The Search for Megalithic Quanta

By Richard Dibon-Smith

> *It will be necessary to make extensive use of statistical theory if any reliable conclusions are to be drawn. ...*
>
> Alexander Thom (1967)

> *It seems to be impossible to [prove] mathematically ... but philosophically the conclusion is quite clear. There cannot be the slightest doubt about the reality of the Megalithic yard.*
>
> A. Thom and A. S. Thom (1978)

In the last few decades a number of important theories have been voiced concerning the mental capacities of early man. These theories attempt to reverse much of the prejudice introduced in the nineteenth century when man's antecedents were seen to be slightly better intellectually than the ape from which he purportedly had so recently sprung. Thus Richard Atkinson, Gerald Hawkins, Peter Newham and others have considered Stonehenge an astronomical calendar. Alexander Marshack has sought to prove that Paleolithic man carved lunar calendars on antler bones. And the late Alexander Thom was convinced that neolithic Britons ranged from one end of Britainto the other, building stone circles and other monuments, all carefully measured with the precision of a modern-day engineer.

Few recent theories have captured the imagination of specialist and layman alike as has this last concept, called the Megalithic Yard. This measurement, exactly 2.722 feet,[1] is said to have been used throughout neolithic Britain and parts of France for several thousand years by megalithic man in the construction of his stone monuments. As the debate has grown over the years, a rather wide gap has imposed itself between the specialists—mostly statisticians—and the interested layman, often completely adrift when faced with the sophisticatedmathematics used in the debate over the 'MY'.

This paper shall attempt to provide the interested—yet comparatively innumerate—layman, with the historical development of the argument around the existence of the Megalithic Yard, and to offer an assessment of its current status.

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* I would like to thank Dr. D. G. Kendall, who at the time was Director of the Statistical Laboratory, University of Cambridge, for invaluable comments and corrections to earlier versions of this paper.

The Theory

In 1955 Thom, then professor of Engineering at Oxford, presented a paper to the Royal Statistical Society. Thom introduced three theories he had been developing over a number of years: 1) the geometry of flattened stone circles, 2) a common unit of length used by neolithic man, and 3) the use of stone alignments as astronomical devices. Of these three we are only concerned with the second.

All of the data for the discussion of megalithic quanta had come from Thom's own meticulous survey of sites in England and Scotland, achieved over several years; in particular 52 circular and near-circular sites (25 in Scotland, 27 in England) formed the basis of Thom's theory. Thom divided these into the two geographical groups, Scotland and England. The diameters were taken in feet and tenths of feet, with a standard error ranging from one-third foot to one full foot for the larger circles. Tables 1 and 2 show the original data.

Thom then plotted his findings on a graph. Results showed a distinct preference for the data to centre itself around points which appeared to be equidistant. Then assuming that these points were all multiples of a smaller unit, Thom stated that "the Scottish and English values were examined separately to find what value near to 5.5 ft. best suited the diameters. It appears that a value of 5.435 ft. closely represents both sets."[2]

Thom then divided each diameter by 5.435, finding its factor, or 'multiplier' (m). He calculated the error 'z' by reversing the procedure, finding 5.435 times (m) and subtracting this value form the real diameters. Thom then solved for $\Sigma D/\Sigma m$: 5.436 for Scotland and 5.434 for England.[3]

To test the probability that the results were not obtained by chance, Thom used an approach initiated by S. R. Broadbent, employing Broadbent's Table 3: 'Lumped Variance Test'.[4] It was found that all Scottish circles have a probability level of .001 (highly significant) and all English circles a level of less than .05 (borderline significance). Thom concluded that "it appears that a unit of about 5.43 ft., or a sub-multiple thereof, was in common use throughout Britain."[5]

At the discussion which followed the delivery of Thom's paper, Broadbent remarked that the significance test which Thom employed should be regarded as a prima facie test only, that is, that the results could be open to question if further supportive evidence was not to be found. Nevertheless Broadbent did not question Thom's results, only some of his statistical methods. Subsequently, Thom would adopt another of Broadbent's tests to measure significance levels.[6]

Seven years after this 1955 appearance before the Royal Statistical Society, Thom reported in the Society's journal that "a large number of megalithic circle diameters is now available. The analysis shows that the unit suggested for the radius (2.72 ft.) can be accepted without hesitation."[7] Thom also proposed calling the double of this length the megalithic fathom, and pointed out that the half-yard (1.36 ft.) might also have been used.

In 1964 Thom's paper "The Larger Units of Length of Megalithic Man" examined the Mid Clyth rows. At Mid Clyth, Caithness, about 23 stone rows spread out fan-like for a length of about one hundred and thirty feet, have been interpreted by Thom and others as

Table 1: Circle Diameters, England

Site*	T/E**	D(ft)	m	5.435(m)	z
S2/4		11.9±.3	2	10.87	1.03
S2/7	E	16.0±.3	3	16.30	0.30
S2/5		22.3±.3	4	21.74	0.56
L2/13		24.0±.5	4	21.74	2.26
S4/1	E	29.7±.3	5	27.17	2.53
L3/1		31.5±.3	6	32.61	1.11
S2/4		41.2±.3	8	43.48	2.28
L1/9	T	47.7±.5	9	48.91	1.21
L1/4	E	51.7±.5	10	54.35	2.65
L1/4	E	53.3±.5	10	54.35	1.05
L1/4	E	54.9±.5	10	54.35	0.55
L1/4	E	66.3±.5	12	65.22	1.08
S2/2		67.4±.3	12	65.22	2.18
S2/8	E	81.4±.3	15	81.52	0.12
L2/13		86.0±.5	16	86.96	0.96
S4/2	T	91.1±1	17	92.39	1.29
L1/3		93.7±.3	17	92.39	1.31
D1/2	E	96.9±.5	18	97.83	0.93
S3/1	E	103.1±.5	19	103.26	0.16
S6/1		103.6±.3	19	103.26	0.34
S2/1		104.5±.3	19	103.26	1.24
L1/1		107.0±.3	20	108.70	1.70
S2/1		108.5±.3	20	108.70	0.20
L1/2	T	113.4±.5	21	114.13	0.73
L2/14	T	145.9±1	27	146.74	0.84
L1/7	T	358.8±.5	66	358.71	0.09
S3/1	T	370.5±1	68	369.58	0.92

Computations:

$$\frac{\Sigma D}{\Sigma m} = \frac{2482.3}{457} = 5.4317$$

For the significance level, the formula used was:

$$\frac{\Sigma z^2/n}{d^2},$$ where

$d = 5.435/2$ and

n = the number of sites.

For England, $\frac{\Sigma z^2}{n} = \frac{47.0968}{27}$

and $d^2 = 7.3848062$.

Therefore,

$$\frac{\Sigma z^2/n}{d^2} = 0.2362$$

Broadbent's Table 3: <0.05 (i.e. 'borderline significance')

Table 2: Circle Diameters, Scotland

Site*	T/E**	D(ft)	m	5.435(m)	z
A2/8		11.2±.3	2	10.87	0.33
A1/2	E	14.0±.3	3	16.30	2.30
G4/9		20.9±.3	4	21.74	0.84
H7/9	T	21.0±.5	4	21.74	0.74
M2/14		21.8±.3	4	21.74	0.06
G8/2		23.2±.5	4	21.74	1.46
H1/1		24.0±.5	4	21.74	2.26
G7/4		38.7±.5	7	38.05	0.65
H1/1		43.3±.3	8	43.48	0.18
M2/14		44.1±.3	8	43.48	0.62
A2/8		44.2±.3	8	43.48	0.72
G4/12		54.5±.3	10	54.35	0.15
A8/6		54.9±.5	10	54.35	0.55
H1/3	E	55.0±.5	10	54.35	0.65
A1/2		65.1±.3	12	65.22	0.12
G7/2		66.4±.3	12	65.22	1.18
G3/7		69.3±.3	13	70.65	1.35
H1/2	E	70.0±.3	13	70.65	0.65
G4/14		82.1±.3	15	81.53	0.57
H4/2	T	87.4±.3	16	86.96	0.44
H3/17	T	124.0±1	23	125.01	1.01
G7/5	T	130.9±1	24	130.44	0.46
H3/18	T	139.0±1	26	141.31	2.31
G6/1	T	288.4±1	53	288.06	0.34

$$\frac{\Sigma D}{\Sigma m} = \frac{1614.4}{297} = 5.4357$$

Using the same formula to test significance:

$$\frac{\Sigma z^2/n}{d^2} = 0.1484$$

This yields a level of significance of 0.001 ('highly significant')

* See Thom (1955) Table 1 for complete identification and exact location of all sites.

** T/E indicates sites either transferred to Table 5.2 in the 1967 analysis or eliminated altogether. See pages 56-57.

a prehistoric computer, assisting ancient man in his calendrical calculations. Thom found here a new quantum (L) of 7.743 feet. Thom explained how he arrived at this figure: "knowing how particular megalithic man was about using integral values, it seems possible that at Mid Clyth he divided 20 MY into 7 parts obtaining 7.77 ft. This hypothesis seems preferable to the assumption that at Mid Clyth he was using an entirely independent unit."[8]

Alexander Thom's first book, *Megalithic Sites in Britain*, was published in 1967. In it Thom expanded his previous data and consolidated his results. It was in this book as well that Broadbent's test for 'C' was introduced for significance testing.

This first book presented a careful revision of all of Thom's earlier research on megalithic units. Thom could now write with confidence that "the Megalithic fathom was first demonstrated in 1955. So from that date we expect all future work to show the same unit."

Indeed, Thom continued to find the same unit in such places as the menhir fields of Carnac, Brittany, and at Avebury. Thom began investigating the Breton menhirs in 1970. Apart from considering several of the menhirs as astronomical calendars, Thom and his son Dr. A. S. Thom meticulously measured the geometry of the stone rows of Carnac and concluded that here a somewhat different value equal to 2.5 MY had been used. They named this value the Megalithic rod (6.802± .002 feet).

While understandably impressed with the huge number of menhirs found in this part of Brittany, Thom held out for a British headquarters: "we must not lose site of the fact that so far none of the Breton sites examined has a geometry comparable with that found at Avebury in ambition and complication of design or in difficulty of layout."[9]

It was some time before the Thoms could devote enough time to the study of Avebury, but by 1976 not only had they carefully surveyed the site, they had also—perhaps not surprisingly—been able to verify the existence of the MY. Indeed, Avebury gave Thom and his associated "the most accurately determined value of the Megalithic yard."[10]

This revised value of the MY (2.722 ± .002 feet) I shall use throughout the remainder of this paper.

The appendage of two one-thousandths of a foot (or less than one thirty-second of an inch) is usually dropped from further calculations; its value is purely statistical. Yet, as the reader may have some doubt as to the relevance of this figure, a brief remark on the use of the standard error might not be out of place. The figure is not intended as a range of error in measurement. That is, one does not add and subtract this value from the principal value to obtain a 'total range of possible values'. It is a measure of variation in the observed data, defined usually as the 'standard deviation of the sampling distribution'. The formula, as presented by Thom, appears to suggest that the total error associated with the principal value is extremely small.

Further on another investigator will add important remarks concerning the standard error, but for the present time let us adopt Thom's formula and see just what it means. Assuming a normal distribution, the standard error of a sampling distribution can give us an estimate of the probable length of the MY, depending on how accurate we wish to be.

Thus if twice the standard error is added to and subtracted from any given mean (2.722 in our case), we can expect any random observation to fall within these two extremes ninety-five percent of the time. In other words, only five observations out of one hundred will fall out of this range. If we wish more accuracy, we can find the minimum and maximum range of 99% of random observations by adding to and subtracting from the mean three times the standard error. This criterion is the usual one adopted by most investigators; it means that we establish maximum and minimum values beyond which any random value is considered 'foreign', not part of the data under question.

We shall have later recourse to this idea of acceptance or rejection of data as applied to Thom's work and others'. For the moment, let us apply the criterion of plus or minus three standard deviations to Thom's value for the megalithic yard. Adding 3(.002) feet to 2.722 feet gives 2.728 feet. Subtracting the same value gives 2.716 feet. Thus we have the megalithic yard, with only one percent error, having a length that varies from 2 feet 8 and 19/32 inches to 2 feet 8 and 23/32 inches, an incredibly narrow range of only one-eighth of one inch. This is at least what Thom's formula seems to be saying. Either one must accept this degree of accuracy in both the building of the circles and in the measuring of them, or one must take issue with Thom over the size of his standard error. This point shall be taken up in some detail later. First we shall follow the debate concerning the concept of the megalithic yard itself.

The Debate

Although the megalithic yard had been with us since 1955, it was the impact of the printed argument, in 1967, that gave it sudden life, for its implications were now difficult to ignore. Professor R. J. C. Atkinson of University College, Cardiff, summed up the dilemma that Thom's hypothesis presented: "unless some flaw in the argument exists, ... the conclusion that a standard unit of length was used by the builders of stone circles in Britain is extremely difficult to explain away, however much it may be at variance with our present view of the societies and the technology of the period concerned."[11]

Such caution was not universal. One of the more enthusiastic appraisers of Thom's conclusions was Dr Euan MacKie, a professional archaeologist, who accepted the existence of the MY outright since, "considering the qualifications of the author, [it] is scarcely likely to be challenged."[12] MacKie also agreed with Thom that standard rods were probably shipped out from a single distribution centre, since the agreements throughout the country of this one unit were so close. Dr MacKie was to become the staunchest supporter of Alexander Thom, defending him in face of mounting attacks by statisticians.

The first of the mathematically critical observations was that of Nathaniel Grossman, who, addressing himself to the problem of prehistoric measurement in general, remarked that "without a mathematical Rosetta stone, all attempts at understanding the megalithic mathematics are merely conjectural."[13] But Thom's data and the hypotheses it contained would prove too tempting to be left alone.

It was Hugh Porteous who turned the examination of Thom's data into the beginnings of quantitative analyses. In a paper that appeared in the 1973 issue of the *Journal for the History of Astronomy* (the same journal that hosted most of Thom's papers), Porteous voiced two objections to Thom's methodology: 1) that Thom had needed to extrapolate Broadbent's formulae in order to fit in his 145 observations, and 2) that Thom should have compared the respective probabilities of the 'pacing hypothesis' and the 'exact quantum hypothesis' since it is clear that the only doubt one can have over the data is whether the stones were paced out or drawn to specifically measured units of length. Porteous then went on to demonstrate that the pacing theory held up even better to Broadbent's formula (see note 6), achieving a value 'very much better' than any of Thom's.

As time went on, the theory that the normal pace was the only measure used by neolithic man would grow in significance and challenge Thom's concept of a measured quantum.

One year after the Porteous article, the discussion on the existence or not of megalithic quanta took an important step forward in the form of a paper presented to the Royal Society by D. G. Kendall of the Statistical Laboratory, University of Cambridge. Dr Kendall's approach was entirely new and very complex, subjecting Thom's data to a Fourier analysis. Kendall looked only at the diameters of true circles and asked the following question of them: "is it reasonable to suppose that the circle-diameters could have arisen from a smooth (but not necessarily uniform) distribution over the range which they cover (from 10 ft, up to several hundred feet), *or* is it more reasonable to suppose that (apart from a small residual error) they are whole-number multiples of a basic unit (to be called, if it exists, the quantum)?"[14]

Kendall, then, in defining the problem he wished to study, did not distinguish between the pace and the measuring rod but asked simply if any value, however derived, could be identified. Thus the results of Kendall's study could be used to either dismiss the quantum theory *in toto* or to accept the evidence as showing that a quantum (whether the MY or the pace) did exist. It could reject Thom's hypothesis; it could not confirm it.

Kendall subjected two groups of data to his tests: 1) the circles of Scotland and England that were accurately measured to within one foot [i.e., Thom's Table 5.1 from (1967)], and 2) all circles of Scotland and England [Thom's Tables 5.1 and 5.2 (1967)].

Results, as usual in these circumstances, were not clear-cut. It seemed that the first group, the 'good' circles, did not reveal any quantum, but the small number of observations (112) may have contributed to this failure. On the other hand, much more positive results were achieved with the second group (of 211 observations). Here Kendall could announce that "the hypothesis of a smooth, non-quantal distribution of circle diameters for [group two] is thus rejected at the 1% level."[15] In other words, the data when lumped together seemed to point to the existence of some kind of unit while the 'better' data, when isolated, showed no such tendency, definite results being clouded by the lack of enough observations. Accordingly, Kendall's closing remarks were an appeal for further studies based on more surveys.

In 1975 Dr P. R. Freeman of the University College, London, read a paper before the Royal Statistical Society. Published the following year, this study subjected Thom's megalithic quantum hypothesis to a Bayesian analysis. Freeman's stated aim was more to look for possible values of an existing quantum rather than to prove or disprove Thom. Table 1 of his paper summarized previous work on the subject, by Kendall and Broadbent; this paper then can be considered a resume of the state of the argument up to the mid-70s. The megalithic rod of Carnac was also examined by Freeman.

Despite his announced intention of not wishing to directly evaluate Thom's work, Freeman did arrive at some definite conclusions. By and large, Thom did not fare well with Freeman. Following his highly complex analysis, Freeman showed no hesitancy at rejecting the idea of a quantum for England and Wales: "... none of the subsets of the data from England and Wales can be said to provide much evidence for a quantum of any kind."[16] Furthermore, he was categorical in his denial of the megalithic rod at Carnac: "... [the obtained results] fail to support the existence of any single unit of measurement, and ... the claim for a 6.8 ft unit is simply not tenable."[17] Freeman did think that the Scottish data held higher promise.

The discussion following the presentation of Dr Freeman's paper displayed a great deal of adeptness in the art of accommodating its conclusions to one's own set of assumptions. Those critical of the quantal theory celebrated Freeman's results as 'decisive' and 'conclusive' evidence of its non-existence; those sympathetic with Thom's ideas turned for support to historical parallels of megalithic quanta in the ancient Near East.

Indeed, if the Freeman paper had no other effect, it was to crystallize the division of opinion. On the one side were those who rely on statistical data and other mathematical analyses; on the other, those who place a lot less reliance on mathematical proofs. Thus, the two archaeologists Aubrey Burl and Euan MacKie (to cite one example) found themselves in opposition on the question of quanta. Burl felt that the only proof of the existence of the MY was to come out of statistical analyses[18] and he agreed with those who argued that the 'pace' was just as likely to have been used by megalithic man when setting out his circles. MacKie attempted to show the historic genesis of the megalithic yard by suggesting that the measuring system of ancient Sumeria was introduced into Britain and Brittany at some unspecified time for later use during the third millennium BC.[19]

This historical approach deserves some consideration, if only because it is often cited as the method of introduction of the megalithic yard into Britain. MacKie has presented a useful schema[20] purporting to show the relationship between the Egyptian remen, the megalithic yard, and the megalithic rod:

MacKie further stated, following an earlier 'history' of metrology by the engineer A. E. Berriman (1953), that fifty shusi—a Sumerian unit of length—equalled exactly thirty-three inches, and that fifteen Sumerian feet equalled six MY. That these values

all meshed so nicely, in round numbers, apparently provided implicit proof to both Berriman and MacKie of their historic relationship.

If AB = one Egyptian remen, then:
AD = one megalithic yard, and
AE = one megalithic rod

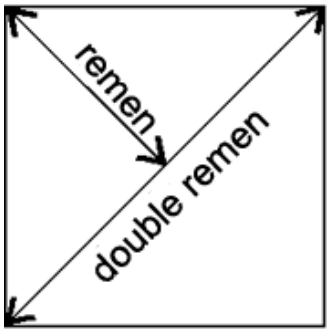

Fig. 1

Other examples of the metrological approach include Fletcher (1968), who found a parallel between the megalithic yard and the Egyptian remen and double remen, such that 108 double remen of 2.42 imperial feet equal 96 megalithic yards. The same writer equated one MY with the length of the diameter of a circle equal in area to a square with a side of two cubits. Another has speculated that the builders of Carnac were acquainted with the decimal system since the megalithic rod (2.5 MY) contains exactly 100 megalithic inches. Williamson (1974) commented on the apparent relationship between megalithic measurements and Sumerian metrology but then opined that the megalithic yard was probably 'a standard step or stride' and that two of these amounted to a pace.

Discussion

As one can see from the foregoing, the pursuit of megalithic quanta has branched out into adjacent disciplines. No longer is the argument limited to the strictly statistical analysis of stone monuments. This widening of the field of enquiry is both inevitable and unfortunate: inevitable in that the implications inherent in the theory come readily to the surface, unfortunate in that once on the surface they tend to muddy the argument with unsubstantiated speculation. Thus MacKie, once he has accepted the existence of the megalithic yard, bases a large portion of several books [1977ab] on the supposed society that had to evolve in order to create and perpetuate the MY throughout vast geographical distances. Britain has now become peopled with an intellectual class of 'astronomers, wise men, priests and bards' who were "doubtless encouraged genetically be selective breeding and culturally by the appropriately favourable social environment."[21]

This is not the place to discuss Dr MacKie's rather special view of neolithic man, except to point out that this highly speculative approach depends wholly on Thom's hypotheses, which themselves have by no means become universally accepted dogma.[22]

As for the historical transmission of megalithic measurement, another major contention of the supporters of the megalithic yard, "the megalithic measuring system provides one clue to the origin of the institution of priesthood itself."[23] This institution is said to have come from Mesopotamia, since the units of measure seem to coincide. Several dissenting remarks regarding 'historical metrology' will now be made.

MacKie claims that fifty shusi equalled thirty-three inches; this statement contains a degree of accuracy that is, I believe, misleading. A Sumerian shusi was the approximate value of the width of one finger (the term means 'finger'). For example, in an early

Sumerian "Farmer's Almanac" one is instructed to plant the barley seeds 'two fingers' deep. When the grain grows to a height that fills 'the narrow bottom of the furrow', one must water it. When the barley has grown as 'high as [the straw of] a mat in the middle of a boat' it is to be watered a second time.[24] These measurements are as precise as they had to be, but they quite obviously do not show any affiliation with exact units of length.

MacKie also adapts from Berriman the idea that one Sumerian foot equalled 13.2 inches, thus 15 Sumerian feet equalled 16.5 imperial feet. But six MY equals 16.32 imperial feet. The semblance is only approximate and probably accidental. To attach too high a precision in what passes now for 'ancient measurement' and then to equate those values to the equally problematic values of megalithic man seems rather over-optimistic.

A similar attempt to find a prehistoric unit from one excavated Near Eastern site has also led to difficulties. Rottländer has taken one article about the excavation of Tepe Yahya and has come up with a number of metrological claims. Thus he finds that here the cubit 'mean value' was 513.7 mm. But his use of the data provided in the Lamberg-Karlovsky's article[25] is entirely unstatistical; this figure is the simple average of all values found on this site, of the brick sizes, room dimensions, and so on. And the very small sample—nine items—does not lend itself to much statistical evaluation.

Further attempts by Rottländer to find values of the ancient cubit prove equally troublesome. At the temple of Nippur, c3000 BC, is found, according to him, 'the best proof' of the cubit's length: a copper rod 1.1 metre in length, with numerous subdivisions. One of these subdivisions measures 51.86 cm, a value Rottländer accepts as the length of the cubit here. The source of this information, a German reference book of 1916, only notes that this subdivision is termed an 'Elle'. Here we meet one of the most general measures of length throughout history. From the Greek ωλενη—meaning elbow—it was always a very good method of measuring such things as cloth throughout the middle ages. As a length of measure it varied considerably from country to country. One must not take the term 'Elle' to mean the 'cubit' of a precise length.

But instead of criticizing, if we were instead to accept this value of 51.86 cm as the forerunner of the MY, then applying this value to Figure 1 should prove the connection. Referring to Figure 2, since it is clear that the remen equals the number of cubits divided by the square root of 2, in our case the remen equals 36.67 cm. Applied to MacKie's schema, AB equals this amount, BD double, and AD therefore is 81.997 cm or 2.690 feet. Comparing this value of the MY ($2.722 \pm .002$ ft) we see that it deviates much more than the limit of three standard deviations. We are probably correct in rejecting it as being unrepresentative; at best we can say that the connection is 'not proven'.

Fletcher's attempt at historical metrology has similar built-in difficulties. He must propose a cubit of length 52.158 cm in order to equate 108 double remen with 96 MY. This value of the cubit is somewhat higher than the two values given by Rottländer

above (51.86 and 51.37). Even granted this extended cubit, the double remen still only approximates the MY value. But the contention that the MY equals the length of the diameter of a circle whose area is equal to a square with sides of two cubits seems to be a desperate grasping at straws. Here, using Fletcher's own value of the cubit (52.158 cm), it is found that the MY would have a length of 1.1767 metres, considerably longer than the 0.82966 metres proposed by Thom. What is needed in 'historical metrology' is a great deal more history. Thus far no cogent theory has effectively traced the transmission of Near Eastern or Egyptian measurements to the British Isles.

An equally troublesome subject is that of numeracy. Just how numerate was neolithic man: if he could count, how high could he go? And if he had a counting system, what number base did he use? Dewez believes a number base of five was used c10,000 BC in Belgium, while in Spain c12,000 BC at El Juyo, the number seven appears to be significant in the earliest sanctuary yet discovered.[26] Burl suggests that 4, 5, and 6 were all used as number bases in different locales throughout the British Isles.[27]

However, the assumptions one must make in order to study numeracy put the whole subject in doubt. For example, Dewez assumes that the stylized grouping of the engraved marks on two bones reflects the base number of these people, one bone having seven groups of five cup marks, the other having six groups of five. Burl postulates that the actual number of stones which were used to make a circle indicates the base number. Is it too facile an argument to suggest that modern equivalents (clock faces, measuring tapes in feet and inches, scales in stones, pounds and ounces) do not reflect our base number ten, so why should we expect the remnants of ancient man's culture to reveal his counting habits. In another context Otto Neugebauer has argued that numerical systems just aren't that simple to deduce.[28] Furthermore, we don't know whether these numbers served as base numbers, used in a counting system, or as part of a system of numerical symbols, with a religious content. It is well known that certain numbers later figure in many outward expressions of religious piety, with 3, 7, and 12 particularly revered in Western culture. The presence of 'religious numbers' cannot be dismissed when reviewing the evidence of prehistoric man, especially as these numbers may relate to a calendrical system or other quasi-religious ideas. Thus, they would have been much more significant to him than would have been a simple base number.

The question remains that if neolithic Britons were numerate enough to construct complicated astronomical computers, why did they not leave some small trace of their numeracy on stone, antler, or bone carving? For as Professor Atkinson has noted, there is no evidence in either Britain or Brittany of even 'the simplest tally of numbers'.[29]

So much for related matters. What of Thom's own work? Two features of Thom's hypothesis concerning the megalithic yard will be briefly reviewed: 1) the original data that formed the MY and its subsequent history, and 2) Thom's use of the standard error. Then, finally, a comment on the overall assumptions contained in the search for megalithic quanta.

It was seen above that Thom's initial study, in 1955, was comprised of 27 English circle diameters and 25 Scottish; for both countries the MY was calculated to be 2.715 feet. In the 1967 revision, Table 5.1 contained 63 English and Welsh circle diameters (46

'perfect', 17 other) and 82 Scottish (66 'perfect', 16 others). With this greatly enlarged data, Thom recalculated the MY and reached very nearly the same value, namely, 2.72 feet, which seems to confirm his original work. Yet the original data, when incorporated into the newer framework, underwent some drastic revisions. Of the 27 English values, nine were eliminated from the 1967 data and six others were transferred to the less precise Table 5.2, which does not go into Thom's computation for the MY. For the original Scottish values, three were eliminated altogether in 1967 and six were transferred to Table 5.2.[30] Overall, 46% of the original data apparently did not show properties of the MY and were therefore discarded from further consideration.

How many more circles were studied, measured, and rejected as unsuitable? It seems that for the 1967 revision a conscious selection of admissible sites was compiled.

The standard deviation as used by Thom has caused some problems and some disagreements among observers. In principle, this value should represent the amount of total error in the given value. Thus it becomes an estimate of the degree of accuracy of the principal value. Now, errors most likely to occur in the measuring of the diameters of stone circles can be divided into six categories:[31] 1) errors in the lay-out of one circle (that is, in variations in the placement of the stones of one circle); 2) errors between circles, caused by different measuring devices used to set up the circles, or different people using the same devices, etc.; 3) constructional variation from circle to circle, caused by the use of different size stones; 4) errors between geographical regions (different people, terrain, etc.); 5) errors in the course of measuring the circles ('today's errors' as the circles are measured); and 6) the error of what Kendall calls "the uncertainty in our knowledge of the quantum."

Each of these six errors has its own degree of accuracy, and each therefore has its own standard deviation. Yet of all these possible sources of error, Thom only reported on the last: he estimated that the actual quantum used by neolithic man was 2.722 feet, with an uncertainty not caused by any of the 'in-built' errors (1-5 above) of only ± .002 feet. This figure is much too small to be of any practical value. Kendall estimates the combined errors (i.e., all of the above) to be about 1.5 feet,[32] a figure which, if generally accepted, would make it impossible to distinguish between the megalithic yard and the pace.

As for the overall theory itself, three brief remarks will be made. First of all, as developed by Thom over the years, the theory suffers from the 'Ptolemaic syndrome'. As each new location (Carnac, Caithness, ...) did not willingly submit to Thom's original model, appendages were added in the form of compatible multiples of the MY. Thus for some reason the people of Carnac supposedly rejected the MY in favour of a local unit, the megalithic rod, equal to 2.5 MY, while at Caithness a length equal to 20 MY divided by seven was devised for some other reason. Then, since Thom used multiples of the MY to arrive at these more compatible values, he was able to state that all these regions used the MY.

Furthermore, this Caithness value raises other concerns. For example, one would like to examine the evidence which led Thom to confidently assert that he knew just how "particular megalithic man was about using integral values." Also, the value 20/7

MY (i.e., 7.777 feet) only approximately matches the found value of 7.740. Burl (1976b) has noted other difficulties concerning Thom's treatment of this site, should the reader wish to pursue this issue.

Next there is Avebury. It will be remembered that this was the site that finally fixed the value of the megalithic yard at 2.722 ± .002 feet. The design of Avebury (two separate inner circles of slightly different diameters, both embraced by a Great Circle, with two avenues radiating from the latter) is unique in Britain. As we have seen, Thom declared that this one site gave the best value yet obtained for all the megalithic monuments of Britain and Brittany.

Three years after Thom's declaration the archaeologist Aubrey Burl produced one of the most thorough study ever made of Avebury.[33] The problem with Avebury, as shown in Burl's work, is the number of moved and missing stones. Throughout the seventeenth, eighteenth, and nineteenth centuries many stones were thrown down by religious zealots, used to construct houses by the more practical, or removed from fields under cultivation by land-hungry farmers. John Aubrey's plan, made in 1663 for Charles II, already showed about half of the outer circle missing, while the majority of stones making up the inner circles were still in place. There were certainly enough stones remaining to delight Charles as he visited the site the same year under Aubrey's guidance. But by the end of the century its destruction was almost complete. A map made by William Stukeley in 1724 and included as the frontispiece in his book on Avebury, published in 1743, indicates that by the 1720s only eighteen of the estimated one hundred stones of the Great Circle were still standing, and three stones in the North Circle and four in the South Circle (each having had at least thirty stones originally). The entire complex had been built with more than 600 megaliths; today only 76 remain.

How did Thom and his associates analyse Avebury? It was admitted by them that the North Circle was too far gone to study, but that the "southern circle is more definite and has a diameter close to 340 feet. This is 50 Megalithic rod. ..."[34] This approximate value quickly became an exact figure, not only for the South Circle but for the North Circle as well. Yet, as Burl points out, most surveyors previous to Thom had considered the North Circle smaller than the South Circle by a diameter difference of about fifty feet. A comparison of four surveys done from 1812 to the 1970s (Thom excluded) shows that for the North Circle measurements range from 270 to 320 feet, and for the South Circle from 320 to 340 feet.[35] Nevertheless Thom and his associates used 340 feet for both circles, thereby providing 'proof' of the connection of Avebury wit the rest of the megalithic nation, and even enabling the calculation of the Megalithic Yard to be fine-tuned to exactly 2.722 feet, give or take a sixteenth of an inch.

Lastly, what of the fundamental assumption contained in Thom's work? Just what is the chance of deducing integral units of measurement from the very ruinous remains of stone age monuments? Put in a slightly different manner, can *known* standard units be shown to have been used in the construction of existing monuments from an analysis of the proportions of such monuments? In this respect the recent work of two investigators, R. Falus and T. Mezös, on Greek temples, deserves some attention.

The aim of Falus and Mezös was to discover 'a common unit of scale', their hypothesis being that "if there is—even in the case of only one temple—a unit (module) suitable for generating all the dimensions, then it must be among the common divisors of the main measurements, seems to be reasonable because enlarging to scale and building the temples must have been easier in this way. However attractive this thesis may be, the facts reflect something else: the number of temples where 'module = unit of measurement' can be proved, is insignificant and even these buildings may have some other common 'modules'."[37]

Furthermore, the belief in Greek reliance on perfect, or agreeable, proportions based on the 'golden section' can, according to Falus and Mezös, 'most kindly be called a mistake'. This opinion seems to contradict Thom's reliance on the Pythagorean 3:4:5 relationship that he finds in so many instances of circle building, including the basis for planning some flattened circles.[38]

Falus and Mezös set out to do with Greek temples what Thom did with megalithic monuments; they examined the standing, extant portions of Doric temples to see what, if any, relationship existed between standard lengths and the proportions of the temples themselves, the only difference being that Falus and Mezös knew beforehand the length and the proportions of temples. It cannot be said with complete certainty that what goes for ancient Greece should also go for megalithic Britain, but the thought does create added ammunition for doubting-Thomists.

These then are some of the problems which face the advocates of the megalithic quantum theory. Or rather, these are some of the unresolved problems which bother some dissenters. As for the advocates, they seem secure in their own minds despite the controversies over methods, conclusions, and inferences. By and large, the debate came to rest between the advocates of a pacing theory[39] and the more rigidly conceived megalithic quantum with its inferred measuring rod. The distinction between the two methods is blurred by the implications contained in the one while absent in the other. That is to say, if one can prove that the quantum exists, it follows that this length and its various multiples may have been reproduced all over the stone-building areas of Britain and Brittany. From this it is a small jump to conceive of a megalithic nation stretching from Shetland to the coast of France, supervised by computer-operating priests.

If on the other hand the pace wins the argument, the foregoing scenario is apparently in jeopardy, for humans throughout the world will have similar sized steps; no nationhood need be prescribed. The argument has then devolved into having us either believe that a 'superior sort' of neolithic being existed, or did not exist. If we chose the pace over the megalithic rod, we seemingly plunge ancient man back into the darkness from which he so recently had been lifted.

It is quite likely that neither extreme is correct. If the MY should enter into a kind of limbo, with reserved acceptance (which seems at present to be the case), by no means should this imply that neolithic man was dim-witted. Even though the pace may eventually be seen as the more likely of the two, there is no need quite yet to deny the intelligence that early man may have possessed. There is enough evidence to suggest

that he was astronomically inclined; the problem now is to resolve the extent and purpose of this inclination. Burl for instance sees the occasional alignment of stone with moon and sun as 'symbolic rather than scientific' and probably related to burial sites.[40]

Controversies between respectable, yet opposing views, are not uncommon. A foretoken of the current debate between the quantum and the pace was the fierce battle waged in the nineteenth century between Max Müller, the proponent of an Eastern-born solar mythology, and Andrew Lang, the great advocate of an anthropological view of folk mythology. After Lang's intractable opponent died, in 1900, he wrote to Müller's widow: "Our little systems have their day, or their hour: as knowledge advances they pass into the history of the efforts of pioneers."[41] That Professor Thom is a pioneer in the study of megalithic man there is no doubt; that his unique picture of their society will rest intact is a matter that can only be resolved 'as knowledge advances', that is, with the systematic, objective study of as many megalithic monuments of Britain that still lend themselves to analysis.

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NOTES

1. While one would normally use metric measurements in a paper such as this, Thom used the Imperial system throughout his work, and we retain his original measurements.

2. Thom (1955)282.

3. Assuming there is no typographical error of the data given in Thom (1955) p. 281, Table 2, the correct English value is 5.4317.

4. Broadbent (1955)53.

5. Thom (1955)283.

6. Given n equals the number of observations, [$s^2=z^2/n$], and d =one-half the suspected quantum (that is, 5.435/2), then if $\sqrt{n}\,[\,^1\!/_3 - s^2\!/_{d^2}] > 1$, the data can be called significant [Broadbent (1956)38f]. Note however Broadbent's remark, p. 41: "When the experimenter is at liberty to choose the quantum, in order to validate his hypothesis, he must obtain agreement better than the conventional one in a thousand level," a point which was consistently ignored by Thom.

7. Thom (1962)243.

8. Thom (1964)530.

9. Thom and Thom (1972)26.

10. Thom, Thom and Foord (1976)190.

11. Atkinson (1968)77.

12. MacKie (1968)282.

13. Grossman (1970)1229.

14. Kendall (1974)233.

15. Kendall, 249.

16. Freeman (1976)28.

17. *ibid*, 34.

18. Burl (1976b)73.

19. MacKie (1977)69.

20. MacKie (1977b)54.

21. *ibid*, 228.

22. MacKie later [in Ellegård (1981)119] reiterated this scenario, since its ideas "have not yet themselves been challenged with contrary evidence" despite the lack of real evidence for MacKie's own argument. He did admit, however, that "the title of the book [*Science and Society in Prehistoric Britain*] was probably a mistake and that 'Science' should be deleted from it."

23. MacKie (1977a)191.
24. S. N. Kramer, *The Sumerians* (Chicago, 1963)341.
25. *SA* (June, 1971)102-11.
26. See L. G. Freeman and J. González Echegaray, "El Juyo: a 14,000-Year-Old Sanctuary from Northern Spain" in *History of Religions* 21(1981)1-19.
27. Burl (1976a).
28. Neugebauer (1969)17.
29. Atkinson (1975)51.
30. It should also be noted that one English circle (L1/1) and two Scottish (G7/4 and G7/2), although retained, were given different diameters in 1967.
31. My thanks to D. G. Kendall (personal correspondence) for this precise information on the standard error.
32. Kendall (1974)253.
33. Burl (1979).
34. Thom, Thom and Foord (1976)191.
35. Burl (1979)67, Table 1.
36. Falus and Mezös (1979)285.
37. *Ibid*, 292.
38. However, see Wood (1980)39f for the argument in favour of its use.
39. E.g.: Porteous (1973)23; Williamson (1974)381; Burl (1976b)73; Ellegård (1981)112f.
40. Burl (1980).
41. Georgina Müller (ed.), *The Life and Letters of the Right Honourable Friedrich Max Müller* (London, 1902)*ii*, 429. For the controversy itself, which has parallels in the current debate, see Richard M. Dorson, *The British Folklorists* (Chicago, 1968)161-86, 206-20.

Bibliography

Atkinson, R. J. C.	"Review of Thom's *Megalithic Sites in Britain.*" *Antiquity* 42(1968)77-78.
″ ″	"Megalithic Astronomy—a Prehistorian's Comments" *JHA* 6(1975)42-52.
Berriman, A. E.	*Historical Metrology* (London, 1953).
Broadbent, S. G. F.	"Quantum Hypotheses" *Biometrika* 42(1955)45-57.
″ ″	"Examination of a Quantum Hypothesis Based on a Single Set of Data"
″ ″	*Biometrika* 43(1956)32-44.
Burl, Aubrey	"Intimations of Numeracy in the Neolithic and Bronze Age Societies of the British Isles (c3200-1200 BC)" *Arch. J.* 133(1976a)9-32.
″ ″	*The Stone Circles of the British Isles* (London, 1976b).
″ ″	*Prehistoric Avebury* (London, 1979).
″ ″	"Science or Symbolism: Problems of Archaeo-astronomy" *Antiquity* 54(1980)191-200.
Dewez, M. C.	"New Hypotheses Concerning Two Engraved Bones from La Grotte de Remouchamps, Belgium" *World Arch.* 5(1973) 337-345.
Ellegård, A.	"Stone Age Science in Britain?" *Current Anthro.* 22(1981) 99-125.
Falus, R and Mezös, T.	"Scales and Proportions on Doric Buildings" *Acta Historiae Artium* 25(1979)281-318.
Freeman, P. R.	"A Bayesian Analysis of the Megalithic Yard" *J. R. Stat. Soc.* 139(1976)I, 20-55.
Fletcher, E. N. R.	"Ancient Metrology" *Survey Rev.* 19(1968)270-77.
Grossman, N.	"Megalithic Rings" *Science* 169(1970)1228-9.
Kendall, D. G.	"Hunting Quanta" *Phil. Trans. R. Soc. Lond. A*. 276(1974)231-266.
MacKie, E. W.	"Stone Circles: for Savages or Savants?" *Current Arch.* 11(1968)279-83.
″ ″	*The Megalithic Builders* (Oxford, 1977a).
″ ″	*Science and Society in Prehistoric Britain* (London, 1977b).
Neugebauer, O.	*The Exact Sciences in Antiquity* (New York, 1969; 2nd edition).
Porteous, H. L.	"Megalithic Yard or Megalithic Myth?" *JHA* 4(1973)22-24.

Rottländer, R. C. A. "On the Mathematical Connections of Ancient Measures of Length" *Acta Praehistorica et Archaeologica* 7/8(1976/77)49-51.

Thom, Alexander "A Statistical Examination of the Megalithic Sites in Britain" *J. R. Stat. Soc. A.* 118(1955)275-291.

Thom, Alexander "The Megalithic Unit of Length" *J. R. Stat. Soc.* 125(1962)243-251

〃 〃 "The Larger Units of Length of Megalithic Man" *J. R. Stat. Soc.* 127(1964)527-33.

〃 〃 *Megalithic Sites in Britain* (Oxford, 1967).

Thom, A. and Thom, A. S. "The Carnac Alignments" *JHA* 3(1972)11-26.

〃 〃 *Megalithic Remains in Britain and Brittany* (Oxford, 1978).

Thom, A., Thom, A. S., and Foord, T. R."Avebury (1): A New Assessment of the Geometry and Metrology of the Ring" *JHA* 7(1976)183-192.

Williamson, J. B. "Megalithic Units of Length" *J. Arch. Sciences* 1(1974)381-82.

Wood, John E. *Sun, Moon and Standing Stones* (Oxford, 1980; revised edition).