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# THE CARNAC ALIGNMENTS

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*Introduction*

In Figure 1 of our previous paper,[1] a key plan is given showing the arrangement of the Carnac alignments and some of the nearby large menhirs. It is shown there that solar and lunar backsights and foresights are to be found among these menhirs, and that the converging rows of stones at Petit Menec and at St Pierre probably form extrapolating sectors for use in making lunar observations with Er Grah (Le Grand Menhir Brisé). It seems possible that the main alignments were intended for the solution of some problem in connexion with the reduction of these observations, but before we can attempt to formulate the problem it is necessary to discover as much as possible about the geometrical layout of the sites. The present paper is a report of the stage reached in our analysis of the surveys made by the groups working with us in 1970 and 1971.

*The Stones at Carnac*

The man who has perhaps done more than anyone else for the antiquities of Carnac is Zacharie Le Rouzic (1864–1939). As a youth he was taught by a Scotsman, James Milne, whose brother Robert ultimately founded the Carnac Museum in James's memory. Le Rouzic, by this time director of the museum, with the help of peasants reerected the majority of the stones in the alignments, and those he set up he marked by a square plug of red cement. He tried to put the stones in their original positions, but in this he was only partially successful. Things are the more uncertain in that some stones were apparently reerected before Le Rouzic's time, and he may have been misled by these. Throughout whole areas of the alignments and cromlechs, every stone carries the red mark; in fact in some sections it is difficult to find stones not so marked. It is evident that practically all the stones have been down flat and the re-erectors, completely ignorant of the original design, may often have raised the wrong end. It follows that many stones may be displaced by their own length or more. One of the objects of our surveys was to attempt to recreate by statistical analysis the original design of the alignments.

A good small-scale survey of Kerlescan will be found in *Steinmale der Bretagne* by Werner Hülle,[2] and a slightly larger version in *Die Steine von Carnac* by the same author.[3] Our survey of Le Menec was plotted to a scale of 1:500 and is much too large to include here, but it is hoped that enough has been given to make clear the development of the reasoning on which the reconstruction is based.

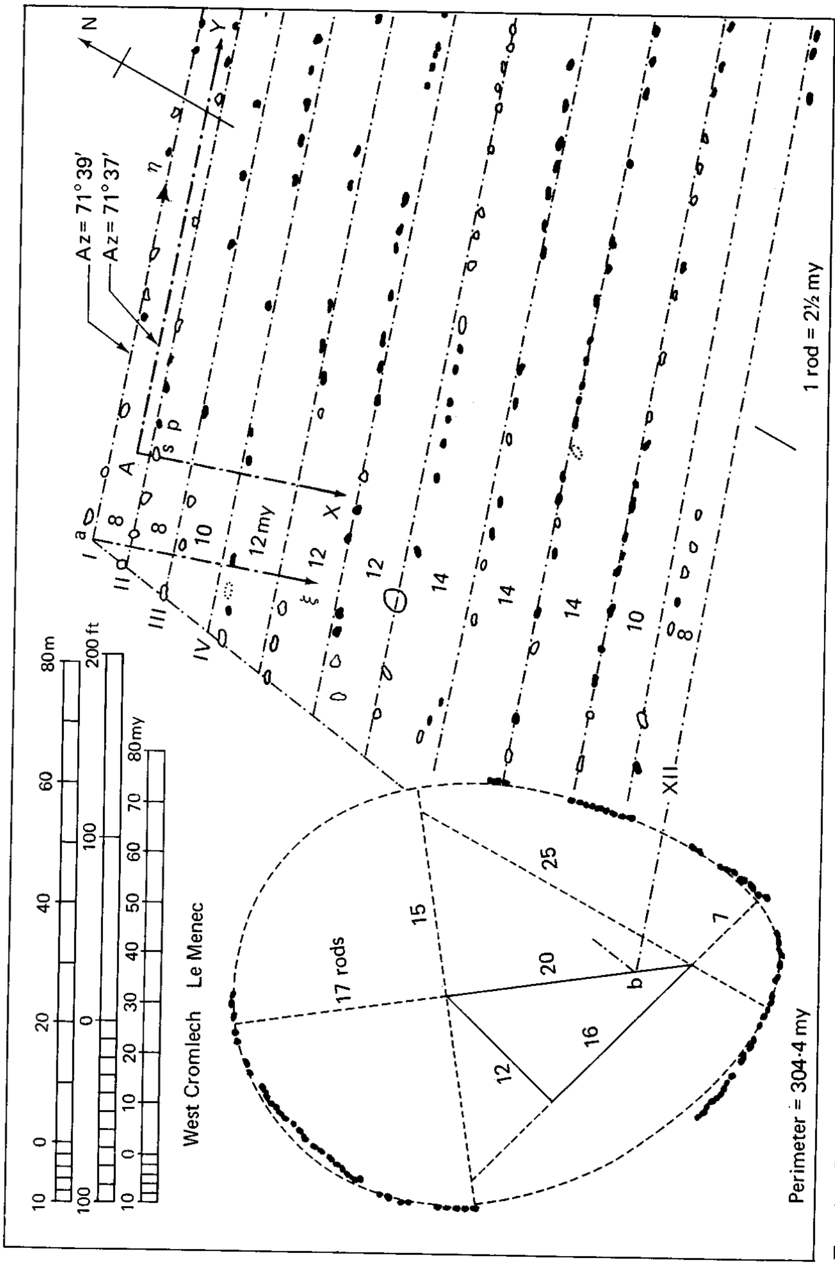



Fig. 1. Le Menec, West End. *A* is 9·4 ft and 18·7 ft respectively from the nearest corners of stones *s* and *p*. The line *AY* passes 11·5 ft north of the corner of an isolated stone 1203 ft from *A*. Triangle shown in full is that used at east end. The coordinates of *a* relative to *A* are −13·2 ft. −52·6 ft.

*Le Menec, West End*

The west end of the alignments at Le Menec is shown in Figure 1. It will be seen that the cromlech was laid out as a Type 1 Megalithic egg[4] based on a 3,4,5 triangle, with sides 15, 20 and 25 in terms of the unit $2\frac{1}{2}$ Megalithic yards (my). For convenience we shall call this the Megalithic *rod.* In Britain it is found that the perimeters of Megalithic rings are always integral multiples of the rod or very nearly so. The calculated perimeter of the cromlech at Le Menec is 304·4 my, low by only 0·2% from the ideal 305. (We found reerection marks on all the stones of the ring except four or five and the suggested construction passes through these.) This in itself indicates that the same units were used in Brittany and in Britain. We shall shortly deduce from the rows convincing evidence that the units were identical.

The 25 stones, which represent all that remains of the cromlech at the east end of Le Menec, are shown in Figure 4. The most northerly of these stones stands in a wall but is so completely buried in 10 ft-deep gorse that it is unapproachable in ordinary clothes and was difficult to survey. The shape of the cromlech is that of a Type II egg-shaped ring[5] based on a 3,4,5 triangle related to that at the west end in the manner shown in Figure 1. If further evidence is needed that this is the original shape, it is provided by the fact that the *calculated* perimeter is 370·0 my, an exact multiple of $2\frac{1}{2}$ my.

Our Le Menec survey was referred to a base line $AY$ so defined in Figure 1 that anyone can pick it up on the ground. The measurements ($y_0$) given[6] in Table A (not reproduced here) are referred to $AX$ as zero, $AX$ being normal to $AY$. The whole survey was controlled by closed traverses considered to be accurate to about 1 in 1500. Our surveying chains were compared almost daily with a steel tape kept in camp, and each chained line along the rows could, where necessary, be adjusted. The figures in Table A are taken from the field books except at one or two difficult places where a large scale plot was made and measured. Each value given is the mean chainage of the two 'ends' of the stone about 1 ft above ground level.

The hope is that a sufficient number of the stones are near enough to their original positions to give, overall, a reliable statistical result. We shall see that this condition is met, but had the disturbances been much greater nothing could have been done. It is essential that no further error be introduced by even small inaccuracies in the surveys.

*Distance apart of Stones in Alignments, West End of Le Menec*

The first task was to find if there was a significant quantum. For Le Menec west end, 1 my showed such relatively poor results that it was discarded in favour of 1 rod of $2\frac{1}{2}$ my. This proved so significant on all the rows that further work on Le Menec was concentrated on this unit.

Suppose that we mark off on the edge of a strip of paper, ticks spaced uniformly 1 rod apart, to the scale of the survey, and try to fit this to a row of stones. Perhaps in the less disturbed lines (*e.g.*, row IX) we shall find enough coincidences to suggest that this unit was indeed used. We do not expect to find stones 6·8 ft apart but twice, three or even four times this, with large gaps where stones have been removed. But this visual demonstration cannot decide

FIG. 2. Le Menec, looking east.

the matter: the disturbances have been too great. However, having chosen the best position for the strip of paper, transfer the ticks to the row or line. We shall call these points 'nodes'. What a full statistical analysis does is to tell us the probability level at which we can accept the quantum, and the most likely positions for the nodes. If the quantum needs a small adjustment a revised value will emerge.

Let us write the position of a stone along the line as

$$y = \beta + 2m\delta + \epsilon, \tag{1}$$

where $m$ is an integer, $2\delta$ is the quantum and $\beta$ is the unknown distance from the zero being used to the first node. The ideal or expected position of a stone is $\beta + 2m\delta$ and $\epsilon$ is the divergence of the stone from this position.

A full exposition of the statistical theory has been given by Broadbent.[7] The method of using the necessary formula for the determination of $\beta$, $2\delta$ and the probability level will be found in *Megalithic sites in Britain*, which also contains a graphical presentation of the probability level.

The engineers who set out the rows would naturally have started their measurements from some zero line crossing the alignments. It was expected that this line would be at right angles to the rows, but a preliminary analysis of each line separately showed that this was not the case. However, the accuracy with which $\beta$ for each line could be found (standard error $\pm 0{\cdot}2$ ft to $0{\cdot}6$ ft, see Table 1) proved to be such that it could be shown on the first analysis that the zero line lay at an angle of about 63°15′ to *AY*. The cotangent of this angle is 0·504, so that the starting point for each row seems to have been displaced

**TABLE 1.** Le Menec alignments: West end to centre. Analysis of the first 1200 ft to find quantum and nodes.

| Row | $y_1$ | $n$ | $\Sigma\epsilon$ | $\Sigma\epsilon^2$ | $\beta = \frac{1}{n}\Sigma\epsilon$ | $\sigma_\beta$ |
|---|---|---|---|---|---|---|
| I | +1·8 | 38 | +16·5 | 126·54 | +0·43 | ±0·30 |
| II | −2·4 | 39 | −4·6 | 124·38 | −0·12 | ·28 |
| III | +0·2 | 25 | +22·0 | 99·60 | +0·88 | ·40 |
| IV | +0·1 | 65 | +17·0 | 208·36 | +0·26 | ·22 |
| V | −2·7 | 53 | −17·7 | 178·41 | −0·33 | ·25 |
| VI | +1·2 | 51 | −25·8 | 222·10 | −0·51 | ·28 |
| VII | −1·6 | 69 | +10·4 | 260·82 | +0·15 | ·22 |
| VIII | −0·4 | 67 | +6·7 | 253·31 | +0·10 | ·24 |
| IX | +0·8 | 83 | −3·5 | 269·07 | −0·04 | ·22 |
| X | +2·0 | 62 | +5·1 | 214·32 | +0·08 | ·24 |
| XI | +1·9 | 7 | +4·1 | 18·54 | +0·59 | ·61 |
| XII | −2·3 | 17 | −5·9 | 69·71 | −0·35 | ±0·49 |
| Totals | | 576 | +24·3 | 2045·16 | | |

*Other totals:* $\Sigma m$ *46,806;* $\Sigma m^2$ *5,479,842;* $\Sigma y$ *318,295·2;* $\Sigma my$ *37,262,867·1.*

relative to its neighbour by half the space between them. It will be seen that the cut-off for rows I to V at the west end (Figure 1) follows closely the line drawn through *a* at a gradient of 2 in 1 to the row. Almost certainly this is the zero line from which the measurements started; they did not start at the other end.

It can be shown that unless the rows are equally spaced there can, in general, be only one straight line crossing the rows which will pick up a node on every line. The rows are *not* equally spaced. Only one straight cross line of nodes could in fact be found and the existence of this line shows that the spacing we assumed (Figure 1) for the 12 lines is that used by the builders.

After we had applied the above analysis to each row separately, it occurred to us that a severe overall check would be obtained if, instead of treating each line separately with its own nodal positions, we took the figures for all 12 lines

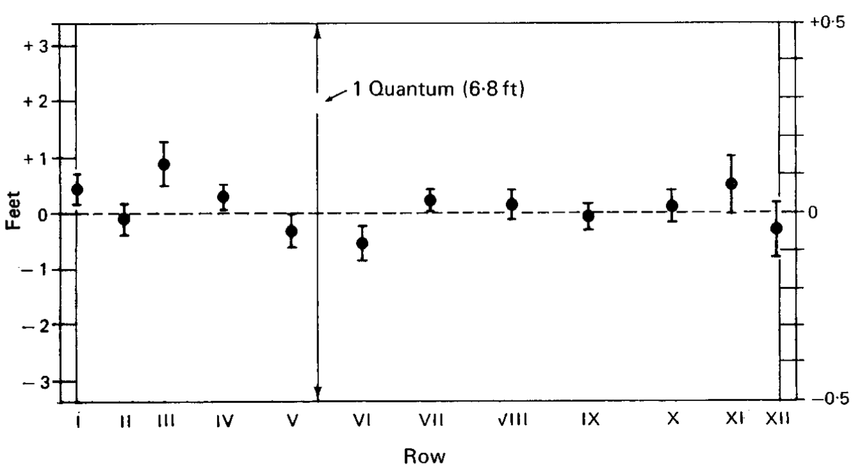



**FIG. 3.** Graphical representation of results given in Table 1, showing how closely the statistical nodes lie on the line defined by Equation (2).

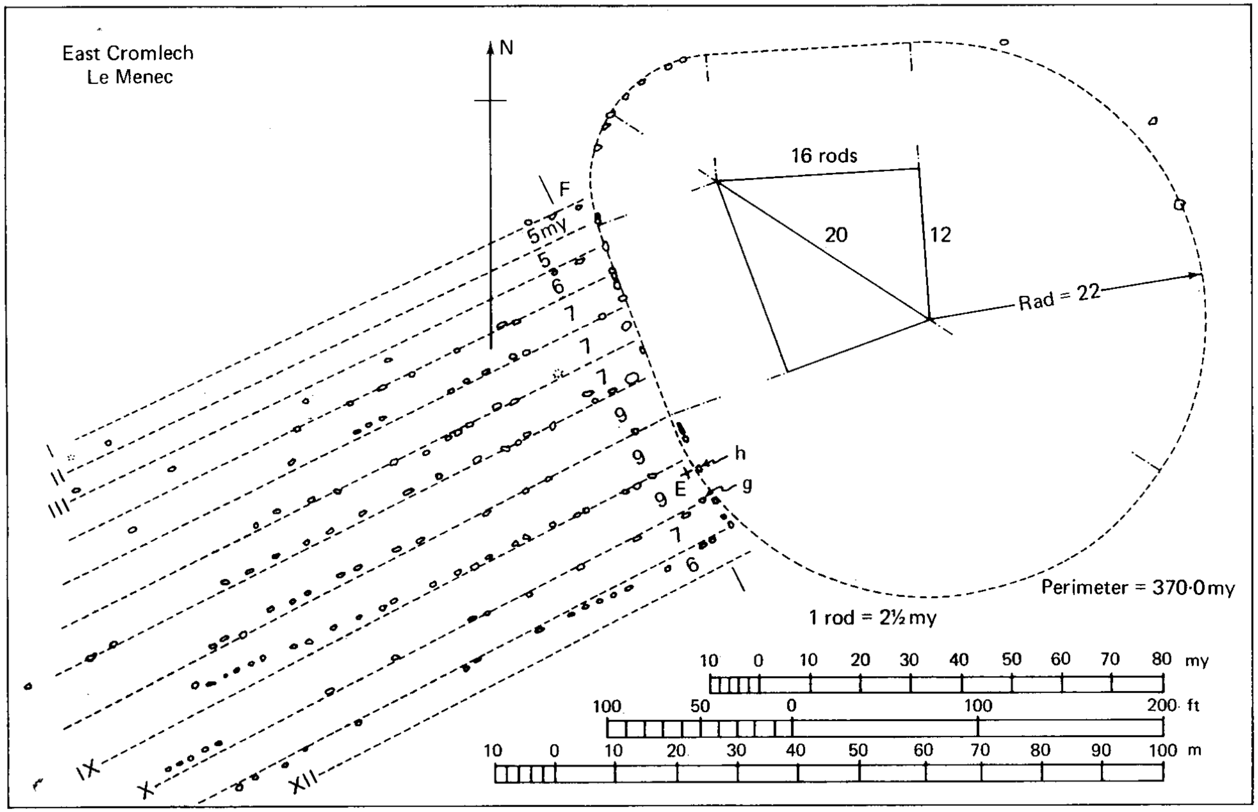



FIG. 4. Le Menec, East End. $E$ is 17·1 ft and 7·2 ft respectively from the nearest points on stones $g$ and $h$. The co-ordinates of $E$ relative to $A$ (Fig. 1) are $x = -12{\cdot}3$ ft, $y = 2948{\cdot}2$ ft.

together. This is possible because, as indicated above, the preliminary work had shown that the nodes on all the rows are given closely in feet by

$$y = 1{\cdot}9 - 0{\cdot}504x \pm 6{\cdot}80m, \tag{2}$$

where $y$ is measured from $AX$ to the east and $x$ is measured *from* $A$ along $AX$ to the row (Figure 1).

There seems to be no theoretical method so far developed for combining the probability levels of a number of contiguous lines to obtain an overall figure, but since Equation (2) relates each line to all the others it appears legitimate to apply Broadbent's formulae to the combined summations exactly as if all the measurements had been made on one row. To do this we have deducted from the measured values, $y_0$, the value $y_1$ given by Equation (2) for the node which lies nearest to the zero on $AX$. The values used for $y_1$ are shown in Table 1. Having made this adjustment, that is, having put $y = y_0 - y_1$, we calculated the values of $\Sigma m$, $\Sigma m^2$, $\Sigma y$, and $\Sigma my$. These are for substitution in Broadbent's formulae:

$$\begin{aligned} \Delta &= n\Sigma m^2 - (\Sigma m)^2, \text{ where } n \text{ is the number of stones,} \\ 2\delta &= (n\Sigma my - \Sigma m\Sigma y)/\Delta, \\ \beta &= (\Sigma m^2\Sigma y - \Sigma m\Sigma my)/\Delta, \\ s^2 &= \frac{1}{n}\Sigma\epsilon^2. \end{aligned} \tag{3}$$

If we care to determine $2\delta$ for each row separately we shall find that it is close to 6·80 ft in every case, but as we are now at the last stage of a series of successive approximations to $2\delta$, it seems more logical to assume it to have the same value for every row and use 6·80 as the starting value. Then for each stone

$$\epsilon = y - 6{\cdot}80\ m. \tag{4}$$

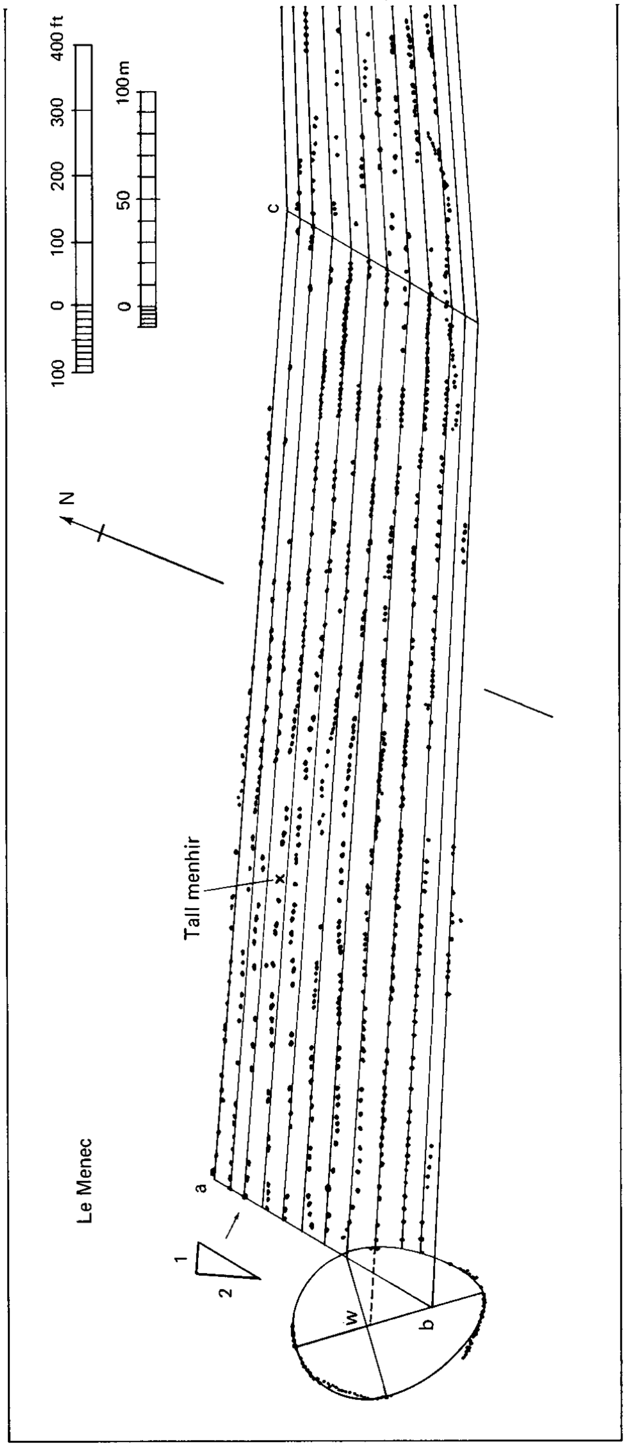
The value of $\beta$ can now be found for each row by

$$\beta = \frac{1}{n}\ \Sigma\epsilon. \tag{5}$$

These values are given in Table 1 and plotted in Figure 3 with a vertical bar having an overall length of twice the calculated standard error.

Note how small, relative to the quantum, are the values both of $\beta$ and of its standard error, indicating that the nodes are indeed given by Equation (2). Accordingly the columns in Table 1 can be summed and substituted in Equation (3) to find the final value of the quantum given by the rows at the west end, namely $2\delta = 6{\cdot}7997$ ft.

The overall value of $\Sigma\epsilon^2$ for the 576 stones is 2045, and so what Broadbent calls the 'lumped variance' is $s^2 = \Sigma\epsilon^2/n = 3{\cdot}55$. This makes $s^2/\delta^2 = 0{\cdot}307$. The more this falls below $\frac{1}{3}$ the lower is the probability level, and so the greater is the probability that the quantum is real. The application of Figure 2.1 of *Megalithic sites in Britain* shows the probability level to be about 1 % but when we find (as we do) that the unit 6·8 ft appears also at the east end of Menec, at the west end of Kermario (survey as yet incomplete) and at Kerlescan, we do not have the slightest doubt about its reality.


400 ft
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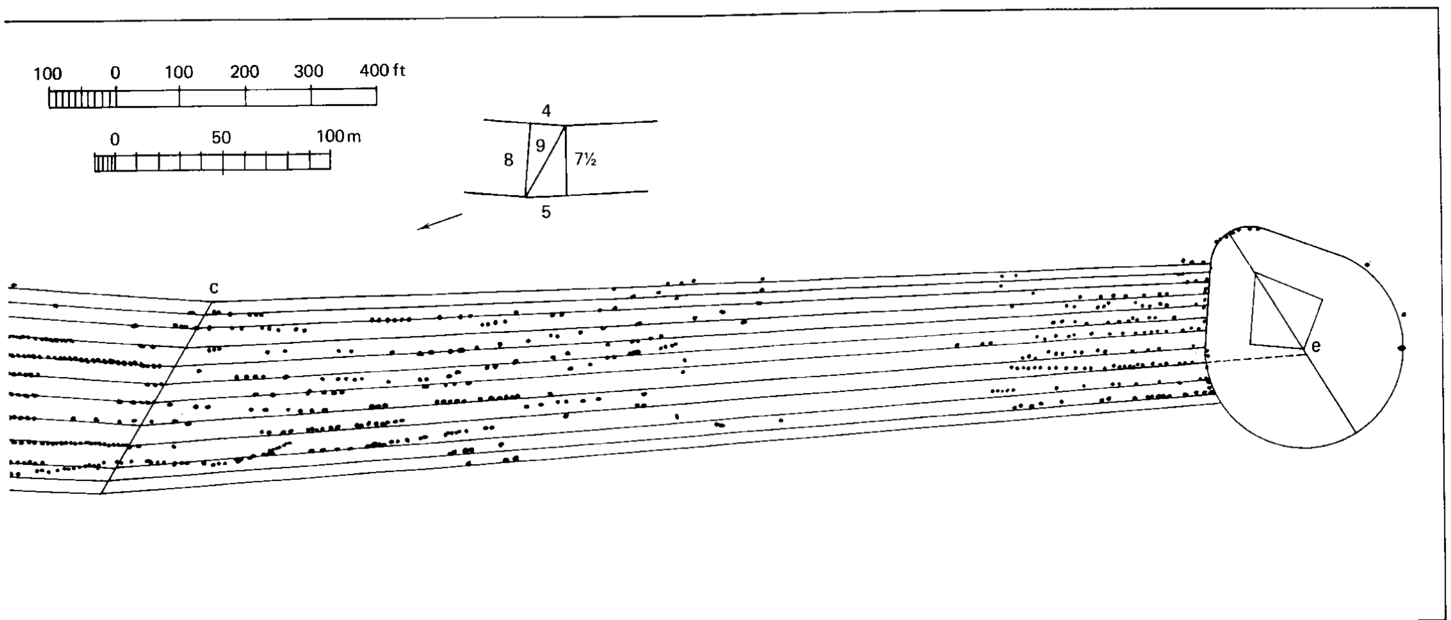


FIG. 5. Alignments at Le Menec. Without excavation it is not possible to be certain of the *exact* position of the axes of the cromlechs but the following dimensions represent closely those used in the original setting out. Distance from centre *w* of the west cromlech to centre *e* of the east cromlech is 495·0 rods. Row IX produced cuts the main axis of each cromlech 1 rod from the centres *w* and *e*. The principal axis of the west cromlech makes an angle of 45° with the line *ab* and meets it very close to, if not on, Row XII produced. The principal axis of the east cromlech makes an angle of 30° with the line *EF* which is normal to the mean direction of the rows.

TABLE 2. Result of the analysis of the remnants of rows at the East Cromlech shown in Figure 4. The positions of the nodes given here are relative to line *EF* (see Figure 6). p.l. = probability level.

| Row | $n$ | node my | node rods | $s^2/\delta^2$ | p.l. % | |
|---|---|---|---|---|---|---|
| I | 5 | 1·65 | 0·66 | 0·030 | — | Too few stones to give a p.l. |
| II | — | — | — | — | — | |
| III | 5 | 1·61 | 0·64 | 0·226 | — | |
| IV | 7 | 0·36 | 0·14 | 0·247 | — | |
| V | 11 | 0·64 | 0·24 | 0·237 | 11 | |
| VI | 10 | 0·71 | 0·28 | 0·091 | <1 | |
| VII | 19 | 0·79 | 0·32 | 0·223 | 6 | |
| VIII | 13 | 2·00 | 0·80 | 0·270 | 13 | |
| IX | 24 | 1·75 | 0·70 | 0·270 | 11 | |
| X | 13 | 2·00 | 0·80 | 0·253 | 11 | |
| XI | 16 | 2·05 | 0·82 | 0·299 | 15 | |
| XII | — | — | — | — | — | |

Broadbent gives a formula for estimating the variance of the quantum; rearranged, it becomes

$$\Delta\sigma^2 = (\Sigma\epsilon^2)/(n - 1) - (\Sigma\epsilon)^2/(n^2 - 2n). \tag{6}$$

With the figures in Table 1, this formula gives for the standard error of the above quantum $\pm$ 0·0001 ft, which is much smaller than the systematic errors which are inevitably involved. The quantum we have found is in fact the relation between the Megalithic rod and the foot, obtained by our survey groups using chains calibrated against our steel tape.

*Le Menec, East End*

The stones in the western part of the Menec alignments are standing on the solid rock, but towards the eastern end the ground improves and has been cleared of menhirs to permit of agriculture. But *at* the east end there is a group of about 127 stones in rows running up to the cromlech (Figure 4). These short remnants of the east end alignments show up the quantum of 6·80 ft almost as well as the longer rows at the west end.

Our survey point $E$ is shown on Figure 4 with the reference distances given so that it can, if required, be picked up on the ground. Table B (not reproduced here) gives the distances of the stones in the various rows measured from our survey line. Analysis has indicated that we can safely take the quantum to be 6·80 ft here also, and so we proceed to find the mean node $\frac{1}{n}\Sigma\epsilon$ for each row exactly as for the west end. In Table 2 these are given referred to the cross-line *EF* defined in Figure 6. Here as at the west end we take the positive direction along the rows towards the *east*.

In dealing with rows like these, it is often desirable to form for each row an approximate value of $\beta$, say $\beta_1$. This is then deducted from the observed lengths and $\frac{1}{n}\Sigma\epsilon_1$ formed for the remainders. The final value for the nodal position $\beta$ is then given by $\beta = \beta_1 + \frac{1}{n}\Sigma\epsilon_1$. (In some difficult cases it may be necessary to repeat the process.) This method avoids the confusion which arises when a stone lies nearly midway between two nodes. When a stone is within 0·1 ft or 0·2 ft of the midpoint it is better to omit it when finding $\beta$, but of course it must be included in finding $\Sigma\epsilon^2$ for probability purposes.

*The Geometry*

The geometry of the Menec site is shown in Figure 5 with the ends in larger detail in Figures 1 and 4.

The knee of each row has been assumed to be exactly 220 rods (550 my) from its nominal start. While it is not yet possible to be sure that this was the exact length used, we know that the uncertainty is only a rod or two, and we shall see that this amount can have no serious effect on the ultimate conclusions to be drawn from the analysis.

The first four rows are parallel up to the knee and spaced 8, 8 and 10 my. The nodes in Row III obviously lag (by $\frac{1}{2} \times 8$ my) behind those in Row II, which similarly lag behind those in Row I. But after the knee we find that the nodes in all three rows are almost exactly in step. That this is so will be seen when we come later to examine Figure 7 where the nodes in these lines are equidistant from the cross line. Another peculiarity is that at the knee the transverse spacing drops automatically from 8 to $7\frac{1}{2}$. The explanation is that the angle of the bend is almost exactly that given by the juxtaposition of two triangles in the manner shown in the inset in Figure 5. These triangles have sides, 4,8,9 and 5,$7\frac{1}{2}$,9. Since $4^2 + 8^2$ and $5^2 + 7\frac{1}{2}^2$ are both close to $9^2$, both triangles are nearly right angled and thus permit at the same time of an integral change in step and an integral change in spacing.

Since this peculiar relation is only possible for the spacing used for the first three rows, we might argue that these rows were the first to be set out. Schuchhardt was right to number the rows from the north and we have retained his nomenclature. The transverse spacing $S$ we have assumed is:

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| at west end ($S_w$) | 8 | 8 | 10 | 12 | 12 | 12 | 14 | 14 | 14 | 10 | 8 | my |
| before knee ($S_c$) | 8 | 8 | 10 | 11 | 11 | 11 | 12 | 12 | 12 | 8 | 7 | my |
| at east end ($S_e$) | 5 | 5 | 6 | 7 | 7 | 7 | 9 | 9 | 9 | 7 | 6 | my. |

These spaces were found to fit the large scale survey, but if the analysis to be given is studied, it will be seen that at the west end no other spacing is possible. From this and what has been said above about the first three rows, it seems almost certain that all the spaces were intended to be integral.

*Comparison of the Nodes at the East and West Ends*

We now proceed to compare the experimentally-determined nodes at the east end (Table 2) with the theoretical positions obtained by assuming that the setting out of the rows proceeded from west to east so that the nodes were carried right through. It is important to note that Figure 6 contains all the data needed to calculate the length of each line up to the cross-line $EF$ apart from the spacings of the Rows I to XII which have just been given.

Take the $\eta$ axis along the first part of Row I and the $\xi$ axis towards the south through $a$. The normal distances of any line $LMN$ (Figure 6) from Line I are $\Sigma S_w$, $\Sigma S_c$ and $\Sigma S_e$ where the summation is taken up to the line considered. The line extends $\frac{1}{2}\Sigma S_w$ (*i.e.*, $\frac{1}{2}\xi_w$) to the west of the $\xi$-axis and is straight for a distance of 550 my to $M$ where it is $\Sigma S_c$ from Row I. It is again straight to $N$

TABLE 3. Comparison of nodes: calculation *vs* survey.

| Row | $\Sigma S_w$ $\xi_L$ | $\Sigma S_e$ $\xi_M$ | $\eta_M$ | $\Sigma S_e$ | $e$ | $\eta_N$ | $\xi_N$ | $l$ my | $l$ rods | c node (cal.) | b node (survey) | Diff. b − c |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I | 0 | 0 | 550 | 0 | +57·57 | 1095·73 | −57·23 | 548·72 | 219·49 | 0·51 | 0·66 | +0·15 |
| II | 8 | 8 | 546 | 5 | +52·57 | 1096·38 | −52·27 | 553·67 | 221·47 | 0·53 | — | — |
| III | 16 | 16 | 542 | 10 | +47·57 | 1097·03 | −47·31 | 558·63 | 223·45 | 0·55 | 0·64 | +0·09 |
| IV | 26 | 26 | 537 | 16 | +41·57 | 1097·81 | −41·36 | 564·84 | 225·94 | 0·06 | 0·14 | +0·08 |
| V | 38 | 37 | 531 | 23 | +34·57 | 1098·73 | −34·42 | 572·21 | 228·88 | 0·12 | 0·24 | +0·12 |
| VI | 50 | 48 | 525 | 30 | +27·57 | 1099·64 | −27·48 | 579·58 | 231·83 | 0·17 | 0·28 | +0·11 |
| VII | 62 | 59 | 518·99 | 37 | +20·57 | 1100·55 | −20·54 | 586·97 | 234·79 | 0·21 | 0·32 | +0·11 |
| VIII | 76 | 71 | 511·98 | 46 | +11·57 | 1101·73 | −11·62 | 595·51 | 238·20 | 0·80 | 0·80 | 0·00 |
| IX | 90 | 83 | 504·95 | 55 | +2·57 | 1102·90 | −2·70 | 604·06 | 241·62 | 0·38 | 0·70 | +0·32 |
| X | 104 | 95 | 497·93 | 64 | −6·43 | 1104·08 | +6·22 | 612·62 | 245·05 | 0·95 | 0·80 | −0·15 |
| XI | 114 | 103 | 492·89 | 71 | −13·43 | 1104·99 | +13·16 | 618·66 | 247·46 | 0·54 | 0·82 | +0·28 |
| XII | 122 | 110 | 488·87 | 77 | −19·43 | 1105·78 | +19·11 | 623·57 | 249·42 | 0·58 | — | — |
| | | | | | | | | | | | Mean diff. = | +0·11 |

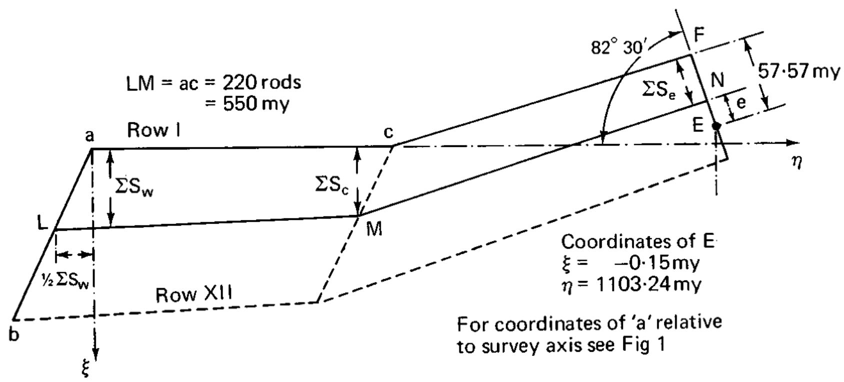


FIG. 6. Specification of the geometry of the alignments at Le Menec.

on the cross-line where it is $\Sigma S_e$ (*i.e.*, *FN*) from Row I. The distance *FE* (57·57 my) is considered to give on our survey a reasonably good fit to the stones shown on Figure 4. The coordinates of *E* (Figure 6) come from our survey, and the relation between the two origins, *A* and *a*, is found by the statistical analysis (see Figure 1).

We have seen that *L* is a node, and since *LM* is an integral number of rods, *M* is also a node. It follows that if we calculate the length *MN* we find the position of the node adjacent to *N*. This can then be compared with what we find on the ground (Table 2).

Since the locus of *M* is not necessarily a straight line, the coordinates of *M* have been found for each line. Using Megalithic yards the calculation proceeds thus:

$$\begin{aligned} \xi_M &= \Sigma S_c, \\ \eta_M{}^2 &= (550 - \tfrac{1}{2}\xi_L)^2 - (\xi_L - \xi_M)^2, \\ e &= NE = 57{\cdot}57 - \Sigma S_e, \\ \xi_N &= -\, e \sin 82^\circ{\cdot}5 - 0{\cdot}15, \\ \eta_N &= 1103{\cdot}24 - e \cos 82^\circ{\cdot}5, \\ l^2 &= (MN)^2 = (\xi_N - \xi_M)^2 + (\eta_N - \eta_M)^2. \end{aligned} \qquad (7)$$

The results are given in skeleton in Table 3. By subtracting the length *l in rods* from the next integer we get the distance from *EF* to the first node to the east, column (c). Column (b) gives the position of the node as found (Table 2) from the rows near the east cromlech.

A comparison of the two sets of nodes is shown in Figure 7. It will be seen how remarkably the two 'curves' follow one another. It is unnecessary to attempt to make a mathematical assessment of the probability of this happening accidentally; the result would obviously be a minute fraction. We can in fact say with certainty that the nodes were carried through from end to end with remarkable accuracy. The mean difference between the 'curves' is only 0·11 rods or about 9 ins. This is so small that to reduce it to zero we need only use 6·8017 ft for the rod instead of 6·8000 ft.

It has been mentioned that we cannot be certain of the position of the knee. Consideration of the geometrical fit of the assumed lines when drawn on the

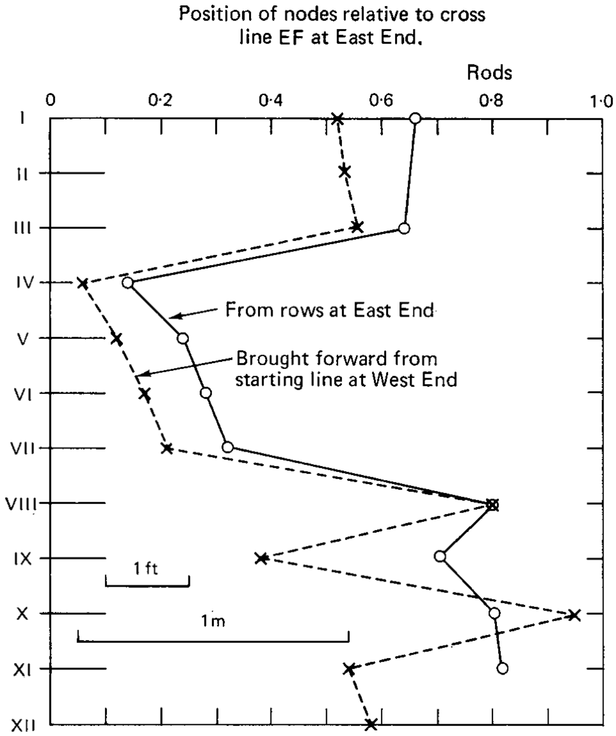


FIG. 7. Comparison of nodes: calculation *vs* survey.

large scale survey indicates that we cannot move $M$ by more than 2 or 3 rods. But a movement of 3 rods has the effect of changing the calculated node (c) at $N$ by only 0·03 rods and so would have no effect on the general conclusions to be drawn from Figure 7.

All the data for a complete recalculation of the lengths $MN$ and the values plotted in Figure 7 have been given. The subject was considered to be so important that when we returned to Carnac in 1971 a remeasurement of the overall length of the site was made with a 100-ft steel tape supported at five points, the end rods being provided with a spirit bubble so that they could be made accurately vertical. The result differed by only 6 ins from the original chaining. All the rows at the east end were remeasured to make sure that the values in Table B were correct. Anyone who cares to do so can remake the calculations and perhaps try the effect of different assumptions regarding the spacing. In this connexion we may note that $dl/d\xi_L$ is roughly $\frac{1}{2}$.

Thus a change in one of the transverse spaces *at the west* by 1 my will move the node *at the east* end by about 0·5 my or 0·2 rods. It can be seen from Figure 7 that this is an unacceptable amount in the first eight rows. Examination of the spacings of the last four rows on the survey in Figures 1, 4 and 5 taken together indicates the difficulty of finding an improvement.

*Le Menec Stones between the Knee and the Gap*

The stones between the knee and the gap, Figure 5, have been so badly disturbed that little additional information can be got from them. Over a hundred lie on or near the original lines, and when the positions of these were scaled from the survey they showed the rod quantum with a probability level of about 5%.

It appears that in some places the reerectors tried to force the stones into lines running across the rows at a small angle (see Figure 5). Three of these lines containing roughly 10 stones each were analysed, and with a 6·80 ft quantum yielded values of $s^2/\delta^2$ of 0·349, 0·321 and 0·428.

Since these figures are not significantly less than $\frac{1}{3}$, these rows show no indication of the 6·80 ft quantum and we can reject the idea that they formed part of the original layout.

*Megalithic Yard*

It seems that the best value we can get for the Megalithic yard from Le Menec is obtained by using the nodes got from the stones at the two ends along with the overall chained lengths. The statistical mean values of the positions of these nodes are unlikely to be in error by more than a few inches and so the error produced is of the same order as the inaccuracy of the overall chaining. It follows that the final value for the rod is 6·802 $\pm$ 0·002 ft or 2·073 $\pm$ 0·001 metres. This makes the Megalithic yard 2·721 $\pm$ 0·001 ft or 0·8293 $\pm$ 0·0004 metres. It is unlikely that a more reliable value will be obtained from any individual site anywhere unless indeed a precision survey of geodetic accuracy be made of Le Menec.

*Other Alignments*

Our survey of Kermario is little more than started, but the first few hundred feet have been analysed and show up the 6·8 ft quantum. The general outline shown in Fig. 1 of our previous paper was constructed by surveying a single row of stones right through and using Schuchhardt's sketch plan to fill in the remainder.

The plan of Kerlescan given by Hülle is a small-scale copy of a survey by Modrigan, but careful measurements, under a magnifying glass, of seven rows showed that it is highly probable that the 6·80 ft quantum obtains there also. The tapering rows at Petit Menec and St Pierre have already been discussed.

*Conclusion*

The original geometrical layout of the Menec alignments and cromlechs has been established. A remarkable feature is the great accuracy of measurement with which the rows were set out. It cannot be too strongly emphasized that the precision was far greater than could have been achieved by using ropes. The only alternative available to the erectors was to use two measuring rods (of oak or whale bone?). These were probably 6·802 ft long, shaped on the ends to reduce the error produced by malalignment. Each rod would be rigidly supported to be level but we can only surmise how the engineers dealt with the inevitable 'steps' when the ground was not level.

It may be noted that the value for the Megalithic yard found in Britain[8] is 2·720 ± 0·003 ft and that found above is 2·721 ± 0·001 ft. Such accuracy is today attained only by trained surveyors using good modern equipment. How then did Megalithic Man not only achieve it in one district but carry the unit to other districts separated by greater distances? How was the unit taken, for example, northwards to the Orkney Islands? Certainly not by making copies of copies of copies. There must have been some apparatus for standardizing the rods which almost certainly were issued from a controlling, or at least advising, centre.

The organization and administration necessary to build the Breton alignments and erect Er Grah obviously spread over a wide area, but the evidence of the measurements shows that a very much wider area was in close contact with the central control. The geometry of the two egg-shaped cromlechs at Le Menec is identical with that found in British sites. The apices of triangles with integral sides forming the centres for arcs with integral radii are features in common, and on both sides of the Channel the perimeters are multiples of the rod.

The extensive nature of the sites in Brittany may suggest that this was the main centre, but we must not lose sight 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 has been shown elsewhere that the divergent stone rows in Caithness could have been used as ancillary equipment for lunar observations, and in our former paper we have seen that the Petit Menec and St Pierre sites were probably used in the same way. We do not know how the main Carnac alignments were used but we do know that careful and continued use of observatories like those in Argyllshire and Caithness would have presented problems which must have intrigued and probably worried the observers. Did they solve these in Carnac?

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6. Tables A and B are too elaborate to be reproduced here. Readers wishing to have copies of these and a more complete version of Table 1 should write to the Editor at Churchill College, Cambridge, England, enclosing 20p (or U.S. 50 cents; for airmail outside Europe, enclose a total of U.S. $1).
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9. *Ibid.*, frontispiece and *passim*.