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Astronomical significance of prehistoric monuments in Western Europe

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[Plate 22]

The accuracy of megalithic man's linear measurements is shown by recent work in Orkney and Brittany. Everywhere his geometry is based on integral right-angled triangles. The Sun was observed at the solstices and equinoxes. The fact that the foresights for the latter show a declination of $+0.5°$ and not $0°$ proves that the year was divided into two equal parts. By similar analysis of other foresights the megalithic calendar has been established.

The evidence that the Moon was observed in its extreme positions is extensive but the most interesting sites are those which show the small perturbation of the inclination of the lunar orbit. To establish the necessary sight lines some method of extrapolation was necessary. The actual sectors used for this are found in Caithness and in Brittany. Alinements at Le Ménec perhaps provide an adjustment for the varying speed of the Moon in its orbit.

1. The megalithic yard in Brittany and Orkney

The results of our researches up to 1970 have been described in two books (Thom 1967, 1971). Here we propose to give briefly some results of the recent work done by the groups who worked with us in 1970, 1971 and 1972 in Brittany and Orkney.

It has been said that the megalithic yard (0.829 m) is simply the length of a man's step and that megalithic circles were set out by pacing. The megalithic culture lasted for a long time and it may be that the earlier circles were set out by pacing but undoubtedly at some time or another an accurate standard yard was established, and universally adopted. Anyone who takes the trouble to study and master the geometry of Avebury will see that it is inconceivable that the Avebury ring was set out by pacing (Thom 1967, p. 89).

Let us look at what we find in Brittany. The Ménec alinements consisted originally of 12 rows about a kilometre long. Most of the 1600 stones carry the re-erection mark and as the people who re-erected them had no knowledge of the original geometry, or indeed of any geometry, the stones are often badly displaced. In 1970 the parties working with us made the first accurate large, 1:500, scale survey of the site. A statistical analysis of the west end shows that the rows were set out originally with a quantum of $2\frac{1}{2}$ megalithic yards which will be called the megalithic rod. Each row started with a node on a line crossing the rows at 1 in 2. After the gap, where the stones have been removed from the agricultural land, we re-determined the quantum and the nodes. These nodes are shown in figure 1 relative to a transverse line. The figure also shows the nodes as brought forward by calculation (using a rod of 6.800 ft or 2.073 m) from the starting line at the west. Considering that the rows are over 900 m long the agreement is remarkable and cannot be due to chance. It disposes completely of the idea that pacing was used and it gives us a value for the megalithic yard of 2.721 ± 0.001 ft or 0.8294 ± 0.0004 m.

1600 km to the north in Orkney the Ring of Brogar gives us an almost identical value. The ring consists of tall flat stones forming a true circle obviously intended to be 50 rods in diameter. Using all the stones and stumps as they are today we find a mean diameter of 340.0 ± 0.6 ft (~ 103.7 m), or neglecting two stones known to have been re-erected 340.7 ± 0.4 ft (~ 103.9 m) so that the megalithic yard from the Brogar Ring is probably between 2.720 and 2.725 ft (0.829–0.831 m). For Britain as a whole I gave 2.720 ± 0.003 ft in Thom (1967). The above values speak for themselves. They could not have been produced by pacing.

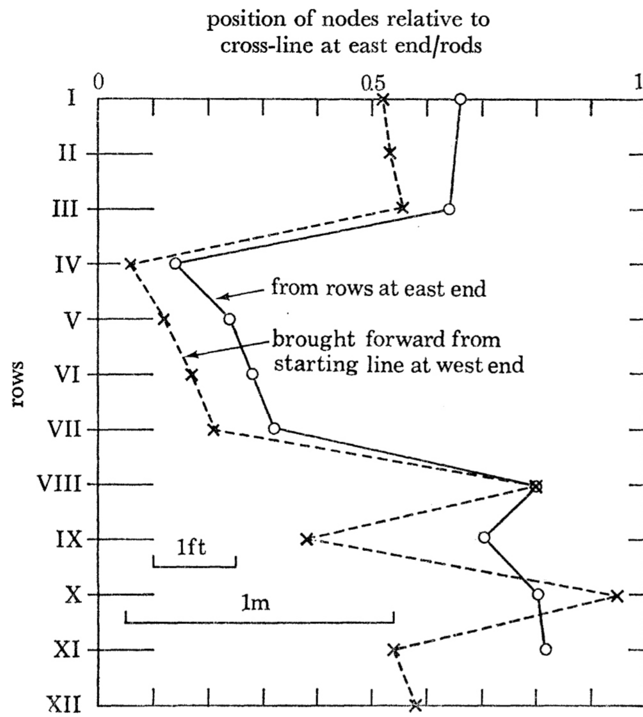

FIGURE 1. Displacement of the nodes in the Ménec rows after 900 m.

2. The astronomy of megalithic man

(a) General

It is necessary to be quite clear about the observing procedure, used by megalithic man at his lunar observatories, which was to observe the setting and rising Moon on two (or three) successive nights straddling the monthly declination maximum. On each night a stake was put in the ground showing the position from which the Moon's limb appeared to graze the foresight. Figure 2 shows on the left the stake positions A and B for 2 nights' observations and on the right at A, B and C for 3 nights' observations. To make the explanations simpler we shall assume that the observer, instead of working along a straight line across the line of sight, moved forward a constant distance $2a$ each night. His stake positions are then as shown at A′ and B′ (or A′, B′ and C′). These points lie on curves which are, to some scale, a graph of the lunar declination. The sagitta G is not constant but the change in 2 days will not effect the result. For three stakes it can be shown that the amount by which the stake B has to be advanced to make it correspond to the maximum declination is $\eta = p^2/16G$. This can be compared with the expression $\eta = p^2/4G$ for the two-stake case fully discussed in (Thom 1971). In both cases $2p$ is the distance between the first and last stakes. If G is assumed to be constant then only 2 nights' observations are required, and the value of $p^2/4G$ can be found using a grid or sector such as we find at six observatories, four in Caithness and two in Brittany. If R is the radius of the sector then,

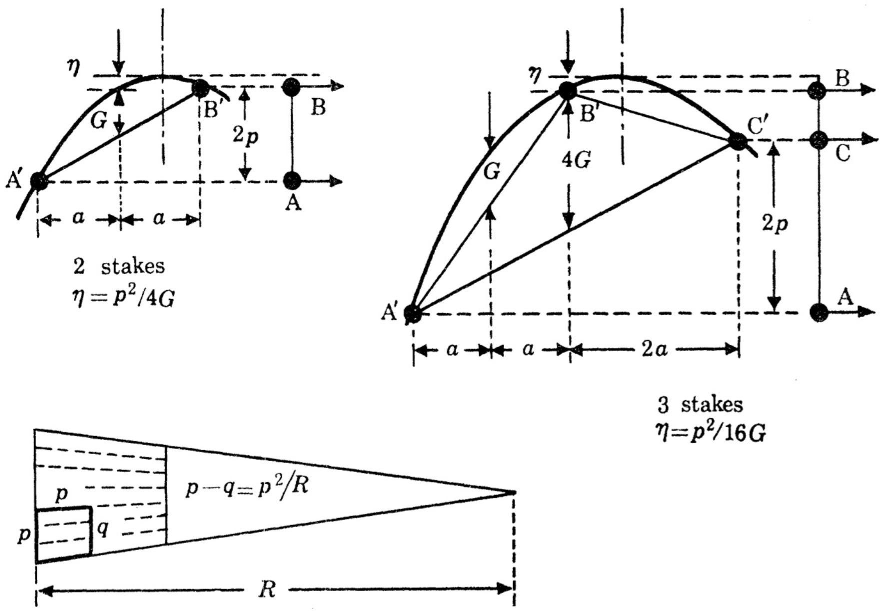

FIGURE 2. Extrapolating to the maximum from two or three observations.

referring to figure 2, by similar triangles $p - q = p^2/R$. Hence the radius R should be $4G$ for the two-stake and $16G$ for the three-stake case. Today when we know the distance to the foresight we can calculate G and so we can show that all the known sectors have approximately the correct radius for the two-stake case. Evidently at these observatories G was assumed constant from lunation to lunation. The three quantities, parallax, semidiameter and the sagitta G all rise or fall as the distance of the Moon from the Earth rises or falls. This distance goes through a cycle in an anomalistic month (perigee to perigee). If at a particular standstill perigee happened to coincide with the declination maximum (period = 1 tropical month), at the next standstill, 18.6 years later, perigee would be only 3 days behind the monthly declination maximum. This means that for several standstills megalithic man would make his observations at a time when the sagitta was nearly a maximum and only after 90 years would he find a minimum. If, for example, the Mid-Clyth sector was built between 1670 and 1570 B.C. then (Thom 1971, figure 7.2) we see that we ought to expect it to have a sector radius less than that calculated with a mean G. In fact the radius *is* low. This happens to lend some confirmation to the date of about 1600 B.C. found at the only reliable solstitial site so far examined in Caithness, namely that at Cnoc na Maranaith (map reference 132332).

(*b*) *Brogar, Orkney*

Figure 3, plate 22, shows the Brogar site from the air. Three of the cairns close to the Ring can just be seen. We made a tacheometric survey (with levels) of the whole site and carefully measured the profiles of the hills in the directions indicated by the cairns. A small-scale copy of this survey will be found in Thom (1973). The azimuths were carefully measured from the centre so that the declination indicated by the notches on the profiles could be estimated from any point on the survey. An examination of figure 4 shows that we are here dealing with a lunar observatory of a most remarkable nature. No less than three natural foresights were used, one for the major standstill and two for the minor (rising and setting). Backsights still remain, showing for each foresight three of the values of $\pm(\epsilon \pm i \pm s \pm \Delta)$ where ϵ is the obliquity of the

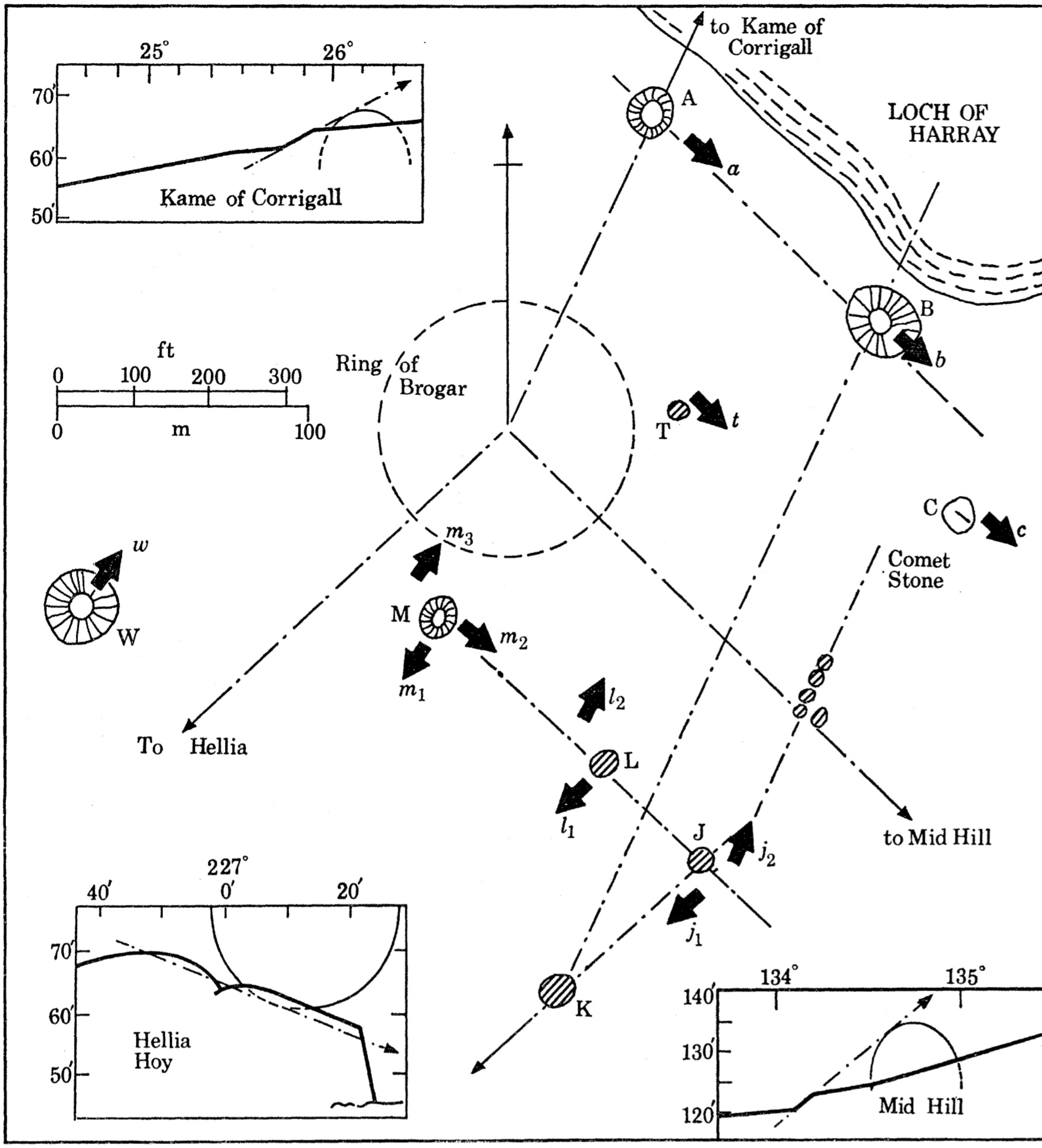

FIGURE 4. Survey of Brogar Ring and cairns: B, W, cairns or mounds about 4.25 m high; A, M, despoiled cairns now about 1.8 m high; C, low mound with Comet Stone oriented on Mid Hill; T, mound recorded in 1849 (Thomas 1851) but not noticed in 1972. The other eight mounds are all low but definite. Arrow heads show the positions which an observer would ideally have occupied to obtain the declinations listed below:

a and b	declination =	$-(\epsilon-i+s)$	on Mid Hill
m_2		$-(\epsilon-i-s-\Delta)$	
t		$-(\epsilon-i)$	
j_1		$-(\epsilon-i)$	on Hellia notch
l_1		$-(\epsilon-i+s-\Delta)$	
m_1		$-(\epsilon-i+s)$	
m_3		$+(\epsilon+i+s-\Delta)$	on Kame of Corrigall
l_2		$+(\epsilon+i+s)$	
j_2		$+(\epsilon+i+s+\Delta)$	

FIGURE 3. The Ring of Brogar from the air.

(Facing p. 152)

ecliptic, i is the inclination of the lunar orbit, s is the Moon's semidiameter and Δ is the small perturbation found by Tycho Brahe. It is not yet possible to be certain which point on the Hellia profile was intended to be used, but fortunately there are no alternatives at Kame of Corrigall. Taking mean values for i, s and Δ we are able to deduce that the obliquity of the ecliptic which best fits the foresights is about 23° 52.9′ (1570 ± 100 B.C.). This enables us to estimate where the observer should have ideally placed the backsights for various combinations of ϵ, i, s and Δ. These positions are shown on the figure by broad arrow heads. It will be seen that in all cases the arrows lie close to one or other of the cairns. The arrows for the cases not shown lie either in the cultivated land to the north, where the smaller cairns would have been ploughed out, or else in Loch Harray.†

The ground at the site rises somewhat irregularly from the shore to the ridge on which the three cairns M, L and J are situated. The level ground at the top provided the necessary freedom of movement for the observer or observers ranging themselves into positions so that the Moon grazed the foresight at Hellia, and 9.3 years later at Kame of Corrigall. When Mid Hill was being used the observer perhaps moved along a line from near M to near A. The Comet Stone is orientated on the foresight but it may have been a warning stone and it is not clear yet why it was not placed further back. The foresights are from 6 to 13 km distant so that the errors shown in the position of the backsights are, in declination, very small (mostly less than a minute). It is remarkable how much of this site has survived. A modern tractor plough could remove all trace of the smaller cairns in a single season. It is little wonder that we have so much difficulty in understanding many of the other Western European sites situated on arable land or near buildings.

(*c*) *Brittany*

In figure 5 we see the immediate neighbourhood of the Carnac alinements and some of the nearby menhirs. The 6.1 m high menhir M on the hill top at Manio would, in the absence of the trees which now surround it, have been visible from all round. We have now run long accurate traverses from M through the woods in various directions and so determined that accurate lunar and solar declinations are given by M as viewed from a number of marked sites details of which will be found in figure 5. On the large-scale map there are stones at Keriaval and these also appear to give lunar declinations with M.

But evidently this observatory was not considered satisfactory. Perhaps some of the lines were too short and the terrain prevented them being lengthened. Whatever the reason the Manio site was replaced by the huge lunar observatory centred on Er Grah or Le Grand Menhir Brisé, the largest artificially cut and dressed stone in Europe. The position of this stone, now fallen and broken in four parts totalling some 340 tons, is shown in figure 6. It is placed so that there were level positions for observing at rising and setting all four cases of $\pm(\epsilon \pm i)$, but whether these were all completed we do not know. There are stones in the right place at Kerran, Kervilor, Le Moustoir and Quiberon, and suitable extrapolating sectors at Petit Ménec and St Pierre. We failed to find anything like a backsight near St Pierre until in 1972 we came upon a large menhir lying on the beach near high tide mark. The gradually rising level of the sea has cut into the land leaving the menhir where it slid down from its original position. Careful

† Some accurate check measurements made in Orkney in 1973 show that the foresights at Brogar do not behave as two-dimensional silhouettes when the observer changes his position. Consequently the arrows in figure 4 may be somewhat displaced. It is proposed to make measurements from each backsight independently.

We also found traces of another cairn as shown on the Ordnance Survey at the intersection of the lines KB and MJ.

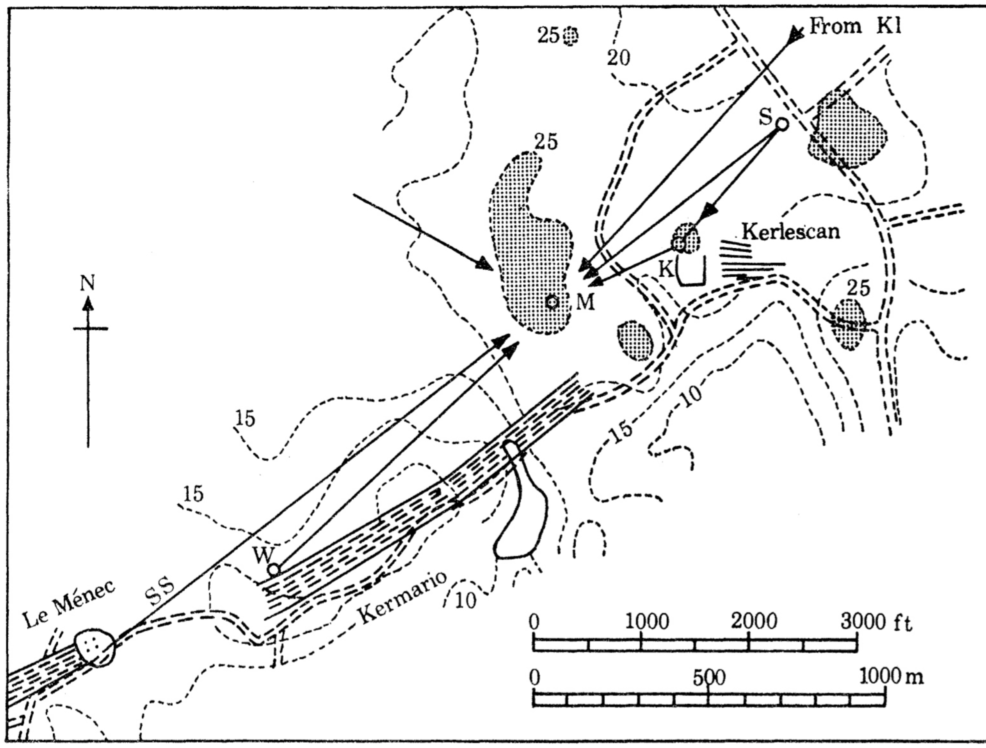

FIGURE 5. Position of menhir at Manio relative to the Carnac alinements. M, menhir at Manio 6.1 m high; S, menhir (2.75 m) to M gives solar declination at winter solstice; Kl, small menhir near Kerlagad to M gives lunar declination; W, group of fallen menhirs close to the alinements to M gives lunar declination; SS, inside Le Ménec east cromlech to M gives solar declination at summer solstice; K, menhir (3.7 m) to M gives a calendar date; and S to K, gives a lunar declination.

calculation based on the large scale map shows it to be in the correct position but this remains to be verified by actual astronomical observations in 1973.

Megalithic man could not have built and operated for many years an observatory of this size and accuracy without noticing the effects of the changes in G. We suggest that his natural reaction was to build a sector longer than normally necessary, such as we find at Petit Ménec. If G were determined at each lunation there would always have been a sufficient length of sector. But to find G necessitated observations on three nights and so presumably the next step was to make use of these three observations directly. The length of the Ménec alinements up to the bend is $16G$ for two of the nearby backsights and the base width at the west end is close to $4G$, the greatest value of $2p$ normally needed. Perhaps at first there was a single sector here, of radius $16G$, built of the larger stones which now form the west end of the lines. But it was almost certainly standard procedure to use for some of the observations the technique of having an observer for each limb and it is possible that the fact that the distance between the two, i.e. the ground equivalent of the Moon's diameter, was approximately equal to $4G$, led the observers to combine these two lengths by taking an average. We know today that this was theoretically wrong but it seems that megalithic man did evolve a peculiar empirical method using the average and in Thom (1972 *b*) it is shown that Le Ménec alinements can be used with this method to give the required extrapolation distance with sufficient accuracy. Here, without going into detail, we shall simply show the remarkable relation which emerges from the analysis of the Ménec rows.

Let the distances of a row from AB (figure 7) at the west end and at the bend be a and b. It is

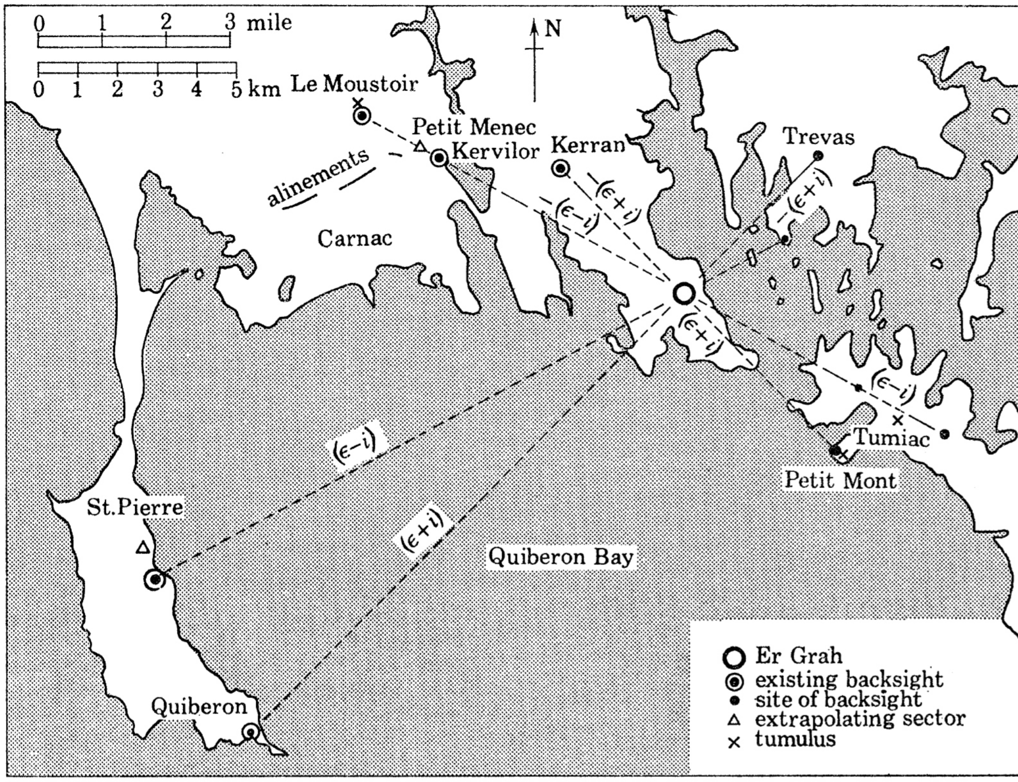

FIGURE 6. Le Grand Menhir Brisé (Er Grah) as a universal lunar foresight.

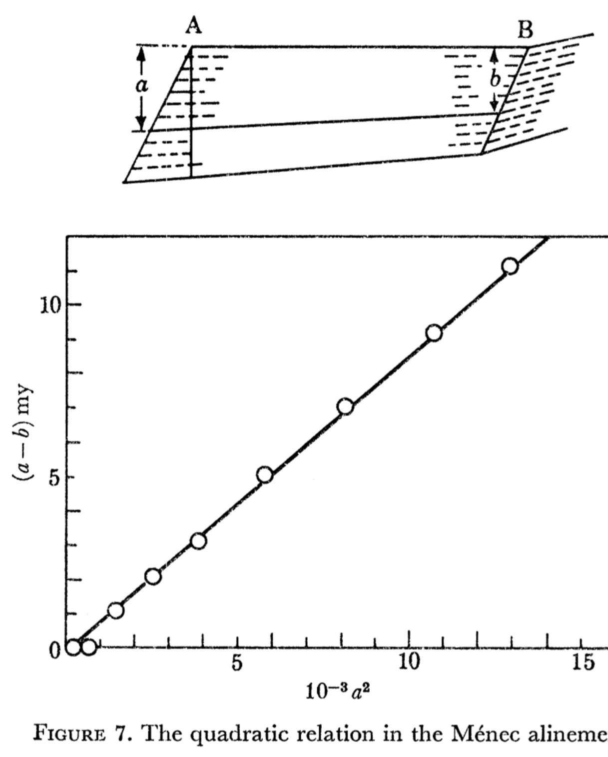

FIGURE 7. The quadratic relation in the Ménec alinements.

shown in the figure that $(a-b)$ is closely proportional to a^2. It should perhaps be said that the statistically determined dimensions of the rows had been sent to the editor of the *Journal for the History of Astronomy* before we noticed the above remarkable quadratic relation which led to the discovery of a method whereby the Ménec alinements could have been used to find the extrapolation distance of any of the four backsights to the west of the Sea of Morbihan. It is suggested that the rows at Le Ménec replaced the simple sectors at Petit Ménec and St Pierre.

(*d*) *Pre- and post-standstill observations*

It is useful to speculate about the methods used by megalithic man at the observatories as the standstill approached. He must have started observing many months before the standstill. At each declination maximum he would establish a position on the ground marked by a stake. The position of these stakes would oscillate with a period of 173 days and an amplitude corresponding to 9′ (Δ). This would of course be superimposed on the gradual rise in declination towards the standstill maximum. I have elsewhere suggested how the observers may have made use of several oscillations occurring before and after the standstill. Observations of these oscillations could have indicated the date of the standstill and how this date was related to the time of the nearest oscillation maximum. Whether this suggestion be substantiated or not the fact remains that at 5 of the known lunar observatories there are extra menhirs so placed as to give a declination about half a degree less than the maximum. Thus the large menhir 200 m to the northwest of Le Ménec village gives with the Manio stone, a declination 29′ below $(\epsilon-i-s)$ and the huge menhir called Goulvarh near Quiberon, shows a declination 27′ below $(\epsilon+i-s)$. There are also extra stones showing declinations below $(\epsilon+i)$ at Temple Wood, Mid Clyth and Yarrows (Thom 1971, pp. 50, 94 and 99).

3. Conclusion

A criticism made of our work is that we failed to produce statistical evidence that megalithic man actually observed the lunar perturbation. It seems to us that the testimony of the Brogar cairns, backing up what we find at Mid Clyth and Temple Wood, is such that it cannot be gainsaid. If this evidence be accepted then it is legitimate to analyse the combined material from the 25 sites as given in my book. This analysis shows among other things that the sites yield a mean value for i the inclination of the lunar orbit of 5° 08′ 52″, very close to the modern value of 5° 08′ 43″.

The conclusions must be that we are dealing with the work of a people who had come far in the application of scientific method to astronomical problems. How many more of their achievements remain to be brought to light when we get rid of our prejudices and make a scientific attack on the evidence scattered over all NW Europe in tumuli, cairns, menhirs, petroglyphs, etc.? There is so much to be done, and there are so few people with the ability to make the necessary measurements.

References (Thom)

Thom, A. 1967 *Megalithic sites in Britain*. Oxford: Clarendon Press.

Thom. A. 1971 *Megalithic lunar observatories*. Oxford: Clarendon Press.

Thom, A. & Thom, A. S. 1971 The astronomical significance of the large Carnac menhirs. *J. Hist. Astron.* **2**, 147–160.

Thom, A. & Thom, A. S. 1972*a* The Carnac alignments. *J. Hist. Astron.* **3**, 11–26.

Thom, A. & Thom, A. S. 1972*b* The uses of the alignments at Le Ménec, Carnac. *J. Hist. Astron.* **3**, 151–164.

Thom, A. & Thom, A. S. 1973 A megalithic lunar observatory in Orkney. *J. Hist. Astron.* **4**, 111–123.

Thomas, F. W. L. 1851 *Archaeologia* **34**, 88–136.