar, the cubit is used to indicate the size of a (magic) crocodile and the changing height of a body of water (also involving magic manipulations).²⁷

The description of the profession of a carpenter in the *Teaching of Khety* also includes specific measurements indicated in cubits:

Vile is the carpenter, working at a ceiling;
it is the roof of a chamber,
a chamber of ten by six cubits.
(Translation: Parkinson 1997: 277)²⁸

In the *Teaching of Khety*, which compares a variety of professions to that of a scribe, the section about the carpenter cited above is the only one that includes specific numerical/metrological data. Much more frequent are references to metrology in the *Teaching of Amenemope*, which (unsurprisingly) comes from a respective 'background'. Its alleged 'author', Amenemope, is identified at the beginning of the teaching as:

(...) the overseer of fields, experienced in his office,
The offspring of a scribe of Egypt,
The overseer of grains who controls the measure,
Who sets the harvest-dues for his lord,
Who registers the islands of new land,
In the great name of his majesty,
who records the markers on the borders of fields,
Who acts for the king in his listing of taxes,
Who makes the land-register of Egypt (...)
(Lichtheim 1976: 148-149)

Based on this introduction, one might imagine that metrology and the cubit were central components of Amenemope's work. However, while several passages of the text refer to the proper use of measurements, there is no specific mention of lengths measured in cubits.

As the examples from literary contexts indicate, scribes often used references to specific lengths in cubits, which could serve various purposes. For example, large numerical values could indicate largeness, as in the *Story of the Shipwrecked Sailor*. Alternatively, they could simply indicate an average size, as in the *Teaching of Khety*.

Contexts of Religion and Magic

As the object class of votive cubits introduced above indicates, length measurements were used within a religious context as well. Information on

votive cubits not only exist in the form of extant objects, but also on sketches on papyrus, presumably used in their creation (cf. Rosati 2017).

The numerical assessment and control of resources in administrative contexts gave rise to an aura of justice associated with the processes of measuring (this also holds for other measuring devices, cf. for example the scale used in the judgement of the dead). Obviously, this requires that the measuring process is carried out without cheating (e.g. by tampering with the measuring devices), and may point to why the cubit became named first the royal and then the gods cubit (*mh ntr*), thereby invoking the power of the king to ensure its validity. The fact that tampering with measuring processes was an issue can be inferred from the number of persons sent to carry out such tasks, cf. e.g. Papyrus Harageh 3 (Smither 1941). In addition, the *Teaching of Amenemope* details various measuring units and the forbidden ways of tampering with them (cf. Imhausen 2016: 158-161).

In addition to votive cubits, references to measuring units can also be found in various religious texts. For example, the cubit is attested in religious contexts as early as the *Pyramid Texts* (e.g., the texts found in the Pyramid of Pepi I), such as in the indication of the length of the ship in which the deceased king supposedly traveled, which is said to be 770 cubits.²⁹

The Amduat contains various attestations of specific lengths expressed in cubits. In the Amduat of the tomb of Thutmose III, it is attested in the text of the twelfth hour (during which the sun-god is reborn) to indicate the length of the spine of a god as 1300 divine cubits.³⁰ The lengths of sandbanks that have to be overcome during the journey through the netherworld are detailed as 450 and 443 cubits, another one is indicated by lengths and width both of 440 cubits.³¹

In the *Book of the Dead*, the cubit is used to indicate the size of various beings (e.g. a 'qfdnw ape' as 3 cubits and 2 fingers, that of a falcon as 4 cubits or even 1000 cubits).³² Several references specify the height of grain in the netherworld.³³ The sizes of those that harvest the grain are also mentioned in cubits.³⁴ The size of an eye which is passed by the god Re is detailed as 7 cubits, its iris as 3 ½ cubits.³⁵ The *Book of the Dead* also contains references to the careful handling of measuring lengths in the context of the negative confession (i.e. the dead details various transgressions that he did not commit in his lifetime).³⁶

Other than the attestations found in descriptions of magic actions in literary texts mentioned above, the cubit is also used in magic texts, e.g. in combination with a very large number to express (magic) power.³⁷

Royal Inscriptions

Further attestations for indications of sizes using cubits can be found in the context of royal inscriptions. Some of these refer to the sizes of buildings or related objects.³⁸ Other than detailing building or construction work, the cubit is also found in the description of a royal bird hunt by Amenemhet II (12th dynasty), to indicate the size of the nets that were used (a translation of the inscription can be found in Dantong 1999). One of the nets is said to have had a width of 12 cubits.³⁹

In the Great Sphinx Stela of Amenhotep II. at Giza, indications of sizes in cubits are found twice: the size of the rudder of the boat the king was travelling in is said to be 20 cubits:

Strong of arms, untiring when he took the oar, he rowed at the stern of his falcon-boat as the strokeoar for two hundred men. Pausing after they had rowed half a mile, they were weak, limp in body, and breathless, while his majesty was strong under his oar of twenty cubits in length. He stopped and landed his falcon-boat only after he had done three miles of rowing without interrupting his stroke. (Lichtheim 1976: 41; *jtrw* has been translated as 'miles')⁴⁰

The use of concrete numerical data in this passage highlights the king's achievement of surpassing his 200 men. The second instance of the cubit in this text is found in the next paragraph, which details the king's ability to shoot a bow and arrow by describing targets placed in the garden.

Conclusion

As the historiography of Egyptian length measures and examples of their usage in various kinds of ancient Egyptian texts indicates, a detailed, critical analysis of Egyptian length measures using archaeological and philological sources is an urgent need in Egyptology. As the final part of this contribution suggests, those who undertake this challenging task will be rewarded with the opportunity to work with a vast array of Egyptian sources from various time periods and contexts. This will give them a comprehensive understanding of not only the metrological aspects of ancient Egyptian civilization, but also its overall workings and concepts.

First insights into the various contexts, in which units of lengths can be found, were presented in this contribution. While some contexts were expected, such as the use of length measures in construction and administration, others, such as references in literary texts and texts describing the netherworld, were surprising, at least in terms of their frequency.

Similar observations can probably be made for other units of measurement. As has been argued elsewhere, ancient Egyptian mathematics was developed to control resources (Imhausen 2023). The king or scribes working for the king exercised this control. The royal right to control resources came with the obligation to handle them according to an ancient Egyptian ideal of justice, i.e., according to the Maat. Metrological units provided the basis for this proper handling of resources and were thus inextricably linked to royal power and obligation. As control over resources evolved, so did the profession of the scribe—someone literate and numerate. Mathematics then became associated with justice because fixed numerical values were believed to protect e.g. against arbitrary greed. In this process, metrological units are a key element. Metrology supposedly provided the guarantee for a correct handling of resources, at least locally. The resulting connection between metrology

and justice led to the use of the former in other contexts, such as religion and literature.

As the texts indicate, tampering with metrological units was a known problem in ancient Egypt. The first provisions to counter fraud included sending teams of scribes to measure the size of a field. Additionally, moral literature included specific ethical guidelines regarding metrology, most notably in the teachings of Amenemope.

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Data de recepció: 19/08/2025

Data d'acceptació: 10/10/2025

Notes

1. I chose to not include the work by John Greaves (1602-1652) 'Pyramidographia: or, a Description of the pyramids in Egypt' London 1646, which discusses the sizes of Egyptian pyramids (he determined) in comparison with those that have been recorded by ancient writers.

2. <https://www.newtonproject.ox.ac.uk/view/texts/normalized/THEM00276> (accessed 4/09/2024).

3. <https://www.metmuseum.org/art/collection/search/557017>; Accessed April 2nd 2025. The Metropolitan Museum has another measuring rod (22.1.678) which is described as being 37 cm long. Unfortunately, there is no image available online. Cf. <https://www.metmuseum.org/art/collection/search/568564>; Accessed 02/04/2025.

4. <https://aaew.bbaw.de/tla/>: Lemma-Nummer 73330. Accessed 13/05/25. (When accessed in February 2025 there were only 286 references – presumably all numbers cited in this contribution will be outdated soon. It is at this point unclear, if the overall impression gained from them, remains unchanged.)

5. <https://aaew.bbaw.de/tla/>: Lemma-Nummer 33360. Accessed 17/02/25.

6. <https://thesaurus-linguae-aegyptiae.de/lemma/82600>.

7. <https://thesaurus-linguae-aegyptiae.de/lemma/121210>. Accessed 28/02/25.

8. <https://thesaurus-linguae-aegyptiae.de/lemma/d4613>. Accessed 28/02/25.

9. E.g. <https://thesaurus-linguae-aegyptiae.de/text/HXDICYWOZNE7XLS2NTABPYXIBY/sentences>, in: TLA (accessed: 25/06/2025)

10. For the description of slanted lines in two-dimensional depictions cf. also Robins and Shute 1985.

11. Examples can be found from the Old Kingdom on: <https://thesaurus-linguae-aegyptiae.de/text/XMSY7B4ABVEZ7FC4ZI4GU2QZHM/sentences>, <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd600Q7W6pE6ip0AJORJmvs0>, <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd2uGolJ2CkwaugZxEeegy>

QU, <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBdz9tLi6XDU8pi2wjTQwTN6c>, <https://thesaurus-linguae-aegyptiae.de/sentence/ICQCFHDvLqScO0lpn6jWtaapU2I>; all in: TLA (accessed 06/24/2025).

12. <https://thesaurus-linguae-aegyptiae.de/sentence/ICQCFHDvLqScO0lpn6jWtaapU2I>; <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd0Q6HWXwN0nvn7EctUqBA3E>; <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd90ZYy9A40htp6DW0vmsYTU>; <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd0RXyiHaTkykvXnLGqiMxGI>, <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd0Q6HWXwN0nvn7EctUqBA3E>, all in: TLA (accessed 26/06/2025).

13. <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBdz9tLi6XDU8pi2wjTQwTN6c>, <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBdxDL9LTUMkNkgQHEgHpHtJQ>, both in: TLA (accessed 26/06/2025).

14. <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd0RXyiHaTkykvXnLGqiMxGI>, <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBdW226C7D6UiQnoxRwUWjUOI>, <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBdQgfEpAYOkvjoe56JZ9YMik>; all in: TLA (accessed 26/06/2025).

15. <https://thesaurus-linguae-aegyptiae.de/text/CLVJOT2XUJFILCEHGMP5YOV3TY/sentences>, <https://thesaurus-linguae-aegyptiae.de/sentence/ICQCUQuPoc7D1kQWrOa7uXX1HVw>; <https://thesaurus-linguae-aegyptiae.de/sentence/ICQCU0pu37wygEGYln6UrrpemRA>, <https://thesaurus-linguae-aegyptiae.de/sentence/ICQCUQuPoc7D1kQWrOa7uXX1HVw>; all in: TLA (accessed 06/04/2025).

16. <https://thesaurus-linguae-aegyptiae.de/sentence/IBcDJwCBQKmTdk1ZjOgYfoloatI>, in: TLA (accessed 06/24/2025).
17. <https://thesaurus-linguae-aegyptiae.de/sentence/ICMCcup29Q8HV0R9hwYVeWQJU2E>, in: TLA (accessed 24/06/2025). Another example for the use of *mh* in a tribute indicating the sizes of an animal skin is found in an inscription by Hatshepsut of the New Kingdom, cf. <https://thesaurus-linguae-aegyptiae.de/sentence/ICMCNisGhjpnUkMmg1ugy6tf2Go>, in: TLA (accessed 24/06/2025). In this example two dimensions of the skin are indicated as 6 cubits and 4 cubits.
18. <https://thesaurus-linguae-aegyptiae.de/text/ZE5THHH7EFDLNMNVJJHEFJLFCM/sentences>, in: TLA (accessed 25/06/2025). Cf. Hassan 1943: 110.
19. <https://thesaurus-linguae-aegyptiae.de/text/XCEGHYZMLZAKLO6HG4TLKNL3U4/sentences>, in: TLA (accessed 25/06/2025).
20. <https://thesaurus-linguae-aegyptiae.de/text/ZHBZYMhULBDS3P474FKTAN3MBY/sentences>, likewise: <https://thesaurus-linguae-aegyptiae.de/text/ZHBZYMhULBDS3P474FKTAN3MBY/sentences>; both in: TLA (accessed 06/04/2025).
21. <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd7tsmdTu9EyOmlcXafXAhEc>, in: TLA (accessed 06/04/2025).
22. <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBdWY1OWv6ykTNPktj2EKSeo>, in: TLA (accessed 25/06/2025).
23. <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd9716bXMU0bmniGQMMmXGIY>, in: TLA (accessed 25/06/2025).
24. <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBdzyylhFcEUajlQzJJpzRBlc>, in: TLA (accessed 26/06/2025).
25. <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBdznZrglRukKGfBaXdxGvxro>, in: *Thesaurus Linguae Aegyptiae*; <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBdzOeFkZodkiMkSW8vpGW3RY>, in: TLA (accessed 26/06/2025).
26. <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd8atTLMFYEK1nXhD2ATuWD4>, in: *Thesaurus Linguae Aegyptiae*; <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBdzGmAdjbn0qcttR4F8SkrKc>, in: TLA (accessed 26/06/2025).
27. <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBdyIRrYWduk57vYiP203kvdM>, <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd39NETu01UNks0qcA4hQ4eo>, <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd4QDbazQkUUIInEWEVba4NsM>, <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd5ssd27v10S0quTns4q8dCc>, <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd2nPuNOXLEEKg5TeSiCYiBA>, all in: TLA (accessed 26/06/2025).
28. <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd1jc2If5UULNgyWUThHeQQw>, in: TLA (accessed 26/06/2025).
29. <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd2mogen9w0QHlzRQ9n38iVo>, in: TLA (accessed 25/06/2025).
30. <https://thesaurus-linguae-aegyptiae.de/text/6BWILK2RZJCRPGPZUNUSJCT6LU>, in: TLA (accessed 26/06/2025).
31. <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBdzwepo4SDUKzgnlo9gyQrrw>, <https://thesaurus-linguae-aegyptiae.de/sentence/MSG5P32T5ZETHBQLIIPWPEOKRPO>, <https://thesaurus-linguae-aegyptiae.de/text/CQHxH4JVD5H3LMENHIDO5OR3VM/sentences>; all in: TLA (accessed 26/06/2025).
32. <https://thesaurus-linguae-aegyptiae.de/text/5GPTF4PVHJASXFVEWJNDIA7SQ/sentences>, <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBdWhUpldJ8E9SmobamxWHmvi>, <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd7QOWYyVI0BCpCUWuYofHho>, all in: TLA (accessed 26/06/2025).
33. Various indications measured in cubits of grain sizes (as well as other items) can be found in the Papyrus of Nu (BM EA 10477), cf. Lapp 1997, e.g. <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd4bcfI4jT0BTg25jXQwOi0w>, <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBdyIAeqWkkrWvMoUJGiknWE>, both in: TLA (accessed: 26/06/2025). Further attestations for the cubit to detail the size of grain can be found in Papyrus Maiherperi (pCairo CG 24095), eg. <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBdWZWt3bNg0cyvEBDWHI4w4Y>, in: TLA (accessed: 27/06/2025) or Papyrus Juja (pCairo CG 51189), e.g. <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBdwdKujfR50jcgUVyn5tYQD4>, in: TLA (accessed 27/06/2025).
34. <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd8vg1UwVtEGvj0odOHuJG9E>, in: TLA (accessed 27/06/2025).
35. <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd9WFQueErEX6sNgUc90sOEQ>, <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd0oDOPZx40XNqLODQ8hmOz4>, both in: TLA (accessed 27/06/2025).
36. <https://thesaurus-linguae-aegyptiae.de/sentence/IBUBd2jQscWqVEdTq9DUPx1mVSI>, in: TLA (accessed 27/06/2025).
37. <https://thesaurus-linguae-aegyptiae.de/text/274VCIEE7NCYPJPST3H3JKNFY/sentences>, <https://thesaurus-linguae-aegyptiae.de/sentence/IBcDOOa1CBNdsUvzgjV2wBizKA>, both in: TLA (accessed 27/06/2025).
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Mesures de la terre et des briques dans les activités de construction en Mésopotamie ancienne à l'âge du Bronze

Measurements of earth and bricks linked to building activities in Ancient Mesopotamia during the Bronze Age

La construction en Mésopotamie a utilisé le plus souvent des briques (séchées au soleil ou cuites au four). La gestion des opérations de construction faisait intervenir les notions de volumes de matériau calculés à partir de la surface générale du bâtiment. Du volume des murs, on obtenait le nombre de briques nécessaires. Plus complexe est le calcul du nombre de journées de travail des ouvriers nécessaire pour le transport des briques, chaque chargement varie en effet en fonction du volume de ces briques. La brique peut en effet varier dans ses trois dimensions mais également dans ses proportions relatives, son volume et donc sa masse. Pour les calculs, la charge de travail journalière demandée aux ouvriers non spécialisés, appelée *iškarum* en akkadien, était utilisée, mais également des coefficients permettant de convertir les volumes en nombre de briques, de calculer le nombre de briques dans un chargement individuel ou le nombre de briques nécessaire pour couvrir une surface.

Mots clefs : construction, briques, tâches journalières, calculs mathématiques, scribes, Mésopotamie ancienne.

Bricks (sun-dried or kiln-fired) were the most common building material in Mesopotamia. The management of construction operations involved knowledge of the volumes of these materials based on calculating the overall surface of buildings while the number of bricks depended on the volume of the walls. More complex was calculating the number of man-days needed to transport the bricks, as each load varied according to their volume. Bricks could vary not only in terms of their three dimensions, but also in keeping with to their relative proportions, volume, and mass. These calculations are based on the daily workload required of unskilled workers, called *iškarum* in Akkadian, as well as on the coefficients for converting volumes into numbers of bricks, on the number of bricks of individual loads, and on the number needed to cover a surface.

Keywords: construction, brick, daily tasks, mathematical calculations, scribes, Ancient Mesopotamia.

Introduction

La Mésopotamie – comprise ici comme la plaine alluviale du Tigre et de l’Euphrate de la depuis la région de Baghdad jusqu’au Chatt al-Arab¹ – a essentiellement utilisé aux âges du Bronze et du Fer (entre 3500 et 300 av. J.-C.) pour l’architecture le matériau terre, et plus particulièrement la brique, comme principal matériau de construction. Des villes entières, parmi les plus vastes de leur époque, ont été entièrement construites en briques séchées au soleil ou cuites au four.

L’émergence des premières villes puis du pouvoir royal a entraîné la mise en place de toute une administration de la construction publique. Celle-ci reposait non seulement sur une standardisation des unités de mesure, en particulier pour les distances et les volumes, mais également sur celle des tâches journalières demandées aux ouvriers non spécialisés mobilisés pour les travaux de construction. Les calculs des scribes pour l’évaluation préalable de la charge de travail que va représenter une construction, et donc pour l’évaluation des rations à prévoir, ainsi que les textes d’apprentissage qui illustrent leur formation, nous permettent de mieux comprendre les relations complexes qu’entretenaient dans la pensée mésopotamienne les notions de distance, de volume et de poids.

La brique : un élément parallélépipédique préfabriqué et standardisé

Du modelage à la recherche de pans rectilignes : pressage, découpage

Pour une construction maçonnée, il s’agit de disposer d’éléments préfabriqués qui vont pouvoir être assemblés sur le mur à l’aide d’un liant : en général un mortier de terre.

On a recherché tout d’abord à obtenir des éléments d’épaisseur constante, et c’est là l’avantage de la terre par rapport à la pierre². On a également très vite cherché à obtenir des éléments de forme allongée aux bords rectilignes

1. Pour les variations du tracé de la côte et des deux fleuves aux périodes anciennes voir Geyer et Sauvage 2020: 8-13.

2. Sur les débuts de l’architecture de terre au Proche-Orient on pourra consulter : Cauvin 1978: 23-63; Aurenche 1981 et 1993; Sauvage 1998a: 87-107; 2009. Les premières briques modelées à la main, apparaissent au Proche-Orient lors du Néolithique précéramique A (PPNA), vers 9000 av. J.-C. (Sauvage 2009: 192). Sur la notion de terre-à-bâtir, le mélange utilisé pour l’architecture de terre, voir Aurenche 1981: 53-54.

afin de faciliter la pose en panneresses (briques disposées longitudinalement : fig. 1) et d’obtenir des faces de mur régulières. Le passage de l’architecture d’abord circulaire à une architecture rectangulaire qui débute au Néolithique précéramique, au PPNA/PPNB (vers 8500-8000 av. J.-C.: Cauvin 1978: 43-44, Sauvage 2009: 197) implique la maîtrise de la technique de la besace (Aurenche 1977: 36; 1981: 119-121), c’est-à-dire du chaînage alterné des assises de deux murs se rencontrant à angle droit (fig. 2): deux murs externes (besace d’angle) ou un mur externe et un mur de refend (besace en T). Afin de pouvoir décaler les joints d’une assise à l’autre, il importe d’utiliser des éléments de maçonnerie plus longs que larges. Plus tard, au II^e millénaire av. J.-C. avec l’utilisation de briques carrées, c’est l’utilisation concomitante de demi-briques qui permet cette alternance des joints (Sauvage 1998a: 63).

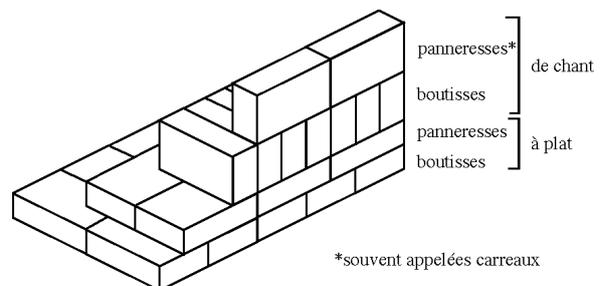


Figure 1. Panneresses et boutisses (dessin M. Sauvage).

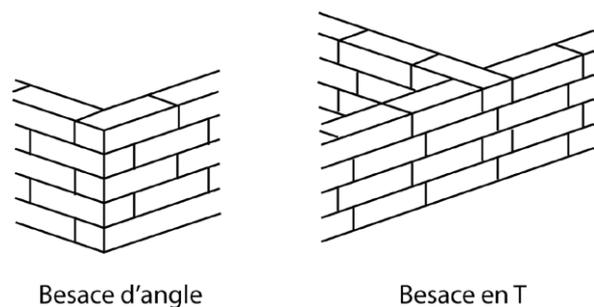


Figure 2. Besace d’angle et besace en T (dessin M. Sauvage).

Aux briques modelées à la main, on va vite, vers 6000 avant J.-C., préférer des briques confectionnées par pressage entre deux planches, comme à Oueili, Iraq (Forest 1987: 24) ou à Djaffarabad, Iran (Dollfus 1975: 14-15) ou même découpées. O. Daune-Le Brun (2003: 155-156) décrit cette dernière technique encore en usage, à Chypre. Au vu du plan publié (fig. 3), on peut penser que les briques de Cafer Höyük (PPNB, vers 8000 av. J.-C.)

étaient découpées et non moulées comme le pensaient les fouilleurs (Cauvin 1989: 76) car, si elles présentent des bords bien rectilignes et une largeur constante, leur longueur varie considérablement.

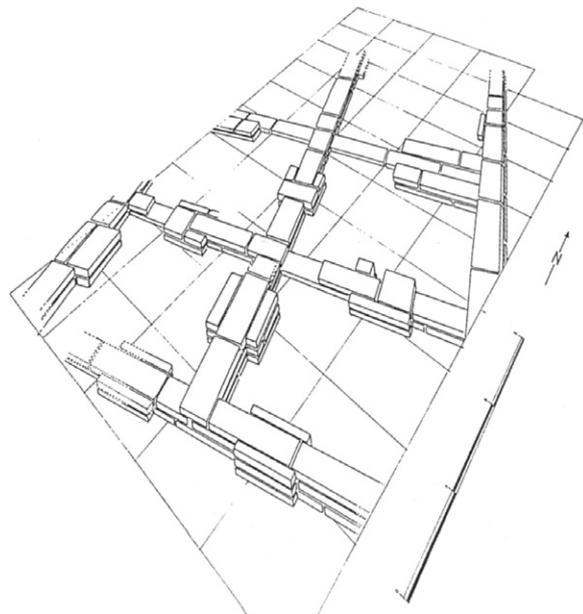


Figure 3. Maison néolithique à architecture rectangulaire de briques moulées ou découpées, avec emploi de contreforts internes et externes, Cafer Höyük (Turquie), vers 8000 av. J.-C. (d'après Molist et Cauvin 1991 : 94).

Le moulage : reproduction standardisée et en série d'un parallélépipède rectangle rectiligne

Cette recherche d'une production d'éléments de forme parallélépipédique rectangle de dimension standardisée amène à l'invention du moule à brique (Aurenche 1981: 60-70; Sauvage 1998a: 90-93 ; voir également Baudouin 2020 ou Choimet 2020). Pour le Proche-Orient ancien, les premières attestations de moulage de briques dateraient, selon les fouilleurs, du PPNB récent, soit vers 7500-7000 av. J.-C. (Sauvage 1998a: 91), mais on peut penser qu'il s'agissait là en fait de briques découpées et non moulées et que les premières attestations sûres de moulage des briques dateraient alors de l'époque de Samarra, vers 6500 av. J.-C.

Il s'agit, dans la technique de départ la plus utilisée ensuite, d'un simple cadre de bois rectangulaire sans fond dans lequel la terre est tassée (fig. 4). On racle la surface, ce qui permet d'obtenir des briques d'épaisseur constante, avant de retirer le moule par le haut et de laisser sécher la brique au soleil. Ces briques séchées au soleil peuvent ensuite être utilisées telles quelles mais elles peuvent également être passées au four pour en faire des briques cuites. Cette innovation apparaît en Mésopotamie à l'époque d'Uruk (vers 3500-3000 av. J.-C.) au départ pour la confection d'installations liées à l'eau : bassins, canalisations (Sauvage 1998a: 23-24). Le procédé du moulage



Figure 4. Moulage des briques à Tell Leilan (Syrie), années 1990 (cliché M. Sauvage).

permet, dès les plus hautes époques, d'obtenir une production standardisée et de masse (pour un ordre de grandeur d'ordre des quantités, voir ci-après).

La notion de module: appareils complexes avec des briques de ratio 1/2 ou 1/2/3, des demies et quarts de briques

Avec l'augmentation de la taille des habitations au Néolithique, il devint nécessaire de consolider les murs, en particulier les murs extérieurs d'un seul tenant (voir la fig. 3). Plusieurs solutions ont été adoptées au début du Chalcolithique (période d'Obeid 1-3, vers 6000-5000 av. J.-C. avec, par exemple, la conception de plan en grille multipliant les besaces en T (fig. 5) ou avec l'usage des contreforts intérieurs ou extérieurs (fig. 6).

Au Chalcolithique final (Obeid 4-5 ; vers 5000-4000 av. J.-C.), avec l'émergence d'une architecture monumentale à décoration ostentatoire, dotée de façades à pilastres et redans, on relève l'utilisation d'appareils complexes associant panneresses, boutisses, demies et quarts de briques. Sur le site de Tépé Gawra (niveau XII: Tobler 1950: 33-35), des briques miniatures cuites ont été découvertes, elles correspondent en format réduit aux différents types de briques qui ont été utilisés pour la confection des façades des « temples » et pourraient selon E. Baudouin (2022) avoir été utilisées pour l'apprentissage des maçons (fig. 7). Pour réaliser ces décors, les modules des briques se réduisent progressivement en longueur afin d'atteindre en moyenne une quarantaine de cen-

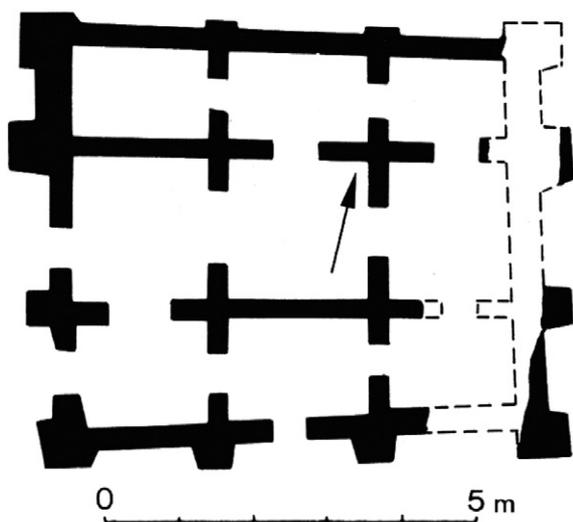


Figure 5. Plan en grille et à contreforts d'angle, Choga Mami (Iraq), vers 5500 av. J.-C. (d'après Oates 1969: pl. XXIV).

timètres et la longueur devient systématiquement le double de la largeur : une brique disposée en panneresse correspond alors à deux briques disposées en boutisses.

À la fin du III^e millénaire (époque d'Ur III), la confection d'appareils associant des briques de chant et des briques à plat (Sauvage 1998a: 61) incite désormais à fabriquer des briques dont la longueur est égale à une fois et demie la largeur et dont la largeur fait deux fois l'épaisseur (avec un module donc de $1 \times 2 \times 3$)³.

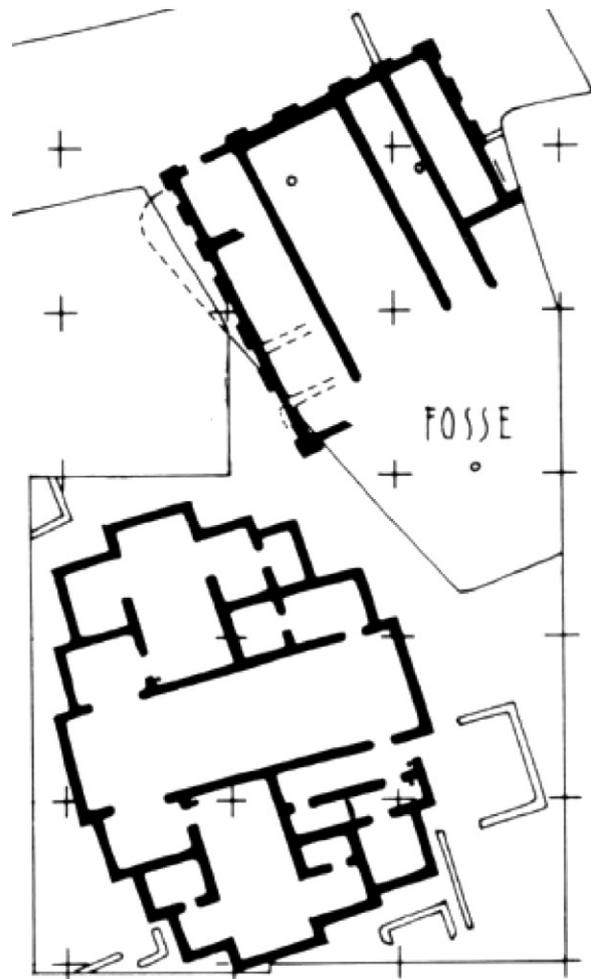
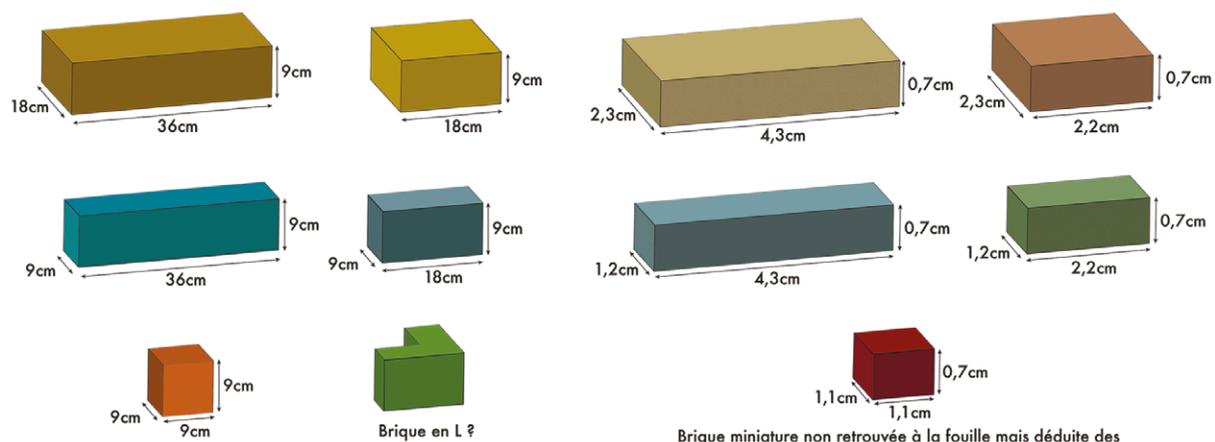


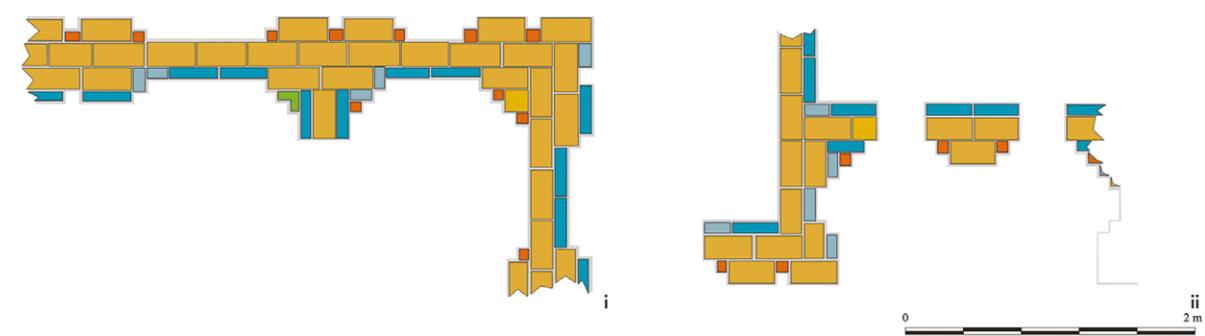
Figure 6. Usage des contreforts extérieurs ou de murs externes à décrochements multiples à Kheit Qasim III (Iraq), vers 5300-4700 av. J.-C. (d'après Forest-Foucault 1980: fig. 1).

3. Voir également ci-après l'intérêt qu'il y avait à disposer pour les calculs de dimensions de briques correspondant à des fractions de la coudée, l'unité de mesure de référence.



a
 MODULES DE BRIQUES CRUES MOULÉES UTILISÉES POUR LA CONSTRUCTION DES MURS
 DU NORTHERN SHRINE ET DU CENTRAL SHRINE (TEPE GAWRA)

b
 Brique miniature non retrouvée à la fouille mais déduite des
 appareillages des Northern et Central Shrines
 BRIQUES MINIATURES RETROUVÉES SUR LE SOL DU EASTERN SHRINE (TEPE GAWRA)



c
 APPAREILLAGE DES MURS DU NORTHERN SHRINE ET DU CENTRAL SHRINE (TEPE GAWRA)

d
 APPAREILLAGE DES MURS RÉALISABLE AVEC LES BRIQUES MINIATURES SELON LES TECHNIQUES DE CONSTRUCTION IDENTIFIÉES
 DANS LES NORTHERN ET CENTRAL SHRINES (TEPE GAWRA)

Figure 7. Appareil complexe et briques miniatures à Tepe Gawra (Iraq), vers 4000 av. J.-C.
 (d'après Baudouin 2022).

La construction mésopotamienne : une question de volumes

L'ampleur des programmes implique une gestion administrative et prévisionnelle de la construction publique

C'est également à l'époque de la Troisième dynastie d'Ur vers 2100 av. J.-C. que l'on commence à disposer de données sur la gestion de la construction publique (c'est-à-dire royale) mésopotamienne notamment grâce à l'abondante documentation fournie par les tablettes d'argile à écriture cunéiforme⁴.

Avec l'apparition à cette période des premières ziggurats, élément caractéristique de l'architecture religieuse mésopotamienne (Sauvage 1998b; 2011; 2015 et 2020; Quenet 2016), et de leurs complexes religieux, ce sont des programmes de construction qui concernent la fabrication, le transport et la pose de millions de briques. L'ampleur de ces programmes de construction va de pair avec la mise en place d'une gestion administrative et prévisionnelle de la construction royale.

La standardisation des unités de mesure, notamment des distances, des volumes et des capacités

La première moitié du III^e millénaire av. J.-C. est celle des cités-États sumériennes ; c'est avec l'émergence d'un pouvoir étatique unique sur l'ensemble de la plaine avec l'empire d'Akkad (vers 2400-2200 av. J.-C.) que la nécessité d'unités de mesures communes commence à se faire sentir. Avec l'empire d'Akkad débutent en effet les premières mises en place d'un système standardisé des unités de mesure (distances, surface, volumes, capacités et masses, fig. 8) commun à l'ensemble de la plaine mésopotamienne (Powell 1987-1990: 458). Ce fut, semble-t-il, un processus progressif qui a concerné tout d'abord les unités de mesure de distance. Ur-Nammu, le premier souverain de la Troisième dynastie d'Ur (r. 2111-2095 av. J.-C.) semble l'avoir achevé à l'extrême fin du III^e millénaire av. J.-C. puisqu'il indique dans le prologue de son code de loi avoir procédé à la standardisation des unités de mesure de capacité (Roth 1995: 13-22; Sallaberger 2022: 192).

4. La Database on Neo-Sumerian Texts (BDTNS): <http://bdtns.filol.csic.es/index.php?p=about&anc=project#project>, recense pour cette époque quelque 97 000 tablettes d'argile à écriture cunéiforme écrites en Sumérien (10 000 d'entre elles sont encore inédites).

Ce système repose sur des multiples ou fractions du système hexagésimal (ou sexagésimal) mésopotamien qui, à la différence de notre système décimal, en base 10 donc, fonctionne en base 60 ; en fait plutôt dans une association de base 6 et de base 10 (Proust 2022a: 200). On le trouve encore de nos jours par exemple dans la mesure du temps ou celle des angles.

Nous connaissons, grâce à plusieurs étalons gravés, comme par exemple, la statue conservée au musée du Louvre du Gudea F dit « l'architecte à la règle » (AO3: Heuzey 1902: n° 46), la valeur de la « coudée » (sumérien *kuš*, akkadien *ammātu*)⁵ qui était de 50 cm et nous pouvons donc transcrire dans notre système métrique les valeurs des unités de mesure des distances, des surfaces et des volumes (et donc aussi des capacités). La valeur de la mine (sum. *mana*, akk. *manû*) nous est également connue, elle équivalait à peu près à une livre (500 g) et nous fournit ici aussi les équivalences pour les masses.

Sar_s, sar_v et sar_b : unités de mesure des surfaces et des volumes mais également de compte pour les briques

Les noms des multiples d'unités de mesure sont les mêmes pour les surfaces et volumes et c'est souvent le contexte du texte qui permet de les différencier.

À la suite d'E. Robson (1999), nous utilisons des indices pour différencier les unités de surface, volume et briques : par ex. sar_s, sar_v et sar_b, pour le sar.

Notons que le rapport entre un sar de surface (1 ninda × 1 ninda) correspond bien à notre logique alors que le sar de volume (1 ninda × 1 ninda × 1 *kuš*) est, lui, différent de notre système où nous attendrions un ninda³ (1 ninda × 1 ninda × 1 ninda).

Notons également que les mêmes termes sont utilisés pour la quantification des briques et que, là encore, c'est le contexte qui permet de faire la différence. Pour les briques cependant, les unités de mesure ne font plus référence à des volumes mais à des unités : un sar de briques est invariablement égal à 720 briques quel que soit le volume des briques (Naugebauer and Sachs 1945: 94; Powell 1982: 117). Il s'ensuit que le volume d'un sar de briques varie en fonction du type de briques concerné (voir plus bas pour une discussion sur les différents types de briques).

5. Par convention, afin de différencier les deux langues, on note les transcriptions du sumérien (sum.) en romain et celles de l'akkadien (akk.) en italiques.

<p>Masses</p> <p>1 še (akk. <i>uṭṭetu</i> « grain ») ≈ 0,046 g</p> <p>1 gin (akk. <i>šiqlu</i> « sicle ») = 180 še ≈ 8,33 g</p> <p>1 mana (akk. <i>manû</i> « mine ») = 60 gin ≈ 500 g</p> <p>1 gu (akk. <i>biltu</i> « talent ») = 60 mana ≈ 30 kg</p> <p>Distance</p> <p>1 še (akk. <i>uṭṭetu</i> « grain ») ≈ 0,28 cm</p> <p>1 šusi (akk. <i>ubânu</i> « doigt ») = 6 še ≈ 1,66 cm</p> <p>1 kuš (akk. <i>ammatu</i> « coudée ») = 30 šusi ≈ 50 cm</p> <p>1 gi (akk. <i>qanû</i> « canne ») = 6 kuš ≈ 3 m</p> <p>1 ninda (akk. <i>nindânu</i> « perche ») = 12 kuš ≈ 6 m</p> <p>1 eše (akk. <i>ašlu</i> « corde ») = 10 ninda ≈ 60 m</p> <p>1 danna (akk. <i>bêru</i> « stade ») = 180 eše ≈ 10,8 km</p> <p>Surface</p> <p>1 sar_s (akk. <i>mušaru</i>) ≈ 36 m² (0,0036 ha)</p> <p>1 kuš_s (akk. <i>kû</i>) = 100 sar_s ≈ 0,36 ha</p> <p>1 bur_s (akk. <i>buru</i>) = 18 iku_s ≈ 6,48 ha</p> <p>Volume</p> <p>1 še_v ≈ 1666 cm³</p> <p>1 gin_v = 180 še_v ≈ 0,3 m³</p> <p>1 sar_v (akk. <i>mušaru</i>) = 60 gin ≈ 18 m³</p> <p>1 sar_v = 5:00:00 [= 18 000] sila (≈ 180 hl)</p> <p>1 iku_v (akk. <i>kû</i>) = 100 sar_v ≈ 1 800 m³</p>	<p>Capacité</p> <p>1 gin (akk. <i>šiqlu</i> « sicle ») ≈ 16,66 ml</p> <p>1 sila (akk. <i>qû</i> « litre ») = 60 gin ≈ 1 l</p> <p>1 ban (akk. <i>sûtu</i>) = 10 sila ≈ 10 l</p> <p>1 bariga (akk. <i>pânu</i>) = 6 ban ≈ 60 l</p> <p>1 gur (akk. <i>kurru</i>) = 5 bariga ≈ 300 l</p> <p>Briques</p> <p>1 gin_b = 12 briques</p> <p>1 sar_b = 60 gin_b = 720 briques</p> <p>1 iku_b = 100 sar_b = 72 000 briques</p> <p>1 eše_b = 600 sar_b = 432 000 briques</p> <p>1 bur_b = 1 800 sar_b = 1 296 000 briques</p> <p>1 sar_s = 1 ninda × 1 ninda (aires, surfaces)</p> <p>1 sar_v = 1 ninda × 1 ninda × 1 kuš (volumes)</p> <p>1 sar_b = 720 briques (pour les comptes de briques, indépendamment des dimensions)</p>
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Figure 8. Les principales unités de mesure mésopotamiennes, termes en sumérien, akk. = akkadien ; entre guillemets sont indiqués les termes français les plus proches, soit du sens, soit de la mesure (M. Sauvage).

La gestion prévisionnelle du travail : les tâches journalières

La gestion prévisionnelle du travail de construction consistait, hormis le calcul de l'apport nécessaire en matériaux de construction, à chercher à déterminer le nombre de journées de travail nécessaires pour des ouvriers non spécialisés. Pour la fin du III^e millénaire et le début du II^e millénaire av. J.-C. en Mésopotamie, les ouvriers non spécialisés étaient en général rétribués en ration d'orge, mais on trouve également des calculs de paye en argent dans les textes mathématiques (Waetzoldt 1987; Proust 2022a: 227 et suivantes). Les ouvriers ou artisans spécialisés (maçons et

maîtres-maçons, maîtres d'œuvre et architectes, notamment: Wiseman 1972; Neumann 1996), rétribués autrement, apparaissent moins souvent sur les textes de gestion de la construction.

Les tâches journalières (akk. *iškarum*) qui pouvaient être demandées aux ouvriers non spécialisés étaient standardisées (fig. 9 : Robson 1999). Pour les travaux de construction, elles étaient, dans nombre de cas, calculées en volume : volume de terre à excaver, de terre à transporter, de terre à mélanger⁶. Pour le roseau, abondamment utilisé

6. Le matériau de construction de base, la terre-à-bâtir, qui servait à confectionner les briques, les murs en terre

Tâches	Quotas journaliers (<i>iskarum</i>)		Nombres de jours de travail par sar de volume ou de surface
	En volume ou surface	En m ² ou m ³	En nombre de jour
Empiler les briques	4 sar _v 30 še _v	1,13 m ³	14,4 jours
Construire un barrage ?	5 1/3 gin _v	1,53 m ³	11,25 jours
Construire un mur de terre	3 2/3 gin _v 15 še _v	1,125 m ³	16 jours
Construire une levée de terre	10 gin _v	3 m ³ 360 m ²	6 jours
Couper des roseaux	10 gin _v 10 gin _a	3 m ³	6 jours
Creuser à moins d'une coudée	20 gin _v	6 m ³	3 jours
Creuser à plus d'une coudée	10 gin _v	3 m ³	6 jours
Démolir un mur	15 gin _v ou 20 gin _v	4 ou 5 m ³	4 ou 3 jours
Mélanger de la terre	10 gin _v	3m ³	6 jours
Mouler des briques (coup d'eau ?)	25 gin _v	7,5 m ³ (2161 briques de type 2, 809 de type 8)	2,40 jours
Mouler des briques (coup de sable ?)	20 gin _v	6 m ³ (1729 briques de type 2, 647 de type 8)	3 jours

Figure 9. Quelques exemples de quotas de tâches journalières (*iškarum*) pour les ouvriers non spécialisés (d'après Robson 1999).

pour la construction⁷, la quantité à couper ou à tresser pour faire des nattes pouvait être calculée d'abord en surface, mais la quantité à transporter en volume (Robson 1999: 109, 139; Heimpel 2022). Pour les murs, la quantité à enduire était calculée en surface, et le total transcrit en volume de terre à préparer (Robson 1999: 70-71).

Les calculs du scribe : formation et pratique

Textes mathématiques et textes administratifs

Les valeurs de l'*iškarum*, la tâche journalière, nous sont connues tout d'abord par les textes administratifs (Robson 1999). La plus grande partie d'entre ceux qui nous sont parvenus datent

modélée (bauge), les mortiers ou les enduits, consistait en un mélange de terre argileuse, d'eau et d'un dégraissant, souvent de la paille hachée. Ce mélange était malaxé à plusieurs reprises (piétiné ou avec des houes) et pouvait être laissé à reposer quelques jours avant l'emploi (Doat 1979: 111-117; Aurenche 1981: 53-54).

7. On intercalait des lits de roseau entre les assises des murs et utilisait des lits de roseau ou des nattes pour la confection des planchers et toits enduits de terre (Sauvage 1998a: 54-55; 2015b: 456-249).

de l'époque de la Troisième dynastie d'Ur, à l'extrême fin du III^e millénaire av. J.-C., mais certains exemples de l'époque d'Akkad (deuxième moitié du III^e millénaire : vers 2400-2200 av. J.-C.) et d'autres de l'époque paléo-babylonienne (vers 2000-1600 av. J.-C.) montrent que la même pratique a perduré pendant près d'un millénaire en Mésopotamie centrale et méridionale. Le même système et les mêmes valeurs sont également documentés par les textes d'apprentissage des scribes qui sont fréquemment qualifiés de textes mathématiques (Proust 2007). La majorité date de la période paléo-babylonienne, mais, là encore, avec quelques exemples antérieurs qui montrent que le système s'est mis en place au moins dans la deuxième moitié du III^e millénaire av. J.-C. (Robson 1999: 192; Heimpel 2022: 168-169).

Ces différents types de textes nous renseignent non seulement sur des ordres de grandeur mais également sur les modes de calcul. Concernant les ordres de grandeur, les comparaisons avec le matériel archéologique et les données ethnographiques montrent que les chiffres choisis par les scribes pour les textes d'apprentissage étaient réalistes: les charges de travail correspondent à ce que l'on pouvait trouver dans les mêmes régions pour des pratiques de construction pré-industrielles; les dimensions des murs ou des bâtiments correspondent à ce que l'on connaît de l'architect-

ture mésopotamienne grâce aux fouilles archéologiques. Les quantités sont également cohérentes : on a par exemple pu calculer le nombre de briques nécessaire à la construction de la première terrasse de la ziggurat d'Ur (Sauvage 1998b: 56-57), les totaux de briques crues et cuites sont comparables à ceux fournis par les textes : près de 7 millions de briques crues et 700 000 briques cuites pour la première terrasse de la ziggurat d'Ur à comparer avec les 14 millions de briques crues et 7,5 millions de briques cuites des temples de Šara et Ninnura à Umma (Robson 1999: 188).

Calcul du volume total de la construction, du volume des murs ou des piles, du nombre de briques avec joints

Les textes d'apprentissage en particulier, nous renseignent également sur les modes de calcul dans le domaine de la construction.

Un exemple de texte d'apprentissage concernant des travaux de terrassement (YBC 4657 #1 : Naugebauer et Sachs 1945, text G; Proust 2022: 227, ma traduction en français) :

Une tranchée. 5 ninda sa longueur, 1 ½ ninda sa largeur, ½ ninda sa profondeur. 10 gin est le volume à traiter (par ouvrier et par jour). 6 še (d'argent) [la paye par ouvrier et par jour]
La surface (« la base »), le volume, le nombre d'ouvriers et l'argent [des payes] combien ?
½ la surface, 45 le volume, 4 × 60 + 30 [ouvriers], 9 gin l'argent [pour les payes]

Ainsi la notion de volume reste fondamentale dans ce domaine ; elle est directement liée à la charge de travail journalière qui peut être demandée à un ouvrier.

Pour leurs calculs, les scribes considéraient qu'un tiers du volume d'une construction était occupé par les murs (Robson 1999: 69). Cet ordre de grandeur peut être confirmée par l'étude des plans des habitations fouillées pour cette époque (Battini-Villard 1999: 161-163). Pour les murs de briques, ils considéraient également qu'1/6 du vo-

lume était constitué de mortier, les 5/6 restants de briques (Robson 1999: 67-69).

Calcul du transport des matériaux : le rapport entre le volume, le chargement et la distance

Les calculs de transport des matériaux dépendent non seulement de la distance mais également de la masse de matériaux à transporter : il s'agit d'un rapport entre le volume total à transporter, la masse volumique du matériau concerné, le chargement maximal qui pouvait être demandé par voyage à un ouvrier (homme ou femme) et enfin la distance totale sur laquelle les matériaux devaient être transportés. Les calculs relatifs au chargement (en général pour des femmes, il semble avoir été égal à 25 kg; Heimpel 2022: 151, 169) dépendent de la masse volumique du matériau transporté, rapporté au poids d'un panier de terre (fig. 10 : Robson 1999: 92). De ce point de vue, c'est l'eau qui est la moins rentable à déplacer, la confection de la terre à bâtir (mortier, enduits ou briques) était donc en général faite près d'un point d'eau et l'on trouve très peu de textes relatifs au transport de d'eau pour la construction.

Problème spécifique de la brique : plusieurs types de format et donc plusieurs types de volumes

Les briques posent des problèmes très spécifiques de deux ordres. Tout d'abord, selon qu'elles sont encore humides (et transportées de la zone de moulage vers les zones de séchage), sèches ou cuites, leur masse volumique varie (Robson 1999: 62-65 et Heimpel 2022: 151-153.) Par conséquent, le nombre de briques qui peuvent être transportées en un chargement devrait varier mais les textes de la pratique ne spécifient souvent pas le type de brique transporté ; je ne suis donc pas ici l'avis de W. Heimpel (2022: 153) qui pense que les scribes prenaient en compte l'état de séchage des briques pour le calcul des quantités à transporter et préfère penser (comme Middeke-Conlin 2022)

Matériaux transportés	Volume d'un chargement	Vol. transporté par jour sur un ninda = 6 m)		Volume transporté par jour sur 30 ninda = 180 m	Équivalent en panier de terre
	Volume en <i>se_v</i>	Volume en <i>sar_v</i>	en m ³ (±)		
Terre	6 2/3 <i>se_v</i>	1 2/3 <i>sar_v</i>	30	1 m ³	1
Briques	12 ½ <i>se_v</i>	3 <i>sar_v</i> 7 ½ <i>gin_v</i>	56,25	1,8 m ³	1 7/8
Paille	13 1/3 <i>se_v</i>	3 1/3 <i>sar_v</i>	60	2 m ³	2
Roseaux	20 <i>se_v</i>	5 <i>sar_v</i>	90	3 m ³	3
Eau	5 1/3 <i>se_v</i>	1 1/3 <i>sar_v</i>	24 (= 24 000 l)	0,78 m ³ (800 l)	4/5

Figure 10. Quelques exemples de quotas de tâches journalières (*iškarum*) pour le transport des matériaux de construction (d'après Robson 1999).

qu'ils n'utilisaient comme référence qu'un seul état : la brique séchée au soleil.

La deuxième particularité est que la brique était décomptée à l'unité et non au volume mais qu'il coexistait plusieurs types de briques de dimensions différentes et donc de volume et de masse différentes. On en dénombre, par les textes administratifs et surtout mathématiques, une

dizaine (fig. 11; Powell 1982: 119-120; Sauvage 1998a: 127; Robson 1999: 72), dont les plus fréquemment utilisées pour la fin du III^e et la première moitié du II^e millénaire av. J.-C. en Mésopotamie centrale et méridionale (fig. 12 et 13; Sauvage 1998a: 125-139; 1998b: 55) étaient les briques crues rectangulaires d'une demie coudée sur un tiers ($25 \times 16/17$ cm) ou de $3/5$ sur $2/5$ de coudée

Types de briques (Powell 1982)	Dim. en <i>šusi</i>	Dim. en <i>kuš</i>	Dim. en cm
1	$10 \times 10 \times 6$	$1/3 \times 1/3 \times 1/10$	$16,66 \times 16,66 \times 10$
2	$15 \times 10 \times 5$	$1/2 \times 1/3 \times 1/12$	$25 \times 16,66 \times 8,33$
3	$20 \times 10 \times 5$	$2/3 \times 1/3 \times 1/12$	$33 \times 16,66 \times 8,33$
4	$18 \times 12 \times 5$	$3/5 \times 2/5 \times 1/12$	$30 \times 20 \times 8,33$
5	$15 \times 15 \times 5$	$1/2 \times 1/2 \times 1/12$	$25 \times 25 \times 8,33$
6	$20 \times 10 \times 6$	$2/3 \times 1/3 \times 1/10$	$33 \times 16,66 \times 10$
7	$18 \times 18 \times 5$	$3/5 \times 3/5 \times 1/12$	$30 \times 30 \times 8,33$
8	$20 \times 20 \times 5$	$2/3 \times 2/3 \times 1/12$	$33 \times 33 \times 8,33$
8a	$30 \times 15 \times 5$	$1 \times 1/2 \times 1/12$	$50 \times 25 \times 8,33$
9	$20 \times 20 \times 6$	$2/3 \times 2/3 \times 1/10$	$33 \times 33 \times 10$
10	$24 \times 24 \times 5$	$4/5 \times 4/5 \times 1/12$	$40 \times 40 \times 8,33$
11	$30 \times 30 \times 5$	$1 \times 1 \times 1/12$	$50 \times 50 \times 8,33$
12	$30 \times 30 \times 6$	$1 \times 1 \times 1/10$	$50 \times 50 \times 10$

Noter que 1 peut être considéré comme le quart de brique de 9 ; 3 comme la demi-brique de 8 ; 5 comme le quart de 11 ; 6 comme la demi-brique de 9 ; 8a comme la demi-brique de 11.

Noter également que 3 et 6, 8 et 9, 11 et 12 ont les mêmes dimensions à l'exception de l'épaisseur (5 et 6 šusi)

Figure 11. Les différents types de briques attestés dans les textes mésopotamiens (d'après Powell 1982: 119).

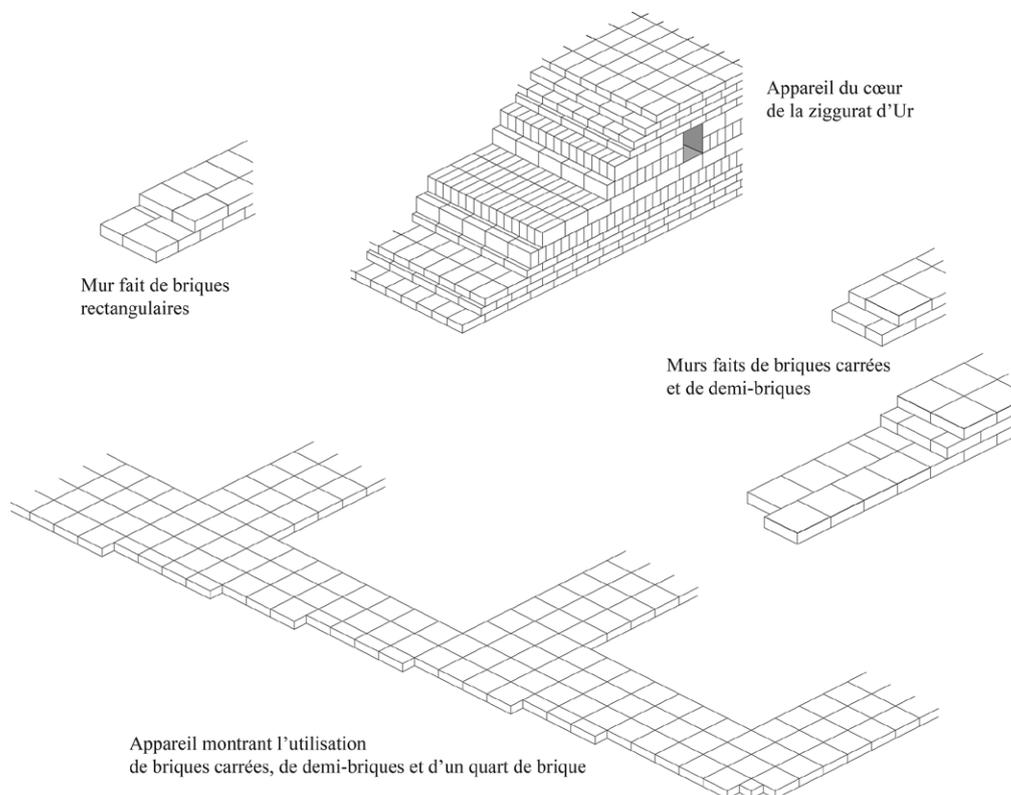


Figure 12. Quelques exemples d'appareils mésopotamiens de briques rectangulaires ou carrées (d'après Sauvage 1998).

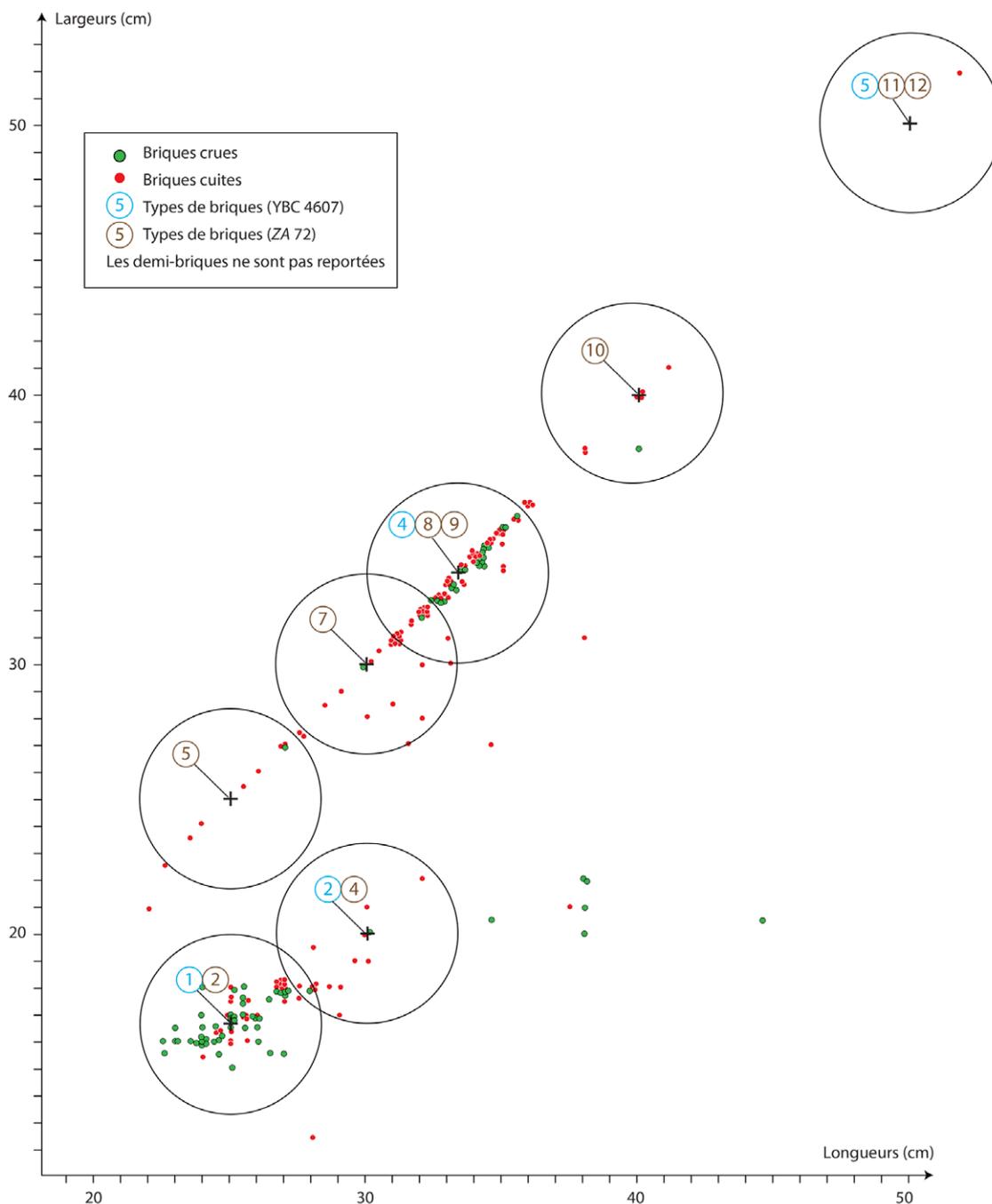


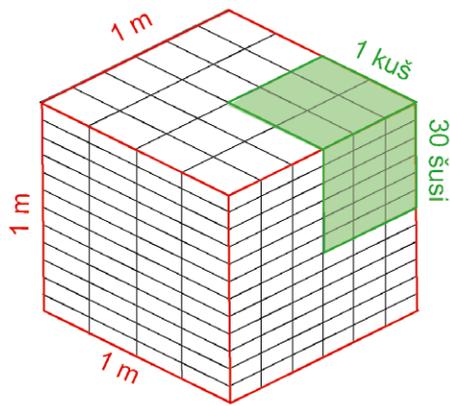
Figure 13. Diagramme de répartition des longueurs et largeurs des briques crues ou cuites datant de l'époque paléo-babylonienne, vers 2000-1600 av. J.-C. (d'après Sauvage 2022: 107).

(30 × 20 cm), accompagnées de briques carrées cuites, le plus fréquemment de 2/3 de coudée de côté (33 × 33 cm, et toujours associées à des demi-briques de 33 × 16/17 cm).

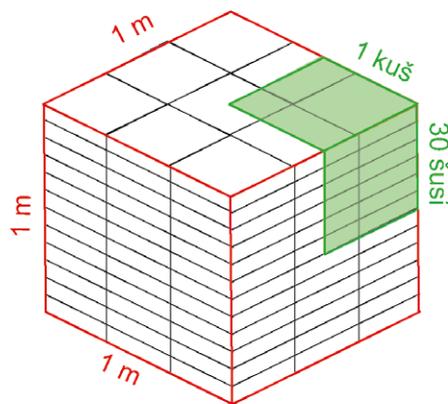
De ce fait, nombre d'exercices de calcul correspondaient en la recherche du nombre de briques contenues dans un mur ou dans une pile de stockage d'un volume donné, en tenant compte du type de brique concerné (fig. 14). Ainsi, un volume total de mur à construire ou d'une pile de

stockage de briques correspond à un nombre variable de briques, variant selon les dimensions, et donc selon le volume, du type de brique concerné.

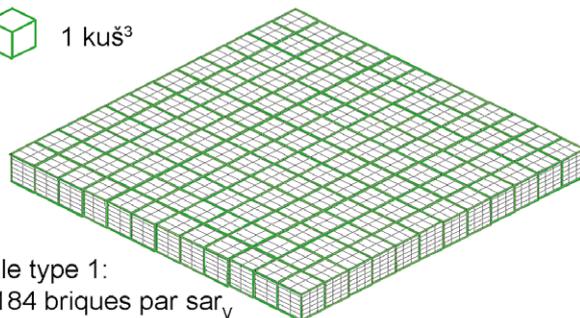
Parmi les coefficients spécifiques aux briques (Robson 1999; Middeke-Conlin 2015 et 2022; Proust 2022a), le *nalbanum* (ou « brickage » : Naugebauer et Sachs 1945: 138; Powell 1982: 120; Robson 1999: 59) permettait de définir le nombre de briques d'un type donné contenues dans un volume donné (fig. 15). Le *nalbanum* d'une



Yale type 1 – Powell type 2
briques crues (sig₄ / akk. *libittum*)
1/2 kuš × 1/3 kuš × 5 šusi
(± 25 × 16.66 × 8.33 cm)
36 briques par kuš³
5 184 briques par sar_v
24 briques par m²
288 briques par m³

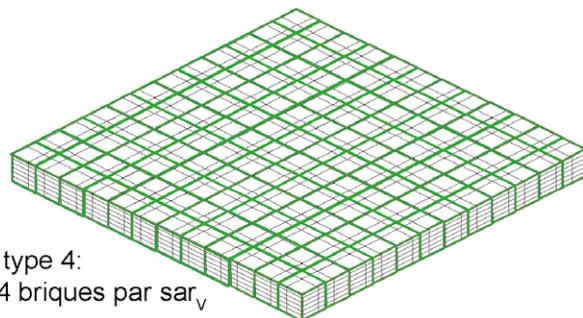


Yale type 4 – Powell type 8
briques cuites (sig₄.al.ùr.ra / akk. *agurrum*)
2/3 kuš × 2/3 kuš × 5 šusi
(± 33 × 33 × 8.33 cm)
13,5 briques par kuš³
1 944 briques par sar_v
9 briques par m²
108 briques par m³



Yale type 1:
5 184 briques par sar_v

1 sar aire (sar_a)
= 1 ninda × 1 ninda
= 12 kuš × 12 kuš
= ± 6 × 6 m = ± 36 m²



Yale type 4:
1 944 briques par sar_v

1 sar volume (sar_v)
= 1 ninda × 1 ninda × 1 kuš
= 12 kuš × 12 kuš × 1 kuš
= ± 6 × 6 × 0,5 m = ± 18 m³

Figure 14. Rapport des surfaces et volumes et du nombre de briques en fonction du type de brique : exemples ici avec un type de briques rectangulaires et un type de briques carrées, les plus courants (dessin M. Sauvage).

brique mesurant 1 kuš × 1 kuš × 5 šusi (50 × 50 × 8,33 cm) est de 720 briques par sar de volume (1 ninda × 1 ninda × 1 kuš). On peut penser que c'est ce type de brique d'une coudée carrée, très peu attesté dans le matériel archéologique, qui a servi à la définition du sar de brique de 720 unités. Les dimensions des autres types de briques reposant sur des fractions de la coudée, leur *nalbanum* correspondait à des multiples de celui de la brique d'une coudée (voir fig. 15). Les modes de calcul des scribes mésopotamiens, qui ignoraient la division, reposaient sur l'utilisation de tables de correspondance, d'où l'importance de rester, avec ces unités de volumes de base que représentaient ces différents types de briques, dans des sous-multiples de l'unité de mesure de référence. Le système hexagésimal (ou sexagésimal) mathématique mésopotamien repose en effet sur la base soixante et ses nombreuses possibilités de fractions entières (pour les calculs de la pratique, voir Proust 2007; 2022a; 2022b).

On connaît également le *tadditum* (ou « layer » : Proust 2022: 216) qui permet de calculer le nombre de briques nécessaire pour couvrir une surface (voir fig. 15). Dans ce cas, c'est la surface de la brique (produit de ses deux plus grandes dimensions) qui est utilisée et non pas son volume. Si ce coefficient peut permettre de calculer des volumes (en multipliant par 6 dans le cas de briques épaisses de 5 šusi ou par 5 pour celles de 6 šusi, on obtient un volume haut d'une coudée et on transforme ainsi la surface en volume (nous avons vu plus haut que le sar de volume n'a qu'une coudée – kuš – d'épaisseur et non pas un ninda). Concrètement, ce coefficient pouvait également servir au calcul du nombre de briques nécessaire pour un carrelage.

Dans le cas des transports de briques, il s'agissait de connaître le nombre de briques pouvant être transportées par voyage et correspondant plus ou moins au chargement maximal demandé à une femme (25 kg: Heimpel 2022) ou à celui d'un homme (probablement 50 kg). On utilisait alors un autre coefficient : le *nazbalum* (Middeke-Conlin 2022: voir fig. 15). Associé à la distance à parcourir, ce coefficient permettait de calculer le nombre de jours de travail à prévoir pour déplacer une quantité donnée de briques. Dans la pratique, ces calculs étaient faits grâce à l'utilisation de tables de conversion, au moins pour l'époque paléo-babylonienne (Proust 2022a et Middeke-Conlin 2022). L'usage des coefficients présenté plus haut n'est connu que par les textes mathématiques paléo-babyloniens mais nombre de textes administratifs de l'époque de la Troisième dynastie d'Ur (Heimpel 2009: 191 par exemple) semblent indiquer qu'ils étaient déjà en usage à l'extrême fin du III^e millénaire av. J.-C.

Les textes de la pratique : quelques exemples

Les textes de transport de briques de Garšana : le rapport type de brique, charge et distance dans la pratique

Dans la pratique, les textes de transport de briques de Garšana sont un bon exemple de l'usage de ces coefficients. Les archives de Garšana (Owen et Mayr 2007; Heimpel 2009) rassemblent un total de 52 textes de transport de briques. Il s'agit de listes de noms associés à des totaux de briques. Un paragraphe final indique le nombre

Types de briques (Powell 1982)	Dim. en cm	Nombre de briques par sar _v , (calculé avec le <i>nalbanum</i>)	Nombre de briques transportées sur 60 <i>ninda</i> en une journée (calculé avec le <i>nazbalum</i>)	Nombre de briques par sar de surface (<i>tadditum</i>)
1	16,66 × 16,66 × 10	6 480	675	1 296
2	25 × 16,66 × 8,33	5 184	540	864
3	33 × 16,66 × 8,33	3 888	405	648
4	30 × 20 × 8,33	3 600	375	600
5	25 × 25 × 8,33	3 456	360	576
6	33 × 16,66 × 10	3 240	337,5	648
7	30 × 30 × 8,33	2 400	250	400
8	33 × 33 × 8,33	1 944	202,5	324
8a	50 × 25 × 8,33	1 728	180	288
9	33 × 33 × 10	1 620	208,75	324
10	40 × 40 × 8,33	1 350	140,625	225
11	50 × 50 × 8,33	864	90	144
12	50 × 50 × 10	720	75	144

Figure 15. Coefficients spécifiques aux calculs avec des briques. Le *nalbanum* pour convertir un volume en nombre de briques, le *tadditum*, pour calculer le nombre de briques sur une surface, et le *nazbalum* pour calculer le nombre de briques transportées (d'après Sauvage 2020 : Table 6.4.).

de briques à transporter par jour ainsi que la distance, en précisant qu'il s'agit de la charge de travail de femmes (sum. *geme*)⁸. Ces textes documentent des distances différentes, selon les chantiers de construction ; le quota journalier, rappelé sur chaque texte en tient compte (Heimpel 2009: 191): 180 briques par jour pour une distance de 60 ninda (± 360 m), 150 pour 72 ninda (± 432 m), 120 pour 90 ninda (± 540 m) et 90 pour 120 ninda (± 720 m). Le produit du nombre de briques et de la distance est toujours le même: 3 soixantaines de soixantaines = 10800. Cela correspond au *naz-balum* des briques carrées de type 5 (½ kuš ou 25 cm de côté ; Proust 2007; 2022; Heimpel 2022 et Middeke-Conlin 2022).

Un devis prévisionnel : calcul des volumes de briques, de terre et de roseaux nécessaires et journées de travail correspondantes

Le texte A 2976 (fig. 16)⁹ est un devis prévisionnel pour la construction d'un entrepôt qui indique

très clairement l'usage dans la pratique de ces coefficients, ou de modes de calcul par conversion utilisant ces coefficients (récente transcription et la traduction anglaise dans Sauvage 2020 : 230-231, ma traduction française ici).

8 sar de briques [= 5760 briques], 24 journées de travail d'un ouvrier pour les faire ;
16 journées de travail d'un ouvrier pour transporter 8 briques par voyage sur 60 ninda ;
8 journées de travail d'un ouvrier pour préparer le mortier ;
90 bottes de roseaux pour les nattes, 9 journées de travail d'un ouvrier pour les transporter ;
3 journées de travail d'un ouvrier pour préparer le mortier ;
90 bottes de roseaux à insérer dans la maçonnerie, 18 journées de travail d'un ouvrier pour les transporter ;
6 journées de travail d'un ouvrier pour préparer le mortier ;
Total: 84 journées de travail d'un ouvrier pour la construction de l'entrepôt... (nom et date)

Le calcul du nombre de briques nécessaire à la construction n'est pas détaillé, on peut pen-



Figure 16. Tablette d'argile à écriture cunéiforme, devis prévisionnel pour la construction d'un entrepôt, datée de Šulgi 46 (2048 av. J.-C.), conservée à l'Oriental Institute de l'Université de Chicago, n° d'inv. A2976 (cliché Cuneiform Digital Library Initiative).

8. On trouvera la transcription et la traduction complète d'un de ces textes (CUNES 48-07-066, Owen et Mayr 2007 n° 324 : 150-151) dans Sauvage 2020: 231-234.

9. Tablette conservée à l'Oriental Institute de l'université de Chicago, texte administratif daté de Šulgi 46 (2048 av.

J.-C.) de provenance inconnue: Farber 1989; Robson 1999 (avec commentaire complet : 153-156); Sauvage 2020; Heimpel 2022 : 151.

ser qu'il est déduit du volume du bâtiment ou de sa surface. Le calcul du nombre de journées de transport implique l'usage du *nalbanum* mais le type de brique n'est pas spécifié. La distance est, elle, spécifiée, on peut donc en déduire le type de briques: 8 sar de briques, ou 5760 briques, sont transportés en 16 jours, soit 360 par jour, sur une distance de 60 ninda = 21600, cela correspond au double du quota vu pour Garšana pour les briques d'une demi-coudée de côté ($25 \times 25 \times 8,33$ cm) qui ont un *nazbalum* de $80 \times 60 = 10800$ (voir fig. 12). Avons-nous affaire ici à un chargement de 50 kg pour des hommes au lieu des 25 kg pour les femmes ? Notons également que, pour le moulage des briques, la tâche journalière demandée est de 240 briques à mouler par jour. Ce chiffre ne correspond probablement pas à la seule tâche du moulage (on obtiendrait des chiffres bien supérieurs, de l'ordre de 2000 briques par jour : Sauvage 2020: 209, n. 10), mais plutôt à une tâche combinée de préparation et de transport de la terre ($\frac{3}{4}$ de la journée) puis de moulage des briques (pendant le $\frac{1}{4}$ de la journée restant : pour ces tâches combinées : voir Robson 1999 : 74-77 ; Sauvage 2020: 223). On retrouve cette même valeur par exemple dans les textes datant de l'époque de la Troisième dynastie d'Ur de Garšana (Heimpel 2009: 167 et 224) ou dans des textes d'époque paléo-babylonienne (Robson 1999: 153), avec une amplitude de nombre de briques moulées par jour, de même format, allant de 180 à 300). Dans les deux cas, il pourrait s'agir des briques les plus couramment utilisées : des briques crues rectangulaires mesurant $\frac{1}{2}$ coudée sur $\frac{1}{3}$ de coudée sur 5 doigts ($\pm 25 \times 16,66 \times 8,33$ cm).

Le texte Hadad 104 (Al-Rawi and Roaf 1984 : 195-218 ; Robson 1999 : 75 ; Friberg et Al-Rawi 2016: 217-219), concerne des briques carrées de $\frac{2}{3}$ de coudée (*kuš*) de côté et 6 doigts (*šusi*) d'épaisseur, soit $33,33^2 \times 10$ cm pour un total de 135 briques produites par jour. Trois tâches sont ici prises en compte : creusement, mélange et moulage, exprimées en volume de terre : $\frac{1}{3}$ de sar peut être creusé en une journée, même quantité pour le moulage, $\frac{1}{6}$ de sar de terre correspondant au volume de terre qui peut être mélangé. De ces quotas journaliers, on en déduit que sur une journée, pour un même volume de terre ($\frac{1}{12}$ de sar ou $1,5 \text{ m}^3$) $\frac{1}{4}$ de la journée était consacré au creusement, $\frac{1}{2}$ pour le mélange) et $\frac{1}{4}$ pour le moulage.

Conclusion

Le principal matériau utilisé dans la construction mésopotamienne à l'âge du Bronze, la brique, représente un élément en volume, de trois dimensions et orienté : on peut la disposer à plat ou de chant, perpendiculairement ou parallèlement à l'axe du mur, en pile ou en couche, etc. Si la plupart des calculs concernant les activités de construction sont fait à partir de volumes, la brique à la particularité d'être un volume décompté en général à l'unité. Elle présente également la particularité de se décliner en plusieurs types (dimensions et modules) qui font que le rapport unité/volume est variable.

Ces caractéristiques ont fait que les calculs sur des briques faisaient partie à la fois de la base de l'apprentissage de scribes mais également de leur pratique quotidienne dans le cadre des activités de construction. Pour les différentes conversions nécessaires entre les volumes et les unités de briques, des coefficients ont été créés (*nalbanum*, *nazbalum* et *tadditum*). Dans la pratique, il semble que c'était plutôt l'usage des tables de conversion, facilité par le système hexagesimal qui étaient privilégiés.

Le décompte des briques à l'unité (utilisé également pour la mesure des murs) et non en volume a incité également à l'utilisation de briques dont les trois dimensions correspondaient à des fractions de la coudée, l'unité de mesure de référence pour les distances). Cette tendance est visible, en tenant compte de la dispersion des valeurs dues au retrait au séchage des briques, sur le matériel archéologique même et c'est là un des rares cas dans les études sur l'Orient ancien où l'on peut valider les informations textuelles grâce aux restes archéologiques.

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Data de recepció: 11/06/2024
Data d'acceptació: 19/07/2024

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Filling the gaps: methodological issues in capacity research of Late Bronze Age Maritime Transport Containers

Omplir els buits: qüestions metodològiques sobre l'estudi de la capacitat dels contenidors de transport marítim de l'Edat del Bronze Recent

Capacity has often been neglected in ceramic studies despite a vessel's inner cavity being a central parameter for its interpretation. Capacity is closely tied to the function and the *raison d'être* of any pottery container as it directly reflects the potential amount of any particular product to be transported, stored, processed, or consumed. The capacity of Maritime Transport Containers (MTCs) such as amphoras of the Late Bronze Age in the eastern Mediterranean determined the economic value of the content. As references to units of capacity are scarce in 2nd-millennium BCE texts, direct examination of archaeological material offers a valuable approach to determining the actual ranges, and thus the possible quantities of commodities traded. This paper presents a methodological framework combining direct and indirect approaches with the aim of laying down a foundation for a solid database for ancient eastern Mediterranean containers. It then presents a case study of Levantine amphoras based on data from 50 sites spread throughout the eastern Mediterranean and outlines the aims of the ERC ComPAS project, which focuses on the various MTCs involved in trade with Cyprus during the Late Bronze Age and early phases of the Iron Age.

Keywords: Capacity study; metrology; eastern Mediterranean; Late Bronze Age; Maritime Transport Container; Levantine amphora.

La capacitat ha estat sovint desatesa en els estudis ceràmics, malgrat que la cavitat interior d'un recipient és un paràmetre fonamental per a la seva interpretació: la capacitat està estretament relacionada amb la funció i la raó de ser de qualsevol peça ceràmica, atès que reflexa directament la quantitat potencial d'un producte concret que pot transportar-se, emmagatzemar-se, processar-se o consumir-se. Al Mediterrani oriental de finals de l'edat del bronze, la capacitat dels contenidors de transport marítim (MTCs), com les àmfores, determinava el valor econòmic del seu contingut. Encara que les unitats de capacitat són escasses a les fonts textuals del segon mil·lenni aC, l'examen directe del material arqueològic ofereix un enfocament valuós per determinar els rangs reals de capacitat i, per tant, les possibles quantitats de mercaderies comercialitzades. Aquest article presenta un marc metodològic que combina enfocaments directes i indirectes, amb l'objectiu d'establir els fonaments per a una base de dades sòlida sobre els recipients antics de la Mediterrània oriental. A continuació, planteja un estudi de cas sobre les àmfores levantines basat en dades de cinquanta jaciments repartits per tota la Mediterrània oriental i descriu els objectius del projecte ERC ComPAS, un projecte que es centra en els diversos MTCs que van participar en el comerç amb Xipre durant l'edat del bronze recent i les primeres fases de l'edat del ferro.

Paraules clau: estudi de la capacitat, metrologia, Mediterrani oriental, edat del bronze recent, contenidors de transport marítim, àmfora levantina.

Introduction

In archaeology, many aspects of ancient pots are usually assessed: decorative and functional features, manufacturing technics, use-wear and forming traces, clay composition, contents, potmarks, and more. The object itself is carefully documented, and various dimensions are recorded, including morphometry details such as height, opening and base diameter; maximal diameter or circumference of the body, and in some cases even wall and handle thickness.

In contrast, the object's capacity often remains neglected in studies of Bronze Age eastern Mediterranean vessels, despite some scholars having argued for the importance of addressing this parameter more systematically (e.g. Raban 1980; Thalmann 2003; 2007). In distinction, Classical archaeology, where both material and textual data abound, is far more advanced on this topic, as numerous studies on amphora capacity and standardisation have long demonstrated (among others, see Grace 1949; 1979; Sealey 1985; Wallace 1986). Recent studies still integrate capacities as a common data for amphora analysis (e.g. Molina Vidal and Mateo Corredor 2018; Demesticha 2022; Lund 2023). Generally, it is as though the empty space of a vessel's inner cavity offers no meaningful contribution to the interpretation of the material. This may partly be because our approach to ceramology reduces these three-dimensional objects in two-dimensional drawings, obscuring their volumetric aspect.

It is here argued that capacity ought to be considered a key parameter for all classes of ceramic. Capacity reflects no less than the amount of a particular product that a container can hold – whether in the context of the transport, storage, preparation or processing of goods, or their consumption. In the case of Maritime Transport Containers (MTC) (for this designation, see Marcus 2002: 409-411; Knapp and Demesticha 2017; more broadly on Mediterranean containerisation, see Bevan 2014) such as amphoras, capacity determines the value of the transported product, without which the container itself would hold little particular interest.

Accordingly, when considering MTCs, capacity was undoubtedly a factor taken into account by many during a container's use-life. Potters, and in some cases their commissioners, were the first to acknowledge this parameter when designing a ceramic vessel and assigning it a specific function. Merchants were also likely inclined to assess it, as capacity determines the amount of commodity they would have been able to exchange. This aspect was equally important for seafarers responsible for freight logistics, who had to ar-

range cargo efficiently. For consumers, knowing the quantity of goods within a container ensured fair transactions.

As such, capacity should be a key element of any study dealing with transport containers and trade, as it can reveal various stages of the exchange process. More generally, when studied diachronically, capacity may offer insights into the economy of a region and highlight potential shifts. It may also shed light on practices and habits that varied from one area to another. Studying a ceramic assemblage from a specific settlement or discovery – for example, the Uluburun shipwreck (Pulak and Matheny 2021) or the deposit at Minet el-Beida (Sauvage 2015), with respectively 150 and 80 Levantine amphoras – can provide insight into the degree of standardisation in ancient ceramic production that potters were able to achieve in different times and regions.

Capacity alone does not provide complete insight, and it should always be analysed together with other parameters – e.g. typological, functional, petrographic, contextual, nature of the contents – to support meaningful interpretations (Webb and Pomadère forthcoming). Although capacity materialises as a simple hollow space, its study can help us fill the gaps in our knowledge about the production and functions of pots, as well as about various aspects such as exchange logistics, metrological systems, storage strategies and cooking and consumption practices.

This paper outlines the issues involved in volumetric measurement and offers a methodological framework. It then presents a short case study based on data from fifty sites spread throughout the eastern Mediterranean and outlines the aims of the COMPAS project, which gives attention to the various MTCs involved in trade with Cyprus during the Late Bronze Age and early phases of the Iron Age.

Challenges and limitations

Volumetric measurement systems for the Late Bronze Age (LBA) eastern Mediterranean are unevenly documented. In Egypt, units of capacity are well-attested in texts. The *hin*-measure, more specifically used for liquids, corresponds to nearly half a litre, while the *heqat*, a unit used for grain measurement, equals about 5 L, or 10 times the *hin* (Pommerening *et al.* 2023: 144). According to a study led by Zapassky, the *heqat* would amount precisely to 4.77 L (Zapassky *et al.* 2012). Hieratic inscriptions, the so-called 'jar docketts', are commonly found on Egyptian vessels, as well as on Levantine amphoras imported into Egypt (Bavay *et al.* 2000; Tallet 2003; Bavay 2015). These dockets served an administrative purpose and provide

a rich source of information, sometimes mentioning the nature of products transported, the name of the transport ship captain, the regnal year, and even, in some cases, capacity. These capacities, which are expressed in *hin*, may be as precise as half a unit, representing about 25 cl (Tallet 2003: 261; Bavay 2015: 134, fig. 12). Jar docketts mentioning capacity come either from ceramics reduced to sherds or from perfectly intact vessels, sometimes still sealed; unfortunately, in neither case can direct measurements be made on the material to assess the recorded capacity expressed in *hin*.

In the Levant, the system of volumetric measure for liquids during the LBA remains largely unknown. In the northern Levant, at Ugarit, the term *kd* is interpreted as a unit of capacity (Heltzer 1989: 197-201), although it may also have referred to a ceramic vessel – possibly a specific type of amphora with a standard size in use at the end of the LBA – whose capacity could have fluctuated over time (Zamora 2003; 2004). This term, frequently appearing in economic texts from Ugarit, may therefore designate a category of containers rather than simply a unit of liquid measurement. Interestingly, *kd* always appears in whole numbers in texts, never as a fraction, reinforcing the idea that it might refer to a container. Additional evidence supporting this interpretation comes from a truncated cone-shaped clay label, inscribed with *kd* in the singular along with the type of product contained and the name of the addressee (Zamora 2003: 239; 2004: 393). In this case, the inscription most likely refers to the vessel to which the clay label was once attached. In the southern Levant, by contrast, the limited use of writing does not offer comparable evidence for units of capacity. Even for the Iron Age (IA), our understanding of measurement practices in the Levant remains limited. The *bath*, traditionally believed to refer to a unit of capacity which corresponds to 22 L, continues to be in discussion (Lipschits *et al.* 2012).

No units of capacity are known from Cyprus. Even line marks incised on various MTCs found throughout the island do not seem necessarily to reflect any volumetric – or weight – measurement system (Donnelly and Georgiou forthcoming).

The discovery of intact ceramic vessels mentioning a unit of capacity would probably help researchers to better understand volumetric measurement systems. It would not, however, necessarily provide the decisive element needed to decipher the units in use around the eastern Mediterranean. It may even generate further confusion, as with the case of Minoan pithoi bearing Linear A inscriptions that record quantities of goods and whose complete profile enables the reconstruction of their capacity (Montecchi 2013:

18–20). Despite such evidence, these inscriptions remain insufficient for determining with certainty the value of the unit employed, since they may in fact designate a whole batch of pithoi rather than the capacity of the inscribed ceramic alone. Likewise, in the case of an intact amphora discovered in a New Kingdom Egyptian tomb (Franzmeier 2017: 1518-1519, pl. 1840: 1955/GKeA/002), the amount indicated in the inscription, expressed in *hin*-measure, does not match with its actual capacity (Cateloy 2022: 388–389): the mention of 80 *hin* ought to amount to some 38 L, yet the amphora barely exceeds 25 L. Thus, even when certain units appear well known from the texts, their correspondence with the actual capacity of the archaeological material is not necessarily guaranteed. Several inscribed vessels would therefore be needed to shed light on the measurement system (whether unitary or by batch), as well as on the effective value of the units employed.

Beyond correlating textual data with actual capacities, estimating the volume of interregional exchange according to texts also appears challenging – particularly when it comes to organic commodities, given that such perishable products have left few traces in archaeological records. Some sources, notably the victory accounts of Egyptian kings in Canaanite lands, convey an image of the intense circulation of goods. The interpretation of other texts, such as a letter from Ugarit in which a Hittite king demands 2000 units (of an indeterminate measure) of grain, has given rise to widely diverging estimates, ranging from 450 tonnes to, more reasonably, 7.7 tonnes (Monroe 2007). Such textual evidence has occasionally encouraged interpretations of the LBA as at times comparable to the vigorous trade of the Classical Mediterranean. To what extent can the actual flows of exchange in the eastern Mediterranean be reconstructed and quantified? Egyptian texts referring to Levantine tributes – which in many respects constituted a significant part of exchange between both regions – list various commodities with precise figures (Breasted 1906); yet the actual volume of goods exported to Egypt is difficult to reconstruct, as they are often expressed in ‘*mn*-jars’ rather than units of capacity. The ‘*mn*-jar’ most likely corresponds to Levantine amphoras (Serpico 2003: 223). The commodities commonly listed in these texts and stored in ‘*mn*-jars’ are, indeed, identical to products exchanged in amphoras originating from the Levant. The annals of Thutmose III notably listed large quantities of oils, incense, honey and wine (Breasted 1906: §447, §462, §491), which are the same products mentioned in the jar docketts from Deir el-Medineh (Bavay 2015: 129-130) or chemically identified at sites such as Memphis and Tell el-Amarna (Serpico *et al.* 2003; Stern *et al.* 2003; Smith *et al.* 2004).

Another layer of uncertainty in measurement practices is that the filling levels of ancient vessels are unknown, with estimates largely resulting from assumptions based on vessel function. An amphora, for instance, might have been filled to the base of the neck, offering an ‘optimal’ practical capacity that maximised its transport and storage potential without hindering the sealing system. This, however, represents only the maximum usable limit, since beyond this level, the container would have been impractical to handle. Were amphoras systematically filled to the same level, or was there instead a standardised filling method – perhaps by using a measuring vessel or by checking the weight of the contents? If the latter, the effective level would have fluctuated from one amphora to another, since their shapes and dimensions may have varied.

Considering the current gaps in our understanding of measurement practices, the difficulties in identifying units of capacity, and the challenges in assessing the actual volume of trade, direct examination of archaeological material is necessary. This involves detecting possible traces of ancient filling levels, to determine the real quantities that could be transported per container, and, consequently, to recognise potential

standard measures. Systematic and extensive capacity measurement of trade containers can further shed light on trade patterns and consumption habits. In this paper, the focus is made specifically on Levantine amphoras, with some broader considerations on MTCs circulating in the eastern Mediterranean during the Late Bronze Age.

Methodological framework

A capacity study dealing with ancient periods should not necessarily aim for the degree of accuracy that is achievable with modern measuring instruments, since ancient standardisation – as well as metrology – did not rest upon the same social or economic norms as those in use today. It should be kept in mind that standardisation is a relative concept rather than a fixed criterion based on absolute values; it fluctuates across time and space, with varying degrees depending on the period and the cultural area (for this topic, see Kotsonas 2014).

In many cases, capacity estimates obtained through indirect methods based on simple scale drawings are sufficient (fig. 1). This approach, which does not require direct access to the material, offers several advantages: it saves time, re-

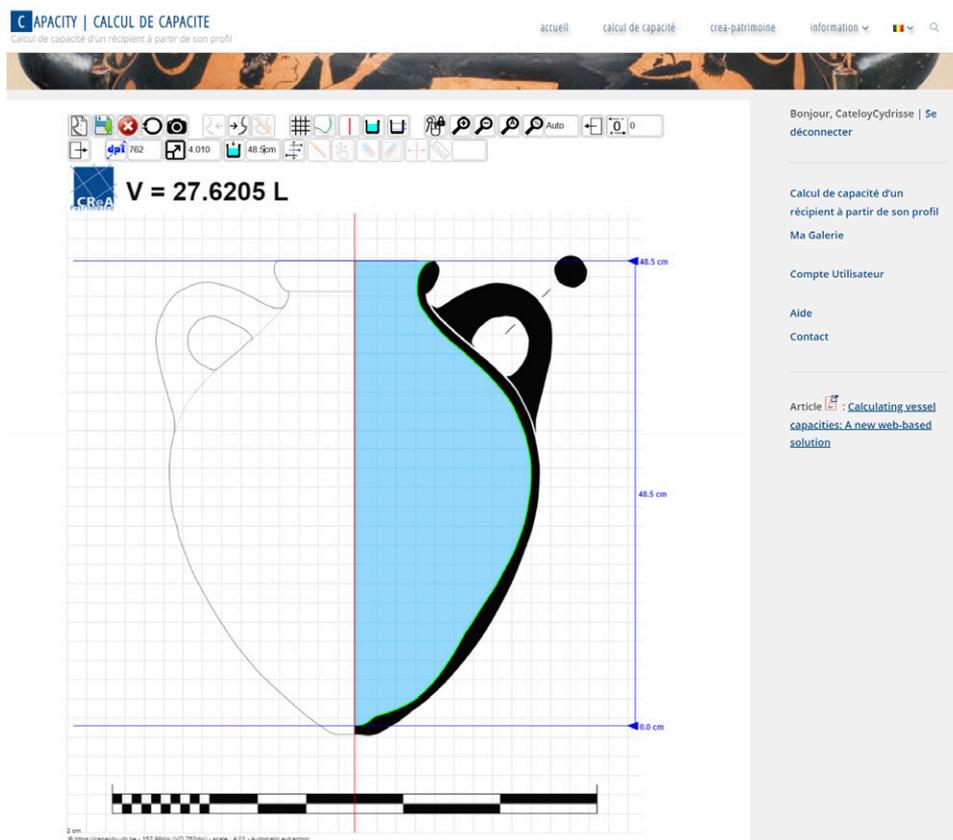


Figure 1. The interface of ‘Capacity’, the ULB web-based tool for automated volumetric measurements (Author).

duces costs, is straightforward to implement, and makes it possible to obtain large-scale measurements from published drawings.

Indirect methods consist of estimating the capacity of a ceramic vessel using mathematics, specifically by dividing a scale drawing into simple geometric shapes whose volumes are easy to calculate. In archaeology, several digital solutions, easy to access and user friendly, are available (see Cateloy forthcoming a). They integrate the appropriate mathematical formula, or a similar algorithm, allowing them to automatically generate quick results. Among them, one of the most efficient tools to have been widely adopted is 'Capacity', a web-based application in open access developed at the Université Libre de Bruxelles (<https://capacity.ulb.be/index.php/en/home/>, Bavay *et al.* 2025).

Although particularly effective and often reasonably close to reality, these indirect measuring methods may nevertheless sometimes produce outcomes that significantly diverge from the actual capacity of a vessel. Mathematical calculations are grounded on the assumption that the shape under consideration is geometric and perfectly symmetrical, whereas in reality no ceramic vessel – being a handcrafted object – is absolutely regular, whether in its form or in the thickness of its wall. Depending on the ceramic section chosen by the illustrator to represent the vessel profile, certain irregularities may or may not be shown. Consequently, calculated results may fluctuate to varying degrees, even for the same ceramic, depending on which part of the vessel is represented. It is not unusual to obtain discrepancies of up to 10% when compared with measurements taken directly on the material, even for ceramic containers that appear regular (Cateloy forthcoming a). Occasionally, even greater deviations may occur when vessels display irregularities, such as variations in wall thickness, an elliptical rather than circular shape, or deformations of the body. In such cases, the discrepancy may reach as much as 15% to 20% from the actual capacity. Indirect measurements may also be affected by scaling inaccuracies introduced during the drawing process, its digitisation, or its reproduction in a publication. Since the dimensions of ceramic vessels are not provided systematically, indirect methods most of the time rely on the graphic scale accompanying the drawing or mentioned in the caption (e.g. 1:3, 1:5, 1:10), which may compromise the reliability of the results if inaccurate. While highly effective and often close to reality, these indirect methods remain approximations, rather than exact measurements, so they should be treated with caution.

However, even though indirect measurement methods generally provide reliable estimates,

their actual degree of accuracy is impossible to ascertain, as it inevitably varies from one vessel to another depending on the quality and representativeness of the drawing. Since the regularity of a ceramic cannot be assessed from a drawing, no correction formula can overcome this issue. In cases where the analysis may require not only a higher degree of accuracy but also results that are more consistent from one measurement to another, direct access to ceramic assemblages may therefore be favoured. Although more demanding to implement, measuring capacities directly on the archaeological material provides particularly reliable results; this approach offers a broader understanding of the material under study. For amphoras, close examination not only refines typological classification and technological analysis, but also enables the reconstruction of ancient gestures, shedding light on their handling and bulk storage practices. Among direct methods, the use of expanded polystyrene (hereafter EPS) microbeads is particularly well-suited for measuring the capacity of ancient ceramic vessels. This foam-like material is highly homogeneous, with excellent fluidity. When manipulated, it behaves like a liquid, filling the smallest recesses inside the pottery. Additionally, it is particularly suitable for measuring fragile containers, as polystyrene exerts minimal pressure on the ceramic wall. Due to their low density, EPS microbeads display limited compaction when carefully handled. Consequently, the volume measured in a graduated container closely corresponds to the space the material occupies once poured into the ceramic vessel. The method has an average error margin of 0.3% compared to measurements made with water (Cateloy forthcoming a).

The method consists of filling ceramic vessels with pre-measured units of EPS microbeads using graduated beakers and measuring cylinders of various sizes (fig. 2). For large vessels, such as amphoras, it is recommended to start with the largest graduated container that can fit inside (e.g. a 5 L beaker) until the remaining volume to be measured becomes too small for this size. Progressively, smaller containers are then deployed (e.g. graduated cylinders of 1 L, 500 ml, 250 ml, 100 ml) until the fixed filling level is reached. Alternatively, one large container might be used until the vessel is adequately filled. The EPS microbeads left over in the container can then be determined with smaller graduated cylinders and subtracted from the total of pre-measured amounts to determine the vessel's exact capacity.

The choice between direct and indirect methods depends above all on the specific goals of the study, but also on practical considerations such as the accessibility of the assemblages and the state of preservation of the ceramics. Direct measure-

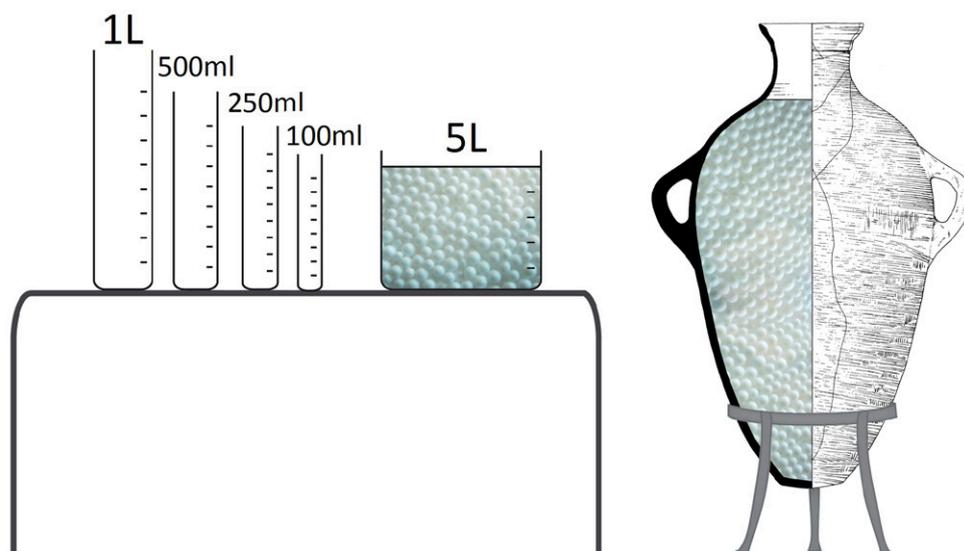


Figure 2. Setup for capacity measurements using EPS microbeads (Author).

ments can be conducted only on complete, or almost complete vessels, whereas fair estimations may be obtained through scale drawings found in the large array of publications readily available. Regardless of the method adopted, the key principle in any capacity study is to ensure consistency in data collection, so that the results remain coherent, comparable and meaningful.

Levantine amphoras case study

Levantine amphoras can provide insight into ancient economies, Mediterranean connectivity, exchange networks and trade logistics. They are among the earliest – if not the very first – amphoras to have circulated across the eastern Mediterranean, and they represent an MTC produced at a large scale that was broadly exchanged during the MBA and LBA (Cateloy 2019; 2025a; 2025b) (figs. 3-4). As such, they were deeply embedded in trade between various cultural areas (the Levant, Egypt, Cyprus and the Aegean), carrying a wide range of liquid commodities, such as oils, wine, terebinth resin and honey. Consequently, Levantine amphoras appear to be an ideal candidate for investigating capacity. Analysis sheds light on the dynamics of exchange and the fluctuations of maritime trade, as well as pinpointing regional patterns and specific preferences in different import areas. If any system of measure was in use throughout the Levant, one might expect this class of ceramic container to have been part of it.

Our volumetric case study aimed first to establish the capacity ranges of the different types of Levantine amphoras that commonly circulated in eastern Mediterranean maritime exchange

(Cateloy 2022). A further goal was to assess the volumetric variation within each typological group, to evaluate whether a particular capacity was a criterion deliberately sought by potters. To meet these objectives, the preferred approach was therefore the direct study of the material, so as to obtain the most reliable measurements. This made it possible to identify potential standardisation and to better appreciate the degree of variability that Bronze Age Levantine potters could achieve. It also provided a solid dataset on which to rely when additional results will be later obtained through indirect methods. Although the reliability of scale-drawing estimates cannot always be guaranteed, their coherence can be checked against ranges obtained through direct methods; results that fall far outside known values can thus be questioned or, in some cases, discarded.

Given the aims of the study, a large and varied corpus of ideally preserved amphoras originating from the Levant was assembled. This material was uncovered in nearly fifty different sites spread throughout the eastern Mediterranean, including several chief ports of entry such as Ugarit, Byblos, Sidon, and Ashkelon in the Levant, Tell el-Dab'a in Egypt, Kommos in Crete, Tiryns in mainland Greece, and Enkomi in Cyprus. In total, about 200 amphoras dating to the MBA and LBA were directly measured with EPS microbeads, and their capacities were processed statistically.

Close examination of these capacity data, correlated with various parameters (e.g. general proportions, typology, chronology, discovery locations), offers a broad range of insights (see Cateloy forthcoming b). To sum up broadly, the study demonstrates that the main types of Levantine amphoras exchanged across the eastern

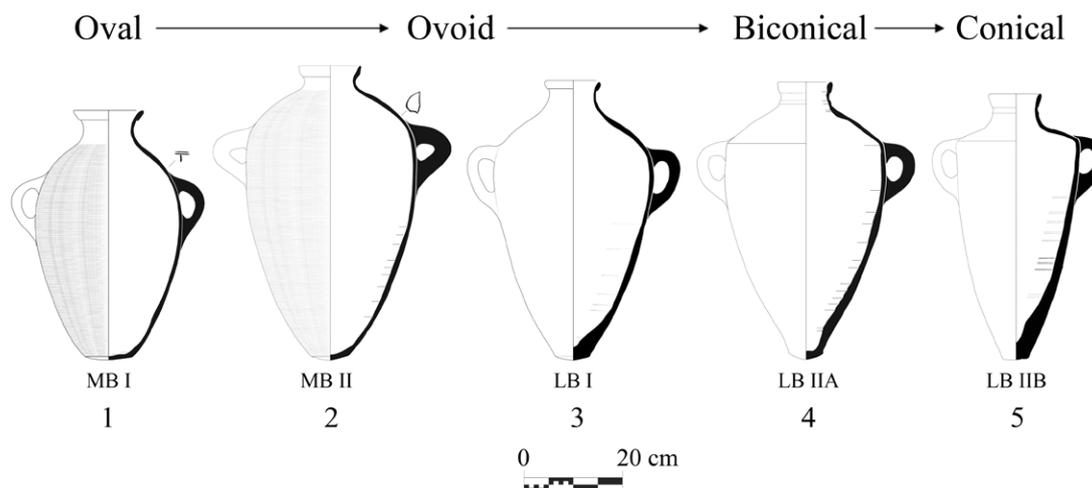


Figure 3. Evolution of Levantine amphora shapes from the Middle to Late Bronze Age (Author).



Figure 4. Two different types of Levantine amphoras dating from LB II (Author).

Mediterranean generally fall within distinct but narrow capacity ranges. The low coefficients of variation (<10%) of each type also suggest a reasonably fair degree of standardisation for such large containers. Potters may have achieved standard capacities by adjusting two external dimensions: about three-quarters of the amphoras – regardless of their capacity range – show a close correlation between height and maximum diameter, pointing to a deliberate proportional design adopted across most production centres. Another noteworthy pattern is the recurrence of amphoras measuring around 22 L, which account for more than one-fifth of the dataset. This capacity inevitably recalls the *bath* unit known from lat-

er textual sources, although it may just reflect an ideal capacity that balances both cost-effectiveness and portability. Amphoras within this range would have been large enough to carry a significant amount of goods while remaining proportionate and manageable by a single person. Previous studies have already shown the frequent use of capacities fluctuating around 22 L (Heltzer 1993: 51-52, n. 15; Docter 1988–90: 161, table 4; Pedrazzi 2007: 236-47; Demesticha 2021: 47; Pulak and Matheny 2021: 23, fig. 3). Finally, the findings also highlight diachronic and regional variations that may offer insights into trade fluctuation through time, as well as into distinct exchange networks and divergent economic strategies depending

on the import regions. For instance, the corpus reveals a striking contrast between Cyprus and the Aegean, which stand at opposite ends of the capacity spectrum. The Aegean displays a preference for the smallest amphoras in the dataset, whereas Cyprus is dominated by the largest, suggesting that distinct exchange patterns coexisted.

This case study, which considers capacity alongside other analytical parameters, thus yielded multi-layered results. As regards data, it allows us to establish precise capacity ranges for each amphora type and acknowledge the degree of standardisation of which Levantine potters were capable, while in terms of interpretation it offers a framework for advancing our understanding of Bronze Age trade organisation and exchange practices across the eastern Mediterranean. It also provides a preliminary context for further research, such as the CompAS project.

Current research and future perspectives

Within the framework of the ERC CompAS project, directed by Dr Artemis Georgiou and hosted at the Archaeological Research Unit of the University of Cyprus, special attention is currently being given to the various MTCs involved in trade with Cyprus during the LBA and early phases of the IA.¹ Among these MTCs, Levantine amphorae represent a significant portion of the imports, but other ceramic containers were also involved, such as Egyptian amphoras or Aegean Transport Stirrup Jars. This ERC-funded research programme aims to investigate commercial strategies and maritime connectivity within the eastern Mediterranean, through a holistic approach to study the material. By examining their morphology, origin, contents, capacity, and other key features, the project seeks – among other goals – to reconstruct the networks that once linked Cyprus with the Levant, Egypt, and the Aegean. This project provides a unique opportunity to explore Cyprus's singular place within interregional trade networks.

Through this project, more Levantine amphorae will be measured to expand the existing dataset. These new data may confirm, or perhaps nuance, the preliminary results indicating that Cyprus favoured large-capacity amphorae, while also refining our understanding of the specific

needs of this region and the strategies developed to address them. Such strategies can then be evaluated to determine whether they reflect economic, logistical, or cultural choices, or whether they simply derived from the nature of the products they once contained. Additionally, new variables that could not previously be examined will now be explored, notably through petrographic and organic residue absorbed analyses conducted as part of the project

Certain key sites, such as Enkomi, will also be further investigated. As one of the major Cypriot centres of the LBA, Enkomi provides a crucial context for the imports of Levantine amphorae on the island. The assemblage recovered there, though largely fragmentary, offers significant parallels with complete vessels previously studied. These comparisons reveal the presence of several major types of Levantine amphoras at the site, thereby integrating Enkomi within various interregional exchange circuits already well-established.

Another aim of this new volumetric study is also to extend the chronological range of our preliminary work to see how exchange networks are organised in the early phases of the IA. After 1200 BCE, the period following the collapse of several major cities and political entities around the Mediterranean, interregional trade underwent profound change and significant restructuring. Yet, Cyprus seems to have maintained some of its long-distance relationships and to have played a central role in the Mediterranean trade of this transitional period. This aspect of the study will offer a great opportunity to investigate the continuity of certain exchange networks and trade mechanisms, as well as to identify the economic shifts that occurred at the turn of the 1st Millennium BCE.

Lastly, the CompAS project will investigate several other kinds of ceramic containers imported into Cyprus, for example the Aegean Transport Stirrup Jars, the Egyptian amphoras, and the Tell el-Yahudiyeh Ware juglets. The capacity ranges of these vessels, also used in maritime transportation, will be compared with each other, as well as with the Levantine dataset described in the previous section. These diverse ceramic classes, originating in various regions and serving different purposes, will provide invaluable insights into other Mediterranean trade networks that coexisted during the LBA. The Tell el-Yahudiyeh juglets, for instance, represent a form of micro-packaging of finer quality used to store more precious commodities; examining their capacities will allow us to assess the degree of standardisation applied to more valuable containers and to search for smaller units of measurement. Likewise, preliminary re-

1. The project CompAS has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (Grant agreement N. 947749). <https://www.ucy.ac.cy/com-pas/the-project/>.

sults already point to converging capacity ranges among different MTCs, notably the 10-14 L range common to a specific type of Levantine conical amphorae and to most Transport Stirrup Jars exchanged contemporaneously (Cateloy forthcoming b). Upcoming analyses, focusing on complete or almost complete Transport Stirrup Jars imported into Cyprus, will test whether these vessels align with the expected volumetric pattern or instead exhibit distinct capacities indicative of regional particularities.

Concluding remarks

The results outlined in this article highlight how the study of capacity can enrich our understanding of certain ceramic classes. Beyond refining typologies and quantifying the amount of products transported, stored, transformed, or consumed, capacity analysis provides an essential bridge between the material dimension and the human behaviours it reflects. Continued efforts to integrate capacity data with the usual parameters already

assessed, as undertaken in the CompAS project, promise to generate a more holistic understanding of ceramic assemblages by situating them within the wider economic, cultural, and social frameworks in which they operated. Future research should therefore aim to record capacity more systematically, particularly when direct access to the material is possible, so that this long-overlooked dimension in ceramic studies can be recognised as an integral component of the broader set of variables through which we commonly interpret ancient potteries and the societies behind them.

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Data de recepció: 4/10/2025
Data d'acceptació: 14/10/2025

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Is it a weight? Methodological challenges in metrological research. A study case of the Late Bronze Age site of Apliki-Karamallos (Cyprus)

És això un pes? Reptes metodològics dins la recerca metrològica. Estudi de cas procedent d'Apliki-Karamallos, Xipre datat del Bronze recent

One of the main issues profoundly affecting the discipline of metrology is the ability of researchers to identify and interpret artefacts as weights. This study, after a critical assessment of the issue, offers a methodological framework serving to determine weights based on testing a group of stones from the site of Apliki-Karamallos (Cyprus). Furthermore, this study allows dismissing the possibility of interpreting these objects as weights and sheds light on its key results of the method

Keywords: weights, methodology, metrology, Apliki-Karamallos, Late Bronze Age, Cyprus.

Dins dels estudis metrològics, una de les qüestions principals i que a més té un impacte profund a la disciplina és la capacitat dels investigadors d'identificar i/o interpretar els objectes com pesos. En aquest article, després d'una avaluació crítica de la qüestió, s'establirà un quadre metodològic que permeti interpretar els objectes com pesos i es testarà sobre un grup d'artefactes en pedra trobats a Apliki-Karamallos, Xipre. Aquest mètode permet descartar la possibilitat d'interpretar aquests objectes com pesos i il·luminar les importants conseqüències d'aquesta qüestió metodològica.

Paraules clau: pesos, metodologia, metrologia, Apliki-Karamallos, Bronze Recent, Xipre.

Introduction

Metrological research, throughout its history, has faced—and continues to face—several issues that have strongly influenced its development. It is possible to distinguish these issues into two main categories: problems and dilemmas. A problem could be defined as a question involved in a syllogism of which the conclusion is the solution (Oxford Dictionary 1993: 2354). On the other hand, a dilemma could be defined as a choice between two (or several) alternatives that are equally unfavorable (Oxford Dictionary 1993: 684). This distinction is quite important because it can allow us to better understand the nature of these issues. This is essential to develop frameworks that can allow us to address them more effectively. Unfortunately, some of these issues are likely to never find an exhaustive and definitive solution for many reasons. First of all, it is important to remember that the available archaeological and textual data are just a minimal fraction of the original data corpus. The second is that, because of the previous reason, our capabilities of fully understanding archaeological contexts could be quite limited and this leaves us with important shortcomings that make elaborating effective interpretations of archaeological data difficult. However, the constant efforts made by scholars allowed us to improve our awareness of limitations and shortcomings. These efforts are essential because they set the basis for the development of new theoretical and methodological frameworks that can assist us in tackling some heterogeneous issues.

In the context of metrological studies, there are some key problems and dilemmas. Among them, it is possible to mention the definition of effective typological classifications for scales and weights, the definition of a functional metrological framework to provide metrological interpretations for weights, how to define the data samples to be analyzed through statistical methods, and how to interpret these results, and the definition of an accurate and reliable error margin in the context of metrological interpretations. In the present paper, I focus on one of the dilemmas of this discipline, which can be summed up in a simple question: Is this object a weight? In the following pages I will introduce the issues involved in interpreting objects as weights and what challenges and risks are involved in this operation from the perspective of evidence from the Late Bronze Age site of Apliki-Karamallos (Cyprus).

The Dilemma

How to interpret an object as weight is probably the main dilemma that affects metrology.

Often it is possible to identify and/or interpret certain objects as weight with a good degree of certainty because they find satisfying iconographic comparisons or bear unequivocal inscriptions. A good example of the first case is given by the copper-based zoomorphic weights. This type of weight, crafted by the lost wax technique (von Rűden *et al.* 2016: 270-271) has been found in Cyprus, Egypt, Levant, Rhodes, and Crete (Courtois 1983a; Evans 1906: 353; Frankfort and Pendlebury 1933: pl. XXVIII; Anderson 1988: 640-641, pl. 39 n. 12; Levine *et al.* 2011). Often, they were filled up with lead to reach a specific mass value. Their shape can be distinguished into two main categories: full-body resting position, and head-only shapes. The most common animal represented in these two main categories is cattle. Less common are felines, gazelle, frogs, birds, boars, fishes, and humans. It is possible to interpret these objects as weights because they find good comparisons in Egyptian wall paintings (de Garis Davies 1943: pl. LV; Wilkinson 1983: 36). Similarly, it is possible to identify certain stone objects with sphendonoid, elliptical, and duck shapes as weights. A good number of these objects bear univocal cuneiform inscriptions that state the weight unit represented by the object (Holland 1975; Bordreuil 2006: 205 and 207; Soutzo 1911: 6-7).

However, it is important to recognize that certain objects could have been used as weights even if they present a morphology and shape which is different from recognizable weights. This represented a primary issue for scholars because there could be the possibility to interpret objects which were not weights as such, or there could be the risk of excluding objects which were weights but do not present any diagnostic feature.

This is a well-known issue (Alberti *et al.* 2006: 5-6; Hafford 2012: 23) and could be better exemplified by a specific class of objects which are usually interpreted as weights. These are pebble-shaped stone objects. Often, they could present a more or less smooth surface and in certain instances, they bear simple incisions such as straight lines and/or dots (for example Ascalone 2019; Bobokhyan 2009: 24, figs. 4, 5, 7, 8 and 37, fig. 13; Müller-Karpe 2015: 152-160). They have been interpreted as weights since the very beginning of the discipline (Soutzo 1911: 9-12), but no background information that can clarify why they have been interpreted as such is usually provided. This is an issue that affects also recent studies (Rahmstorf 2023: 27).

Some scholars addressed directly this key issue. Michailidou adopted a methodology in which a more in-depth analysis of the context is paired with metrological analysis (Michailidou 2006). Rahmstorf addressed this issue from the

perspective of central and Western Europe context (Rahmstorf 2019: 1). First, two macro-categories are designed: canonical and non-canonical weights. According to Rahmstorf, the first category is substantially unproblematic in terms of identification, while the latter is more challenging. He provided then a methodological framework to assist scholars in identifying non-canonical weights. He also acknowledges the importance of context and especially the eventual presence of other weighing equipment such as parts of a scale. Rahmstorf also considers the Cosine Quantogram Analysis as a valid instrument to allow interpretations to be testable on a quantitative scale.

Chambon and Otto (Chambon and Otto 2023: 4-5) adopted another approach. They define a first macro category, irregular-shaped weights, which is further divided into two sub-groups: irregular weights and pebble weights. The first are described as weights of various amorphous forms which show traces of intentional working. The latter is described as made of unworked stones used as weights and can be detected only by their archaeological context or if they bear marks or inscriptions.

Ascalone (Ascalone 2022: 1-20) recognized the challenges in designing an effective typological classification for weights. In doing so, the author sees a non-interpretative typology as the only viable option to escape this impasse. In his framework, Ascalone defines three groups to classify the objects: weights, potential weights, possible weights, and associated finds. The first group is defined by their standardization in shapes and mass value, combined with the textual evidence from Mesopotamia, that easily allowed their identification as weights. The second includes all objects that most likely were not used as balance weights, but that nevertheless cannot be outright rejected as weight. They include pebbles from Mesopotamia and cylinder-shaped weights from Susa. Associated finds include objects that cannot be considered weights. Only in two cases, further interpretative analyses were considered for the typologies proposed. These are spherical objects that are classified into 'pebble' and 'rounded' types to distinguish between naturally occurring (pebble) and artificially modified (rounded) forms. Additionally, cuboid and discoid-shaped terracotta objects are considered specific sub-categories of the main types. Ascalone also notes how most weights lack a precise archaeological context or associated finds, making their chronological classification complicated. He considers understanding how these objects were used and how to securely identify them as weights to be the greatest challenge.

The Cypriot perspective

This issue not surprisingly concerns also Cypriot archaeology. It emerged when dedicated metrological-focused studies were carried out. What we know about metrology in Cyprus must be credited mainly to Courtois, who was the first to study objects he interpreted as weights found in different sites on the island (Courtois 1983a; 1983b; 1984a: 43-45 and 107-134; 1984b; 1985a; 1985b; 1988; 1990). If we review his work, it is possible to note how he adopted a metrological framework strongly influenced by Parise's theory (Parise 1970-1971; 2009) to provide metrological interpretations. Even more important for the present article, he interpreted objects as weights without an explicit methodological framework. This is possibly one of the reasons why more recent contributions about metrology in Cyprus focused on objects that can be safely interpreted as weights (Petrucci 1984; Lassen 2000; Alberti 2006).

In the following pages, I present a study case from Cyprus for which I adopt a framework to assess the nature of certain stone objects to determine if they could be interpreted as weights. These objects come from the site of Apliki-Karamallos, located in the northern part of the Troodos mountains (fig 1). Some of the stone objects found on the site have been interpreted as polishers, and it has also been suggested that they served as weights (Kassianidou 2007: 281). This again underlines the difficulties in recognizing weights in the archaeological record.

The framework here proposed to analyze the objects is based on five analytical parameters: material, morphology, context, mass, and incised features. These parameters must be considered organically to assess the nature of a given object as weight.

Material: Material analysis consists of assessing the nature of the material of the object. One of the main requirements of weight is that their mass must be reliable in time. Materials that are susceptible to mass fluctuations and/or present challenges in controlling their mass, especially during the crafting process, could be excluded. A good example of that is clay. In fact, besides being fragile after firing, this material also does not allow control over mass, as the firing process alters the mass of the raw objects. Therefore, it is possible to hypothesize that resistant and stable materials were usually selected to produce weights.

Morphology: Morphology and wear analysis are also important parameters because they allow us to identify traces of wearing and pecking that are incompatible with an object being used as a weight, and instead make it highly likely that it was used as a polisher, hammer, pounder, etc. On

the other hand, features such as a flattish base are an essential feature of most weights because they provide stability during the weighing process and greatly reduce errors in the process.

Context: When available, it provides an essential contribution not only to understanding the context of the use of weighing equipment but allows also to accept or dismiss the interpretation of certain objects as weights. If certain objects that perform well in the other parameters are also found in contexts in which they are associated with other weighing equipment, then they can be quite safely considered as weights. It is also important to assess whether activities that required weighing practices were carried out in the context.

Mass: This is an essential parameter because weights are produced to represent specific mass values corresponding to units of a given weight standard. Therefore, the mass value of weights cannot be casual. The framework adopted to provide metrological interpretations is based on metrological texts and considers Mesopotamian and Syrian standards (De Benedictis 2024; De Benedictis and Meneghetti 2024). The Mesopotamian standard is based on the absolute value of the main unit, the shekel, which is 8.33 grams (Powell 1987-1990: 510) and by the subdivision of this unit into 180 smaller units (še or grains), while 60 shekel make 1 mina and 60 mina form 1 talent (Marti and Chambon 2019: 53). As it concerns the Syrian standard, interpretations are based on a unit of 9.3 grams which has been proven to be statistically consistent (Ialongo and Lago 2021: 4). The units used for the interpretations are provided by the entries found in metrological texts from Ugarit and other metrological texts (Nougayrol *et al.* 1968: 254-256, Bordreuil 2006: 216-217, 223-224; Friberg 2007: 101-121). Then, once the theoretical mass values of these units are calculated, an error margin of 3.4% is considered (De Benedictis 2024; De Benedictis and Meneghetti 2024).

Incised features: When incised features are present on the surface of weights, they can be distinguished into two categories: univocal and disputable. Univocal incisions are those that convey indisputable and straightforward meaning, for example, objects bearing cuneiform and hieroglyphic inscriptions informing us about the metrological unit represented by the weight. Disputable are those incisions (usually straight lines) that do not convey a straightforward and clear meaning. When a given object presents a univocal incision, it could be interpreted as a weight. Otherwise, disputable features alone are not a solid ground for interpretation (De Benedictis forthcoming).

A case study: a group of stone objects from Apliki-Karamallos

The site is located in the northwestern foothills of the Troodos mountains (fig. 1). It was discovered in 1938 when the Cyprus Mines Corporation began explorations at the Apliki copper mines, fortuitously uncovering the remains of a large storage jar, stone tools, and architectural remains. Following these discoveries, Joan du Plat Taylor, at the time assistant curator of the Cyprus Museum, was sent to the site to carry out rescue excavations for a total of seven weeks between 1938 and 1939. These excavations did not identify Late Bronze Age mines or smelting installations, but the evidence found at the site has been interpreted as compatible with metallurgical activities (du Plat Taylor 1952). Because primary copper production sites in Cyprus for the Late Bronze Age are still unknown, Muhly in 1985 reexamined the metallurgical material from Apliki to enhance our understanding of the copper industry and society for this period. However, this effort was strongly hampered by the fact that the site was obliterated by modern mining activities, and also because the site is located in the buffer zone created after the Turkish army invasion of 1974. This latter issue means that the area is not accessible (Kling and Muhly 2007: xi).

Apliki is located on the high slopes of the Troodos foothills on the east coast of the Marathasa River. The area where it is located is considered part of a copper-rich area which is known as the Solea axis. The Apliki copper mines are well known by archaeologists because Lead Isotope Analyses show that it is most probably the mine that generated the copper used to produce the vast majority of copper oxhide ingots found in Cyprus and abroad (Gale 2011: 218; Kassianidou 2018: 346). Considering the dimensions of the copper slag heaps found in the area it is estimated that in antiquity this area probably issued more than 50% of the total amount of copper produced in Cyprus (Kassianidou 2018: 346). The site is interpreted as a copper production center and its output was exported through a non-better-identified center on the coast. The area of the modern village of Karavostasi could have been the perfect location for a coastal emporium (Kassianidou 2018: 352-354).

Several trenches were excavated on the site (du Plat Taylor and Kling 2007: 7) (fig. 2). The most important finds are reported from Trench A (on the map called Site A). Here remains of an L-shaped building which was destroyed by a fire were found. In Trench B the architectural remains were instead untouched by the fire and were abandoned at the end of the occupation of the site. In Trench C architectural features are re-

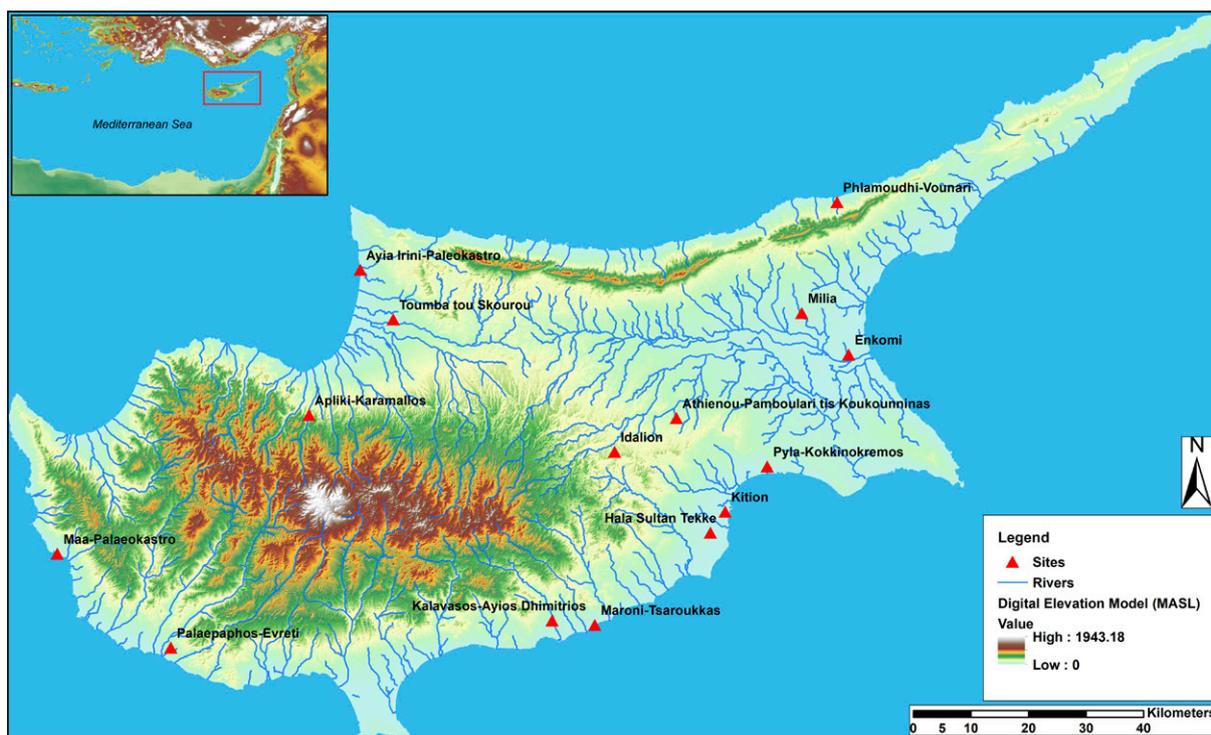


Figure 1. Location of Apliki-Karamallos and other Late Bronze Age sites (De Benedictis).

ported but are not fully described. Trenched D-H provided no architectural remains but only Late Bronze Age pottery. Finally, in trench F a possible old shaft entrance was found. Trench A is considered to provide the most interesting finds because the fire that destroyed the building also sealed the floor and the objects that were lying on it after the wooden roof collapsed. Radiocarbon dating samples taken from this context attest how the building was built just after 1300 BC and was destroyed between 1200 and 1180 BC. This data confirmed the Late Cypriot IIC date provided by pottery analysis. The L-shaped building is composed of eight rooms arranged around a courtyard. In these spaces, large storage vessels were found together with baskets that contained legumes, cereals, barley, bread wheat, horsebean, lentil, grape, olive, and coriander. What appears important is that none of these plants could have been cultivated in the area where the site was located and must have been brought there. In the storage rooms, large amounts of copper slags and unused tuyeres were found attesting to metallurgical activity, even if no metallurgical installations were identified. Among the stone tools retrieved, some were used to process cereals, while perforated stone hammers and large and heavy pounders must have been used for copper ore beneficiation (du Plat Taylor and Kling 2007: 10; Kassianidou 2018: 348-349).

In room 5 of this building six stone objects were found together in a niche located in the northern wall (du Plat Taylor 1952: 135) (fig. 2 B and C). Five of them have been interpreted as loom weights and polishers, while the last was tentatively interpreted as a weight (du Plat Taylor and Kling 2007: 31; Kassianidou 2007: 281). This last interpretation is based on the wide and shallow cross-shaped grooves on the surface of the object, on the fact that it was found together with other stone objects in a niche, and on the similarities in mass between some of these objects. Based on these parameters and a metrological framework borrowed from Courtois, it has been hypothesized that this object conforms to the Syro-Egyptian standard (Kassianidou 2007: 281). The context of these findings is not what could be defined as informative from a metrological perspective. Besides a few pottery (bowls, jars, jugs, pithoi, and a stirrup jar), other finds include polishers, hammers, a grinder, a rubbing stone, a whetstone, a funnel, spindle whorls, a bronze drill, a bronze 'engraving tool', a slag, a tuyere, a pottery scraper, a wall bracket, and a crucible fragment (du Plat Taylor and Kling 2007: 28-32). But, considering the possible interpretation of one of them as a possible weight, it is necessary to examine this object together with others that were found together in the niche because weights often are found in groups. It was possible to study only four of these six objects (fig. 3) because it

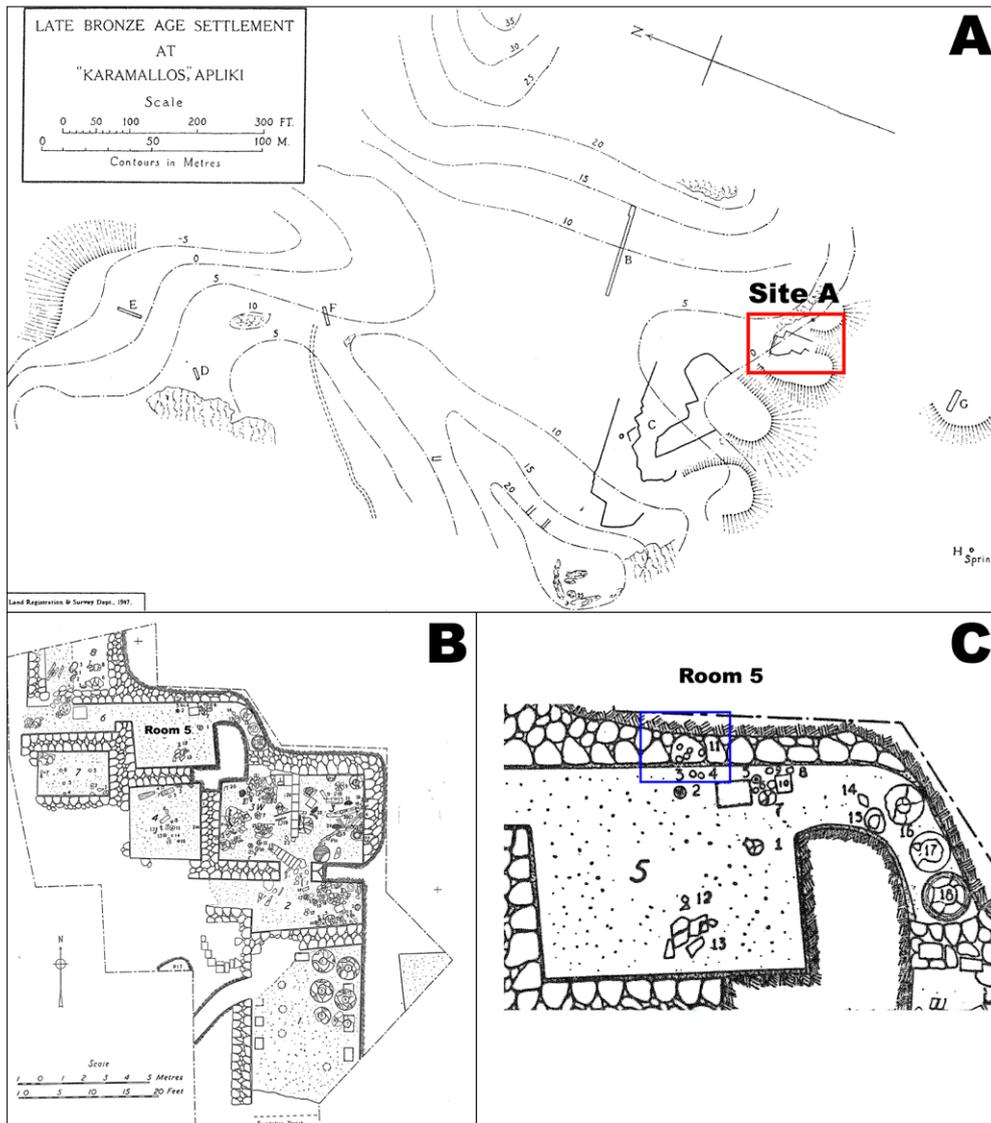


Figure 2. Maps of the site of Apliki-Karamallos. A: The entire site of Apliki-Karamallos. B: Site A. C: Room 5 of Site A. In blue the findspot of the analyzed objects (after du Plat Taylor 1952).

was not possible to locate two of them (inv. n. Apliki R.5 11 A; Apliki R.5 11 B) in the museum storerooms:

Inv. No. Apliki R.5 11 C: the object is made of an unidentified rock. It presents a discoid convex shape. Good preservation state, grey color, black dot-size inclusions. The surface is rough and does not reflect light. The top and bottom surfaces present two incised features each. They are composed of two orthogonal lines forming a cross. These features are shallow and wide and appear not to be incised but possibly the result of the abrasion technique. On the side of the object, eight short carved short lines are present along the edge. Also, these latter features are shallow. The object is very weakly paramagnetic. Its mass value is 238.38 grams.

Inv. No. Apliki R.5 11 D: the object has a pebble shape and is made of an unidentified reddish color stone, maybe red jasper. It presents a barely smooth surface and reflects light poorly. It has a very small flattish base and has almost no stability. It is not paramagnetic. No apparent traces of wearing and/or pecking are visible. Its mass value is 159.34 grams.

Inv. No. Apliki R.5 11 E: it is made of an unidentified dark grey rock and has a fairly smooth surface that does not reflect light. The object does not present a flat surface and has poor stability. It does not show traces of wearing and/or pecking. The object is barely paramagnetic. Its mass value is 113.61 grams.

Inv. No. Apliki R.5 11 F: the object is made of a grey color stone which shows dark reddish spots



Figure 3. Photos of the objects studied. A: Inv. No. Apliki R.5 11 C. B: Inv. No. Apliki R.5 11 D. C: Inv. No. Apliki R.5 11 E. D: Inv. No. Apliki R.5 11 F (Ph. by Enrico De Benedictis, Courtesy of the Department of Antiquities).

on the surface which seems to be the product of iron oxidation. Its surface is rough and does not reflect light. It has a barely flattish surface which allows it to have mediocre stability. No traces of wearing, but it appears to show traces compatible with pecking at both ends. It is weakly paramagnetic. Its mass value is 188.35 grams.

Observing the material of these objects, they appear to be made of different solid stones. However, it was not possible to scientifically determine the types of stone because it requires the acquiring of samples to perform specific analyses and that is not possible. Their surfaces appear to be not highly polished. Most of the objects appear to be weak paramagnetic, suggesting that the stones contain an unknown amount of iron. As it concerns morphology, most of the objects do not show traces of wearing and/or pecking and inv. n. Apliki R.5 11 F appears to be the exception. Their morphology does not show any flattish base which allows the objects to have stability. If we analyze the context

of these findings, it is possible to note how no weighing equipment was reported, while several objects are compatible with metallurgical activity, namely: a whetstone, a slag, a tuyere, and a crucible fragment. At the same time, the context does not provide evidence for the necessity of weighing practice.

If we consider the mass parameter (fig. 4), it is possible to provide the following metrological interpretations based on the text-based metrological framework (De Benedictis 2024; De Benedictis and Meneghetti 2024). In two cases, the mass values of the objects appear to be compatible with the theoretical mass value of the units of the two standards (inv. n. Apliki R.5 11 E; Apliki R.5 11 D). In one case (inv. n. Apliki R.5 11 F) the object appears to have a mass compatible with a unit of the Mesopotamian standard only. Inv. No. Apliki R.5 11 C, which was the only specimen that has been tentatively interpreted as weight, does not appear to be relevant to any standard.

Inv. N.	Mass value (Gr.)	Metrological interpretation (3.4% Error margin)
Apliki R.5 11 E	113.61	14 Mesopotamian shekel (116.67 gr.)
		12 Syrian shekel (111.6 gr.)
Apliki R.5 11 D	159.34	19 Mesopotamian shekel (158.34 gr.)
		17 Syrian shekel (158.1 gr.)
Apliki R.5 11 F	188.35	1/3 Syrian mina (186 gr.)
Apliki R.5 11 C	238.38	-
Apliki R.5 11 A	-	-
Apliki R.5 11 B	-	-

Figure 4. Metrological interpretations (De Benedictis).

Discussion

The first conclusion that can be reached concerns the inventory number Apliki R.5 11 C. Although the object is made of solid rock, its shape does not find any comparison with other objects interpreted as weight, and this last characteristic together with the lack of a flattish base, makes this object unlikely to be interpreted as weight. Instead, two close comparisons found for this object are loom weights. These are two stone loom weights from Amorgos (Greece) and Jemdet Nasr (Iraq) dated respectively to 3100-2700 and 3100-2900 B.C. (<https://www.ashmolean.org/collections-online#/item/ash-object-447497> ; <https://www.ashmolean.org/collections-online#/item/ash-object-469203>). Furthermore, mass appears not to be metrologically meaningful. All these elements could allow us to dismiss its possible interpretation as weight. inv. n. Apliki R.5 11 F shows traces of pecking on both ends and it could be interpreted as a hammer or as an object which had a similar function.

The remaining two objects cannot be interpreted as weights because even if their mass value could be metrologically relevant their characteristics relative to the remaining parameters are inconclusive in that sense. In conclusion, the analyzed objects, despite in some cases being metrologically and materially relevant, cannot be interpreted as weights because these parameters alone do not allow a reliable interpretation. However, it is also important to remember that two other stone objects that were impossible to locate in the museum storerooms, and this does not allow a complete analysis of this context. Therefore, their interpretation as weights cannot be considered conclusive.

Conclusions

The framework adopted in this study to analyze these objects from Apliki has many points in com-

mon with the one adopted by Ascalone (Ascalone 2022: 1-2) in his study about weights from Iran and the Indus Valley. Summing up, it is possible to note how the interpretation of certain objects as weights appears to be a complex issue with no definitive and widely acknowledged solutions at hand. Of course, certain objects can be interpreted as such with a good level of certainty. This is the case with sphendonoid weights, as abundant data provide a clear morphological profile of these objects, allowing us to interpret them easily. However, for other objects, despite the efforts made by different metrologists, unfortunately, there is no solution in sight to this issue, making it a dilemma. It is possible to define this status of affairs as a dilemma because the deadlock described previously does not have a definitive solution, but it brings us to a situation in which we have to select an interpretative framework (or create a new one) that, despite all the efforts, will always present issues and will inevitably expose the analysis to risk. This risk could be exemplified in two possible main scenarios. One is to have a relatively open approach following which objects that do not present a shape and morphology easily interpretable as weights, are included in the data sample. The risk here is to reach metrological and statistical conclusions based on a data sample that includes also non-weight objects, making them potentially biased. The second option is to adopt a strict methodological approach following which only objects that can be safely identified as weights are included in the data sample. This could potentially expose the analysis to a different type of bias, that is not considering objects that were potentially used as weights.

However, any selected method involves the creation of definitions and parameters. These elements can be questioned or accepted depending on the reader. But despite all the uncertainties of the case, it is necessary when we acknowledge (or not) a given object as weight, to state clearly

what are the parameters behind that decision. In this way, the reader can have full insight into this *chaîne opératoire* and then accept, improve, or reject the interpretation. A possible middle-ground solution could be to first analyze a data sample composed of objects that can be safely interpreted as weights, then create and analyze a second sample composed of more problematic objects. Finally, the third stage is to create and analyze a data sample inclusive of both groups. After that, it could be possible to perform analytical comparisons between the results by adopting a critical approach.

The Apliki-Karamallos study case proves how pebble-shaped objects were, are, and unfortunately will be a problem for metrological studies. These objects can be interpreted as weights only if they are made of adequate material, are morphologically and metrologically coherent. Finally, their context must be compatible with this interpretation. For example, they must be in close association with parts of a scale to interpret them as weights or at least the context in which they are found must hint to the necessity of weighing practices. Otherwise, there is the concrete risk of analyzing objects that are not weights, creating a bias in our analysis. Considering the status of Cypriot metrological studies and its issues, it is necessary to reexamine the evidence to assess previous conclusions. In this context, it could be a good idea to reassess previous interpretations by starting to focus on objects that can be safely interpreted as weights and then analyze the remaining objects. This could help in avoiding biased interpretations that could lead to misleading conclusions that could eventually propagate further.

In other words, this approach allows the creation of a solid base that could be expanded further by testing other potential weights such as pebble-shaped objects. It is also important to note how one framework cannot necessarily apply to all geographical areas and chronological periods because these could have their specific characteristics and peculiarities which must be considered.

But at the same time, it could provide a valid contribution to establish standardized base parameters that can be adequately updated to the necessities of specific contexts.

The evidence discussed in this paper shows how metrological studies have and will always deal with what could be defined as a structural issue. It originates mainly from the characteristics of archaeological contexts which often limit scholars' capabilities to provide reliable interpretations. That is why it is essential to acknowledge the nature of the issue when defining the data sample for metrological studies. Even if it will not solve the issue, the methodology presented in this paper could provide some standardized methodological guidelines which can be adopted and/or adapted to try to minimize the impact of this structural issue on metrological studies.

Acknowledgments

I would like to express my sincere gratitude to the Cypriot Department of Antiquities, its former Director Dr. Marina Solomidou-Ieronymidou, and the present Director Dr. Georgios Georgiou for allowing me to study the material and publish the pictures taken at the Cyprus Museum. I am also grateful to the staff of the Museum: Chrysanthos Chrysanthou, Giorgos Masouras, Giannis Oikonomidis, and Charalampos Charalampous for their precious assistance. Finally, I also thank the Archaeological Research Unit (University of Cyprus) and Prof. Emanuela Alberti (University of Florence) for their important support.

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Data de recepció: 13/07/2024

Data d'acceptació: 02/11/2024

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