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The use of the 'ceremonial' cubit rod as a measuring tool
An explanation

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The so-called[1] ceremonial cubits, the majority of them fragmented and incomplete, incorporate a remarkable quantity of technical inscriptions given their compact dimensions.[2] While it has been established that the texts are mostly of a religious nature with an apotropaic character, information about timekeeping and distance measurements collected on them clearly reveal another more technical role as *vade-mecum* and official standard.[3] In spite of that evidence, previous studies have not yielded a full understanding of the inscriptions which are engraved on these singular objects.

In the first instance, this article reviews the types of inscriptions that are usually found on these artefacts. In the second instance, we set out to demonstrate that the inscribed subdivisions which divide these 'ceremonial' cubits into submultiples of a finger, have the property of allowing this kind of instrument to serve as a graduated ruler. This could have been helpful for producing architectural drawings and carrying out artisanal projects requiring a high level of precision, for example when creating high quality decoration or statuary.[4]

Description of a 'ceremonial' cubit rod

The oldest examples of the so-called ceremonial cubits date back to the New Kingdom.[5] In addition to their symbolism they are distinguished from the more common cubit rods by the prestigious material utilized for their manufacture; stone or metal (wood is more rarely used),[6] and by the wealth of texts and information that would appear to have been superfluous for ordinary measuring tools (see below).

Fig. 1. Maya's cubit (18th Dyn., Louvre Museum, N 1538)
(photo courtesy of Alain Guilleux).

1. We gratefully acknowledge Alain Guilleux for providing the photos for the article, and David Ian Lightbody for proof-reading the english text.

2. Readers should refer to Lepsius (1865); Petrie (1926), pp. 38-42, pl. XXIV-XXV; Scott (1942); Schlott-Schwab (1981); Clagett (1999), pp. 9-15, fig. IV.24-IV27e; Zivie (1972); Zivie (1977a); Zivie (1977b); Zivie (1979).

3. Zivie (1979), p. 343.

4. Arnold (1991), pp. 251-252.

5. Maya's cubit rod (18th Dyn., Louvre N 1538) and Amenemope's cubit rod (18th Dyn., Turin no. 6347) (Saint John (2000)).

6. Maya's cubit rod (18th Dyn., Louvre N 1538) and Any's cubit rod (20th Dyn., Liverpool Museum 03/061/4424).

When accurately made, they employ a sleek section in the form of a long parallelepiped rectangle and are 0.523 m long. This is the exact length of a royal cubit (*mḥ nswt*).[7] The section has a chamfered top edge, and with the inclusion of the ends this results in a total of seven faces, which will be referred to using the letters from A to F, according to the nomenclature established by Adelheid Schlott-Schwab.[8] The carved inscriptions on these objects can be summarized in five main groups.

The graduation/subdivisions

The graduations and associated metrical nomenclature are the most regularly reproduced information on all of the cubit rods. These rods adopt a digital system which consists of dividing the royal cubit into 28 fingers and multiples of fingers.[9] The multiples include the palm (4 fingers), the hand's breath (5 fingers), the fist (6 fingers), the double palm (8 fingers), the small span (12 fingers), the great span (14 fingers), the sacred cubit (16 fingers), the remen cubit (20 fingers), the small cubit (24 fingers) and the royal or pharaonic cubit (28 fingers).[10] Finally, the last fifteen fingers of the graduated part are further subdivided successively into 2, 3, 4, 5, ..., 14, and 16 equal parts. All the subdivisions are finely cut and emphasized with white paint, and are superscripted by their unit fractions written in hieroglyphs.

The submultiples of a finger given in the last fifteen sections are all displayed with their measurements expressed as parts of a finger : *r*(*ꜣ*)-2, *r*(*ꜣ*)-3, *r*(*ꜣ*)-4, *r*(*ꜣ*)-5, ..., *r*(*ꜣ*)-15, *r*(*ꜣ*)-16, which are usually translated in our modern language into fractions : 1/2, 1/3, 1/4, 1/5, ..., 1/15, 1/16.[11]

The calibration table of the setjat[12] (*sṯꜣt*)

The setjat (or aroura in Ancient Greek) is an area measurement, the unit of which is equivalent to a square of 100 royal cubits per side, that is to say 10,000 square cubits.[13]

Although for reasons still not understood, this standard was adopted all over Egypt, but with slightly fluctuating values from one nome to another.[14] It was subsequently necessary to define a variable for each nome allowing adjustment for[15] the 100 cubits side involved in the calculation of this surface area. This is one of the parameters that is incorporated on the ceremonial cubit rods. This was occasionally used during the New Kingdom, but more commonly after the Third Intermediate Period. It is important to note, however, that this system was in use far earlier, given that this table is depicted on the walls of the white chapel of Senwosret I at Karnak.[16]

This corrective value was indicated for the 22 nomes of Upper Egypt and 17 nomes of Lower Egypt, usually on faces A and B, but also on face E. Each nome is usually superscripted by the name of its protecting god. In the oldest known copies, the names of the gods stand alone, sometimes even without any reference to the setjat.[17]

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7. or 'great cubit' (Carlotti (1995), p. 129).
8. Schlott (1969), p. 43.
9. Carlotti (1995), p. 129.
10. Carlotti (1995), pp. 129-131.
11. Michel (2014), p. 74.
12. Lacau and Chevrier (1956), pp. 216-217; Schlott-Schwab (1981), p. 32; Graefe (1973).
13. Michel (2014), pp. 129-132.
14. Graefe (1973); Zivie (1979), pp. 335-336.
15. In all cases, the adjustment was carried out by a subtraction. The 100 cubits value represents an upper limit for the calculation of the setjat.
16. Lacau and Chevrier (1956), pp. 216-217.
17. Saint John (2000), p. 2.

Fig. 2. Ceremonial cubit of Osorkon II (Cairo Museum, RT 31/12/22/2)
(photo courtesy of Alain Guilleux).

Chronometric tables

All the cubit rods dating to the Late Period incorporated substantial tables recording measurements in connection with the hours of the day, on their face D. The Ancient Egyptians divided daylight and nighttime into two equal parts, 12 hours each, regardless of the time of the year.[18]

This fixed division had the disadvantage of requiring a decrease in the length of the hours of daylight during the 6 months around winter time, and an increase during the 6 months around summer. The instruments they used for accurate timekeeping, the clepsydra and the gnomon, therefore had to be calibrated periodically to take account of this annual evolution.[19] Two tables refer to this practice. The first one gives a volume indication for each of the twelve months of the year, each one being preceded by the mention 'hour of the water which is the *ʿnḏ*-vase (clepsydra)' (*wnw.t mw ḥr*(*y*)*.t-jb ʿnḏ*).[20] The second table specifies length measurements for the three decades (10 day period) of each month of the year. Its annotation 'darkness ("shadow" ?) which is in the hour of day' (*grḥ ḥr*(*y*)*.t-jb wnw.t ḥrw*) seems to refer to some type of shadow clock; a gnomon or sundial.[21]

Topographical distances

Given in iteru (*jtrw*, approximately 10.46 km in length), these measurements are restricted to the dimensions considered to be distinctive characteristics of Egypt; a total of 106 *jtrw*: 86 between Elephantine and *Pr-jʿpy*, and 20 between *Pr-jʿpy* and the *pḥw* of *Bḥd.t*.[22]

The meaning and operation of another succession of measurements preceded by the mention of an iteru has not yet been resolved.[23]

Dedications and eulogia

The faces D, E, and lateral faces could be inscribed with royal protocols, and dedications were made to the pharaoh or by a pharaoh to an individual (see below). This was particularly common during the late periods with formulas indicating their ritual purpose and their religious context.[24]

18. von Bomhard (1999), pp. 66-69.
19. Borchardt (1920); Clagett (1995), pp. 48-165; von Bomhard (1999), p. 66 (n. 26-28).
20. Schlott-Schwab (1981), p. 44.
21. Schlott-Schwab (1981), p. 45.
22. Schlott-Schwab (1981), p. 49; Schlott-Schwab (1972), pp. 109-110. Data which are collected on the walls of the white chapel at Karnak (Lacau and Chevrier (1956), pp. 242-243).
23. Schlott-Schwab (1981), p. 50. These measurements are also replicated on the white chapel at Karnak (Lacau and Chevrier (1956), pp. 246-247).
24. Schlott-Schwab (1981), pp. 53-63.

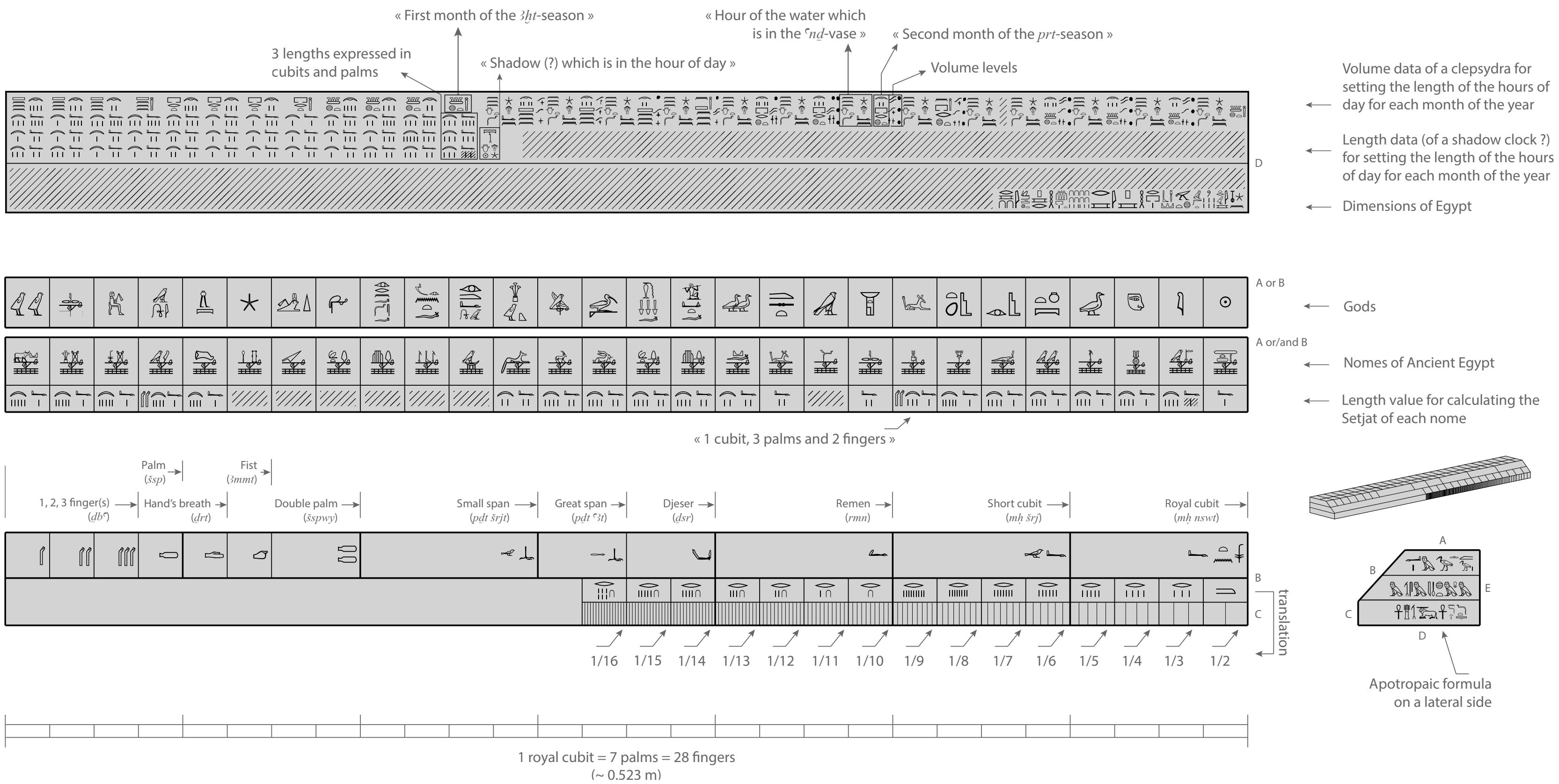

Fig. 3. Traditional data on a late ceremonial cubit rod. Scale: 1/3.
(after Gabra (1969), fig. 2; Zivie (1972), pl. XLIV; Saint John (2000); Schwab-Schlott (1972), taf. XXIV-XXVI; setjat values after Lacau and Chevrier (1956), pls. 3, 40, 42)

The annotations also reveal their apotropaic value: 'Cubit as life, strength, health, as a protection that repels the enemy (...)' (*mḥ m ʿnḫ, wḏꜣ, snb m sꜣ ḫsf sbj*).[25]

Nature of the 'ceremonial' cubit rod

The information immediately above clearly indicates that these objects were not primarily utilitarian, but ceremonial. Some models recovered from private tombs also show that they could be provided as honorary awards; a distinguishing offering to some particularly deserving craftsman or architect. In that case the boon is addressed to the gods, like an intercession in favor of the recipient, such as in the dedication on the wooden cubit rod discovered in the tomb of Any, a craftsman of Deir el-Medineh:[26]

ḥtp dj nsw jmn-rʿ ptḥ nsw tꜣwy ḏḥwty nb mdw-nṯr nṯr ʿꜣ ḥr(y)-jb wnw dj.sn ʿnḫ wḏꜣ snb ʿḥʿ.w nfr ḥr šms kꜣ.sn n kꜣ n sḏm-ʿš m st-mꜣʿt ꜣny

'A boon which the king gives (to) Amun-Re and (to) Ptah, lord of the two lands, and (to) Thoth, lord of divine words, great god who dwells in Hermopolis, that they may give life, prosperity and health, and a good lifespan, following their ka's, for the ka of the servant in the place of truth, Any.'

A similar inscription is found on one offered by Horemheb to Amenemope (Turin Museum, no. 6347):

ḥtp dj nsw nṯrw nbw mḥ-nsw dj.sn ʿḥʿw nfr m ʿnḫ tp tꜣ

'An offering that the king gives to all the gods of the royal cubit so that they may give a perfect span of life upon earth (...).' [27]

This symbolic aspect cannot overshadow the origin and the significance of the usual information that is found on these miniature monuments. Mostly they are of a technical nature, and all of them are related to spatial and chronological measurement.

The hieroglyphic texts of the temple of Edfu refer to the cubit by calling it 'cubit of Thoth',[28] or 'cubit of establishing Maat'.[29] One text indicates that the god Thoth was considered to be the 'lord of the cubit'.[30] On certain specimens, this cubit is called the 'cubit of accuracy',[31] or 'being in accordance with the writings of Thoth'.[32] As Thoth is the god of writing, arts and technical skill,[33] the lord of scribes, and the one who makes measurements,[34] everything suggests that this instrument

25. Zivie (1972), p. 188.
26. Liverpool Museum 03/061/4424 (http://www.globalegyptianmuseum.org/detail.aspx?id=4424 [date accessed : 11 june 2016]).
27. Lightbody (2008), fig. 8, p. 6 (translation by Angela McDonald).
28. Edfou VI, 7, 2-3.
29. Edfou VII, 126, 15 et 127, 7.
30. Edfou V, 91, 2.
31. *mḥ tp-ḥsb* (Gabra (1969), p. 130).
32. Schlott- Schwab (1981), pp. 46-47. See also Zivie (1977a), p. 34.
33. Boylan (1922).
34. Zivie (1977a), p. 26; Hart (2005), pp. 156-159.

was an essential tool, or even the emblem, for craftsmen and technicians who were involved in all kind of architectural works. Symbolically, this ‘standard ruler’ in its ‘votive’ form, this precious collection of tables, ensures the control of time and space. Essential to Maat, the balance of which it is one of the guarantors, the cubit is preciously and perhaps secretly kept within the temple.[35]

These cubit rods are ritual and factitious objects, above all symbolic and not intended for a technical or a practical use. As a matter of fact, they often incorporate mistakes,[36] and the graduations

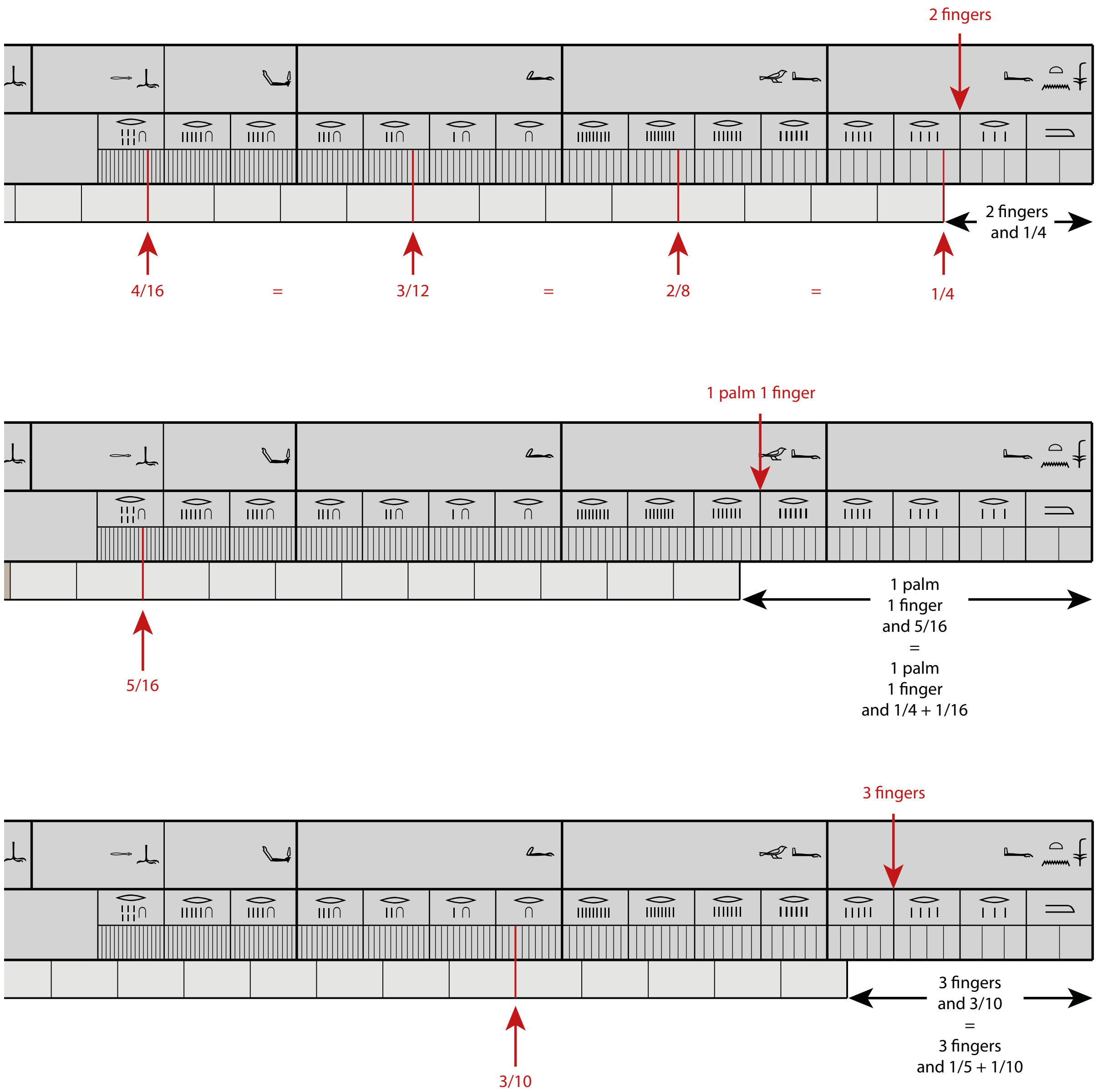

Fig. 4. The measuring method using a cubit rod and rule together suggested by the authors.

35. Zivie (1979), p. 343.
36. Zivie (1979), pp. 335-336; Lacau and Chevrier (1956), pp. 245-246, 248.

are sometimes clumsily drawn.[37] There can be no doubt that there was one, or even several standard rods, which were closely guarded and better manufactured to the expected accuracy, reference objects that inspired the replicas under discussion in this paper. This does not affect the analysis and the interpretation of the inscriptions whose meaning was not related to the quality of the reproduction.

The use of the cubit rod as a measuring ruler

The arrangements of the graduated parts show great consistency from one cubit to another. These cubit rods allow easy measurement of lengths that are equal to a whole number of fingers, and the expression of these in the required units of palms, small or great spans, sacred cubits, and so on. It is more complicated, at first sight, to see how they could have been used to take measurements involving subdivisions of a finger such as those listed on the face C.

Our modern numerical system is established on a base 10 just like in Ancient Egypt. This allows us to write decimal numbers which are in fact fractions of whole numbers over powers of ten. That is the reason why our rulers are graduated in decimeters, centimeters and millimeters; each part being equal to the tenth of the previous one.

The Egyptian numerical system was fundamentally different in its treatment of numbers less than one, as it used unit fractions to decompose single units into equal parts. A measurement less than one finger was then expressed as 1/2, 1/3, 1/4, 1/5, ... down to $1/16^{th}$ of a finger, which means in fact that the finger was divided into 2, 3, 4, 5, ... or 16 equal parts.[38] As it was materially impossible to graduate all these measurements in one single section, the Egyptians wrote the different subdivisions on subsequent divisions, one after the other in decreasing order.

Some scientists suppose that these marks and their associated fractions are only intended to reflect the Egyptian numerical system, without constituting any practical application.[39]

Such a point of view is surprising when one sees the contextual importance of the recorded data on these objects. It is very clear that the fractional subdivisions are an integral part of the graduated ruler and its measuring system. We will show that there is a clever practical measurement method that may explain the ordered fragmentation of digits, almost down to millimeter lengths.

It is unlikely that the system of subdivisions utilized would have required the user to move the ruler to take measurements in two stages (in fingers, and then in fractions of a finger). Such a clumsy process would contradict the demonstrated precision of the subdivisions. In fact, everything seems to indicate that the subdivisions are there to respond to various specific cases when the object to be measured did not coincide with a whole number of fingers.

If this cubit rod is used in conjunction with another, or with a simpler ruler subdivided only into whole fingers, the related graduations reveal a noteworthy property. The user first has to position the cubit rod alongside the object to be measured, then hold one side of the ruler against the rest of the cubit. The whole digit lines on this same edge then act as cursors that align against the cubit, either at an existing graduation, or between two graduations (fig. 4). In this last case the periodic offset of the 'cursor' from one finger to another on the ruler means that it eventually reaches a location where it coincides exactly with one of the fine cubit's subdivisions. A reading has to be taken at this coincidence and added to the number of whole digits measured alongside the object.

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37. Lepsius (1865), p. 18 ; Sarton (1936), p. 401; Zivie (1972), p. 185, fig. 2. Some of them even comprise an incorrect number of graduations (Saint John (2000), pp. 14-15).

38. Michel (2014), p. 74.

39. Sarton (1936), pp. 401-402; Michel (2014), pp. 120-121.

Practical experimentation shows that this technique is undoubtedly effective, and this can explain the presence and arrangement of the subdivisions. According to our reconstruction, accurate measurement would have certainly required the use of the additional element that we suppose to be a ruler or a second cubit rod, but we can also imagine that a stem or a simple annotated papyrus could serve equally as well, with the benefit that they could be made and marked out by the scribes or artisans using the cubit rod which was available to them. Several similar and plausible scenarios can be envisaged.

As the subdivisions are only spread over 15 fingers, accurate measurement can be applied using this full method only to the lengths less than 10 fingers. Beyond this value all the subdivisions are no longer in a position available to read.

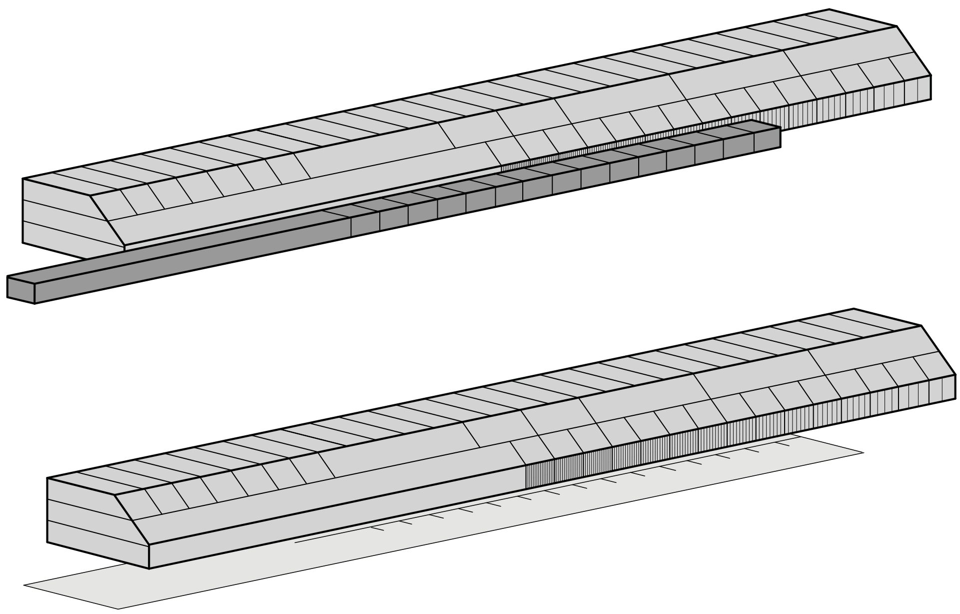

Fig. 5. Two possible methods for using fractions of a finger in the measurements.

This research has led to a plausible interpretation of an obscure part of the inscriptions reproduced on the ceremonial cubit rods. The arrangement of subdivisions makes a coherent set for measuring objects, following a technique that would have been easily available to Ancient Egyptians. It is highly doubtful that the graduations set out in order and engraved with a great accuracy on these cubits were conceived in that way without any practical purpose.

The explanation presented in the second part of this article demonstrates that the graduated ruler of such cubit rods was fully operational on the condition that it was used in conjunction with another metrical element (a cubit rod, marked papyrus, or marked reed stem). The measuring method we suggest would have been dedicated to small subjects requiring precision,[40] prefiguring in a rather primitive, but nevertheless rather clever form, the Vernier caliper that was invented during the 17th century A.D.

40. 1/16th of a finger is equal to 1.2 mm. Known mathematical texts do not detail any calculation involving such precise values (Michel (2014)). There is however one document in the archives of Abusir that reveals the measurement of an object with dimensions of fractions of a finger: pBM EA 10735 sheet 17 (Posener-Kriéger and Cenival (1968), pls. 23-24; Posener-Kriéger (1976), pp. 143-144, fig. 7). We would like to thank Luca Miatello for having brought it to our attention.

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