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THE USES OF THE ALIGNMENTS AT LE MENEC CARNAC

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1. *Introduction*

In the second of the two previous papers in this series,[1] we analysed an accurate large-scale survey of Le Menec alignments and showed that these had been set out originally with remarkable accuracy to a definite geometrical design. The sheer size of the project and the great care taken in the design and execution shows that the erectors attached great importance to the scheme. The site was chosen by the erectors to be in a position central to the four backsights (see Thom I and Figure 1) for observing the Moon rising on Er Grah at the stand-stills. Thus there is almost a certainty that these two huge engineering projects at Le Menec and Er Grah (Figures 3 and 4) are related. We now show that the layout of Le Menec alignments was such that they provided, for four of the backsights, a means of extrapolating to the position on the ground corresponding to the declination maximum from observations made on three successive nights. We cannot be certain that we have interpreted exactly the builders' intentions, but we show a method which *could* have given a sufficiently close approximation to the ideal extrapolation distance.

2. *Method of Observing*

Briefly, the observing procedure was for a man to get into such a position that to him one edge of the Moon as it rose (or set) appeared to graze the foresight several miles away, in the present case the huge menhir Er Grah. This position was marked by a stake. The observation was repeated on several nights around the monthly declination maximum that occurred nearest to one of the extreme positions of the Moon, *i.e.*, when the declination was $\pm (\epsilon \pm i)$, ϵ being the obliquity of the ecliptic and i the inclination of the Moon's orbit. The object was to find where the stake would have been, had the maximum coincided with the time of observation. In general the maximum would occur between two observing times, and so would be missed. The problem was then to find this maximum stake position from the positions obtained on two or perhaps three nights.

A Megalithic lunar observatory such as that we believe to have been centred on Er Grah would have been useless for obtaining the data necessary for eclipse prediction unless there was some method of making this extrapolation. We have shown in Thom II that the sectors at Petit Menec and at St Pierre were perhaps used for making the extrapolation from two nights' work. N. I. Bullen drew our attention to the fact that the eccentricity of the lunar orbit may sometimes have produced considerable error in the simple sector method of extrapolation, especially if it were used for the three-night case. But if the sector were made some 25% larger than normal, then an adjustment could be made on each occasion when it was used. Perhaps this was realized by the builders of Petit Menec which at first sight appears to be too long (Thom I, p. 156). But Petit Menec is the only sector so far known to us which is definitely *over length*. We

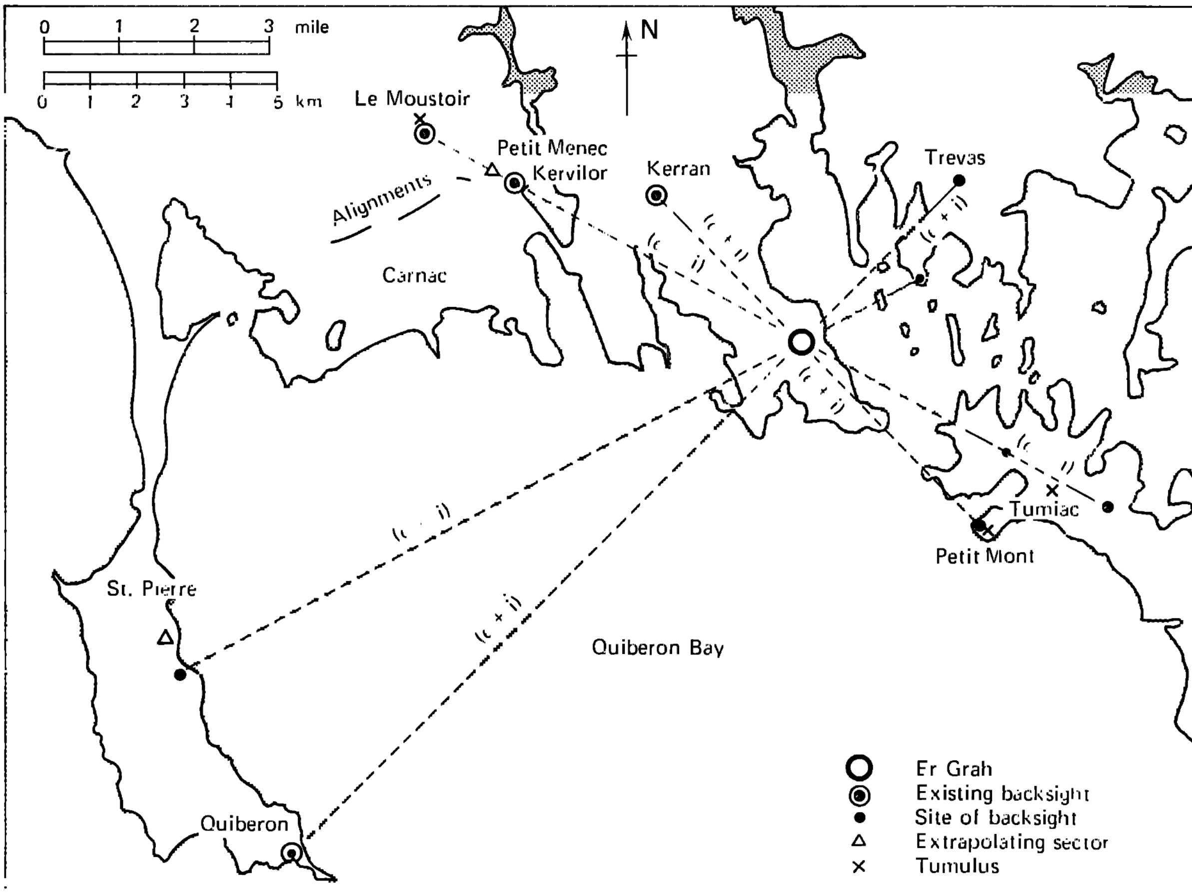

FIG. 1. Er Grah as a universal foresight.

shall examine the great alignments at Le Menec to see if they could have been intended to provide a method of extrapolation which would apply on every occasion.

3. *Outline of the Simple Theory*

At the right-hand side of Figure 2 the stake positions for three consecutive nights are shown at 1, 2, and 3. The observer would have remained on this line but for clarity of explanation we shall assume that he moved forward each night a constant distance a towards the foresight. We then get the positions as shown on the left of Figure 2, and if we assume that the distance a represents one day, then the curve (to some scale) shows the lunar declination plotted on time. In so far as the curve may be taken as parabolic the sagitta, marked $4G$, is constant along the curve. We have put the sagitta equal to $4G$ because G is then the sagitta for the shorter chord extending over one day instead of two. This convention is in keeping with the two-stake problem in *Megalithic lunar observatories*[2] and Thom I. Since $4G$ is the distance from Stake 2 to the point

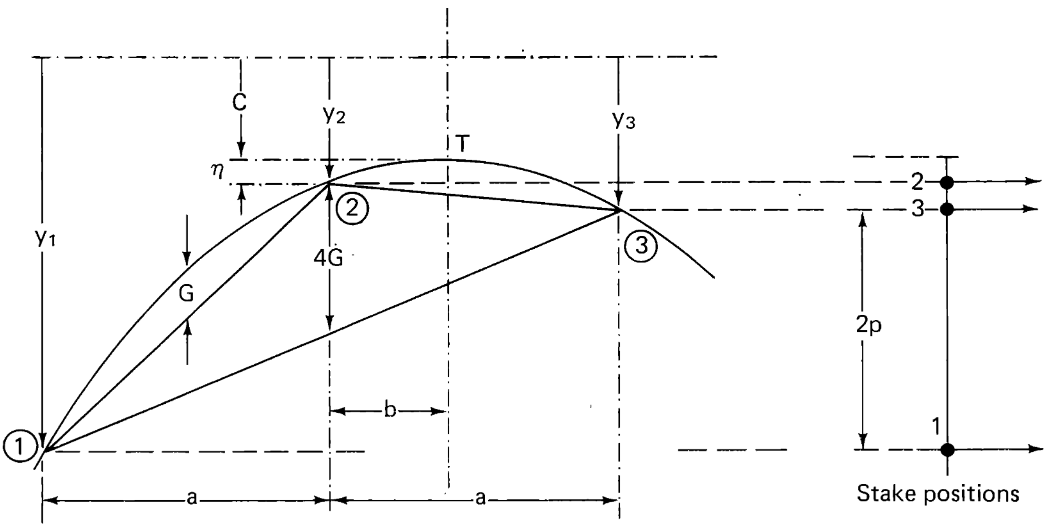

FIG. 2. The ground equivalent of the declination near a maximum. The stake positions on the right represent the situation where the observer does *not* step forward each day.

midway between Stakes 1 and 3, it can easily be found by the observer. G however is affected to some extent by the speed of the Moon in its orbit, and the changes in G would eventually have been noticed. The lunar parallax and G vary together (but not linearly), each having its maximum value at perigee. But perigee can happen *at* the declination monthly maximum *at* the standstill only at long intervals, and so to decide that G was not constant would have needed a long series of observations extending over perhaps a century.

The sectors that are found in Caithness in Scotland and at Petit Menec and St Pierre are probably for extrapolating from two nights' observations. But the converging rows at Le Menec are much too long in radius to be used in this way. We shall now examine what would happen if Le Menec were used in some way for extrapolating from observations made on *three* successive nights instead of two.

Suppose that the middle observation (2) was made b lunar days (see Figure 2) before the declination maximum at T. The time interval b was always less than half a day; if it were greater, *i.e.* if $y_2 > y_3$, then the observations at (2), (3) and (4) (not shown) would be used.

Defining y_1, y_2 and y_3 in Figure 2 as distances from an arbitrary zero and assuming the curve to be parabolic, we have

$$\begin{aligned} y_1 &= C + K(a^2 + 2\,ab + b^2), \\ y_2 &= C + K\,b^2, \qquad (1) \\ y_3 &= C + K(a^2 - 2\,ab + b^2). \end{aligned}$$

We want to find the distance η that the centre stake (2) has to be advanced to bring it up to the unknown maximum position T.

Evidently $$\eta = y_2 - C = K\,b^2. \qquad (2)$$

FIG. 3. Er Grah at a distance (below) and, partially, in close-up (above).

Solving the equations, we find

$$\eta = p^2/16G, \qquad (3)$$

where $2p = y_1 - y_3$ is the distance between the stakes for the first and third nights and G is the distance *on the ground* corresponding to the declination deficiency half a lunar day before or after the maximum, i.e. $\frac{1}{4}\, Ka^2$. Equation (3) can be compared with the expression $\eta = p^2/4G$ in paragraph 8.4 of *Megalithic lunar observatories.* Armed with $16G$ and p, the Megalithic astronomer could have used a geometrical construction to find η, but if he used (for example) the sector method he would have needed a new length of sector for every lunation.

4. *Theoretical Value of the Sagittas* g *and* G

Let g be the *declination* deficiency half a lunar day before or after the maximum. (For our purposes a lunar day is the time interval between two successive observing times.) The simple method of estimating g adopted in *Megalithic lunar observatories* is not sufficiently accurate for dealing with the three-night case, and accordingly N. I. Bullen undertook an accurate evaluation. He calculated that at the major standstill g = 13·66 arc minutes, and at the minor 8·29. Both of these are larger than the values in *Megalithic lunar observatories* and in Thom I.

It can be shown that g is not constant from lunation to lunation but varies inversely as the fourth power of the radius vector (r) of the Moon from the Earth. Let r_0 be the mean value of r and e the eccentricity of the orbit. Then r varies between $r_0\,(1-e)$ and $r_0\,(1+e)$, where $e = 0{\cdot}0549$. In §3 we have put G as the ground equivalent of g, *i.e.*, the shift in the observer's position corresponding to a declination change of g. We can obtain G by multiplying the angle g by the distance D to the foresight and by $\partial A/\partial\delta$ (A azimuth, δ declination). Taking D in kilometers we obtain the mean value G_0 of G in megalithic yards (my) as

$$\text{major standstill: } G_0 = 4{\cdot}79\; D\; \partial A/\partial\delta \text{ my}, \qquad (4)$$

$$\text{minor standstill: } G_0 = 2{\cdot}91\; D\; \partial A/\partial\delta \text{ my}. \qquad (5)$$

We shall write $r = 1 + \alpha$, where $-e < \alpha < +e$, and we shall assume that for this investigation it is sufficiently accurate to write $(1+\alpha)^n = 1 + n\alpha$. Then we have

$$G = G_0\,/\,(1+\alpha)^4 = G_0\,(1 - 4\,\alpha). \qquad (6)$$

Put L as the ground equivalent of the Moon's apparent diameter; that is, L is the distance between two observers, one using the upper limb and the other the lower limb (where upper and lower refer to declination and not to altitude). Taking the mean diameter of the Moon to be 31 arc minutes, we find the mean value of L to be

$$L_0 = 10{\cdot}9\; D\; \partial A/\partial\delta \text{ my},$$

and since L varies inversely as the distance r,

$$L = L_0\,/\,(1+\alpha) = L_0\,(1 - \alpha). \qquad (7)$$

The ratio $L_0/4G_0$ we shall call Q and this is the same as the Moon's apparent angular diameter (31 arc minutes) divided by $4g$.

FIG. 4. A view of Le Menec alignments.

We thus have

$$\begin{aligned} &\text{for major standstill:} \quad Q = 31/(4\times 13{\cdot}66) = 0{\cdot}57, \\ &\text{for minor standstill:} \quad Q = 31/(4\times 8{\cdot}29) = 0{\cdot}94. \end{aligned} \tag{8}$$

The positions of the four sites using Er Grah as a foresight for the rising Moon at the standstills are shown in Figure 1. Numerical particulars for these sites are given in Table 1, and it will be seen that the values of $4G_0$ for Kerran and Kervilor are roughly equal. The value at St Pierre is twice that at Kervilor, while that at Quiberon is rather less than four times the value at Kervilor or Kerran. The stone at Quiberon is just above the south shore, presumably placed there to get it as far away from Er Grah as possible in an attempt to make the ratio exactly 4. This would have made the work at the extrapolation centre easier than it would have been with a non-integer.[3]

TABLE 1. $\partial A/\partial\delta$ and $4G_0$ calculated from Latitude, Altitude and Declination.

	Lat.	Alt.	Declin.	Azimuth	$\partial A/\partial\delta$	D km	$4\ G_0$ my
Kervilor	47° 35′·2	− 01′	− 18° 45′	118° 54′	1·603	7·45	139
St Pierre	47° 30′	00′	+ 18° 45′	62° 04′	1·586	14·9	275
Kerran	47° 35′·9	+ 03′	− 29° 03′	136° 45′	1·892	4·1	149
Quiberon ..	47° 28′·4	+ 03′	+ 29° 03′	44° 46′	1·838	15·5	546

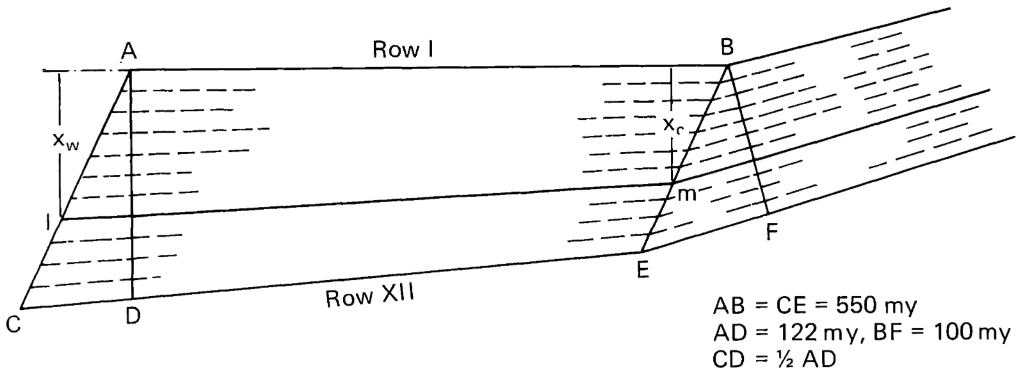

FIG. 5. Diagramatic arrangement of Le Menec alignments.

5. *The Menec Alignments*

Figure 5 shows diagramatically the geometry of the rows as determined statistically in Thom II. The principal dimensions are given on the Figure.

It will be remembered that for the extrapolation distance we had $\eta = p^2/16G$, and so an extrapolation sector ought to have a maximum radius of $16G$. But the radius to which Le Menec rows are set out is much larger than the largest value of $16G_0$ from Table 1. Nevertheless the main dimension AB is close to $16G_0$ for Kervilor and Kerran, and one can imagine that AB formed an essential part in the original construction at Le Menec. $4G$ is the greatest value of p ever needed and the length of AC is approximately equal to $4G$ for Kervilor (compare with Mid Clyth where the base of the sector is about one quarter of the maximum radius). Let x_w and x_c be the distances of row lm from AB at l and m (Figure 5). The values of x_w and x_c as found in Thom II are given in Table 2. The fourth column shows $Z = x_w - x_c$, and Figure 6 shows this quantity plotted on x_w^2 and also on x_c^2. The approximate quadratic relations are obvious but are

TABLE 2. The transverse distances of the rows from AB at the west end (x_w) and at the knee (x_c), and functions of these.

Row	x_w my	x_c my	$Z = x_w - x_c$ my	$Z_w = 8{\cdot}5\, x_w^2 \times 10^{-4}$	$Z_c = 9{\cdot}9\, x_c^2 \times 10^{-4}$
I	0	0	0	0	0
II	8	8	0	0·05	0·06
III	16	16	0	0·2	0·3
IV	26	26	0	0·6	0·7
V	38	37	1	1·2	1·4
VI	50	48	2	2·1	2·3
VII	62	59	3	3·3	3·4
VIII	76	71	5	4·9	5·0
IX	90	83	7	6·9	6·8
X	104	95	9	9·2	8·9
XI	114	103	11	11·0	10·5
XII	122	110	12	12·6	12·0

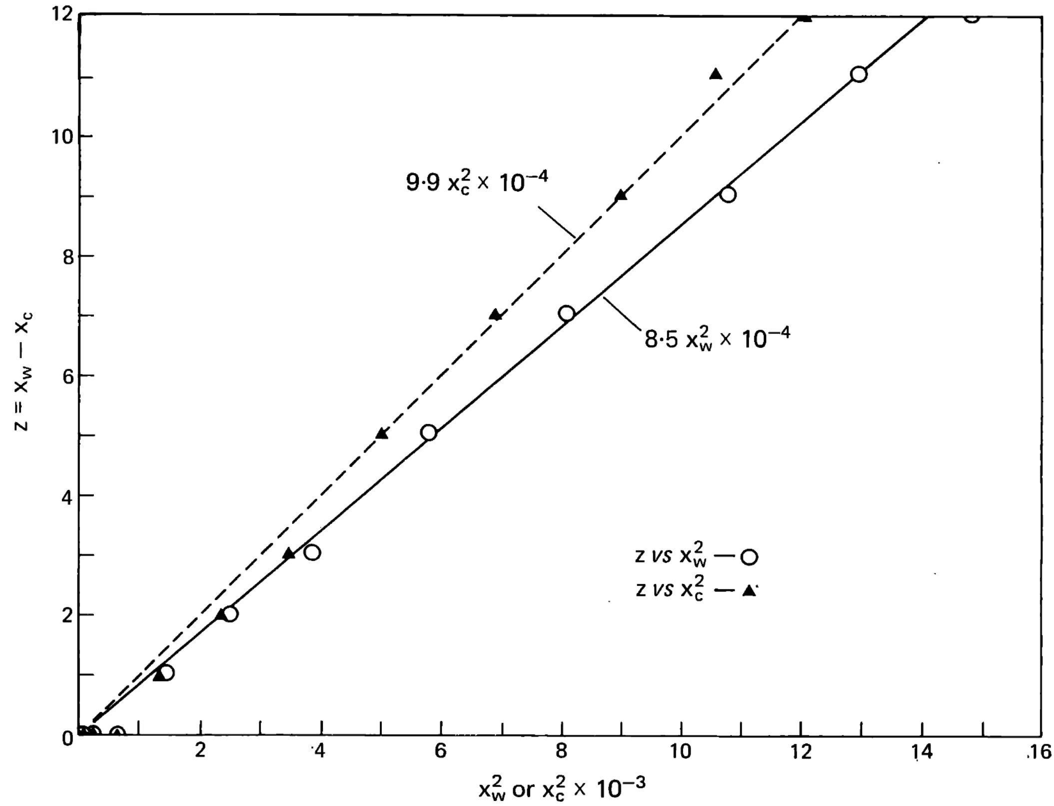

FIG. 6. The quadratic relation between x_w—x_c and x_w and between x_w—x_c and x_c.

brought out numerically in the fifth and sixth columns, which show

$$Z_w = 8{\cdot}5\ x_w^2 \times 10^{-4}\ \text{my} \tag{9}$$

and

$$Z_c = 9{\cdot}9\ x_c^2 \times 10^{-4}\ \text{my}. \tag{10}$$

It will be seen how closely Z_w, Z_c and Z agree. It ought to be mentioned that the quadratic relation was noticed after Thom II had been dispatched, so there is no possibility of the values x_w and x_c having been adjusted to suit in any way.

There can be no doubt about the square law but what does it mean? Let us try it out as a means of finding η at Kervilor, where $4G_o$ is 139 my. If 1 rod = $2\frac{1}{2}$ my, we get for mean conditions the true value

$$\eta = p^2/16G_o\ \text{my} = 0{\cdot}4\ p^2/16G_o\,\text{rods} = 7{\cdot}19\,p^2 \times 10^{-4}\,\text{rods}. \tag{11}$$

If we compare this with (9), we see that the value of Z in megalithic yards is roughly the extrapolation length η in rods. It thus appears that the alignments give an approximate value of η if the actual length of p is set off and Z is obtained for the row so found. It seems likely that the method of storing the value of η as the amount by which two rows of stones approach one another was an inheritance from the (presumably earlier) sector method, which had probably been taught to generations of practitioners. The above method also applies in this simple case to observations made at Kerran; for St Pierre we must divide the observed p by 2 and multiply the resulting η by 2. If we compare Equation (9) with Equation (11), we find that setting p along AD gives a result which is 18% too large. If, however, in Figure 5 or 7 we set out p along AC instead of AD we shall obtain a result about 7% too small. There is thus some line between AD and AC which will give the correct result for occasions *when* G *has its mean value* G_o. This gives a clue as to how the alignments may have been used. We shall follow up this clue.

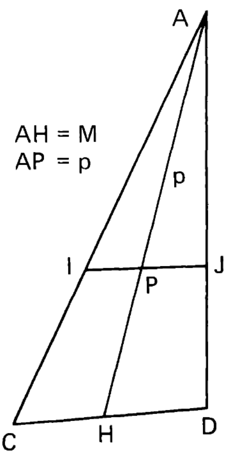

FIG. 7.

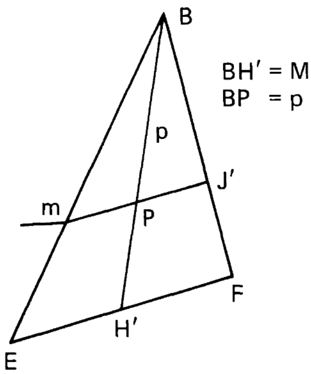

FIG. 8.

6. *Correcting for the Variation in* G

The advantage of using two observers, one for the upper and one for the lower limb (where "upper" and "lower" refer to declination and not to altitude), has been explained in *Megalithic lunar observatories* (pp. 47 and 108). Almost certainly this method would have been employed at all major observatories, and so we assume that at each observing period the headquarters at Le Menec would have had the following information brought in from the backsight position being used:

(1) the value of p,

(2) the value of $4G$,

and (3) the ground equivalent, L, of the Moon's diameter.

They would have noticed that $4G$ and L were roughly equal (*i.e.*, $Q \doteqdot 1$), but over the years they would have noticed that $4G$ varied more than L. Let us assume that they took the obvious step and used the average M of the values of $4G$ and L obtained at that lunation. We now calculate the result they would have obtained if they chose a point H on CD such that $AH = M$, and then measured p along AH to P (Figure 7). The values of x_w at P and the corresponding value of x_e could then be measured and the difference of these, Z (measured in megalithic yards), assumed to be the required value of η (in rods).

To find the result which this gives, we have to consider the effect of the eccentricity of the orbit on M.

We have from (6) and (7)

$$4G = 4G_o (1 - 4\alpha)$$

and

$$L = L_o (1 - \alpha).$$

M is the mean of these and so, using $Q = L_o/4G_o$, we have

$$M = 2\, G_o (1 + Q) \left(1 - \frac{4 + Q}{1 + Q}\, \alpha\right). \qquad (12)$$

For Kervilor $Q = 0{\cdot}94$ and $4\, G_o = 139$. Hence

$$M = 135\,(1 - 2{\cdot}55\, \alpha).$$

Now find a point H on CD (Figure 7) such that $AH = M$, and set off $AP = p$. Then move parallel to the rows or along a row from P to J on AD. The desired extrapolation length η is the value of Z corresponding to J, *i.e.*, to a value of x_w equal to AJ. Doing this by calculation, we have

$$AJ/AP = AD/AH \quad \text{and} \quad AD = 122\, my,$$

therefore

$$x_w = AJ = 122\, p/M$$
$$= 0{\cdot}905\, p\, (1 + 2{\cdot}55\, \alpha).$$

Z_w can now be found from Equation (9), and so if we take $\eta = Z = Z_w$, we have

$$\eta = 6{\cdot}96\, p^2 (1 + 5{\cdot}1\, \alpha) \times 10^{-4}. \qquad (13)$$

For comparison we have the true value of η obtained by using (11) with (6), namely

$$\eta = 7{\cdot}19\, p^2 (1 + 4\, \alpha) \times 10^{-4}. \qquad (14)$$

We see that (13) is a good approximation to the true value (14), and since it contains an approximate correction for α it will, for the larger values of α, be better than the value got by using G_o with the usual sector method. In fact this latter method can be in error by some 25% whereas (13) cannot at the worst be more than 10% wrong. Since the greatest η corresponds to about 8 arc minutes of declination, an error of 10% produces an error in declination of about 0·8 arc minutes. In general, the actual error will be much less than this, since η is normally much less than its maximum value. There were other anomalies producing errors over which Megalithic Man had no control; for example, the 9 arc minutes perturbation, the study of which we suggest motivated the whole scheme, does not have an absolutely constant amplitude, and atmospheric effects on refraction can be considerable. We see, however, that Le Menec alignments, if used as described above, were capable of giving the extrapolation length with all the accuracy required.

7. *The Other Sites: St Pierre, Kerran and Quiberon*

The demonstration given above makes use of the fact that Q is nearly unity, *i.e.*, that L_o and $4\, G_o$ are nearly equal. Since this is always true at the minor standstill, the method will apply to St Pierre provided that the factor of 2 is introduced. But for the backsights at Kerran and Quiberon, dealing as they do with the major standstill, Q is no longer near unity but is about 0·57. This invalidates the construction suggested above and some other method would have to be used. Let us try the effect of using the triangle *BFE* instead of *ADC*. Making the calculation for Kerran (with $4G_o = 149$), from (12) we have $M = 74{\cdot}5\ (1 + 0{\cdot}57)\ (1 - 2{\cdot}9\ \alpha) = 117\ (1 - 2{\cdot}9\ \alpha)$ my. *BF* (Figure 8) is almost exactly 100my, and if we put $BH' = M$ and set out p along BH' we have

$$BJ' = BF \times p/BH'$$

which becomes

$$BJ' = 0{\cdot}855\ (1 + 2{\cdot}9\ \alpha)\ p.$$

We see in Figure 6 or in Table 2 that Z is given approximately by $Z = Z_c = 9{\cdot}0\ x_c^2 \times 10^{-4}$ my, and if we assume that x_c was taken as being equal to the above value of BJ' then we find

$$\eta = Z_c = 7{\cdot}24\, p^2 (1 + 5{\cdot}8\ \alpha) \times 10^{-4}\ \text{my}. \qquad (15)$$

Comparing this with the true value, namely $6{\cdot}71\ p^2\ (1 + 4\ \alpha) \times 10^{-4}$, we see that if the rows were used in the manner suggested they would have given a reasonably accurate value for the extrapolation length.

If this were the method of use intended by the builders, it explains the peculiar bend in the rows at the knee. By shortening the perpendicular distance from *AD* to *BF*, *i.e.*, from 122 to 100, allowance was made for the lower value of Q at the major standstill. The reason for the similarity of (13) and (15) is that the ratio of $(1 + Q)$ at the minor standstill to $(1 + Q)$ at the major standstill is $(1 + 0{\cdot}94)/(1 + 0{\cdot}57)$ or 1·24, and $AD/BF = 1{\cdot}22$.

The algebraic demonstration in the preceding paragraphs obscures the difficulty which occurs when M approaches its minimum value. Actually it can, at infrequent intervals, become slightly less than *AD*. The operator could not have established H on the ground, but if he put $BJ' = p$ the error would have been small.

8. *The Accuracy Obtainable*

We give now an overall assessment of the errors produced by using the methods described above at all four sites, assuming arbitrarily that St Pierre was intended to be used with a factor of $F = 2$ and Quiberon with a factor of 4. Making the calculations as before and using Equations (4) and (5) but bringing in the factor F, we find for the minor standstill

$$\eta = 0{\cdot}099\ (1 + 5{\cdot}1\ \alpha)\ F p^2/k^2$$

where $k = D\partial A/\partial\delta$, while the true value is, by (6) and (11),

$$\eta_{\mathrm{T}} = (1 + 4\ \alpha)\ p^2/40G_o,$$

G_o being equal to 2·91 k. The ratio η/η_{T} is given by

$$\eta/\eta_{\mathrm{T}} = 11{\cdot}56\ F\ (1 + 1{\cdot}1\ \alpha)/k.$$

Similarly, for the major standstill

$$\eta/\eta_{\mathrm{T}} = 8{\cdot}39\ F (1 + 1{\cdot}8\ \alpha)/k.$$

α lies between $-\ e$ and $+\ e$. Using these values in the above equations, we obtain the limits shown in Table 3, which are also shown in Figure 9. It will be seen that, with the exception of Quiberon, the Menec rows always give a better

TABLE 3. The limits of the error in the extrapolation length η found by using the Le Menec rows in the way suggested.

Standstill	Site	F	$\frac{D}{F}\cdot\frac{\partial A}{\partial \delta}$	$\frac{\eta}{\eta_T}$
Minor	Kervilor	1	11·94	0·968 (1 $\pm$ 1·1 e)
Minor	St Pierre	2	11·86	0·975 (1 $\pm$ 1·1 e)
Major	Kerran	1	7·76	1·079 (1 $\pm$ 1·8 e)
Major	Quiberon	4	7·12	1·176 (1 $\pm$ 1·8 e)

F is the factor by which the lengths brought in from the backsights are divided and by which the results obtained at the alignments are multiplied to obtain the extrapolation length η. η/η_T is the ratio of the final value of η so obtained to the ideal value $0{\cdot}4p^2(1 + 4\alpha)/16G_o$.

value than the simple sector method, and we do not know that 4 was the factor used for the Quiberon site; $3\frac{1}{2}$ would have given a much better extrapolation length.

An objection which may be raised against the suggested method of using the rows is that it would be difficult because of the height of the stones to set out the length M from A to meet DC. It would however come to the same th ng if the length were set out from C to meet BA produced. In fact, provided one end is on AB and the other on CE, it is immaterial where the line crosses the rows, provided it is near the west end. The stones in the vicinity of the knee are smaller and would not prevent a rope of the necessary length being used there.

Another possible objection is that the rows are unnecessarily long and apparently no use was made of the fact that AB is approximately $16G_o$. Perhaps the site originally carried a simple sector of size $4G_o$ by $4G_o$ with radius $16G_o$ and centre at the knee. This might have been built of the large stones found at the west end where the sector could have stood. When the design was changed these stones would have been pulled into the new rows which were then completed with the smaller stones we find after the first 500 ft.

It will also be noticed that we do not yet know a reason for the long section from the knee to the east end.

The necessity to use a little algebra to demonstrate that the alignments could have been used to find the extrapolation length may have given the impression that in actual use the operations were complicated and difficult. To show that this is far from the truth, an explanation of the whole operation will be given using Kervilor as an illustration.

Two observers, we suggest, worked simultaneously, one for each limb, for three nights. One would always obtain a position some distance to the right of the other. The mean separation we have called L. Each observer established three stakes, 1, 2 and 3. The distance from Stake 2 to the point midway between Stakes 1 and 3 was then measured. This length ($4G$ of the analysis) was then compared with L and the average M taken (perhaps by doubling on itself a length of rope equal to the sum of L and $4G$).

The distance from Stake 1 to Stake 3 was then halved to obtain p. At Le Menec a rope of length M was then laid across the rows at the west end and moved until one end lay on Row I and the other on Row XII. The length p was then measured along the rope from the end on Row I. Suppose that the point

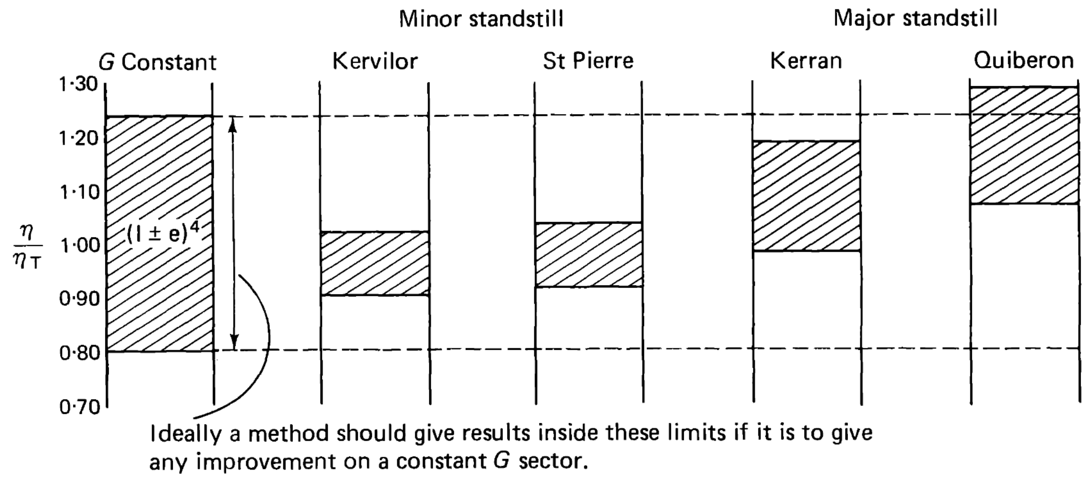

FIG. 9. Comparison of the suggested method of extrapolation with the result which would be obtained with a fixed sector (*G* constant).

so found was on or near Row IX. Then the amount by which this row came nearer to Row I in the stretch from the west end to the knee was measured and found to be 7my. This figure was then sent to Kervilor where Stake 2 had now to be advanced 7 rods, when it would mark the position corresponding to the maximum declination at that lunation.

It may be asked why this method was used when the theoretically correct method of using a sector of radius 16*G* was available. This latter method had perhaps been used at Petit Menec for the Kervilor site (Petit Menec is close beside Kervilor) for many standstills. But in the search for greater precision the observers may have started comparing 4*G* and *L*. They would have found that while *L* was usually slightly smaller than 4*G* it could occasionally be larger. They could not have explained this and so perhaps attempted to combine them. This would not have given good results on the simple sector, and so they were led to develop some other method. We know that they were wrong to combine *L* and 4*G*, but once they had taken this step the construction we find at Le Menec would have given a sufficiently accurate solution.

If the whole design was empirical, an enormous amount of work must have preceded its erection. Must we continue to believe that everything was entirely empirical? It seems much more likely that there was a sound geometrical knowledge behind it all, a knowledge which was extensive, confined to the privileged few, and never 'written down'.

9. *Conclusion*

A method is suggested whereby the extrapolation length can be found with sufficient accuracy for all four sites to the west of the Sea of Morbihan. We do not yet know if we have uncovered the exact method used by Megalithic Man, but the peculiar square-law relation shown in Table 2 cannot be the result of chance, and when we find that it gives approximately the extrapolation length for the mean value of G there can be little doubt that the rows were intended to be used with Er Grah in some such way as we have described. But to reduce the three-day observation case needed greater accuracy than could be obtained simply by using a mean G and so there must have been some method of allowing for the variations in G. It seems possible that we have found it.

Before rejecting the suggestions we have made as to how the rows were used, the reader should bear in mind the number of coincidences which exist at Le Menec. We have

(i) AB approximately equal to $16G_o$, the theoretical sector radius for Kervilor and Kerran;

(ii) AC approximately equal to $4G_o$ the greatest value of p needed;

(iii) $AD/AC = (1 - e)/(1 + e)$;

(iv) $AD/BF = (1 + Q_{\max})/(1 + Q_{\min})$;

(v) The square law shown in Table 3 gives a first approximation to η;

(vi) G_o is the same for Kerran and Kervilor and bigger by factors of 2 and 4 for St Pierre and Quiberon;

(vii) The alignments provide a method of allowing for variations in G for all four backsights.

The road from Le Menec past the Kermario rows seems, even today, to be heading straight for the high ground above Kervilor (Figure 1 of Thom I) and the road from what was a very small hamlet in the cromlech at Le Menec runs directly south, and so is making straight for St Pierre and Quiberon across the shallows which would in Megalithic times have been dry land. These are the routes along which the information might have been carried nightly to Le Menec from the backsights.

Acknowledgement

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REFERENCES

1. A. Thom and A. S. Thom, "The Astronomical Significance of the Large Carnac Menhirs", *Journal for the history of astronomy*, ii (1971), 147–160 (hereafter cited as Thom I), and "The Carnac Alignments", *ibid.*, iii (1972), 11–26 (hereafter cited as Thom II).

2. A. Thom, *Megalithic lunar observatories* (Oxford, 1971).

3. In a private communication, Monsieur Jean-Luc Quinio informed me that he has made inquiries of local people regarding the history of this stone. He finds that it was erected in its present position in 1928. He also inquired at Quiberon for any knowledge of menhirs along the line proposed by the authors for a backsight for Er Grah (see Thom I, p. 157). In a letter of 29 June 1972, he writes: "M. Jacques m'a dit qu'effectivement it avait fait des sondages dans la zone que vous m'indiquez et qu'il a ainsi retrouvé l'emplacement de plusieurs menhirs. Ces menhirs selon lui ont dû être concassés pour être utilisés comme pierres-de-taille pour les constructions environnantes. Il a trouvé près d'un des "trous" une clochette en bronze avec un grelot en fer, mais il n'a pas pu me la montrer car il ne sait pas où il l'a mise. Ces travaux ont eu lieu en 1942 je crois, et Monsieur Jacques n'a relevé aucun plan et la végétation interdit actuellement de faire un travail sérieux. Cependant, Monsieur Jacques m'a précisé que la ligne de menhirs correspondait à la ligne que vous avez tracée sur votre plan. Je suis allé avec un ami essayer de repérer quelquechose sur le terrain, mais c'est très difficile."