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METROLOGICAL RESEARCH INTO THE FOOT MEASUREMENT FOUND IN THE CELTIC OPPIDUM OF MANCHING

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ABSTRACT.—*An unusually clear ground-plan of a quadrangular building from the first settlement of the La Tène oppidum of Manching offered an excellent base for the investigation into the measuring unit utilized for the lay-out of the buildings. Observations showed a geometrical cord-measuring system, based on the ratio of the length to the width of each respective ground-plan. From the position of the post-holes it was possible to calculate the dimension of a foot and the unit or the modulus of the measuring sytem used (310 mm). A parallel to this modulus was discovered in an important find from the 1972 excavation -an iron rod with bronze markings 154.5 mm long, half the length of the modulus, thus fixing it more precisely to 309 mm. The origin of this unit raised many problems, since comparisons between the Manching modulus and the Greek, Roman and Near Eastern systems have not proved very fruitful, but two recent finds though are of importance: a shiplike cultic basin found in Mont Beuvray with a basic modulus of 304.2 mm and the ground-plan of an Etruscan house in Bagnolo, giving a basic modulus of 308 mm. So it is possible to come to the conclusion that although the origin of the Manching foot measurement cannot be explained exactly, similar units can be found in the immediate vicinity of some of the Celtic oppida.*

RESUMEN.—*La planta de un edificio cuadrangular del primer poblado del* oppidum *de La Tène Final de Manching ha permitido la investigación de la unidad de medida empleada. Las observaciones realizadas muestran un sistema geométrico de mediciones con cuerda, basado en la proporción entre la longitud y la anchura de cada planta constructiva. Los agujeros de los postes permiten calcular la unidad o módulo del sistema de medidas empleado, basado en un pie de 310 mm. Un paralelo para este módulo se descubrió en la excavación de 1972: una barra de medidas de hierro con marcas de bronce de 154.5 mm de longitud, la mitad del módulo de Manching, que fija a éste más exactamente en 309 mm. La investigación sobre el origen de esta unidad de medida plantea problemas, ya que faltan trabajos similares sobre plantas constructivas y no han sido fructíferas las comparaciones con los sistemas empleados en el mundo griego, romano y del Próximo Oriente. A pesar de todo, hay dos hallazgos recientes importantes: el estanque cultual barquiforme de Mont Beuvray con un módulo de 304.2 mm y la planta de una casa etrusca de Bagnolo cuyo módulo es de 308 mm. Por ello, aunque el origen del módulo de Manching no se puede explicar con exactitud, medidas de pie similares se encuentran en algunos otros* oppida *célticos.*

KEY WORDS: *Celtic foot. Length unit. Measurement systems. Manching. La Tène.*

PALABRAS CLAVE: *Pie céltico. Unidad de longitud. Sistemas de medida. Manching. La Tène.*

1. INTRODUCTION

The oppidum of Manching (see map 1 a and b),[1] situated on the flood-plane of the river Danube in upper Bavaria about 70 kms north of Munich, was probably the city-like centre of the Celtic tribe Vindelici. The main reason for the choice of this site was its position in relation to two important traffic routes: one coming from the south and crossing the Danube near the modern city of Ingolstadt, and the other - an east-west communication - used the river or took the low terrace south of the Danube and went right through the middle of the Celtic oppidum. The settlement was fortified by a 7 kms long rampart - constructed during the early period in the "murus gallicus" technique - which enclosed an area of nearly 400 hectares. Two gates are well known and two others can only be hypothetically located. The excavations, which started in 1955 and continued until 1987,[2] brought to light traces

[1] Reproduced from J. Collis (1984: No. 1-8, 6-8).

[2] Excavations carried out by the Römisch-Germanische Kommission des Deutschen Archäologischen Instituts. Publ. by the Römisch-Germanische Kommission in a series under the title of: Die Ausgrabungen in Manching. W. Krämer and F. Maier (eds.). Vol. 1 (1970) - Vol. 15 (1992).

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of an intensive Celtic occupation in the centre of the oppidum, with a high density over an area of about 80 hectares, surrounded by a sparsely populated strip of land a few hundred metres wide. Only small areas just inside the rampart appear to have remained free of buildings (see map 1 b). Investigations into the lay-out of the oppidum suggest that the settlement was well planned and organized, with several types of building complexes such as houses for craftsmen and traders, small farmsteads, quarters for a higher social group - similar to the "nobilites" in Caesaric Gaul - and religious buildings. Architectural and metrological investigations in the oppidum showed that not only the plan of the whole settlement was highly organised, but that the lay-out of the ground-plans of the various types of buildings was based on geometrical rules and measuring units, which indicated that a knowledge and use of linear measures based on the unit of a Celtic foot was present.[3]

Investigations into the reconstruction of the building remains within the oppidum of Manching raise the question as to the existance of a fixed measuring unit used for the lay-out of these buildings.[4] No architect would disregard measuring systems or proportions when investigating the buildings of the ancient civilizations, especially those of the Mediterranean world.[5]

Many attempts have been made in the past to indicate and interpret prehistoric measuring systems,[6] but strangely enough, the cultural area and period of time of the early and late Celtic societies, which had a very close relationship to the Antique world of the Mediterranean civilisations, were ignored.[7]

During the investigations of the ground-plans of Manching it became very noticeable that apart from a few exceptions, the post-hole rows of the walls, on meeting at the corners, formed an exact right angle. Therefore it can be assumed that the right angle must have been carefully constructed, probably with the help of the so-called Pythagorean triangle using the three lengths - 3, 4 and 5 (ancient Babylonian and Egyptian sources seem to point to a much earlier knowledge of this triangle). According to the foregoing explanation, it is now possible to imagine a process in which a cord with the length of 12 (3+4+5) is marked with knots at the corresponding distances between 3,4 and 5, which would allow a right angle to be marked out easily, and it can be assumed that the single intervals were divided into feet. But there would be no evidence whatever for such an assumption, if the proportions of the ground-plan sides themselves didn't suggest the use of the Pythagorean numerical combination. On examining the measumements of the Manching rectangular ground-plans, it can be surprisingly established that the ratio of the short side to the long side always amounts to a multiplication in feet of the basic numbers 3 and 4. In a similar way the accompanying diagonals show a multiplication in feet of the basic number 5.

The construction of a right-angled triangle according to Pythagoras however, is not the only geometrical form represented. A second solution based on the fact that each and every circumference of a circle can be divided six times by its radius, shows that a rectangle can now be formed when two pairs of the opposing points on the circular periphery of the created hexagon are joined. But for further implementation of this method, it is of importance that the short side of this rectangle always has the same length as the radius, and its diagonal twice the length of the radius. Exactly this observation that the hexagon drawn within the circumference of a circle, can be divided into six equilateral triangles, the sides of which correspond to the radius, allows for another variation of this graphical solution for the construction of the above described rectangle. Taking any equilateral triangle (with the base x) and its mirror image, it is possible to draw a rectangle which is similar to that drawn within the circle divided into six parts (see footnote 3).

Apart from the previous hexagonal constructions mentioned, there is a third variation which was also used, although it only leads to an approximate solution. Proceeding from the above mentioned rectangle drawn within a circle, in which the ratio of the short side to the diagonal is 1:2; now give the short side the value of 4, which consequently results in the diagonal having a value of 8. Further calculations show that the long side of the rectangle has a value of 6.928, which can be taken as 7. This means that the rectangle, derived from the compass construction can also be drawn from a triangle with full numbers which is similar to the Pythagorean triangle. The acceptance that the rectangular ground-plans in their basic form are actually a result of the numerical 4-7-8 construction and not of the constructions based on the circular incision nor on the equilateral triangles, can be supported by the observation that the foot measurements of these ground-

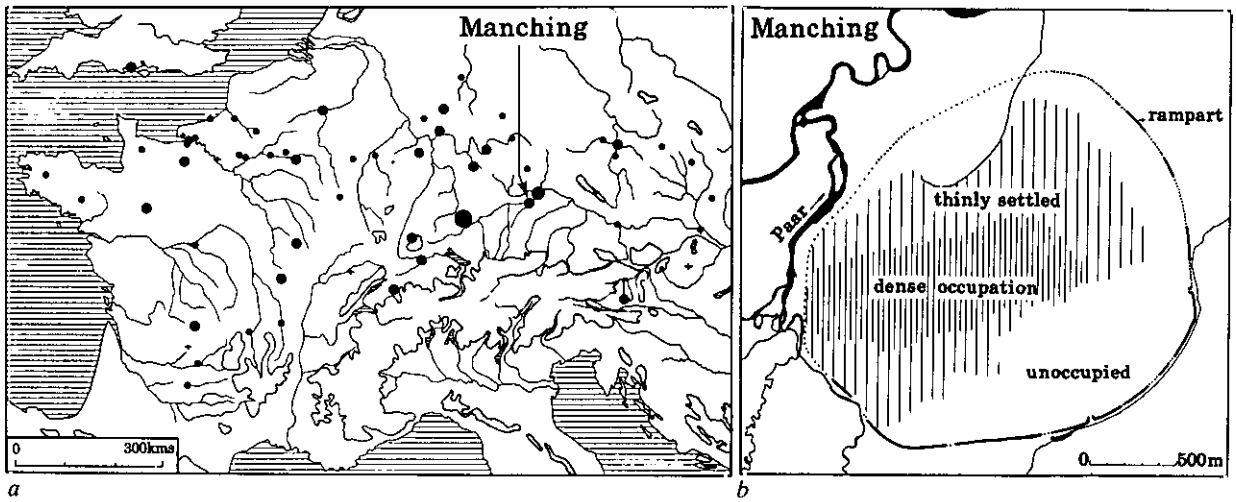
[3]. The author gave a detailed explanation of this research in a lecture at the Departamento de Prehistoria, Universidad Complutense Madrid in 1992, titled "Investigations into the measurement and design of the ground-plans of the Celtic oppidum of Manching". These results will be published in *Germania* (Schubert, 1994).

[4] First reference in F. Schubert (1983).

[5] Questions regarding Greek and Roman building measurements have been examined recently in two detailed works. H. Bankel (1983) produced new and important results. He deals with previous interpretations and building designs, as well as with their measurement systems and the measuring units on which they are based, comprehensively refering to literature and ancient written sources. Secondly, K. Hecht (1979) examines the particular tolerance limits of the foot measuring unit. These two works provide an easy access to the older literature. Regarding the building designs, compare as well L. Haselberger (1980).

[6] R.C.A. Rottländer (1979) tried to complete a summary of metrological finds and references, including those from prehistoric cultures, but failed to raise questions regarding measurements within the Celtic La Tène culture. The measuring units from Ancient civilisations are cited according to the level of research advancement at that time; but generally he failed to critically examine the results. Though the work seems, at first glance, to give an overall view, it is unfortunately not of much use for the following investigations. Compare the research done by H. Dannheimer (1985) on the post-hole ground-plans of the Early Middle Ages and P.Huggins/K.Rodwell/W.Rodwell (1983: 21ff).

[7] Dehn (1957: 78-99, esp. 94), for his part, drew attention to the close connection between Heuneburg clay bricks and the Greek clay brick walls, indicating in particular the correlation between the measurements of the Heuneburg clay bricks with those of Apollonia and Gela. Here he was able to show that the length of the Heuneburg bricks had similar measurements to those which Vitruv cited for the Greek bricks: the Tetradoron measuring 4 palmae and the Pentadoron measuring 5 palmae.



a b

Map 1.—*Distribution of La Tène oppida (a) and plan of the Manching Oppidum (b).*

plans mostly represent a multiple of the combination of the figures 4-7-8 (see footnote 3).

All the ground-plans which have been investigated up to now in Manching can be traced back to the basic forms of: Pattern I, fixed in its proportion to the Pythagorean triangular with the side ratio of 3:4, and Pattern II which is based on a rectangle within a circle, and depending on the construction, with a side ratio of 1:√3 or 4:7. The basic rectangles with the ratio 3:4 and 4:7 can be connected in many different ways so as to form larger more complicated ground plans.

The starting point for the investigations, reflections, and results put forward here is the unusually clear ground-plan of an almost quadratic building based on six posts, which belongs to the first settlement period of the oppidum of Manching (Fig.1).[8] This structure, possibly a storehouse of tower-like form, appears to have been erected on six stilts. All the post-holes of the ground-plan of this building show a noticeable uniformity, they tend to have either quadratic or rectangular contour and are shallow, not having been dug very deeply into the subvirgin soil. The standing position of the wooden four-cornered posts are clearly marked at the ground level in the large post holes, and this enables the distance between the wooden posts to be measured exactly. The precision of these measurements is extremely high. The second characteristic of this building has made it possible to recognize the measurements on which the ground-plan was based, and to calculate the unit or modulus of the used measuring system. The cross section of the wooden posts is very similar and clearly larger than the defined measuring unit, which makes it easier to discover whether the measurement was set to meet the middle, the external or the internal edge of the wooden posts. Observations have shown that the cord-measuring system was the principal and most important basis for the ground-plan design and that the setting of the posts followed more a practical usage than strict theoretical rules (see footnote 3).

[8] Manching excavation 1972. Section No. 636.

As already mentioned the cord measuring system observed while working on the Manching ground-plans follows fixed geometric rules. The ratio of the length to the width (for example 3:4 or 4:7) within the system shows which geometric pattern was used for each respective ground-plan. The analysis of the ground-plan design of Manching forms the basis for calculating the modulus (the actual analysis itself will be dealt with later).[9] Proceeding from this analysis, it can be seen that the cord measuring system of the ground-plan of the previously mentioned store house is made up of two rectangles, each having a width to length ratio of 4:7. These rectangles are joined lengthways thus giving an entire width to length ratio of 8:7 (Fig.1 and 2). One rectangle taken on its own, forms a basic element used for the construction of the ground-plans in Manching. This rectangle was originally derived from the circle construction previously explained, based on the exact ratio of 1:√3. But the rectangle can be formed in a more simple way by using two triangles each with the numerical series of 4, 7, and 8 (Fig. 2). This seems to have been the most usual method used in Manching. These triangles, unlike the Pythagorean triangle, don't produce an exact right angle, but show a deviation of 1° from their nominal measurement. This difference causes a little distortion of the basic rectangle giving it a slight trapeze form. But when a symmetrical reflection of this trapeze is drawn, by using the shorter side of the rectangle as a basis, this deviation can be corrected giving the above mentioned form of two rectangles joined lengthways with the ratio of 8:7 and containing exact right angles (Fig. 2).

Returning to the store house ground-plan, it can be seen that the distance from post 1 to post 3 (measured from the middle of both posts) is 6.53 m (Fig. 1).[10] The length of the modulus can be calculated by dividing the

[9] See footnote 3.

[10] Post-hole 1=636/1 in the excavation plan; Post-hole 3=636/65 in the excavation plan. Neither the external (6.92 m) nor the internal (6.14 m) measurement taken between post 1 and post 3 is of importance to this research.

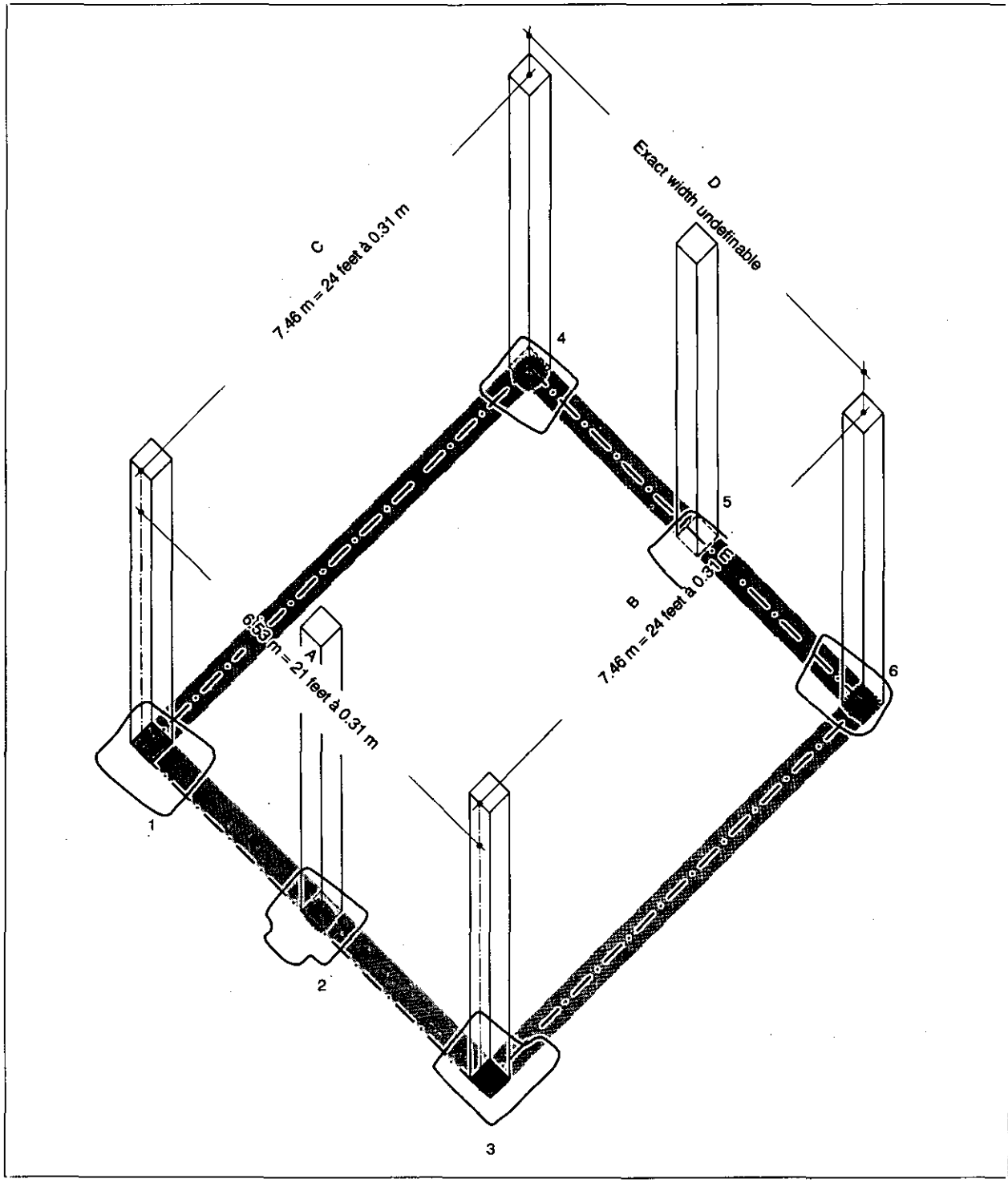


Fig. 1.—*Ground-plan of the six post building of the Manching Oppidum from which the measuring unit is derived.*

above measurement 6.53 m by the number 7 or a multiple of 7. The length of a modulus in the dimension of a foot can be reached by assuming for the distance of A (6.53 m) a divisor of 21 (that means 7 times the factor 3), which gives a length of 0.31 m for the modulus. The length of the other side B (Fig. 1) which is composed of 2 parts in the drawing, gives when measured a distance of 7.46 m.[11] The ratio 7.46 m to the above 6.53 m reflects exactly the ratio 8:7. Likewise, if the distance of 7.46 m

[11] Post-hole 4=636/4 in the excavation plan; Post-hole 6=631/3 in the excavation plan. The external and the internal measurements between these two posts (7.62 m and 6.88 m respectively) are only being noted here. Neither these measurements nor those mentioned in footnote 10 were used as a basis for the ground-plan.

is divided by 24 (that means 8 times the factor 3) a measurement of 0.31 m is reached for the length of the modulus. The precisely determined measuring unit of 0.31 m discovered in the above mentioned ground-plan, is also found in other buildings in Manching with variable ground-plan designs.[12] This attempt to derive the size of the modulus directly from the clearly defined measurements of the ground-plans is similar to the way pursued by the architects of the antique Greek and Roman buildings.[13] Although the starting point for such metrological investigations of the antique stone buildings is fundamentally better than that offered by prehistoric ground-plans, the results in the former are not as clear as one would expect them to be, as different modulus lengths have often been suggested for the same building despite its clearly identifiable measuring points. However, more critical investigations of antique stone buildings have recently shown on the one hand the problems which can arise when trying to extract a measuring unit from the ground-plans, and on the other have made very clear, how important it is to take into account other metrological research sources. Therefore it can be taken to be a great stroke of luck, that the foot unit derived from the investigations of the ground-plan measurements in Manching can be determined in a completely different way through the support of an original iron measuring rod.

During the excavation of 1972, an iron rod with markings in bronze was discovered in the central part of the oppidum,[14] the importance of which remained unknown for a long time as there was no analogy to it anywhere. The use of this find was at first unclear, but due to its form and to the bronze markings found on it, the suspicion was raised that it may be a measuring rod. After this assumption had been confirmed, the existance of an established 309 mm foot measurement for Manching could be concluded, completely independent of the leading evidence derived from the building measurements. The find was very rusty, and details were difficult to recognize; the resulting depicted form (Fig. 3a-b). was only possible after the find had been fully restored.[15] The basic form consists of a round iron rod with a constant diameter of 6.5 mm. The recognizable metal core seen by X-ray is more slender and measures 5.5 mm. One end of the rod is cut straight and the other end carries a half-spherical head, with a diameter of 11mm, sharply set off against the cylindrical shaft. The basic area of the calot falls slightly in a conical form to the shaft. The total length including the head is 162 mm.

Three very carefully worked small bronze rings only 1.8 mm wide, with a rounded-off quadratic cross-section, were found on the shaft. The rings were open to

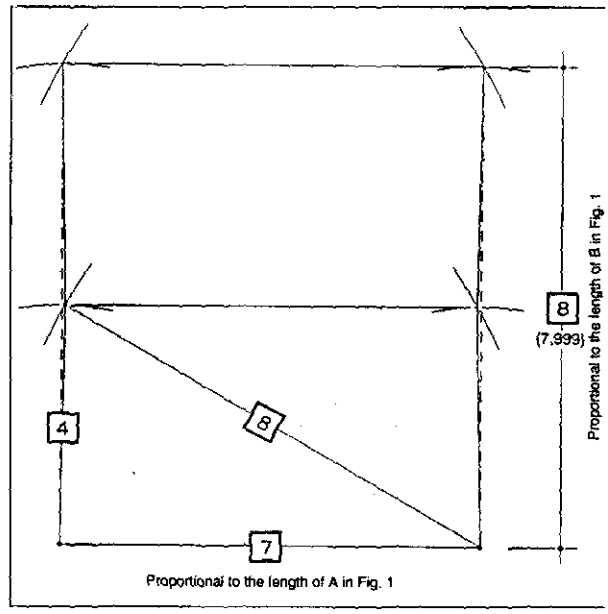


Fig. 2.—*Geometrical construction of the ground-plan layout.*

a width of 1.5 mm at one section with each of the opposing ends formed so as to give an overlapping connection. These openings were possibly due to the fact that the rings were wrenched open at a later date due to the strong corrosion of the rod. Probably this is also the reason for the present oval form of the rings, the outer diameter of two of the rings varies between 7.7 mm and 8.2 mm, and that of one between 7.2 mm and 8.2 mm. If the rings were closed in their probable original shape, the result would give an exact circular form. Despite the damage carried out by the corrosion and a slight curvature of the shaft very careful metal working can still be recognized, especially in the production of the bronze rings. This tends to suggest that the rod was some kind of instrument, the use of which required very high precision and exactitude. Taking together the delicateness of the rings in connection with the solid iron shaft, it is hardly possible to explain its function as anything other than for marking, and this raises a very strong suspicion that the find is a measuring rod. The length of the cylindrical part of the shaft as far as the point where the head begins is 154.5 mm (Fig. 3b-c), and this is practically half the length of the modulus of 310 mm determined by the building measurements. Based on the measuring rod the length of which is 1/2 foot (or 154.5 mm), the modulus can now be determined more exactly to 309 mm, that is double the length of the measuring rod. The word "foot" will be used from now on to indicate this modulus.

At the beginning there was great difficulty in interpreting the section marked by the three bronze rings. The different intervals between them as well as their number, lead one to suspect that the unequal divisions were actually pre-fixed. The distance measured from the front edge of the second ring (B) to the head amounts to 56.4/56.7 mm, and that from the further edge of the same ring to the head gives a distance of 58.2/58.9 mm (Fig. 3). The respective minimal und ma-

[12] See footnote 3. Also F. Schubert (1992: 302).

[13] Compare to footnote 5.

[14] Inventory No. 1974/2391, found in section 769, pit c2. It is remarkable that in pit c3, as well as in the neighbouring humus layer, broken pieces of two bronze beams from a gold scales were found.

[15] I would like to take the opportunity here, of thanking the Römisch-Germanisches Zentralmuseum Mainz for the completion of the X-ray photographs and restoration of the measuring rod, and especially the director Dr. U. Schaaff for willingly taking on the work.

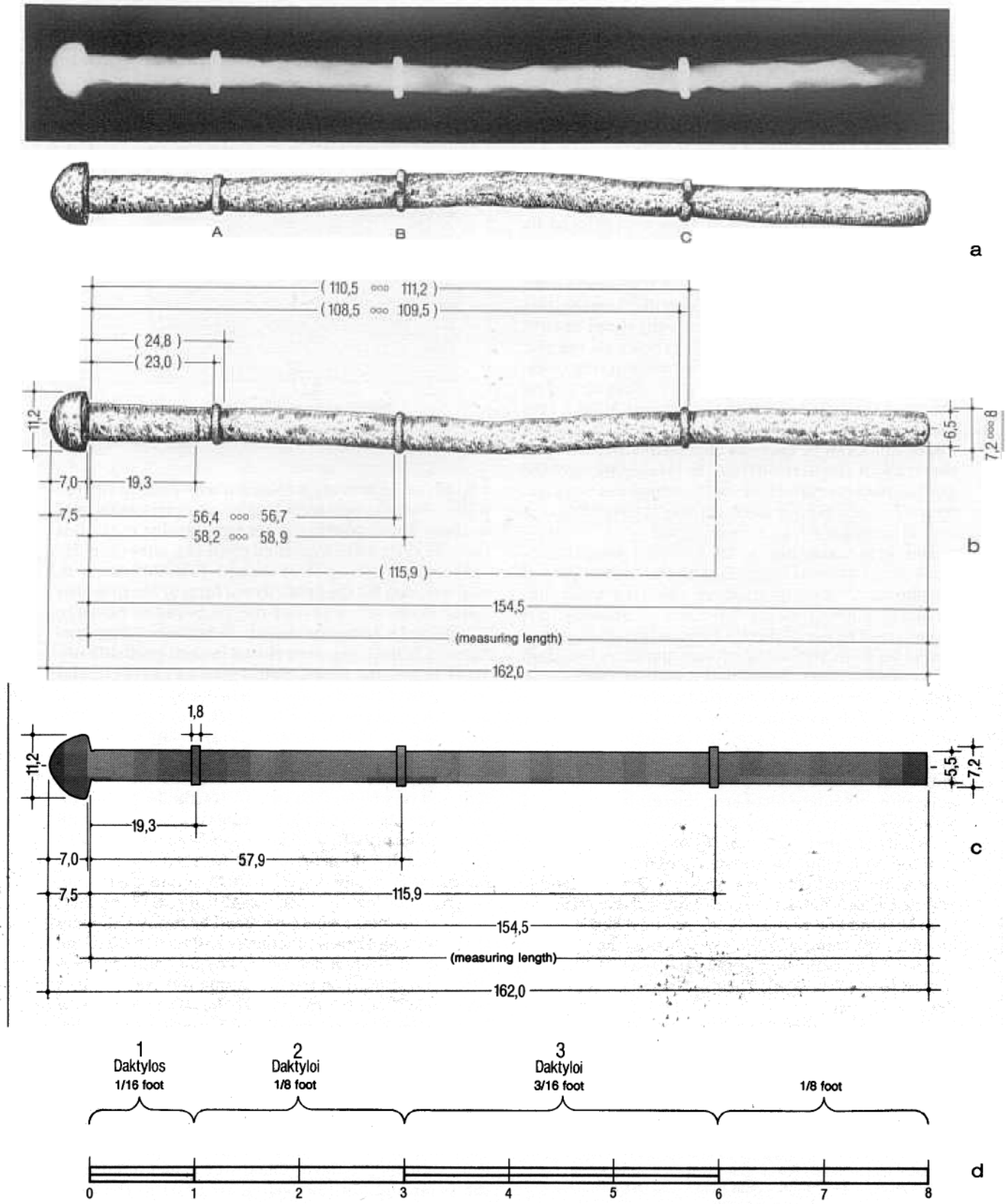


Fig. 3.—*The Manching measuring rod, half a foot long. 1. X-ray image. 2. a) and b) Drawing of the original after restoration; c) and d) Explanation of the divisions based on a foot divided into sixteen daktyloi (digiti).—Scale 1:1.*

ximal distances resulting from the ring being set slightly slanted on the round rod. The mean value of these distances corresponds exactly to 3/16 of the established foot of 309 mm, thus giving a calculation of 57.9 mm (Fig. 3c). In comparison to the second ring, the position of the first ring (A) was totally inexplicable, neither the distance to the head (23.0 mm or rather 24.8 mm) nor to the second ring gave a meaningful proportion. Therefore it is open to suspicion that this ring was not in its original position when the object was found, and the fact that the rings were open, substantiates this suspicion. On closer examination of the shaft, a slight hollow impression becomes apparent about a distance of 19 mm from the head, and it is very probable that this can be considered as being the original position of the ring. Assuming that this is the original position of the ring, the distance of 19 mm (or rather 19.3 mm) is exactly 1/16 of the established foot. It can also be accepted that the position of the third slightly slanted ring (C), found at distances of 108.5/109.5 mm and 110.5/111.2 mm from the head (Fig. 3b-c), is not in its original position. Evidence for an earlier position for this ring is not recognizable, as the X-ray picture shows strong corrosion in this area which has caused possible marks of the original position of the ring to vanish. Accepting such a movement of the ring and assuming that the foot is divided into 16 parts - as the position of the rings suggest - then the 6/16 (3/8) ratio would come into question, and this would give the original position of ring (C) as being 115.9 mm from the head (Fig. 3b-c). This suggested position lies, unfortunately, in the area of the heaviest corrosion, but it can be supported in that the movement suggested is similar to that of ring (A). On closer examination it can be seen that the two divisions - 1/16 and 3/16 - as well as the hypothetical third division of 6/16 (or rather 3/8) of the whole foot, in other words, all the important intervals of a foot divided into 16 parts can be read on this measuring rod. A sketch may clarify the number of the resulting ratios (Fig 3d).

It must be accepted that the use of such a measuring rod with its represented intervals was both convenient and practical in antiquity. This would tend to raise the question as to whether this rod was originally marked out with single digits (or daktyloi), each with its accompanying ring, the rings being lost while in use during antique times. However, this interesting question which cannot be answered with certainty, is really insignificant for the result of the metrological research carried out here. A metrological system has been calculated from the total length of the foot unit with its sixteen divisions and set out in tabular form (Tab. 1). While doing this a limit of tolerance between 309/310 mm was taken into consideration, as happens in extreme cases between the units calculated from the buildings and those from the measuring rod. Thus the actual measuring rod and the resulting metrological investigation carried out, not only confirm the existence and use of a developed foot measurement for the building remains of the oppidum of Manching (and with it for the Late La Tène Celtic civilization), but also testify to the accuracy of the established length. The slight difference of 1mm between the size of the modulus of the building measurement and the length of the measuring rod is practically without significance.

TABLE 1
Division of the foot in sixteen daktyloi or digiti and their respective values in millimetres

Daktyloi Digiti	*Fractions of a foot*	*Length of the modulus 309 (a)*	*Length of the modulus 310 mm (b)*
1	1/16	19.31	19.38
2	1/8	38.63	38.75
3	3/16	57.94	58.13
4	1/4	77.25	77.50
5	5/16	96.56	96.88
6	3/8	115.88	116.25
7	7/16	135.19	135.63
8	1/2	154.50	155.00
9	9/16	173.81	174.38
10	5&8	193.13	193.75
11	11/16	212.44	213.13
12	3/4	231.75	232.50
13	13/16	251.06	251.88
14	7/8	270.38	271.25
15	15/16	289.69	290.63
16	1	309.00	310.00

(a) Length of the measuring rod (309 mm).
(b) Length of the food unit derived from the building measurements (310 mm).

Now that the Manching foot modulus has been adequately proved to be 310 mm or rather fixed more precisely to 309 mm with the help of the discovered measuring rod, the question can be raised as to the origin of the used measuring unit. Comparable investigations of ground-plans in prehistoric Europe, as well as analogies to the measuring rod are absent at present, so a glance can be directed towards the metrology of the Greek, Roman and Near Eastern world. It would however, be irresponsible to uncritically select appropriate foot lengths as a comparison, from the abundance of metrological literature and information about measurements found in these areas. In his examination of the "Foot measurements of the Attic Buildings" H. Bankel pointed out,[16] how unreliable it can be, even in the Greek mother country, to determine and to name measuring units. As a result of his research, he suggested that two foot units were used for the Attic buildings, the Ionic foot measuring 293/295 mm and the Doric foot measuring 325/327 mm.[17]

The existance of an Ionic foot has been confirmed by L. Haselberger in Dydyma, who fixed it more precisely to 296.4+-0.4 mm.[18] In the same way as Dörpfeld, Bankel used the building measurements of Erechtheion to calculate the Doric foot, and in doing so he fixed this foot unit more precisely to 326.74 mm.[19] But according to R.C.A. Rottländer, this measurement put

[16] Bankel (1983: 92ff.) (see footnote 5.).
[17] Bankel (1983: 93ff.).
[18] Haselberger (1980: 211).
[19] Bankel (1983: 89).

forward by Bankel is unrealistic, and he suggests instead, a foot unit measuring 333.19 mm, which is the result of his statistically calculated measurements of the same building. He also compares this foot of 333.19 mm to the so-called Cretan-Aeginetian-foot of 333 mm put forward originally by Dörpfeld for the pre-Solonic period.[20]

In her comprehensive research on measuring systems, E. Pfeiffer went into great detail to examine the background origins of ancient measuring systems. She came to the conclusions, firstly that a measurement which she called the 'Egyptian-Greek-Roman pous' was embedded in a large metrological system and had, based on a unit of 370.66 mm (pygon), an initial value of 296.853 mm[21] a measurement which is nearly identical to that of Haselberger's Ionic foot of 296.4+4 mm. Secondly she showed that a foot unit measuring 333.96 mm which she calls the 'Babylonian-Tungrian-Druisanic' foot did not develop from the above initial unit of 370.66 mm (pygon), but from a cosmographical unit originally used in Babylonia.[22] She also mentioned that this unit of 333.96 mm was known in Egypt, and possibly used there in that a length of 333.96 mm was found clearly marked on an Egyptian measuring rod.[23] Yet another foot unit called by F. Hultsch the Olympian foot with a measurement of 321 mm[24] (320.601 mm)[25] was discovered at Olympia, but neither this unit nor those mentioned above coincide with the Manching foot.

In comparison, the foot from F. Hultsch, given the name "Attic-Solonic foot",[26] would agree with that from Manching, but it is not reliable. Hultsch assumed that the Solonic reform brought the Attic measuring length into relationship with the newly created metrological capacity and weight system - thus giving a closed Attic metrological system. He came to the conclusion that the value of the original foot amounted probably to 308.8 mm, but Hultsch's assumption and the resulting calculations proved very doubtful.[27]

The length of an Attic foot of 310.4 mm, calculated by R.C.A. Rottländer from a metrological examination of red-figured Attic pottery of the fifth century B.C. is near to Hultsch's "Attic Foot" and the size found in Manching. But his results can only be looked upon as an average statistical value taken from divergent foot measurements, rather than an actual measuring unit.[28] It is still more tempting to take as comparison an antique measuring length in which the measurement of the foot corresponds exactly to the Manching unit, and as well as that, the existence of which seems to be beyond all criticism - the so-called "small Ptolemaic foot" with a length of 308.33-309.22 mm.[29] In his writings "De conditionibus agrorum",[30] the Roman agrimensor or field measurer Hyginus reported, that the estates in the province of Kyrene, which Ptolemaeus Apion 96 B.C. gave to the Roman people, were divided into Centurians, based on a square area called "plinthis", the sides of which being one mile long or 1.85/1.855 kms, which corresponds to 1250 Roman iugera. From these field measurements, he calculated a "small Ptolemaic foot" which measured 1 1/24 times the length of a Roman foot. In a brilliant train of thought, A. Oxé[31] expounded that the above mentioned square mile was based on the unit calculated by Eratosthenes and that Hyginus' efforts to use this calculation to support his "small Ptolemaic foot" is unrealistic. He mentions that the measurements suggested by Hyginus are very unreliable, as are the calculations he used for further explanations to extract the original ground measuring unit, the so-called "small Ptolemaic foot" of 308.33 mm, from the length of the Acre and the Centurian measured by him, and that in reality this foot never existed. Pfeiffer has shown in detail that the Ptolemaic foot (25/24 pous = 309.222 mm)[32] wasn't a primary foot measurement like the Egyptian-Greek-Roman pous of 296.853 mm, but was derived from a field measurement based on the pygon (371.066 mm).[33] The Ptolemaic foot is the unit which originates when a rod with a side measurement of 10 pygon is divided by twelve (10 x 371.066 mm: 12 = 309.222 mm)[34] This result confirms partly the assumptions of Oxé, but doesn't leave any doubt as to the real existance of this foot unit. With regard to the foot measurement of 309 mm determined in Manching, it can now be suggested that the correspondence between it and the Ptolemaic foot (25/24 foot) is not pure coincidence, but that the Manching foot unit, like the above mentioned pous/foot must have been taken from an ancient metrological system.

In view of the fact that the square rod, with a side length of 10 pygon, is a very old basic unit of ground measurement, the question can now be raised as to what extent this rod forms the basis for the Gaulish

[20] Rottländer (1991: 145ff.).

[21] Pfeiffer (1986: 62ff.).

[22] Pfeiffer (1986: 531ff.).

[23] Pfeiffer (1986: 534).

[24] Hultsch (1882; Reprint 1971: 530).

[25] Pfeiffer (1986: 401, 459ff.) calculates two measurements for the "Olympic foot", that of 320.601 mm which is taken from the given measurement of 192.36 m for the "Rennbahn" in Olympia.

[26] F.Hultsch (1882; Reprint 1971: 69ff) See also F. Schubert (1992).

[27] Comprehensively explained in Bankel (1983: 97. 82ff. and footnote 148) (see footnote 5). See also K. Kraft (1959/60: 27, 30 and 82ff.) See also Hultsch (1882; Reprint 1971: 66ff., esp. 68).

[28] Rottländer (1979: 74, no. 7.2.2/6). Upon closer examination of the "attischer Fuß" established as 310.4 mm by Rottländer as a possible comparison to the Manching foot, one observation is of importance: The analysis and evaluation of the measurement which the author carried out on provincial Roman pottery produced a constant value of 296 mm for the Roman foot. This agrees strikingly with the length of 295.7 mm mentioned in the current literature. Compare Hecht (1979: 108). In comparison, similar measurements made by Rottländer on red-figured Attic pottery of the fifth century, gave an average value of 310.4 mm. This shows no similarity either to the length of the Ionic foot, the Cretan-Aeginetian foot nor the "Doric foot". Concerning Rottländer's Attic foot compare Pfeiffer (1986: 554).

[29] Hultsch (1882; Reprint 1971: 70) calculated the "small Ptolemaic foot" (308.2 mm) from the Roman foot, which he assumed to be 295.7 mm. - C.F. Lehmann-Haupt (RE Ser. 11, Bd. 6, p.1934 u. p.1949) took the Roman foot to be 297 mm and arrived at a slightly larger value for the Ptolemaic foot - that of 309.4 mm. - whereas Pfeiffer (1986: 136, 457ff.) calculates an original length of 309.222 mm.

[30] F. Blume/K. Lachmann/A. Rudorff (eds.) (1967: 122).

[31] A. Oxé (1926: 235ff.).

[32] Pfeiffer (1986: 457ff.).

[33] Pfeiffer (1986: 432ff., 454).

[34] Pfeiffer (1986: 136ff.).

ground measurements which have been handed down under the names of libra, parallela, candetum and arapennis. But it is not possible to answer this question here.[35]

A new find from the oppidum of Bibracte which has aroused attention in an entirely different sphere seems to us to be much more important for the discussion of the Celtic foot measurement. In the year 1987, M. Almagro-Gorbea came across a shiplike cultic basin carefully built of rectangular stone blocks.[36] From the ratio length to width, based on a circular lay-out, a foot of 304,2mm could be determined as the basic measurement. Although the situation of the basin cannot be dated exactly, it seemed to belong to a late phase of the building of the oppidum, that means the last century B.C. Even though there is a clear difference between the length of the Manching foot unit of 309 mm and that of the foot measurement of 304.2 mm found in Bibracte, it is possible to assume that the latter measurement belongs to the lower section, and the Manching unit to the upper part of the variation scale of the so-called Ptolemaic foot.[37] Unfortunately metrological investigations on Mont Beuvray, which would give some information about the building measurements of the other well-known ground-plans found there during the last century, are absent at present.

Another ground-plan found in an entirely different cultural and geographical area is worth mentioning. In the recently discovered Etruscan city of Bagnolo S. Vito (Loc. Forcello) not far from Mantua, in the plains of Mincio, the post-hole ground-plan of a house was excavated and exactly measured by R. de Marinis.[38] Using the cord measuring system established by the Manching buildings as a basis, the length of a foot there was ascertained to be 308 mm, practically identical with the Manching foot measurement.

The above results point clearly to the fact that in the immediate vicinity of the Celtic oppida, foot measurements which resemble the established Manching foot seem to have been in existence, and in all probability were connected with the measuring system of the Ptolemaic foot of 25/24 pous.

CONCLUSIONS

From the foregoing information, it has been shown that investigations into the existence and use of a foot measurement within a Celtic oppidum during the Late La Téne period, had to be restricted to deriving the modulus length from the building remains, supported by an unique find in the form of an original iron measuring rod. The deductions taken from the Manching and Gallic Bibracte research results, now make it possible to come to the conclusion that exact linear measurements, based on the unit of a foot were known and used for the lay-out of the buildings. The precise division of the Manching foot into sixteen part digiti or daktyloi tends to suggest that the use of standard measurements were also used in other areas of life, such as in craftsmanship and trade. In view of the absence of comparable finds in the Celtic sphere,[39] coupled with an abundance of often contradictory studies on ancient metrology, the general question of the origin of the Celtic foot unit and its connection to other ancient metrological systems could only be touched on here. However, if we have managed to raise the discussion about the Celtic unit of length to a new level of interest, we feel we have reached our goal.

[35] Hultsch (1882; Reprint 1971: 692f.).

[36] M. Almagro-Gorbea (1988, 38 ff.); M. Almagro-Gorbea / J.Gran-Aymerich (1988); M. Almagro-Gorbea/J. Gran-Aymerich (1991). At this point, I would especially like to thank M. Almagro-Gorbea for information regarding the results of his excavation and for allowing me to use his plans.

[37] Regarding the question of the variation of foot measurements compare Pfeiffer (1986: 454ff.).

[38] R. de Marinis (1986: 140 ff., esp. 168 (Fig)).

[39] A recently published article by M. Feugère (1992, 133 with footnote 29 and Fig. 72; 150, 29), on a notched bronze rod dated to the middle of the first century B.C. which R. Gebhard was kind enough to point out to me, measures 148mm - that is exactly half the length of a Roman foot. The varying lengths of the intervals between the six hammered-in double notches, which Feugère interprets as being partly divided into half 'pollices' of a twelve part division, and partly as 'digiti' of a sixteen part division of a foot, don't seem to suggest a measuring unit, in that the length of the given pollex/digitus modulus doesn't work out for the whole length of the rod. The one-sided pointed emphasis of the rod and its curved end suggest rather that its function may have been that of a writing utensil, with the double notches being purely ornamental.

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