

MEGALITHIC SITES IN BRITAIN

BY

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Chapter 6. Circles and Rings

Chapter 7. The Compound Rings

Chapter 8. Megalithic Astronomy

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6

CIRCLES AND RINGS

(Thom 1971:56-83)

THE stones used for setting out the circles and rings vary greatly in size and shape. Sometimes small boulders of two or three cubic feet were used, sometimes small slabs set on edge along the periphery, but, for the casual visitor, the most impressive circles are those consisting of tall pillars five, ten, or more feet high. Examples of many types will be found in the plans given here and in the references. In most of these surveys the bases of the upright stones are shown cross-hatched or in black. Fallen stones are shown in outline only. A dotted outline usually means that the stone is below ground and its position estimated by prodding with a bayonet. From our present point of view the circle of small slabs is not to be despised. The small stones define the outline with greater accuracy and are very unlikely to have been disturbed. Undoubtedly many such circles have vanished completely. Particularly good examples are seen in Figs. 6.1 and 6.2, where, largely due to the small size of the stones, the geometrical design can be exactly determined. The slabs of the circle at Cauldside (Fig. 6.3) are of such a soft stone that several have weathered away above ground leaving only a crumbling sandy stump below the turf.

There is very little relation between the size of the circle and the size of the stones. Some small circles are built of very large stones. The example mentioned above at Dinnever Hill (S 1/8) is 130 ft across and yet the stones hardly show in the long grass. But the largest circles, Avebury, Stanton Drew, Long Meg and her Daughters, and the Twelve Apostles, are mostly of large stones. It is exceptional to find the stones in a circle of a uniform size or uniformly spaced and only in a few circles are the stones placed on opposite ends of a diameter. There is a suspicion that diametrically opposite stones may define a sight line so this arrangement would only be used where it was desired to define an azimuth. The largest stone in the Castle Rigg circle was certainly used in this way as will be seen later. Cauldside circle (above) uses at least two diameters as indicators of other marks.

The 'recumbent stone circles' of north-east Scotland belong to a class by themselves and will be discussed later. They often had an outer ring of very large uprights with a particularly big slab in the south-west quadrant. These slabs are too large to define of themselves an azimuth as seen from the centre, but they may have supported or located other structures or sighting devices long since rotted away.

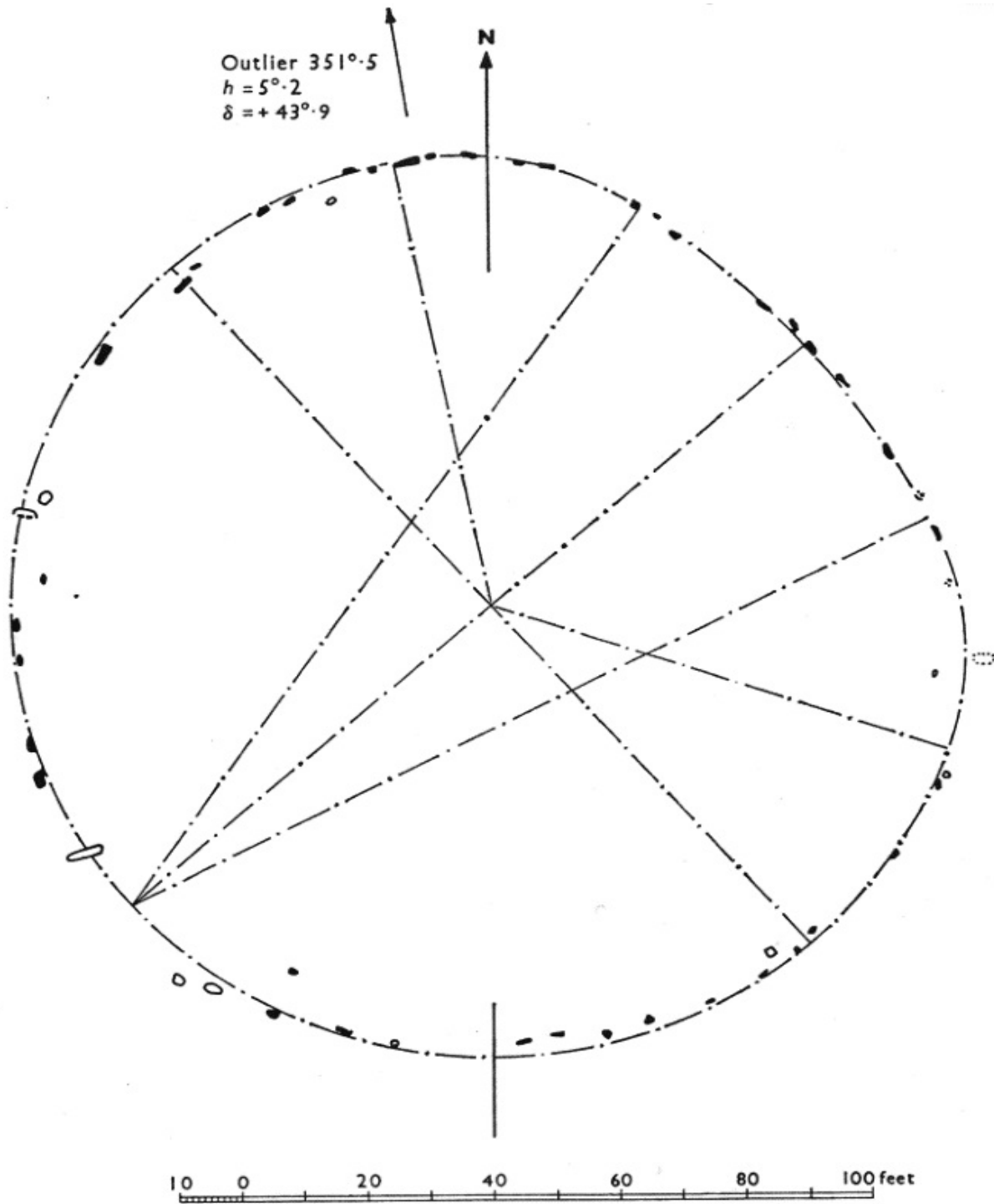


Fig. 6.1. Rough Tor, S1/7 ($50^{\circ} 35' \cdot 4$, $4^{\circ} 37' \cdot 4$).

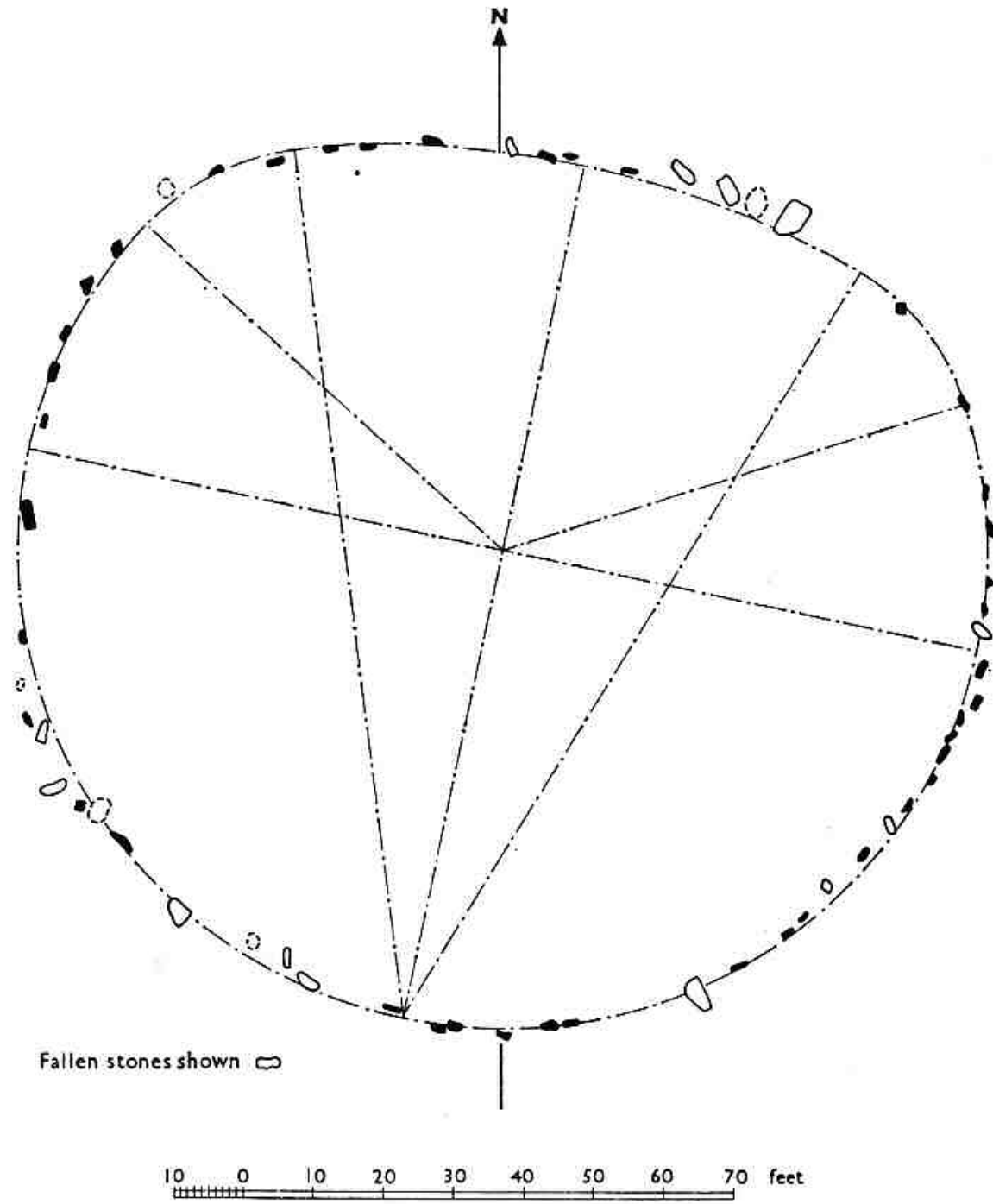


Fig. 6.2. Dinnever Hill, S1/8 ($50^{\circ} 35' \cdot 4$, $4^{\circ} 38' \cdot 8$).

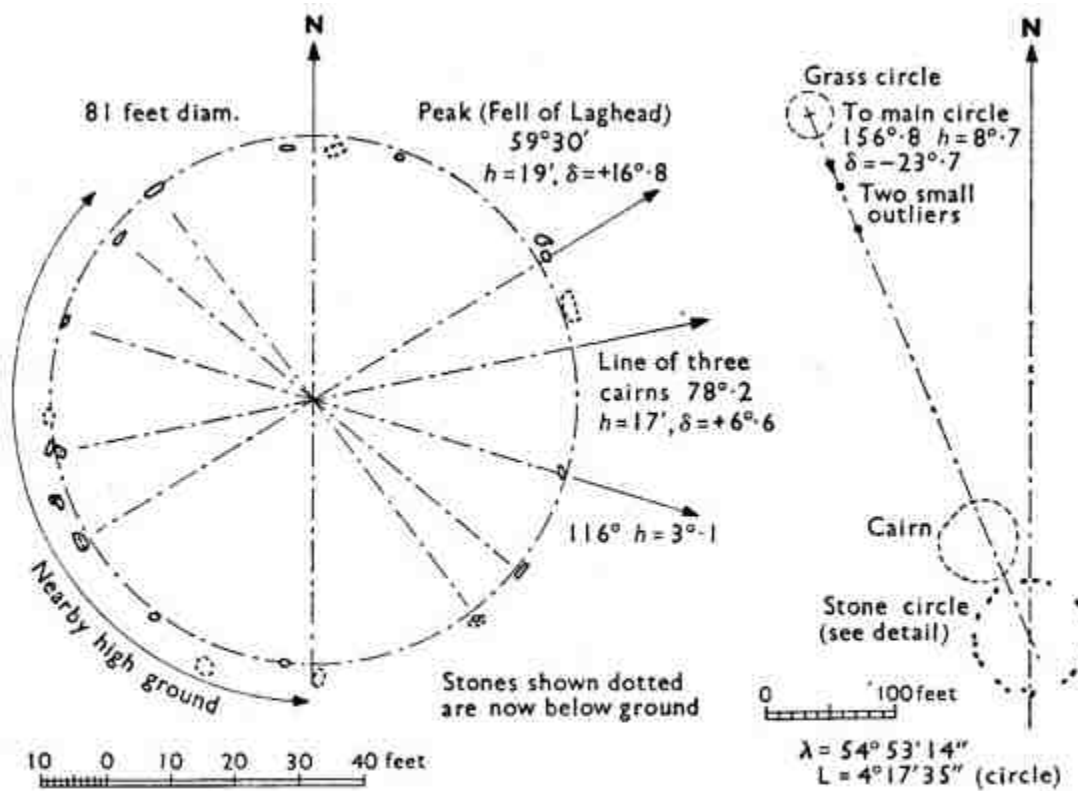


FIG. 6.3. Cauldside, G 4/14.

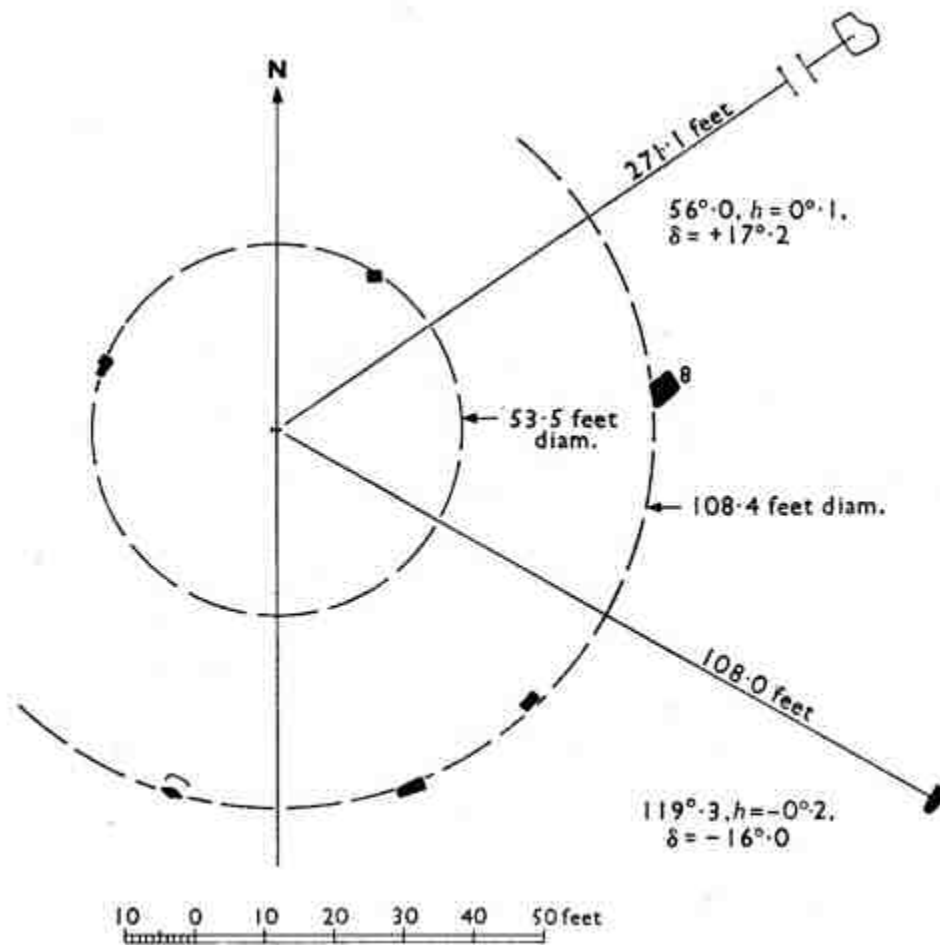


FIG. 6.4. Sheldon, B 1/8 ($57^{\circ} 19'$, $2^{\circ} 18'$).

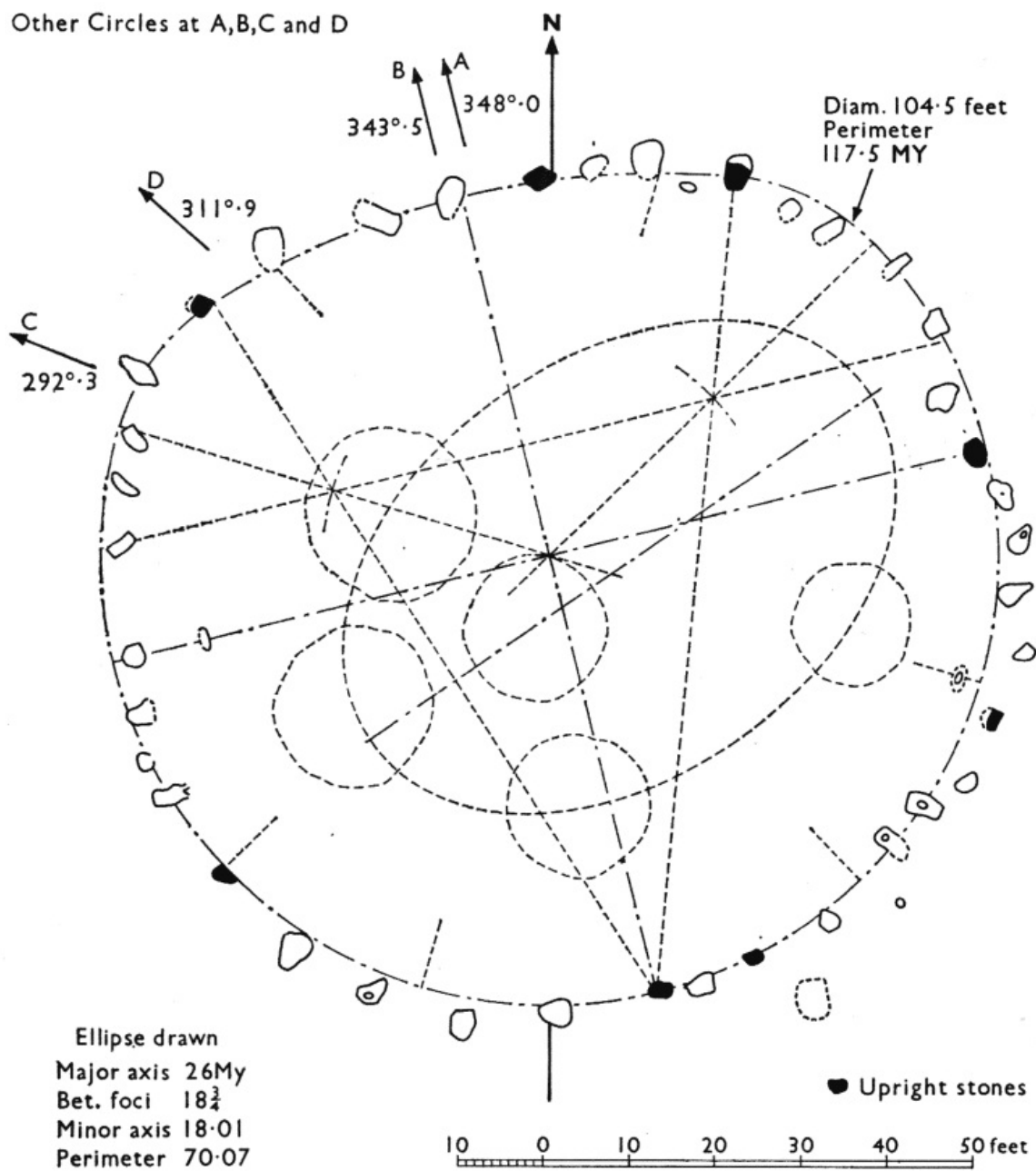


Fig. 6.5. Burnmoor E, L1/6 ($54^{\circ} 24' \cdot 6$, $3^{\circ} 16' \cdot 5$).

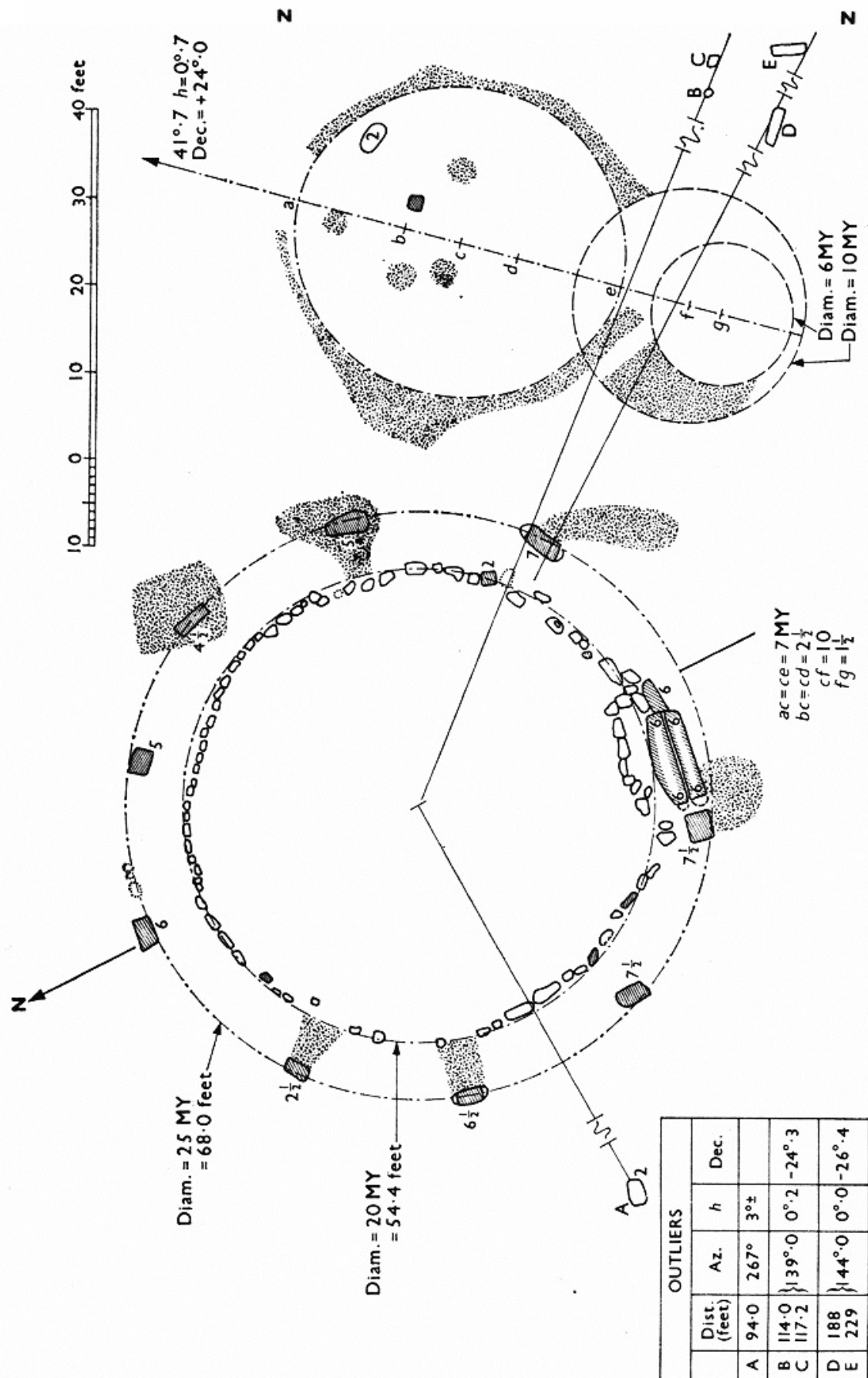


FIG. 6.6. Loanhead, B 1/26 (57° 21', 2° 25').

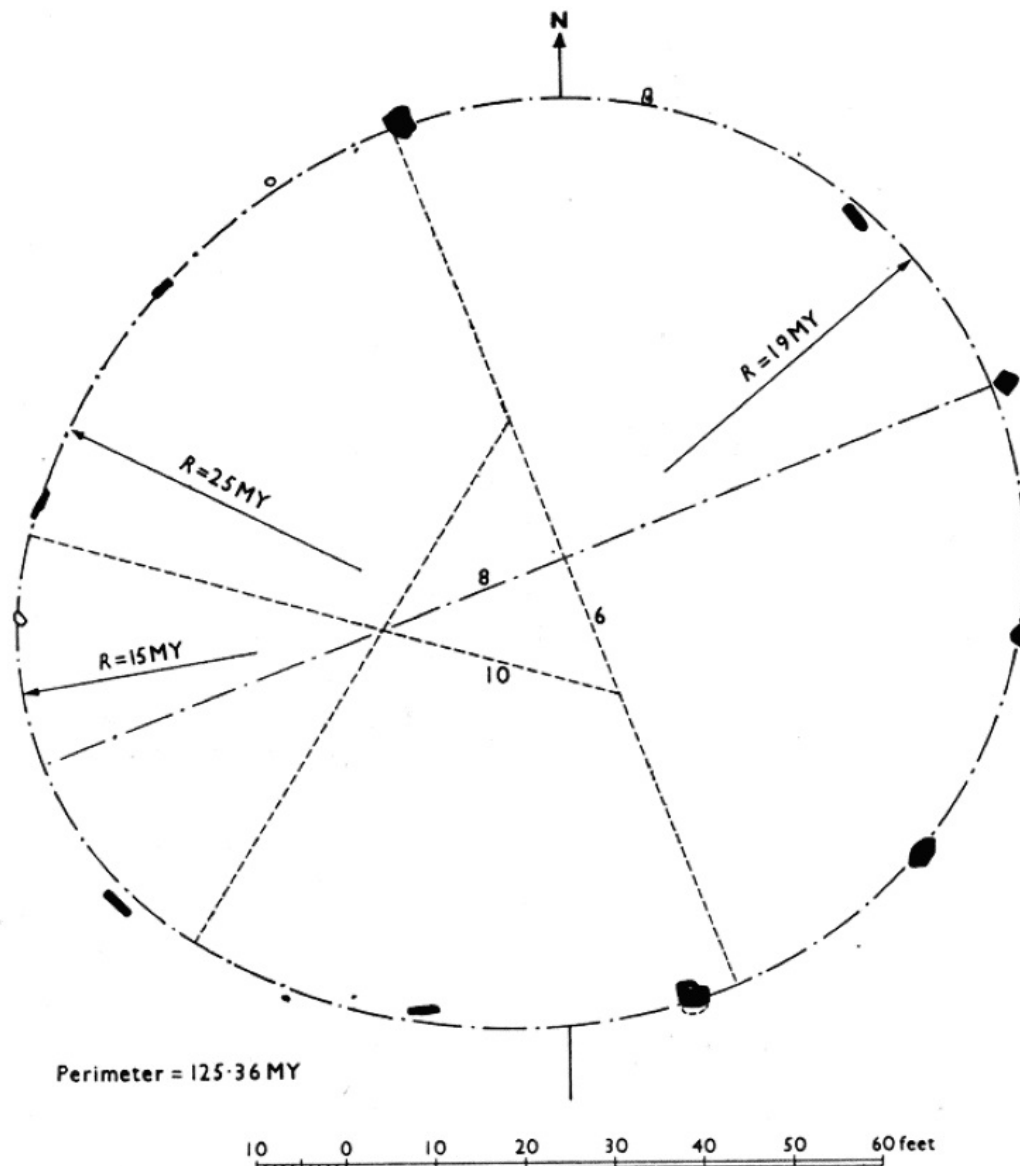


Fig. 6.7. Clava, B 7/1 ($57^{\circ} 29'$, $4^{\circ} 5'$).

In looking at a stone circle we see only what remains after more than 3000 years. Much of the smaller detail has probably vanished, as certainly have all those parts of the structure originally made of perishable material. There must have been posts at the centre or centres for setting out and for sighting purposes. It is significant that none of these centres is occupied by a stone although there are several places where a stone stands against the centre of the circle or against one of the auxiliary centres. We may picture all sorts of ancillary structures of wood such as raised platforms, roofed portions, sighting posts, fences, or marked out divisions, but in our ignorance we probably fail completely to picture the complete structure.

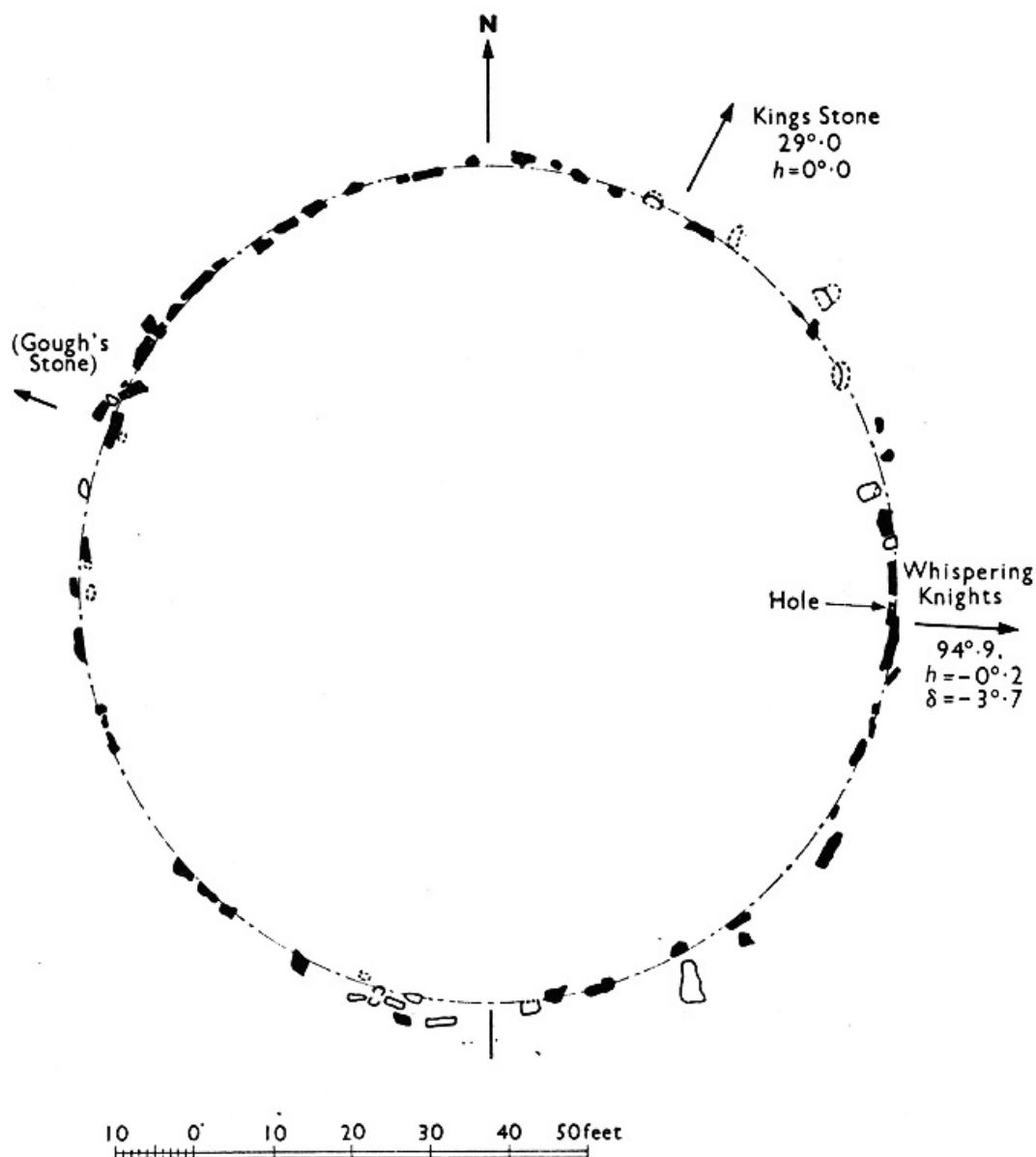


Fig. 6.8. Rollright, S6/1 ($51^{\circ} 58'$, $1^{\circ} 34'$).

At some sites we can be misled by super-imposed modern work; for example, at Sheldon of Bourtie (Fig. 6.4) the walls have evidently been put there long after many of the menhirs had vanished. The walls are so placed that they show their builders to have been in complete ignorance of the original plan, which can only be deduced by making use of our recently acquired knowledge of the units of length used by the original builders. The plan in Fig. 6.4 ignores these walls. But in some places there are remains of structures which presumably belonged to the original plan. For example, in the main circle of the Burnmoor group there are five peculiar hollow cells. These are shown by dotted rings in Fig. 6.5. Perhaps by accident, but more likely by design, four of these lie on an ellipse which has the expected properties of a Megalithic ellipse. Its major and minor axes are 26 and 18 MY and the calculated perimeter is almost exactly 70 MY. The fifth cell lies on the major axis. This Type A circle is very nearly the same size as the Type

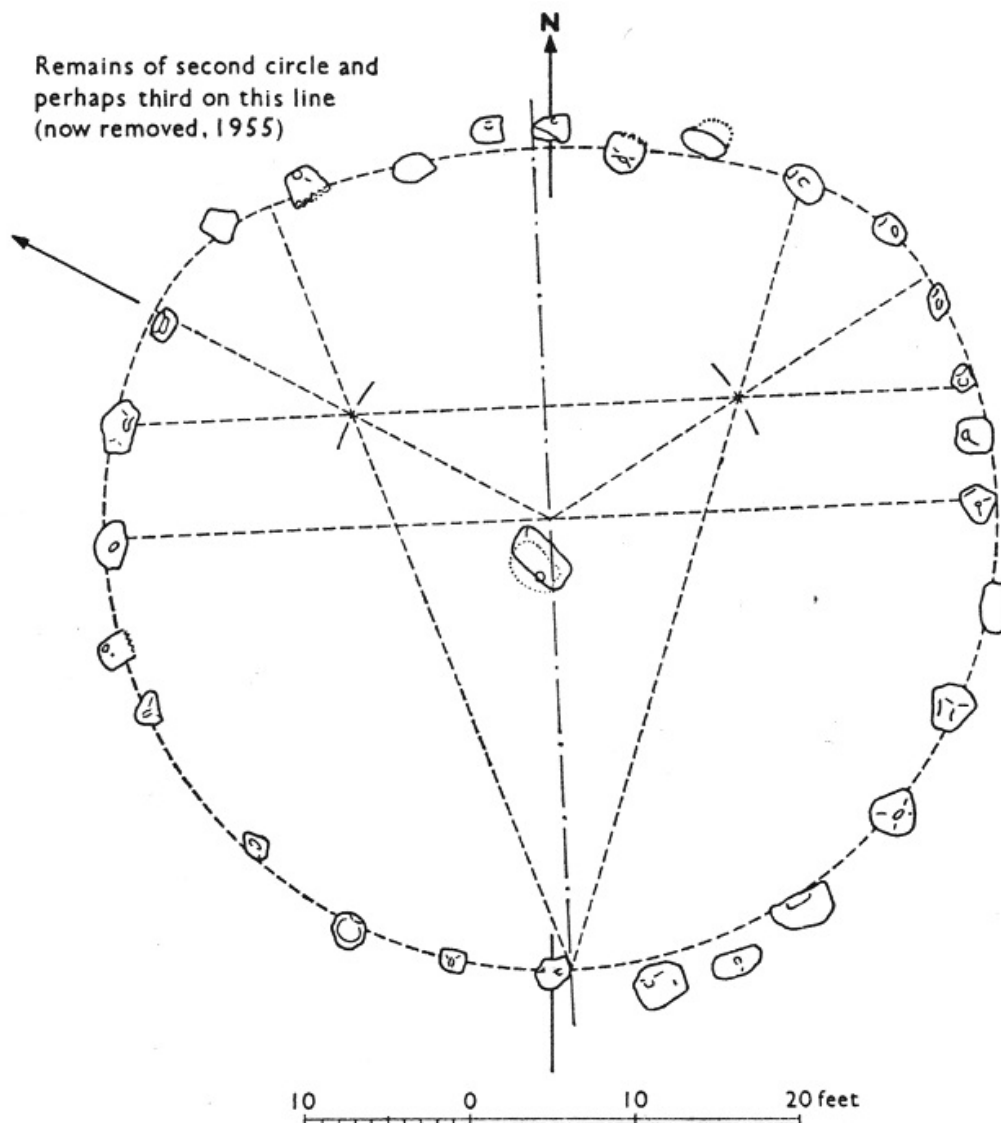


Fig. 6.9. Cambret Moor, G 4/12 ($55^{\circ} 53' 47''$, $4^{\circ} 19' 28''$).

A circle at Castle Rigg, also in the Lake District. Curiously enough, in the latter circle can be seen a grass ring in such a position that if transferred to the Burnmoor circle it would lie on the ellipse. While this is probably accidental, it shows the necessity for a careful excavation at both circles. Such an excavation at Loanhead of Daviot shows how much can be discovered (Kilbride-Jones, 1934 and Fig. 6.6). There, a complex of two circles and an ellipse all aligned on the rising solstitial sun has been revealed outlined in beds of small stones. Similarly the clearance at Callanish I (Fig. 11.1) has revealed a peculiar design which includes a small ellipse, again with its axis indicating the solstitial sun, the backsight being one of the auxiliary centres of the Type A circle. The importance of these auxiliary centres will also be demonstrated when the astronomical significance of Castle Rigg is discussed. Here we should also mention the internal structures at Clava B 7/1 (Fig. 6.7; Piggott, 1956), the cells in other Burnmoor circles, and the isolated stones

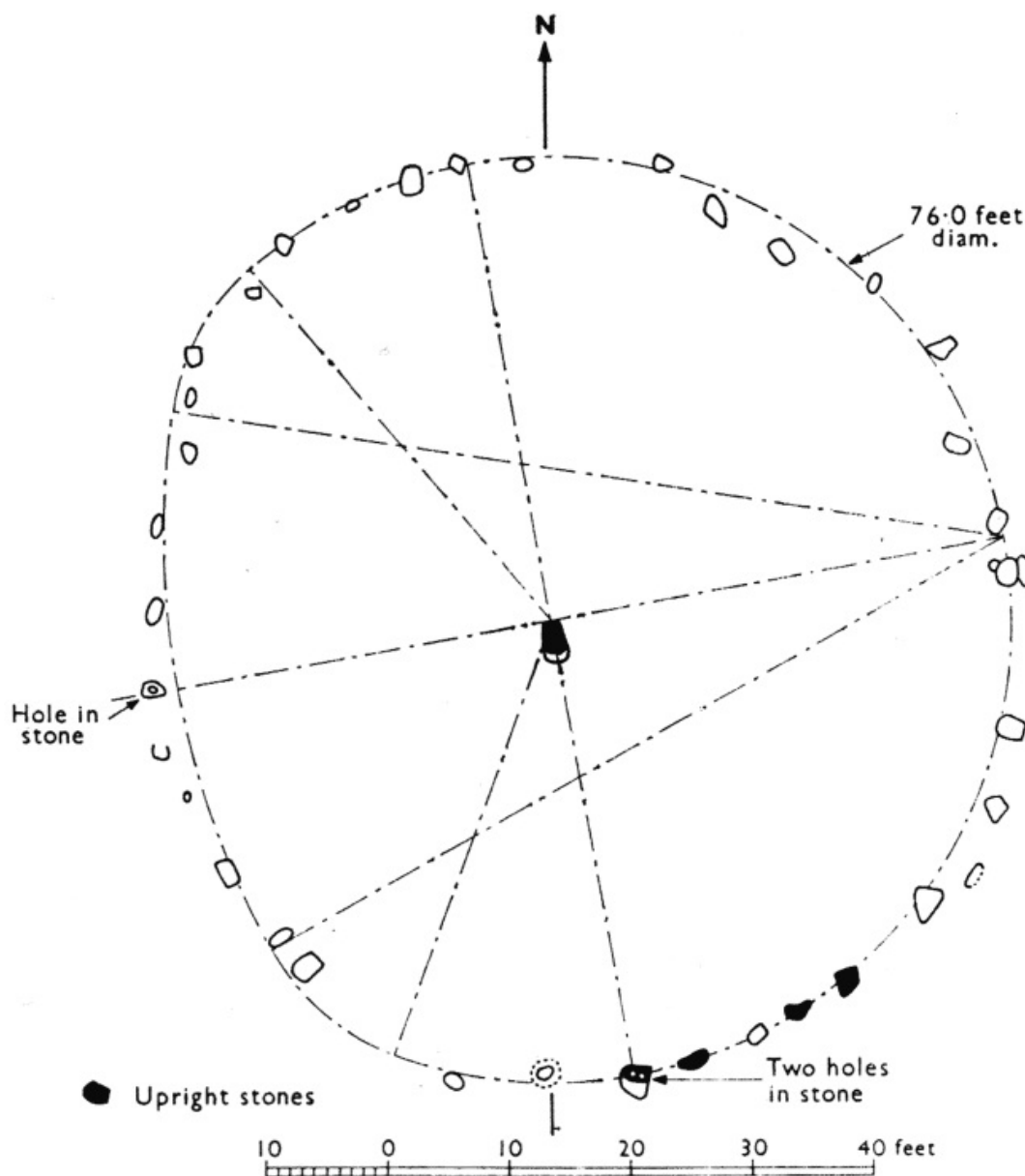


Fig. 6.10. Black Marsh, D 2/2 ($52^{\circ} 35' \cdot 5$, $2^{\circ} 59' \cdot 9$).

found inside some circles, notably at the Hurlers (S 1/1) and at the south circle, Stanton Drew.

A cairn supported at its edge by large stones may be removed to provide road-making material. The ring which is left looks like a stone circle. The position becomes more complicated if the cairn was originally inside a circle of free-standing stones. One sees that if one of the Clava cairns was denuded the remains might look like three concentric circles. Traces of what may be entrances or may be sighting directions are found in several free-standing circles, e.g. Rollright S 6/1 (Fig. 6.8), Sunkenkirk L 1/3, and Pobull Fhinn H 3/17. The peculiar 'entrance' arrangement at many of the recumbent stone circles of the north-east of Scotland should also be mentioned (p. 135 and Keiller, 1934).

The layout of some of the multiple circle sites was apparently very complicated, as is shown by Borlase's plan of the Botallack circles reproduced by Lockyer. One of the circles

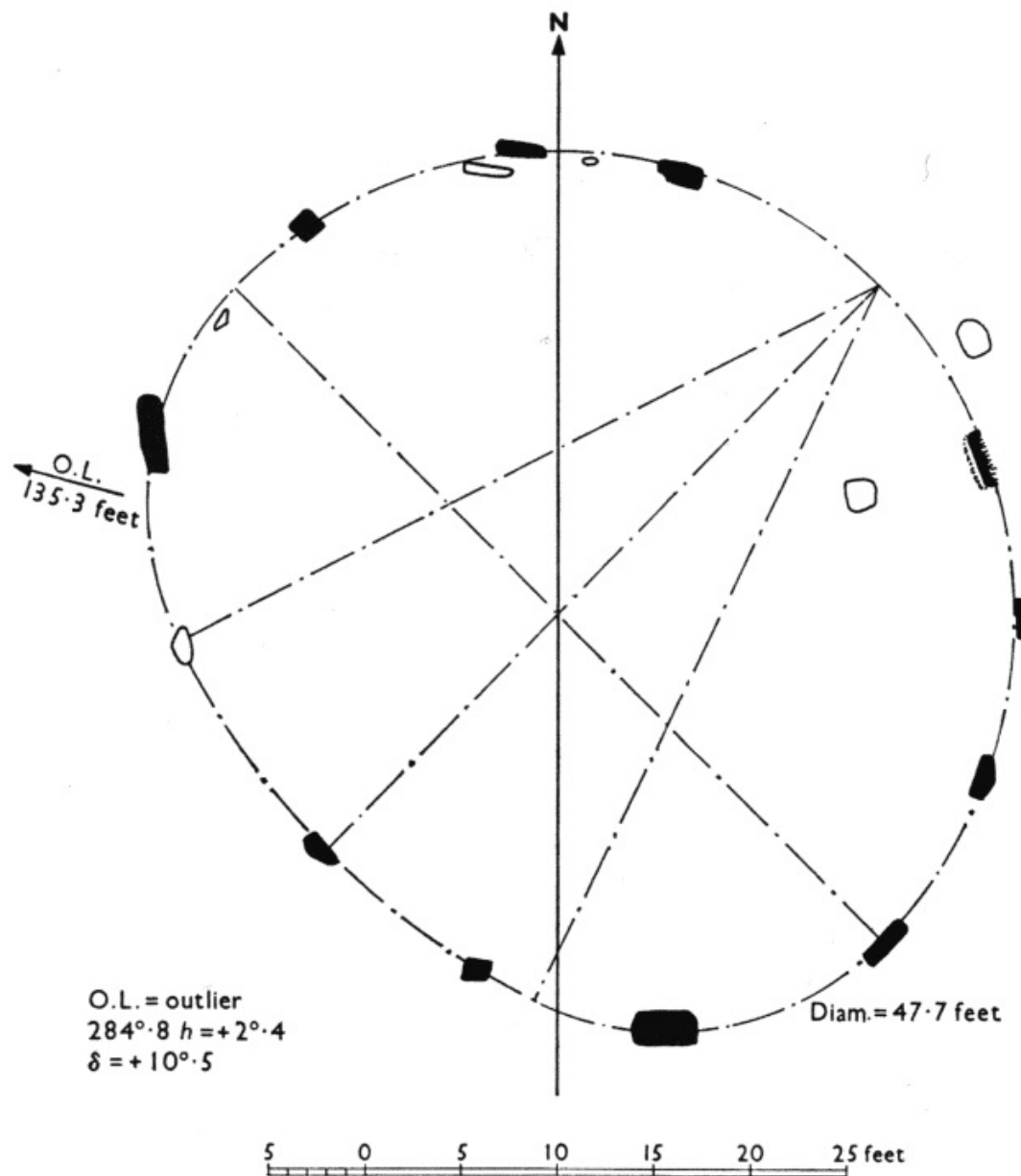


Fig. 6.11 Bar Brook, D 1/7 ($53^{\circ} 16' \cdot 6$, $1^{\circ} 34' \cdot 9$).

in the group is evidently of the flattened type. This group has been completely destroyed so that today we cannot determine the azimuths.

There are still remains of at least thirty-three flattened circles of Type A, B, or D. These rings differ from the egg-shaped rings and ellipses in that they all conform to definite designs: for example, all Type A circles are geometrically similar whatever the size, whereas there are very few known examples of geometrical similarity amongst the eggs and ellipses. As a result one would expect to find in the flattened circles a preference for diameters giving acceptable perimeters. But the actual sizes lend no support to this idea. There is, however, some evidence that the diameters were adjusted slightly to help the circumference to conform, just as we found with the circles. This indicates that the size and design were controlled by factors unknown to us today. The size might have

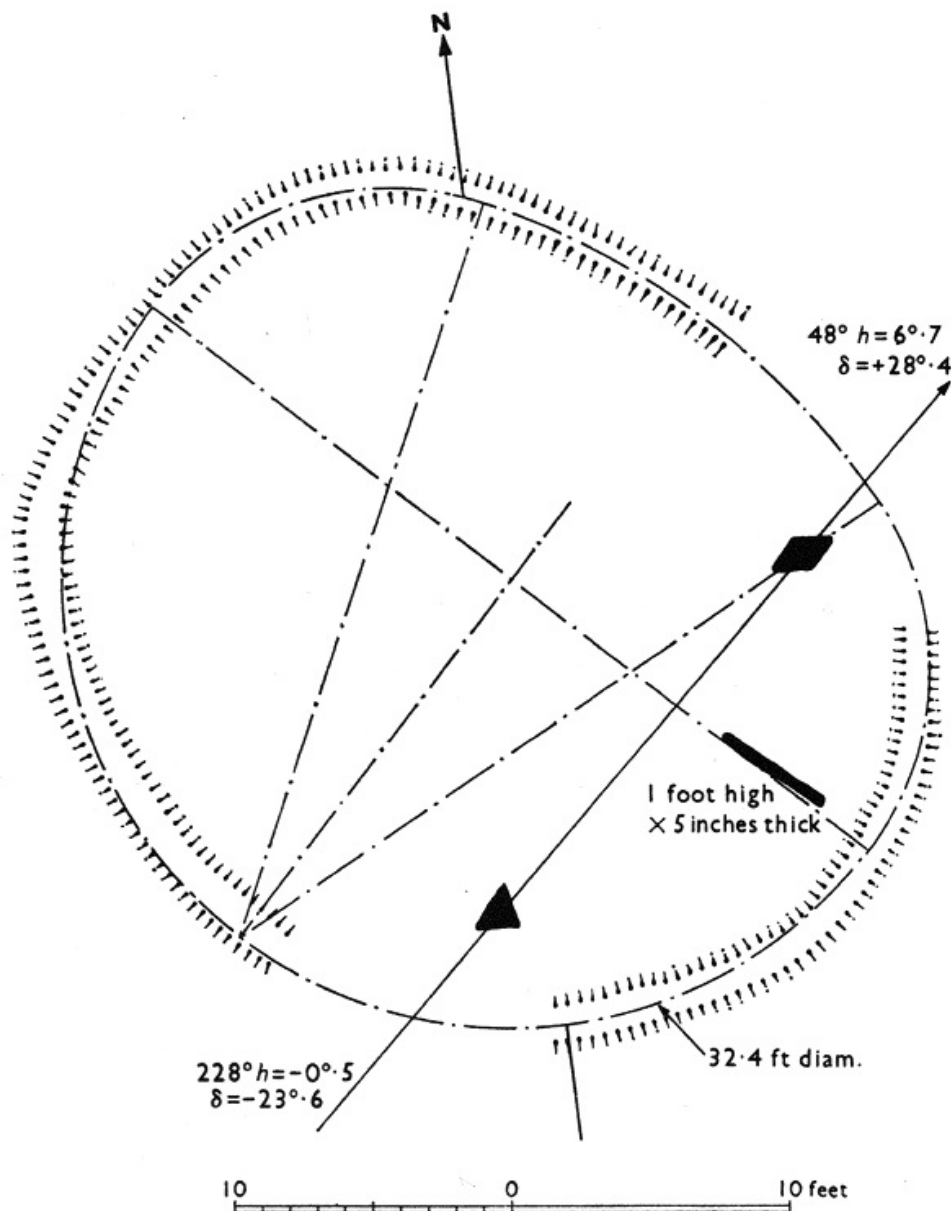


Fig. 6.12. Thieves, G 4/2 ($55^\circ 01'$, $4^\circ 35'$).

been connected with the size of the local population, and certainly the largest circles in Britain are in districts capable of supporting a large community. But against this we find large circles and small circles in the same district. The shape is sometimes related to the orientation. For example, the very large Type B circle Long Meg and her Daughters L 1/7 (Fig. 12.11) has its axis of symmetry in the meridian and the axis of the central circle at the Hurlers lies east and west as does the axis of the Type B circle near Porthmeor S 1/12. Other orientation peculiarities will be mentioned in connexion with the astronomical uses of the rings.

A good example of a Type A circle is seen on Cambret Moor (Fig. 6.9). Here we see that six points on the geometrical construction are marked by stones. Notice also that the line through the left auxiliary centre pointed to two other similar circles in line. Remains

of these were seen and surveyed in 1939 but both are now removed although they were on the Ordnance Survey. It is interesting that the north and south points are accurately marked but that the whole construction is slewed slightly to get the above-mentioned indication of the other circles. As usual the centre stone stands beside, not at, the centre.

It is interesting to see that in the Type A circle at Black Marsh (Fig. 6.10) one end of the axis of symmetry is marked by a stone with a hole cut in it, and one end of the cross axis by a stone with two cut holes. In neither case do the holes go right through.

A good example of a Type B circle is seen at Bar Brook Derbyshire, (Fig. 6.11). An interesting example is found at the Thieves in Galloway (Fig. 6.12). The Thieves are two tall menhirs but they are surrounded by a low bank of earth and small stones. Stakes were stuck in the estimated top of the bank and the position of the stakes surveyed. A Type B circle adjusted to size was later superimposed. It will be seen that it is almost exactly 12 MY in diameter and that the transverse axis lies along a long low slab set on edge. The Thieves themselves show a limiting lunar declination in one direction and the midwinter setting sun in the other.

The largest circle in the north is at Long Meg and her Daughters and is Type B, while at two of the most important sites in Britain we find Type A, namely at Castle Rigg and Callanish I.

The circle at Whitcastles is in a class by itself. It is like a Type B but the cross axis is divided into four instead of three. Since the main radius is 34 MY we get very nearly a Pythagorean triangle, because $34^2 + 17^2$ is 1445 and 38^2 is 1444. This was probably the reason for departing from the usual Type B. All good Type A, B, and D rings will be found listed in Table 5.1.

Egg-shaped rings

Ten examples of egg-shaped rings are now known and will be found listed in Tables 6.1 and 6.2. The geometry of these rings has already been discussed in Chapter 4. A good

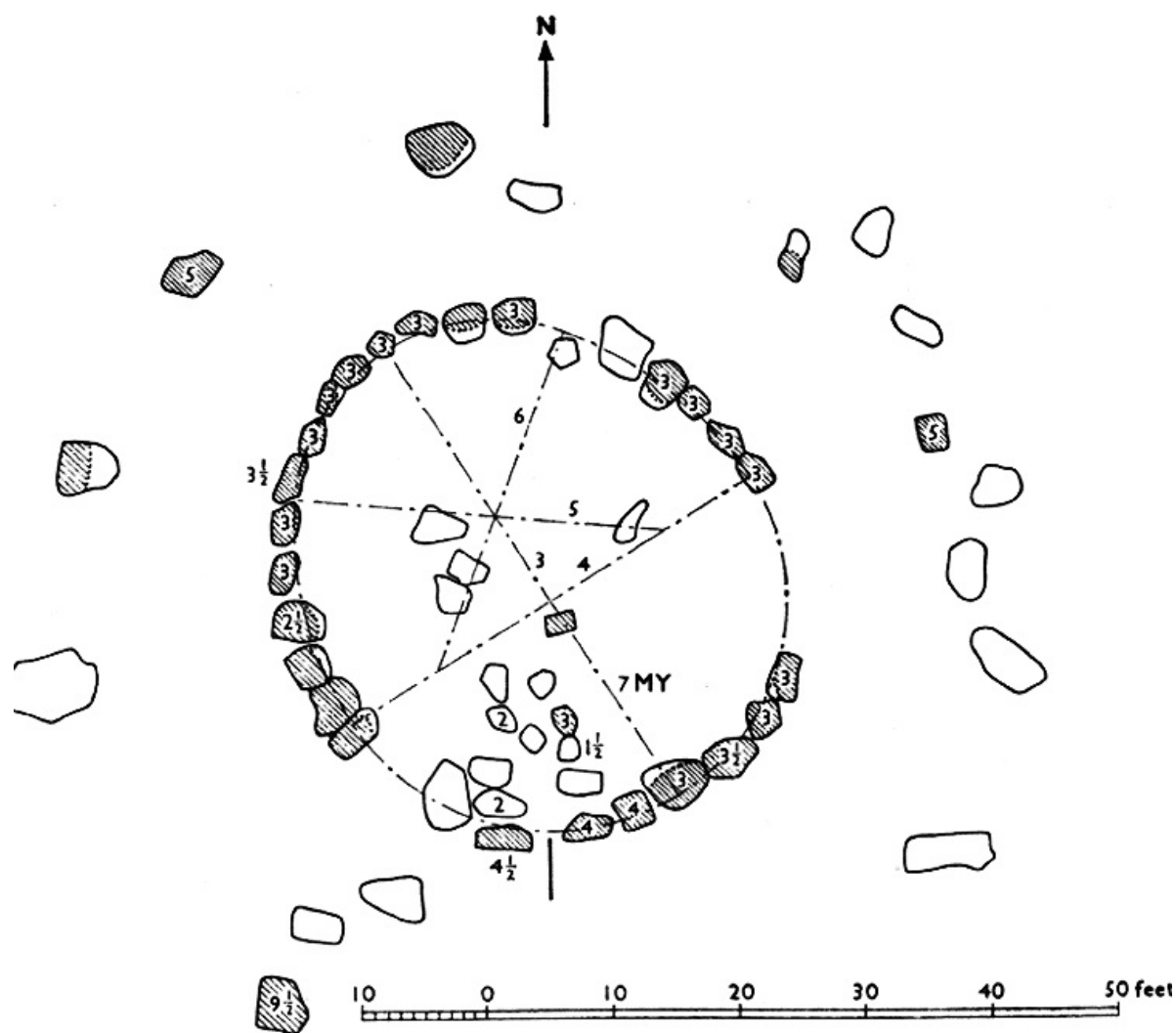
Table 6.1. *Egg-shaped rings-type I*

Site	<i>b</i>	<i>c</i>	<i>a</i>	<i>r</i> ₁	<i>P</i>	<i>P</i> - 2½ <i>m</i>
B 2/4 Esslie Major	3	4	5	14	90·95	+0·95
B 7/1 Clava	6	8	10	19	125·36	+0·36
B 7/18 Druid Temple	4	3	5	7	47·28	-0·22
G 9/15 Allan Water	5½	6½	8·51	8	55·60	+0·60
P 7/1 Cairnpapple Hill	12	16	20	17½	121·91	-0·59
S 5/4 Woodhenge	17½	6	18½	Six values	40	0·00

example of a Type I ring will be found in the inner ring at Druid Temple near Inverness (Fig. 6.13). This ring is based on the 3, 4, 5 triangle with the 3 side along the axis of symmetry. Note how near the perimeter 47·27 MY comes to being a multiple of 2½.

Table 6.2. *Egg-shaped rings-type II*

Site	b	c	a	r_1	P	$P-2\frac{1}{2}m$
G 9/10 Borrowston Rig	$9\frac{1}{2}$	$12\frac{1}{2}$	$15\frac{1}{2}$	25	164.27	-0.73
S 1/1 The Hurlers	6	$4\frac{1}{2}$	$7\frac{1}{2}$	25	158.36	-0.86
Leacet Hill	$1\frac{1}{2}$	2	$2\frac{1}{2}$	$6\frac{1}{2}$	42.06	-0.44
W 11/3 Maen Mawr	2	$2\frac{1}{2}$	3.01	11	70.24	+0.24

Fig. 6.13. Druid Temple B 7/18 ($57^\circ 27'$, $4^\circ 11.4'$).

At Clava (Fig. 6.7) and at Esslie (B 2/4) the 3 side is across the axis. An interesting triangle is found in the ring high up on a hill above Allan Water (Fig. 6.14). Here we have in units of $\frac{1}{2}MY$, $11^2+13^2 = 290$ and $17^2 = 289$. The discrepancy in the hypotenuse is only 1 in 580 and would hardly be appreciable.

The best example of a Type II ring is that on Borrowston Rig (Fig. 6.15). The over-all size is exactly $56 \times 50 MY$. The hypotenuse of the basic triangle is $15\frac{1}{2}$. Taking one side

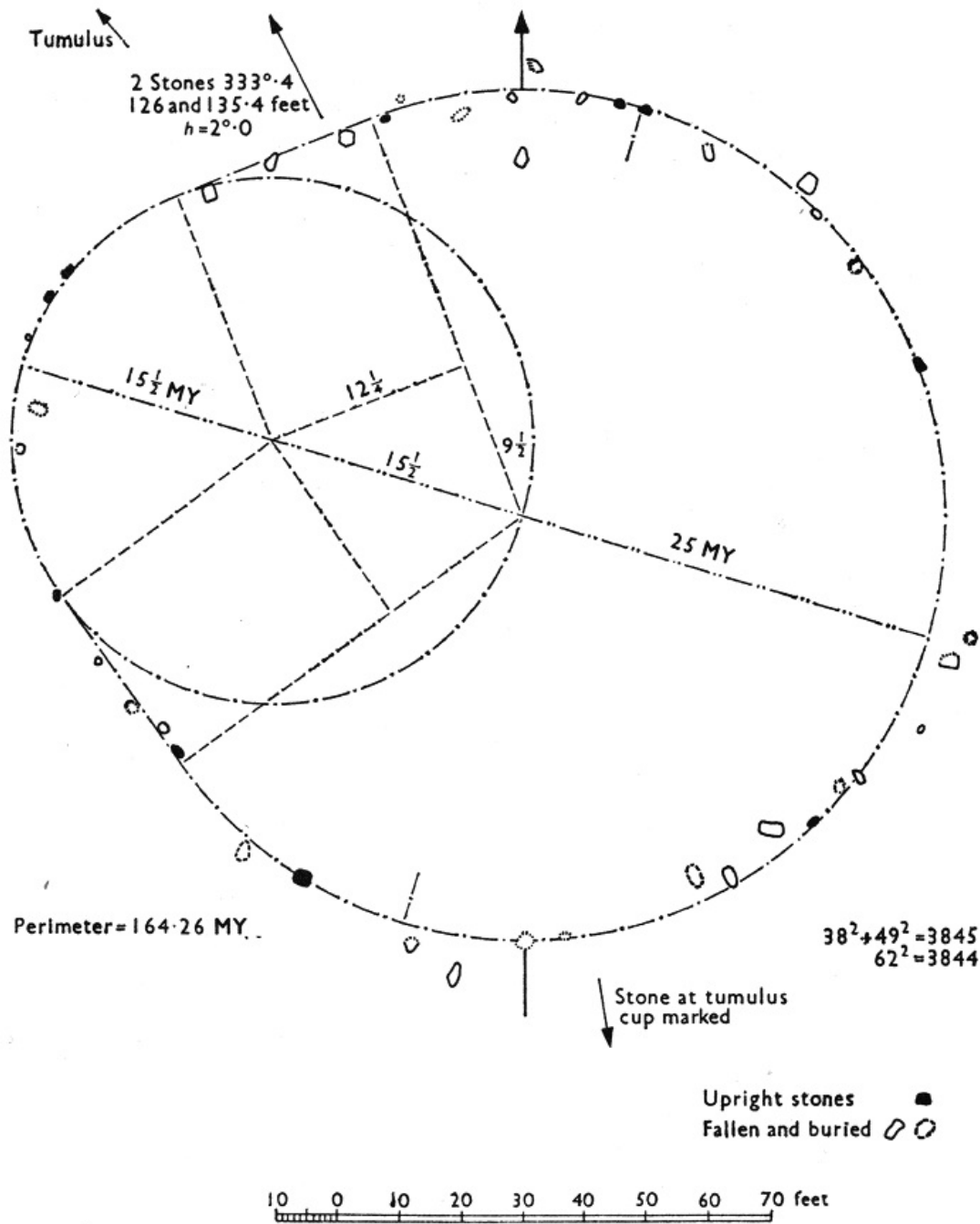


Fig. 6.15. Borrowston Rig, G9/10 ($55^\circ 46'$, $2^\circ 42'$)

The perimeters (P) have been calculated as outlined in Chapter 4 and are tabulated together with the amount by which they differ from the nearest multiple of $2\frac{1}{2}$. The discrepancy in the actual statistical diameters, as calculated from the actual stones, from the nominal diameters will be found in the main list (Table 5.1). It is found that $(\sum e_2^2 / n)$ for the eggs and compound rings is only 0.08 as against 0.51 for the table as a whole. This may be due to greater care, but is also probably due to the design of these

Table 6.3. *Compound rings* (see Chapter 7)

Site			r_1	P	$P - 2\frac{1}{2}m$
W 5/1	Moel ty Ucha	See Fig. 7.1	14	42.85	+0.35
B 7/10	Easter Delfour	See Fig. 7.4	22	67.56	+0.06
W 6/1	Kerry Pole	See Fig. 7.5	32	97.38	-0.12

Table 6.4. *Ellipses*

Site		$2a$ (MY)	$2c$ (MY)	$2b$ (MY)	P (MY)	$\epsilon =$ $ P - 2\frac{1}{2}m $
<i>(a) Definite ellipses</i>						
A 9/2	Ettrick Bay	18	12	13.42	49.61	0.39
B 1/24	Blackhill of Drachlaw	10 $\frac{1}{2}$	5 $\frac{1}{2}$	8.88	30.08	0.08
B 1/26	Loanhead of Daviot	14	5	13.08	42.54	0.04
B 1/27	Sands of Forvie	16 $\frac{1}{2}$	6	15.37	50.08	0.08
B 7/4	Boat of Garten	17 $\frac{1}{2}$	7	16.04	52.89	0.39
B 7/5	Daviot	18 $\frac{1}{2}$	6	17 $\frac{1}{2}$	56.56	0.94
P 1/3	Killin	12	6 $\frac{1}{2}$	10.09	34.76	0.24
P 1/16	Mickle Findowle	9 $\frac{1}{2}$	5	8.08	27.66	0.16
P 2/2	Ballinluig	9 $\frac{1}{2}$	5 $\frac{1}{2}$	7.75	27.16	0.34
S 2/7	Lee Moor	7	4	5.75	20.07	0.07
S 2/8	Postbridge	10 $\frac{1}{2}$	3	10.06	32.30	0.20
S 4/1	Winterbourne Abbas	11	5 $\frac{1}{2}$	9.53	32.28	0.22
W 2/1	Penmaen-Mawr	31	9 $\frac{1}{2}$	29.51	95.06	0.06
W 11/4	Usk River	25	10	22.91	75.30	0.30
P 1/19	Croftmoraig	11	7 $\frac{1}{2}$	8.05	30.10	0.10
<i>(b) Definite ellipses from other sources</i>						
	Tormore	18	9 $\frac{1}{2}$	15.29	52.38	0.12
	Auchengallon	18	6	16.97	54.94	0.06
	Clauchreid	13	7	10.95	37.70	0.20
	Braemore	34	17	29.45	99.79	0.21
	Learable Hill	24	12 $\frac{1}{2}$	20.48	69.99	0.01
<i>(c) Less-definite ellipses</i>						
B 7/13	Loch nan Carraigean	22 $\frac{1}{2}$	5	21.93	69.79	0.21
G 4/1	Carsphairn	30	20	22.36	82.68	0.18
H 1/1	Callanish I	5	3	4	14.18	0.82
H 1/2	" II	26	14	21.91	75.39	0.39
H 1/3	" III	21	12 $\frac{1}{2}$	17.06	59.94	0.06
"	"	12 $\frac{1}{2}$	9 $\frac{1}{2}$	8.12	32.75	0.25
H 1/4	" IV	15 $\frac{1}{2}$	10 $\frac{1}{2}$	11.40	42.50	0.00
H 1/10	Steinacleit	21	13	16.49	59.10	0.90
H 3/11	Leacach an Tigh Chloiche	20	15	13.23	52.74	0.24
L 1/6	Burnmoor	26	18 $\frac{1}{2}$	18.27	70.07	0.07
L 2/12	Harberwain	8 $\frac{1}{2}$	4	7 $\frac{1}{2}$	25.16	0.16
P 2/9	Guildtown	12	8 $\frac{1}{2}$	8.47	32.39	0.11
P 2/11	New Scone Wood	9	5	7.48	25.95	0.95
S 3/1	Stanton Drew	39	15	36	117.86	0.36
"	"	52	20	48	157.14	0.36

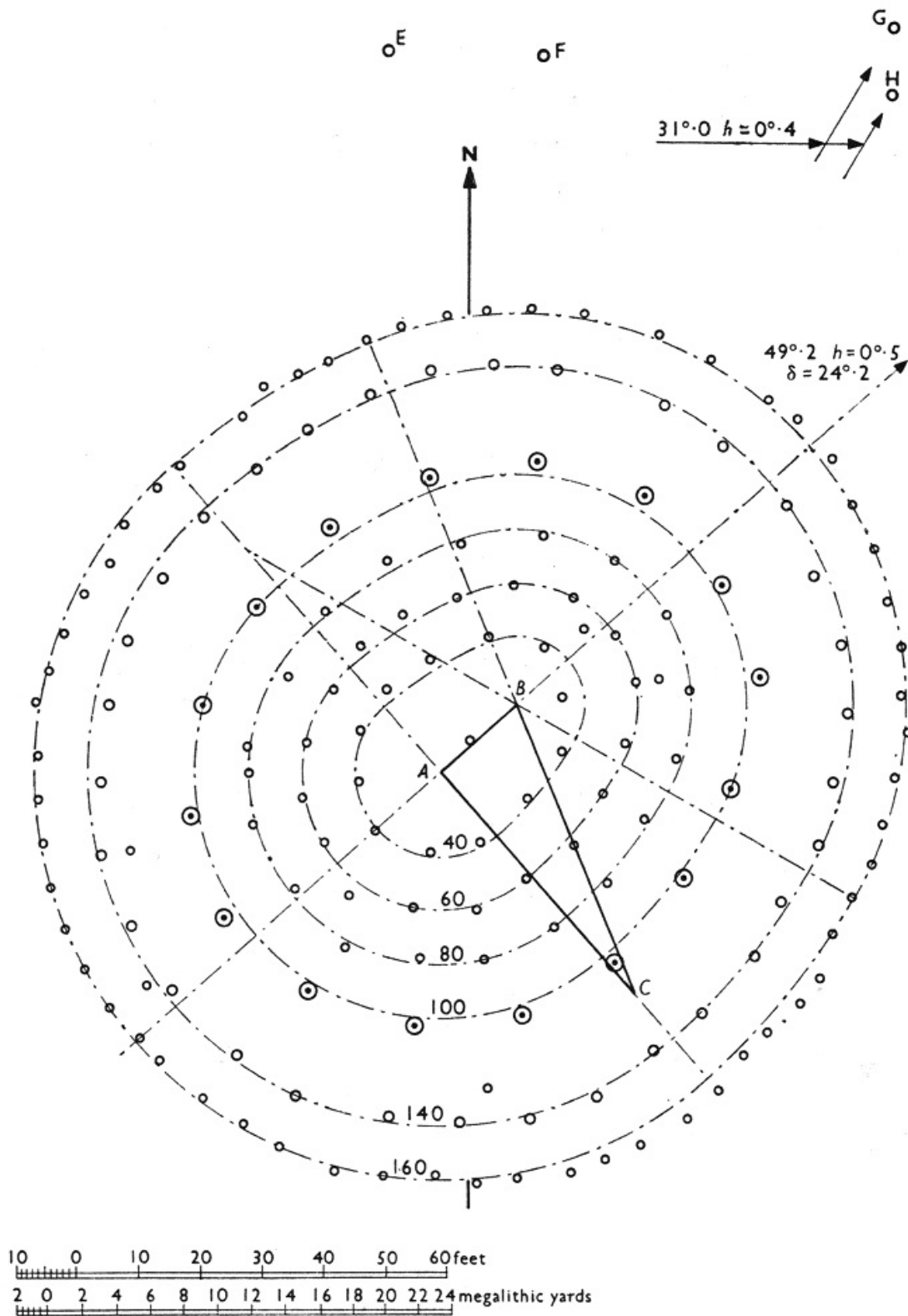


FIG. 6.16. Woodhenge, S 5/4 ($51^\circ 12'$, $1^\circ 48'$). Construction superimposed: $AB = 6$, $AC = 17\frac{1}{2}$, $CB = 18\frac{1}{2}$ MY; $r =$ radii struck from $A = (P - 9.08) \div 2\pi$; $P = 40, 60, 80, 100, 140,$ and 160 MY ($P =$ perimeter).

being nearer the desired value were unnecessary or at least seldom made.

When we remember that in each case an attempt was made, with considerable success, to fulfil two conditions, triangle and periphery, we realize how remarkable these designs are. A statistical examination will be made of the perimeters of these rings together with the ellipses in a later section. Meanwhile it is desirable to examine in detail that most remarkable set of egg rings found at Woodhenge.

Woodhenge

A very careful survey, using a steel tape and theodolite, was made of the concrete posts which the excavators placed in the post-holes in-the chalk. A reproduction to a very much reduced scale is shown in Fig. 6.16. The axis drawn is chosen to be along the azimuth of the point on the horizon where the midsummer sun first appeared about 1800 B.C. Using centres on this axis we then find

- (1) the arcs at the large end have a common centre at A ,
- (2) the arcs at the small end have a common centre at B ,
- (3) the distance AB between these centres is 6 MY,
- (4) the arcs are equally spaced with one gap,
- (5) the radius at the small end is in each ring 1 MY smaller than the radius at the large end.

These facts are indisputable but in themselves they do not explain the construction, because the radii are not integral multiples of the yard.

With the method and notation explained on p. 30 we write:

$$\begin{aligned} r_1 - r_2 &= a - b = 1, \\ c &= 6, \\ a^2 - b^2 &= c^2 \end{aligned}$$

The solution of these equations is $a = 18\frac{1}{2}$, $b = 17\frac{1}{2}$. The fact that these are rational numbers shows that we are dealing with a Pythagorean triangle. In units of half-yards the triangle is $12^2 + 35^2 = 37^2$. The discovery of this triangle must be considered as one of the greatest achievements of the circle builders. That they themselves considered it important is shown by the use they made of it at Woodhenge. Its use at another site will be discussed later.

But we have yet to show how the radii of the rings were chosen. The scheme used only becomes apparent when we realize that the rings were intended to have perimeters which were multiples of 20 MY. The values selected were 40, 60, 80, 100, 140, and 160 MY. Accepting these we can easily calculate the necessary radii. These can then be compared with what we find on the ground.

We have seen on p. 30 that for a Type I ring the perimeter is

$$P = 2\pi r_1 + \pi b - 2a\beta$$

where $\tan \beta = b/c$. Substituting $a = 18\frac{1}{2}$, $b = 17\frac{1}{2}$, $c = 6$, we find

$$2\pi r_1 = P - 9.0794.$$

Values of r_1 corresponding to the various values of P can now easily be calculated and will be found in the table below. Values of r_2 and r_3 follow from $r_2 = r_1 - 1$, $r_3 = r_1 + 17\frac{1}{2}$.

Table 6.5

Ring	P (MY)	r_1 (MY)	Major axis (MY)	π'	P_a (MY)
I	160	24.02	53.04	3.02	161.0
II	140	20.84	46.67	3.00	138.2
III	100	14.47	33.94	2.95	104.2
IV	80	11.29	27.58	2.90	79.9
V	60	8.10	21.21	2.83	61.3
VI	40	4.92	14.84	2.70	39.4

Egg-shaped rings were drawn very carefully on tracing paper to these radii and superimposed on the survey (Fig. 6.16). It was then possible, by the method of p. 35, to determine the adjustments necessary to each ring to obtain the best agreement with the concrete posts. The perimeters of the rings so found are given in the last column. It will be seen that ring III is some 4 per cent large. This ring is very nearly represented by taking $r_1 = 15$ and $r_2 = 14$, which gives a ring about 0.53 MY or 1.44 ft outside the hypothetical 100-MY ring everywhere. It thus appears that if the posts were 2.88 ft (or about 1 MY) diameter the inside of the structure would be a perfect fit. The excavators found that there were deep ramps to all the holes in this ring, indicating that very large posts had been used carrying perhaps a platform or roof.

We can, by the statistical method described and used earlier, find from P_a , neglecting ring III, the value of the Megalithic yard which best fits Woodhenge. This turns out to be about 2.718, a value so close to 2.72 (used in drawing the rings) as to show that we can be quite certain we are using the identical geometric construction to that used by the builders.

In the above table π' is the theoretical ratio of P , the nominal perimeter, to the greatest diameter ($2r_1 + 5$). It will be seen that π' gradually increases as the rings get larger until at ring II it is 3.00. A more exact calculation gives 2.9994. No matter how carefully the builders made their measurements they could never have detected the difference between this and 3. One is tempted to surmise that the whole set of rings may be a permanent record of an elaborate empirical determination of a geometrically constructed

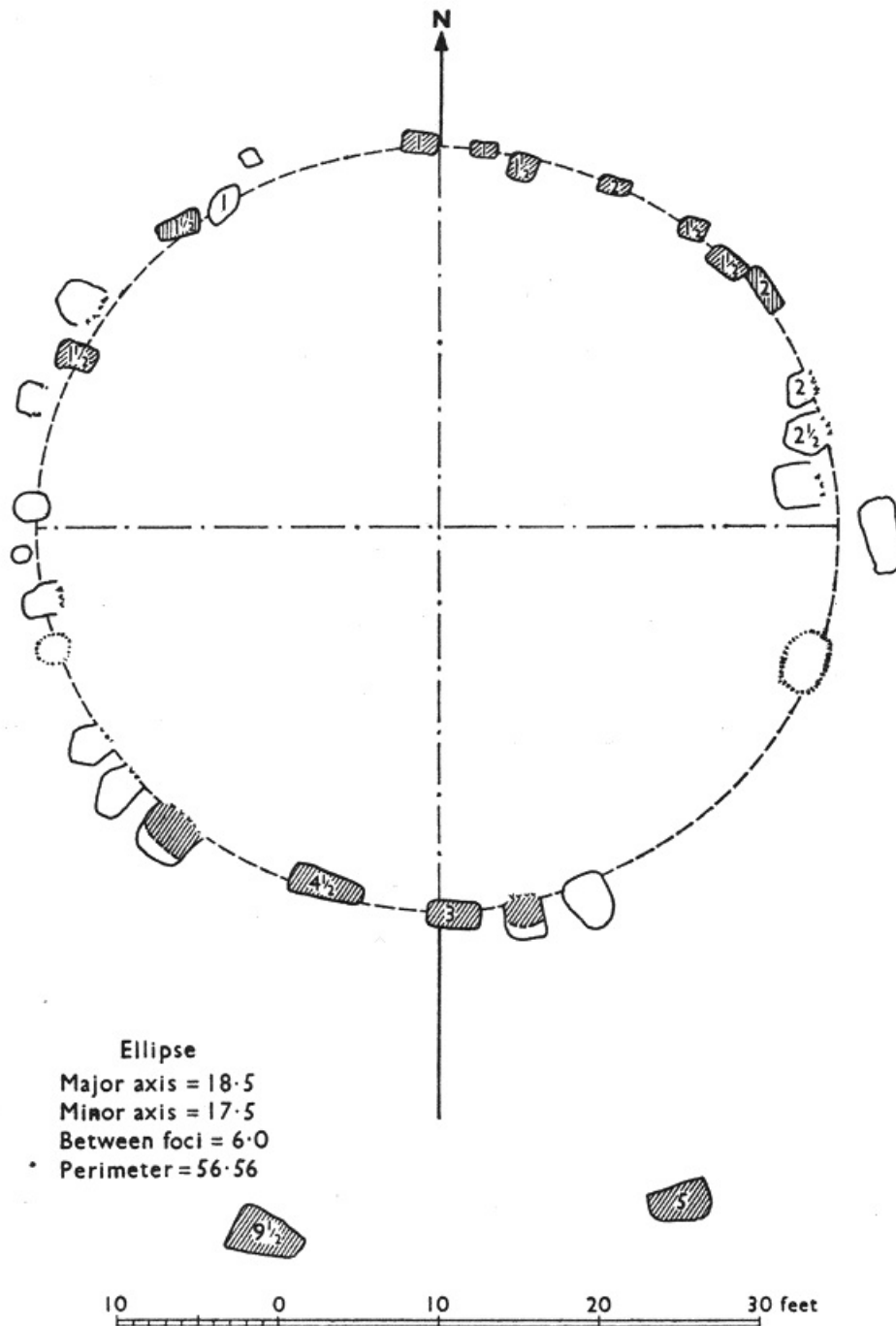


Fig. 6.17. Daviot, B 7/5 ($55^{\circ} 46'$, $2^{\circ} 42'$).

a ring which would have as it were $\pi = 3$ and at the same time have a circumference a multiple of 20 yds. Certainly none of our modern circle squarers have obtained a closer approximation. It may be remarked that ring-II post-holes are better marked than ring I which overshot the mark with $\pi = 3.02$. Presumably the inner ring was laid out first. One wonders how many rings were set out before the builders discovered that every 20 yds they added to the circumference gave them the same increment to the radius (actually $10/\pi$).

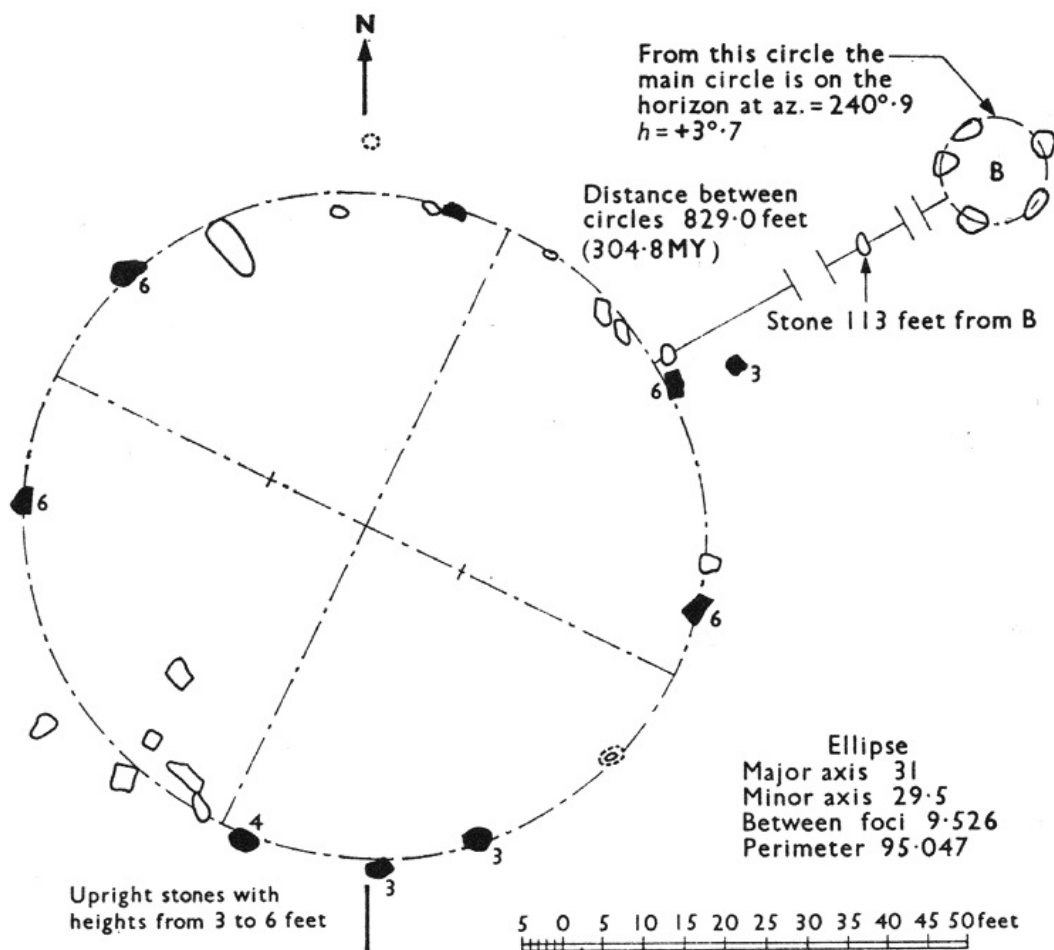


Fig. 6.18. Penmaen-Mawr, W 2/1 ($53^{\circ} 15'$, $3^{\circ} 55'$).

Did they notice this after four rings and then attempt an extrapolation? It is much more likely that they already possessed this kind of knowledge, because this cannot have been their first attempt. They had probably experimented with many other triangles before arriving at the 12, 35, 37.

One is entitled to reject the above reason for making the structure, but everyone must be impressed by the laborious, painstaking work which preceded the discovery of the sixth member of the list of perfect Pythagorean triangles and the construction of a set of rings based on this triangle with perimeters exact multiples of 20 yds.

Ellipses

There are about twenty known stone rings in Britain which are definitely ellipses and another dozen or so less certain. In most cases the uncertainty is a result of the ruinous condition of the site making it difficult to be certain of the exact outline. There is seldom much doubt about the shapes being elliptical.

In Table 6.4, $2a$ and $2b$ are the major and minor axes, $2c$ is the distance between foci, and P is the perimeter calculated from $2a$ and $2b$. The amount by which P differs from

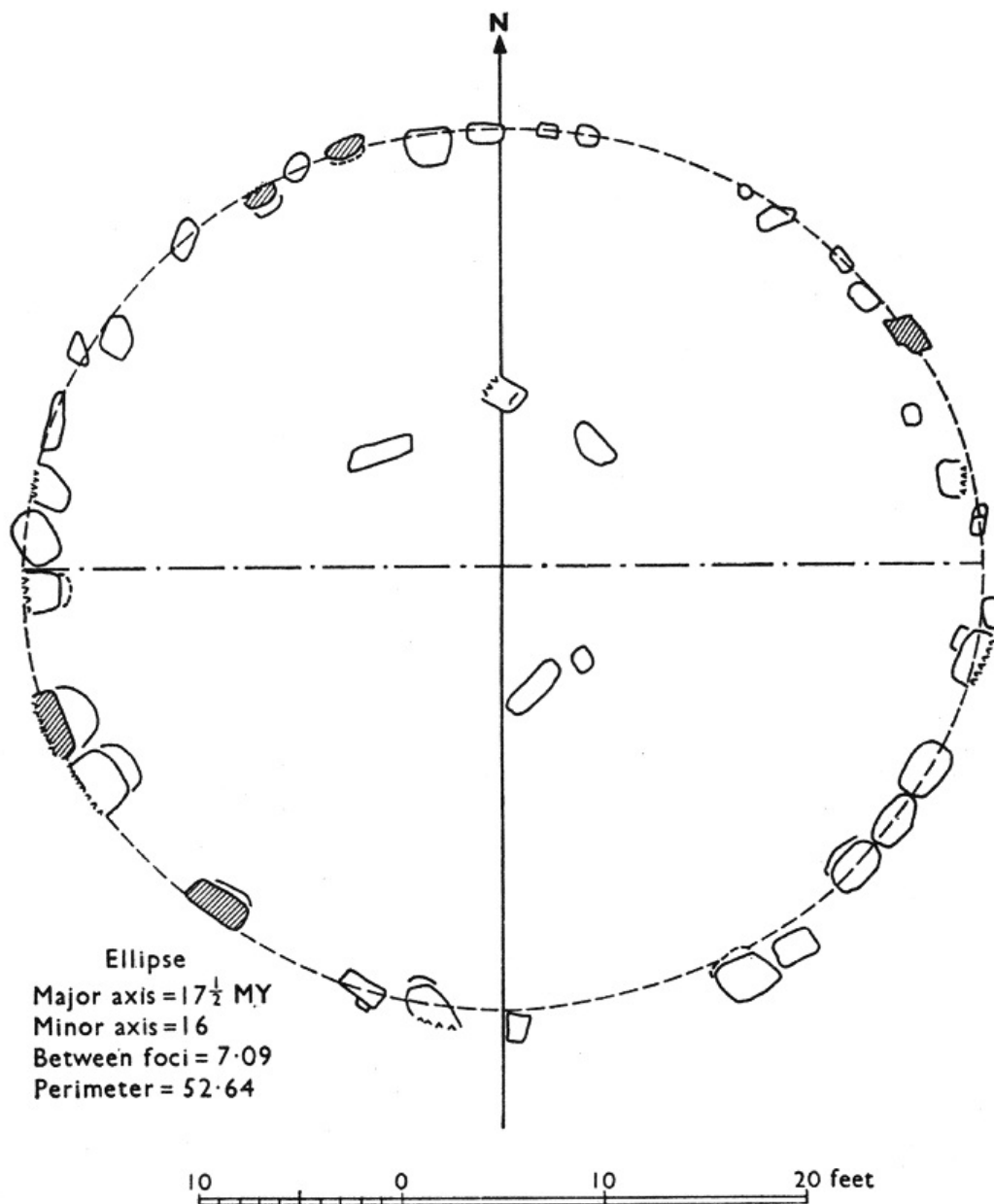


Fig. 6.19. Boat of Garten, B 7/4 ($57^{\circ} 16'$, $3^{\circ} 43'$).

the nearest multiple of $2\frac{1}{2}$ MY is given in the last column.

We have seen that in an ellipse a , b , and c must be capable of forming the sides of a right-angled triangle and it appears that in Table 6.4 nearly all the ellipses are based on triangles which are nearly Pythagorean but in only five is the triangle exact. One is the ellipse at Daviot (Fig. 6.17) near Clava, but we see that at the same time it shows the largest ϵ in the table. The triangle used is the 12, 35, 37 which figures so prominently at Woodhenge and one is tempted to surmise that the builders knew of the perfection of the triangle they were using and were prepared to sacrifice the perimeter.

One of the almost perfect triangles is that at Penmaen-Mawr, where in half-yard units we get $19^2 + 59^2 = 3842$ against $62^2 = 3844$. It would have been quite impossible for the

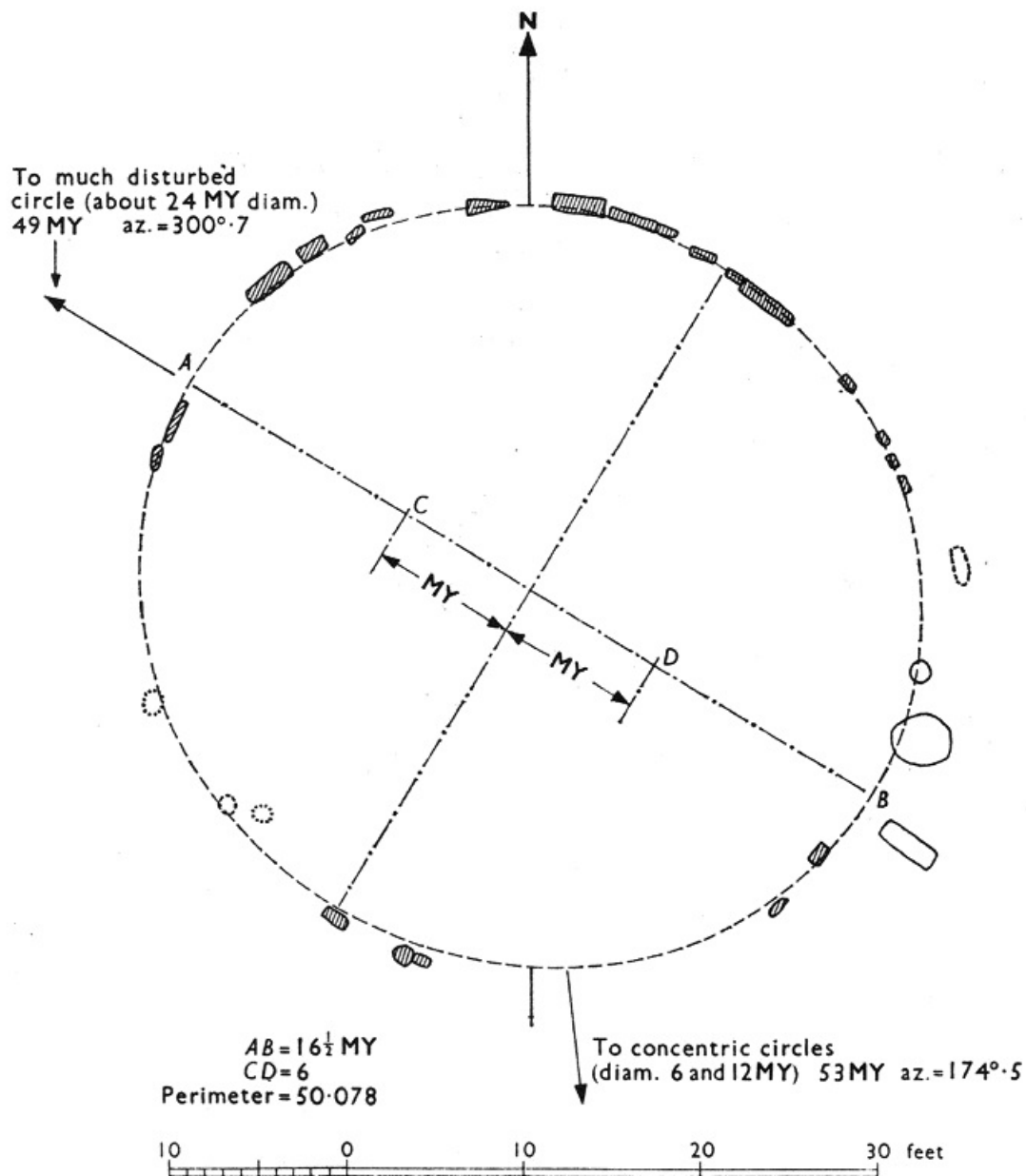


Fig. 6.20. Sands of Forvie, B 1/27 ($57^{\circ} 19' \cdot 6$, $1^{\circ} 58' \cdot 8$).

builders to detect the discrepancy in the hypotenuse (1 in 3800). From their point of view the perimeter was also perfect with an error of only 1 in 1500. It will be seen in Fig. 6.18 how nearly the ellipse drawn to the values given passes through those stones which are still upright.

The ellipse at Boat of Garten, that at Sands of Forvie, and that near Postbridge (Figs. 6.19, 6.20, and 6.21) are also good examples.

It seems that at Blackhill of Drachlaw (B 1/24), in order to get a perimeter of 30, the builders used a major axis of $10\frac{1}{4}$ and an eccentricity of one-half giving $2b = 8\frac{7}{8}$ and $2c = 5\frac{1}{8}$. The triangle is $41^2 + 71^2 = 6722$ against $82^2 = 6724$. They also used eighths at Sands

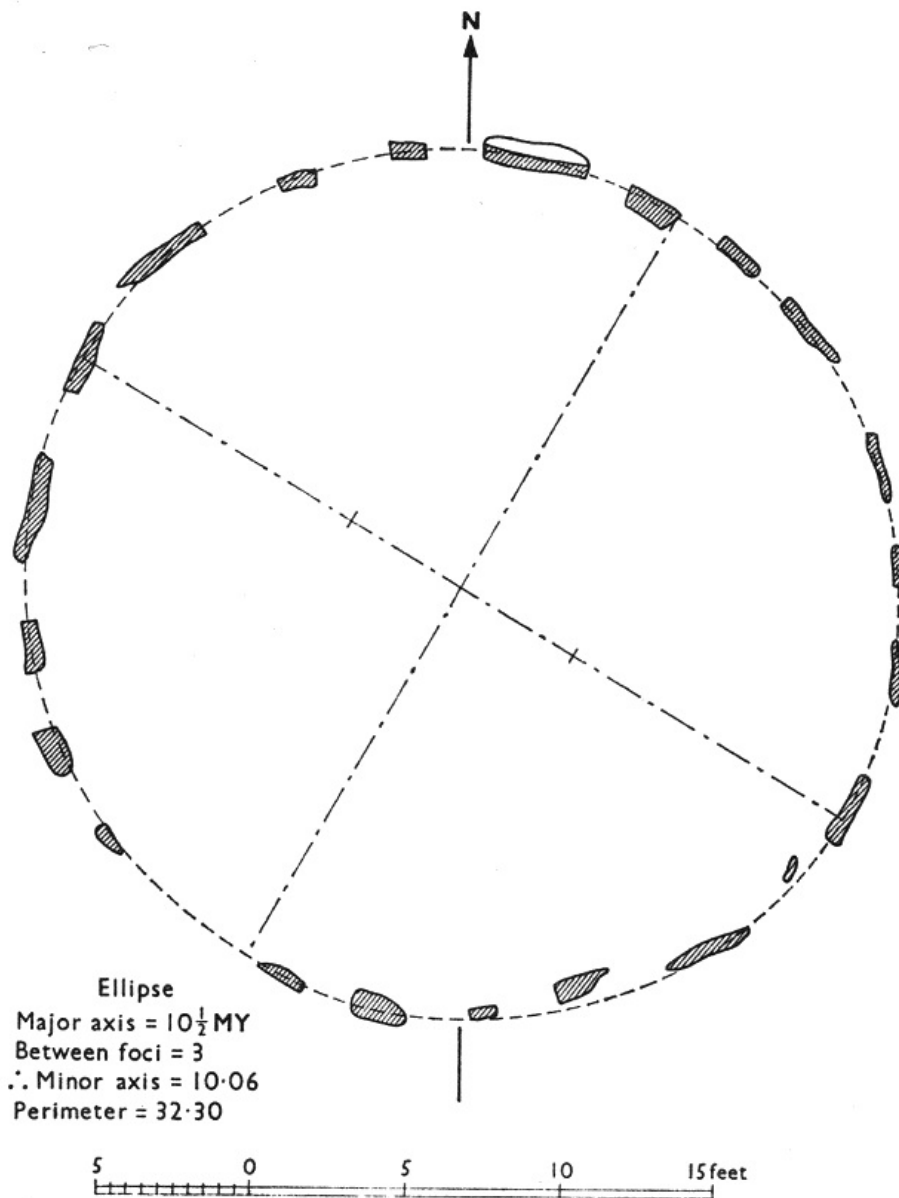


Fig. 6.21. Postbridge, S 2/8.

of Forvie, the triangle being $48^2 + 123^2 = 17433$ against $132^2 = 17424$. This subdivision into eighths was done here to achieve a perimeter of 50, actually 50.08. In some places they used quarter-yards but in most ellipses they succeeded without subdividing beyond halves.

No good purpose would be achieved by discussing the sites in Table 6.4 (e) because, as already said, the dimensions are uncertain. Major Prain, after his recent accurate survey of Stanton Drew, suggested that the north circle was an ellipse. On looking into the matter it appeared that an ellipse based on a 5, 12, 13 triangle fitted much better than a circle. When an ellipse was fitted to the third circle it proved to be again based on the 5, 12, 13 triangle but it was of a different size. Table 6.4 (c) shows that the perimeters of

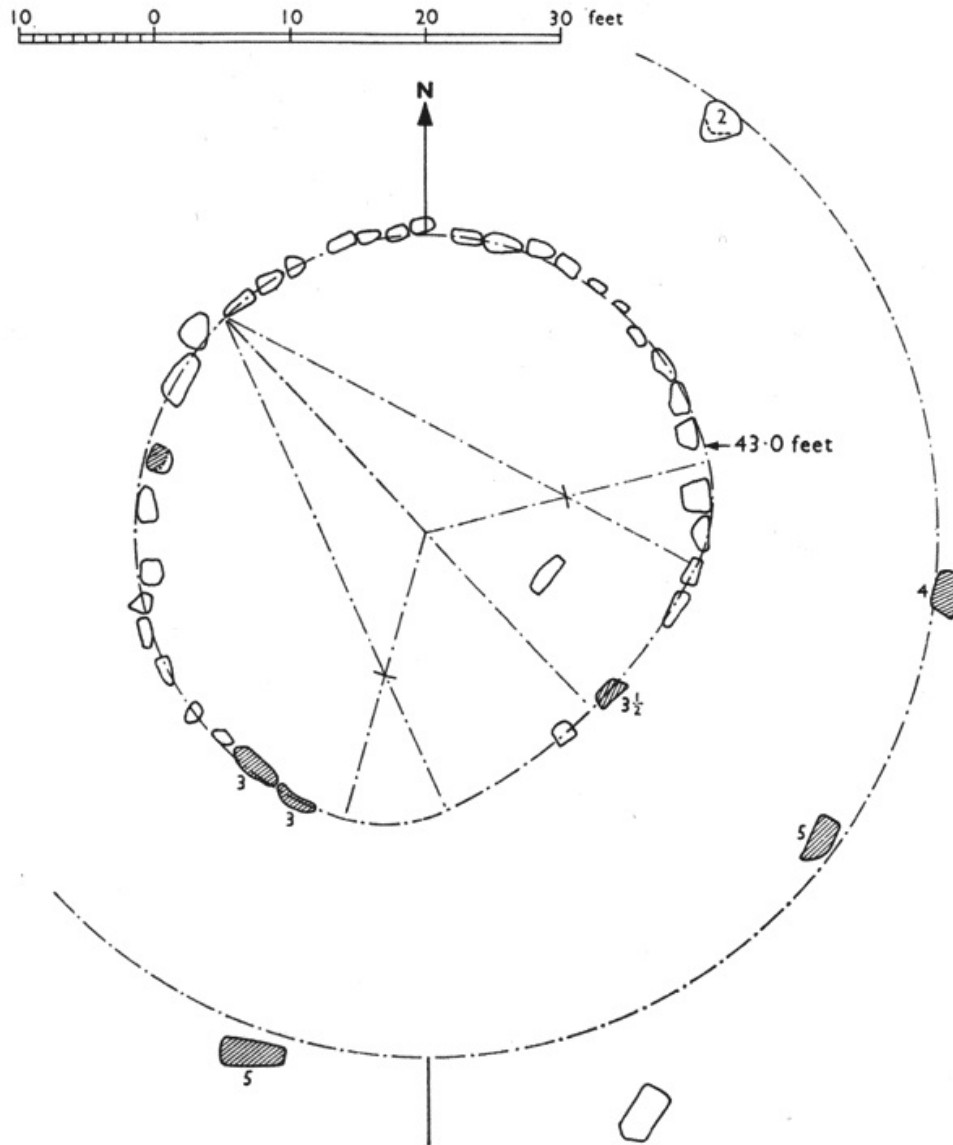


Fig. 6.22. Aviemore, B 7/12 ($57^{\circ} 12'$, $3^{\circ} 50'$).

both satisfy the usual requirement. The major axes of both ellipses seem to lie on the same line.

The construction near Loch nan Carraigan near Aviemore (B7/13) consists of a large ruinous hollow cairn which apparently, like the Clava cairns, was surrounded by a circle of menhirs now presumably in the foundation of the railway. It did not seem worth while to make a detailed survey but spot points were put in on the outside of the cairn wall. Curiously enough an ellipse $22\frac{1}{2} \times 22$ seems to fit these excellently, which could well be a coincidence but when one finds that the calculated perimeter is very close to 70 MY one wonders.

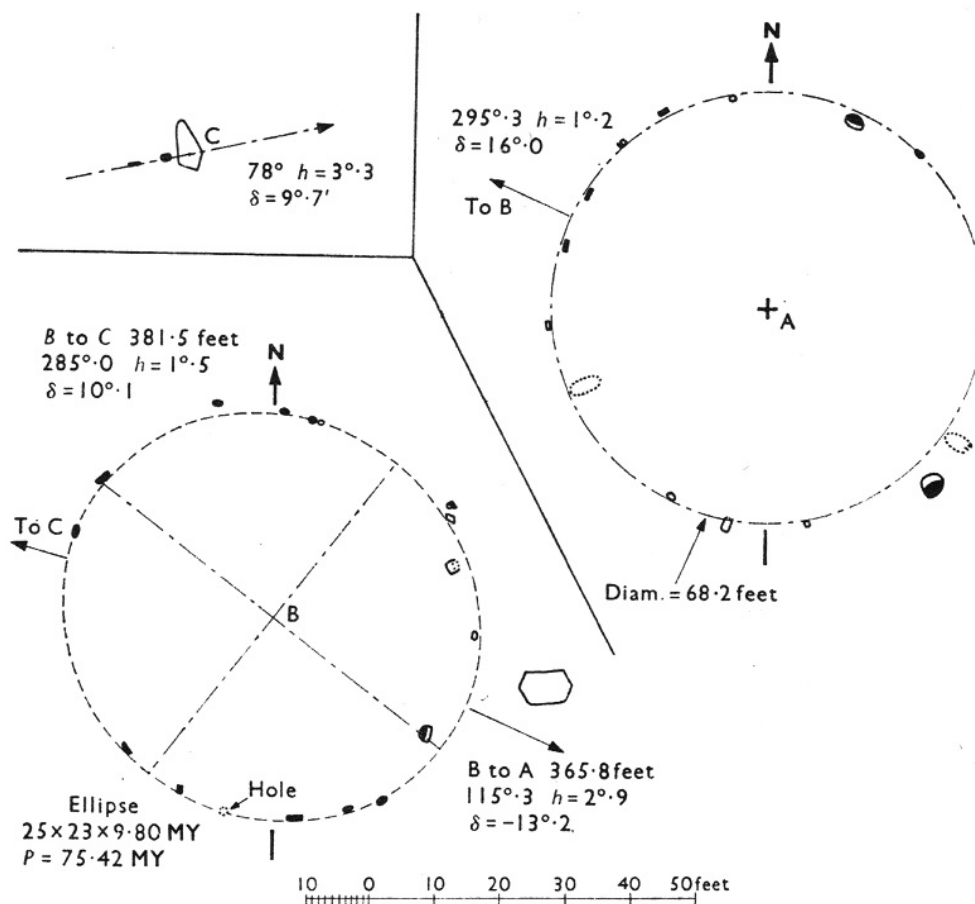


Fig. 6.23. Circles near Usk river, W $11\frac{1}{4}$ ($51^\circ 55'$, $3^\circ 43'$).

In the ellipses in Table 6.4 (b) whole or half-yards were used except perhaps at Tormore. It was this fine ring which first suggested to Dr. Roy (Roy, 1963) that ellipses were used and his interpretation is that, as at Blackhill of Drachlaw, the eccentricity was intended to be one-half, with a slightly different major axis.

The $2\frac{1}{2}$ yard unit in ellipses and eggs

A glance at the values of P for the ellipses in Table 6.4 shows that there is no doubt that the perimeters were intended to be multiples of $2\frac{1}{2}$ yds. In fact, s^2/δ^2 is lower for this group than for any so far examined, but in view of the small number it is best to take the eggs and ellipses together.

For all eggs, compound rings, and definite ellipses, for P we get

$$\sum e^2 = 5 \cdot 15, \quad n = 33, \quad 2\delta = 2\frac{1}{2},$$

so $s^2 = (\sum e^2)/n = 0 \cdot 156$ and $s^2/\delta^2 = 0 \cdot 100$.

Applying this to Fig. 2.1 to obtain the probability that the unit of $2\frac{1}{2}$ was real we find that s^2/δ^2 is so small as to be off the sheet but it is evident that the probability level is well

below 0·1 per cent. Broadbent's criterion turns out to be 1·34 so that even with no *a priori* knowledge of the yard we must accept the reality of the $2\frac{1}{2}$ MY unit. It will be remembered that in the distances between circles units of $2\frac{1}{2}$ and 5 MY appeared, though not so conclusively as the $2\frac{1}{2}$ unit above. Five MY or 13·6 ft is about as long a rod as can conveniently be handled on the straight but it would be much too long for measuring circumferences. Perhaps for a preliminary measurement in the trial-and-error process of finding a suitable ring a $2\frac{1}{2}$ -MY rod would be used, but the error per yard would be, as we have seen (p. 32), about $c^3/24R^2$, which works out about 0·2 yds in a circle of 16 yds diameter.

Chapter 6: Circles and Rings. Thom, A. *Megalithic Sites in Britain*,
Clarendon Press, Oxford 1971:56-83.

7

THE COMPOUND RINGS

(Thom 1971:84-91)

WE shall discuss Avebury in this chapter, but before doing so it is advisable to look at three rings whose designs lead up to the Avebury construction. These three sites seem to the author to be amongst the most important in Britain. Their geometrical construction shows a mastery of the technique of finding designs which, while possessing an elegance of symmetry and proportion, yet incorporate a hidden significance in that integral lengths were obtained for the basic dimensions and the perimeters were multiples of $2\frac{1}{2}$ MY.

It is true that today we can be petty and apply our short-cutting knowledge of trigonometry to show that their lengths were only approximations. Their $13\frac{1}{2}$ is our 13.503, their 15 our 14.99, but this does not show that they failed. Within their limitations they succeeded. To our modern thinking they were attempting the impossible, but in more advanced spheres so are we.

In the last chapter we examined rings based on Pythagorean triangles and we saw how successfully close approximations to these triangles had been invented as required. But in Moel ty Ucha the builders were attempting something much more difficult. They started with a circle 14 yds diameter and therefore $3\frac{1}{7} \times 14$ or 44 yds in circumference. But this was not enough: they wanted also to have a multiple of $2\frac{1}{2}$ yds in the perimeter. So they proceeded to invent a method of drawing flattened portions on the ring which, with a minimum of distortion, would reduce it to $42\frac{1}{2}$. To introduce these flattened portions they had to use at least two radii and each had to be integral. Finally the finished ring had to have, like nearly all others, an axis of symmetry. Later we shall see that they had still another external condition to fulfill if possible. Deneb rose at an azimuth of $17^\circ.3$ and they wanted this angle to be shown on the construction so that when the cross axis pointed to the rising star true north would also be shown. They did not get $17^\circ.3$, they got 18° . This is the complement of 72° , which is one-fifth of 360° . The Greek geometers showed much later how to construct an angle of 72° , but it can hardly be imagined that the builders of Moel ty Ucha used anything more elaborate than trial and error. Having divided the circle into five or perhaps ten parts the construction proceeds as in Figs. 7.1 and 7.2. Draw an inner circle of radius 4 and centred on this draw the five short arcs of radius 3 touching the main circle at its subdivision points. Two of these arcs are half length, because the final ring lies on the original circle for 72° at the left. Finally the short-radius arcs are connected by flat arcs centred as in the flattened circles on the far side of the main circle at the 'corners' where this is touched by the short arcs. We wish

now to calculate the radius of these closing arcs and the length of the circumference.

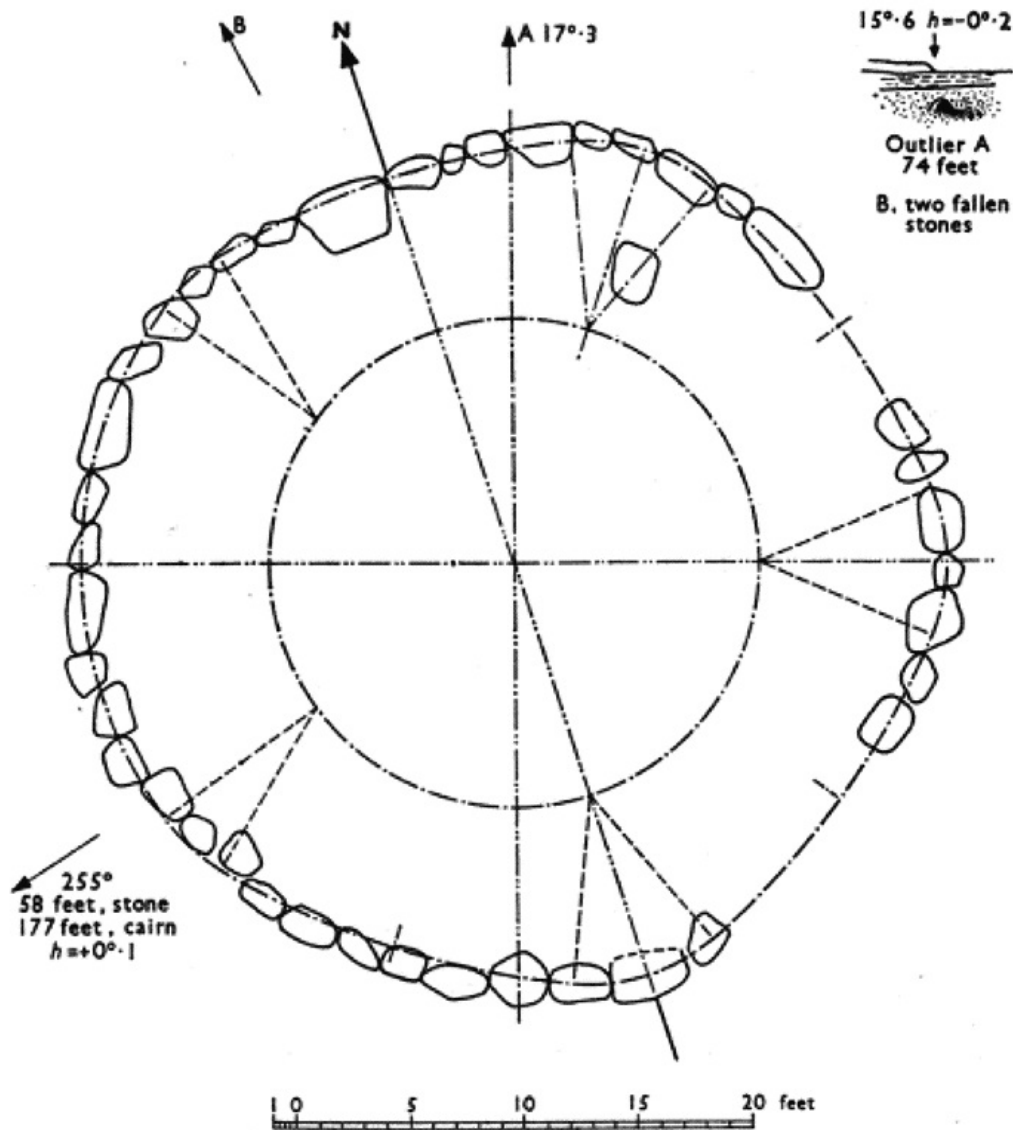


Fig. 7.1. Moel ty Ucha, W 5/1 ($52^{\circ} 55'.4$, $3^{\circ} 24'.2$).

Referring to Fig. 7.3 we have $a = 4$, $b = 7$, and so $r = 3$.

$$c^2 = a^2 + b^2 + 2ab\cos\pi/5 \quad \text{and so } c = 10.503.$$

The required radius is AD which is $c + r$ or 13.503 . We also easily find $\angle A = 0.22578$, $\angle B = 0.40254$, and the perimeter P is found to be

$$P = 8 \times r \times B + 8(r + c)A + 2b \times \pi/5,$$

which is 42.85 .

Thus we see that the required radius exceeds $13\frac{1}{2}$ by only 0.003, an amount which could only be detected by the most advanced modern techniques, and the discrepancy in the perimeter is only 0.35, which is comparable with the discrepancies we have seen in the circles, eggs, and ellipses.

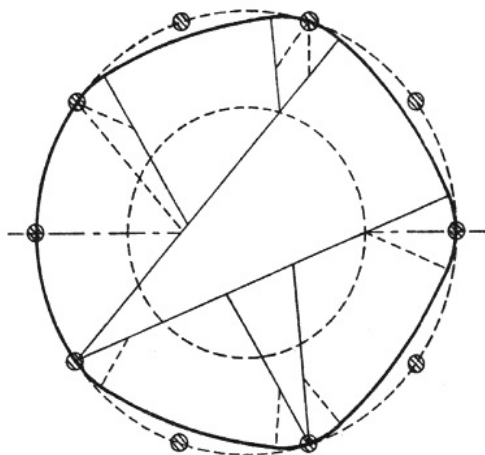


Fig. 7.2. Geometry of W 5/1

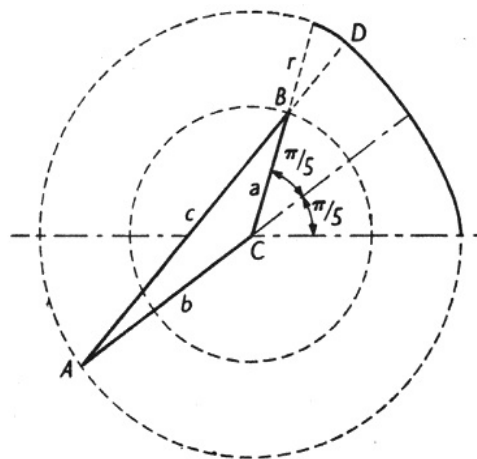


Fig. 7.3. Geometry of W 5/1

Fortunately this beautiful little ring has been very little disturbed and we can see how perfectly the construction fits the stones. One must of course expect frost to have moved some of the stones slightly. The gaps seem symmetrical and may have been entrances to the original structure.

Because of the importance of this site the calculations have been given in detail, but there seems to be no necessity to treat the next sites so fully.

Easter Delfour

The outer ring at this site (Fig. 7.4) is partly buried in rubble, showing that the original structure was perhaps a hollow cairn. This view is borne out by the dimension of the inner ring, which measures 8 MY diameter to its *inner* face. So the rings are retaining walls and measurements will be taken to the outside of the outer stones. This ring has much in common with Moel ty Ucha but it is divided into four instead of live. With an even number of sides the centre of any one of the flat arcs must be on the radius bisecting the opposite arc, not as at Moel ty Ucha on a 'corner'. So if the usual convention was followed of putting this centre on the circumference ambiguity would arise, is it on the arc or on the circumference of the circumscribing circle? Perhaps for this reason all eight centres lie on a much smaller circle with a diameter of $6\frac{1}{2}$ MY. We can be sure of this dimension because

- (1) its use produces a figure which fits the stones perfectly,
- (2) it makes the length AB (as calculated by the method shown for Moel ty Ucha) 6.005,
- (3) it makes the minimum diameter of the ring across the flat arcs 21.010,
- (4) it makes the perimeter 67.56.

These remarkable dimensions cannot be accidental. So we can be certain that we have uncovered the geometry of this site.

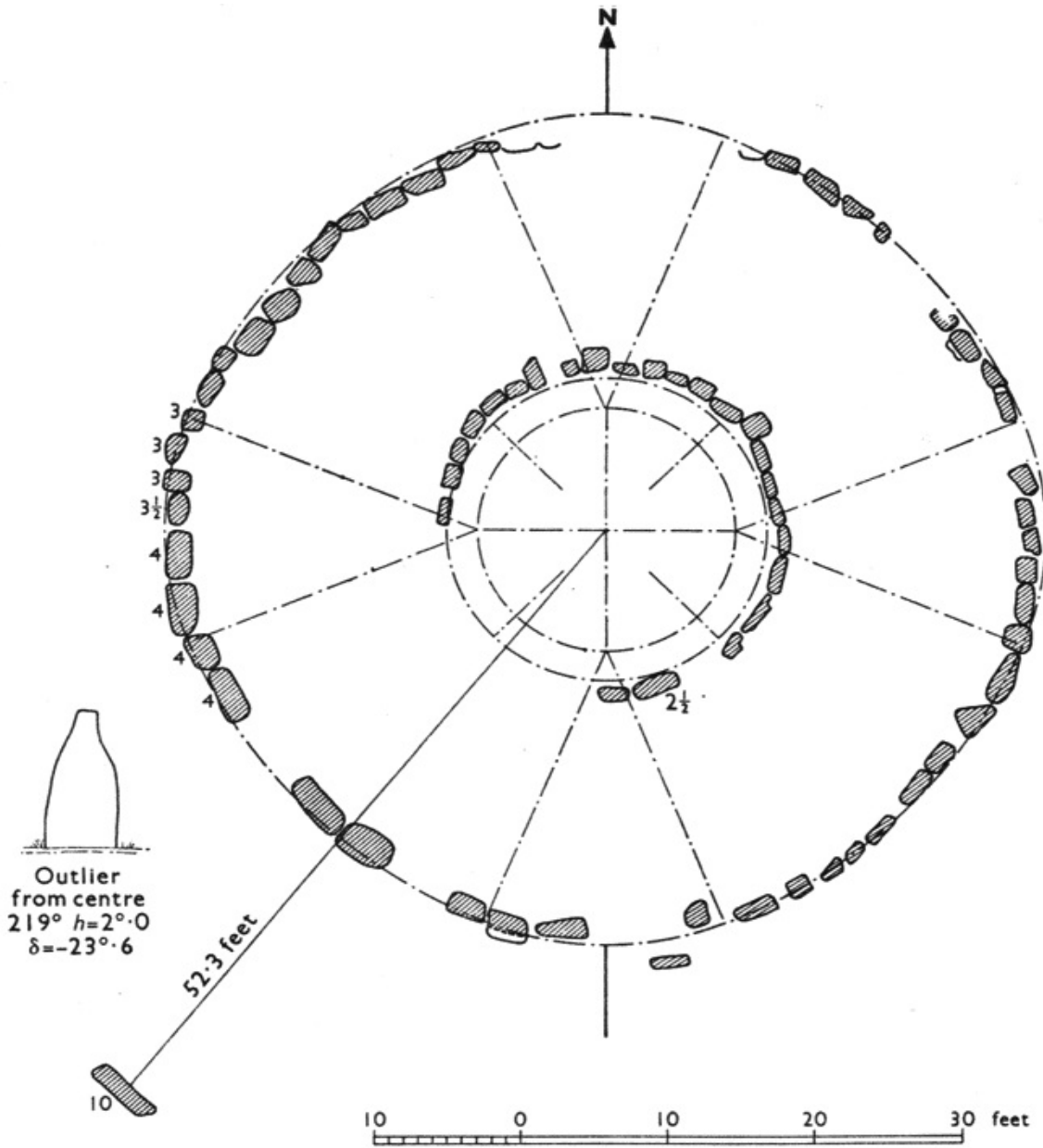


FIG. 7.4. Easter Delfour, B 7/10 ($57^\circ 09'$, $3^\circ 54'$). Taking maximum outer diameter = 22 MY and diameter of small circle = $6\frac{1}{2}$ MY, calculation shows minimum outside diameter = 21.01 and $P = 67.56$

Ring near Kerry Pole

On the ground this is a very unimpressive site, but when it is surveyed (Fig. 7.5) and the geometry studied it turns out to be another member of the group we are examining.

The construction is again based on two circles. Here their diameters are definite, 32 and 16 MY. Two points are then established on the outer circle, *E* at 5 MY from the axis

and G at 14. Bisect the angle GOE by the line LOK . Draw KP_2T and KP_1S . The corner arcs ES and TG are centred on P_1 and P_2 and the closing arc on K . A little trigonometry gives the radius KS of the closing arc and the perimeter. The remarkable thing is that these are 29.98 and 97.38 MY. Thus all the radii are integral, 16, 8, and 30 MY, and the perimeter only 0.12 different from a multiple of $2\frac{1}{2}$.

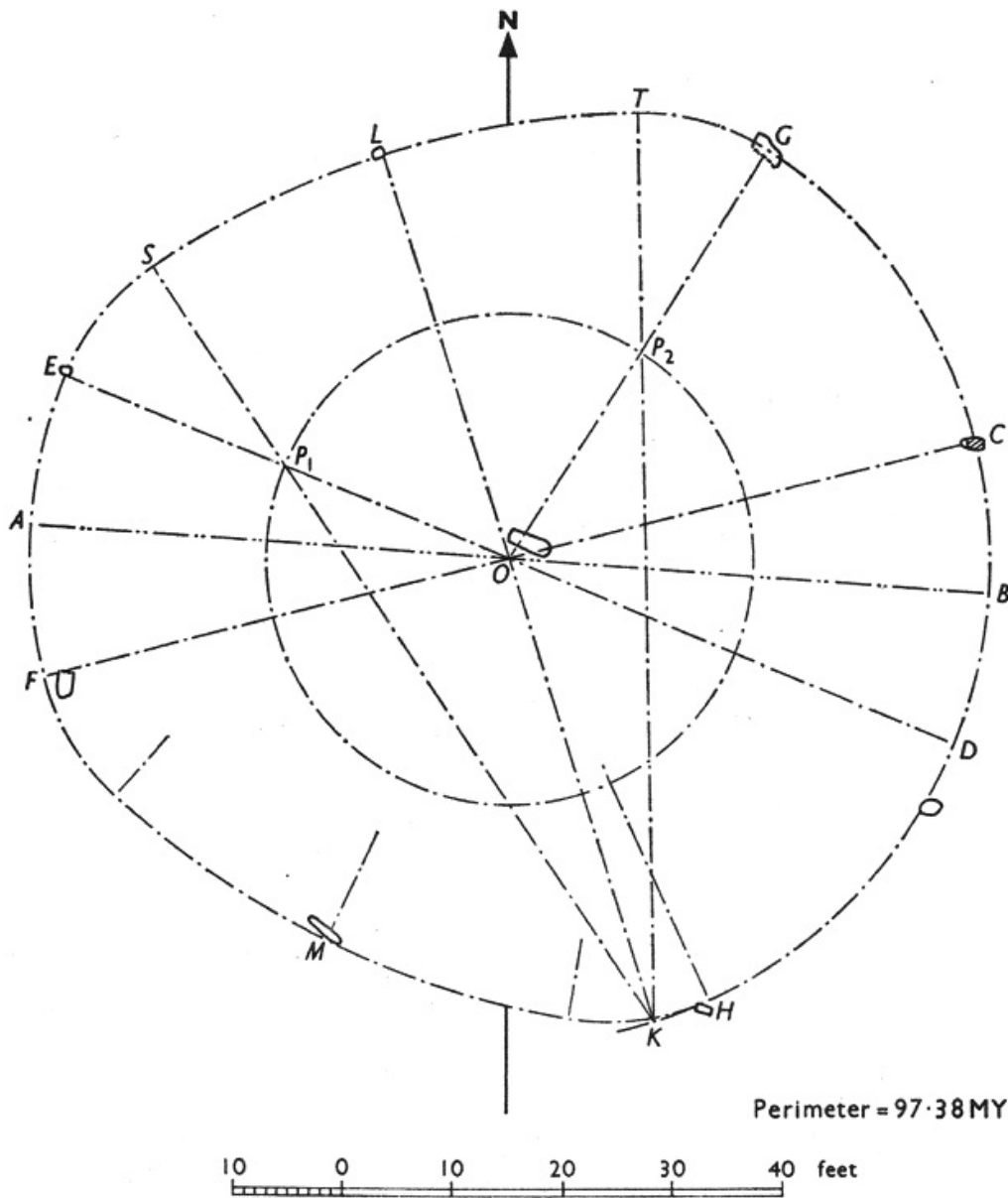


FIG. 7.5. Kerry Pole, W 6/1. ($52^\circ 28'$, $3^\circ 14'$). Construction: $AB = 32$ MY; $CD = 10$ MY; $EF = 10$ MY; $GH = 28$ MY; $OP = 8$ MY; then $KS = 29.98$

It is indeed fortunate that this ring is so little disturbed. We see that the changes of radius at G, H, F , and E are still marked, as are the points at L and M bisecting the angles GOE and HOF and so fixing the centres for the long arcs. Note also that while the axis is not east and west the line KT is very nearly due north.

Avebury

The tragic destruction of Avebury is perhaps one of the worst acts of vandalism of recent centuries. But the present educated generation driving its tractors and bulldozers through other monuments is even more unforgivable. Today our power of destruction is greater and we remove the monuments without leaving a trace and often without allowing time for a survey. At Avebury more than a trace is left. Careful excavation made possible and controlled by Alexander Keiller has re-established the positions of many of the menhirs in the main ring and has indeed made it possible to establish the diameter and position of the older circles inside the ring. The extensive excavations are described in detail in a work prepared by I. F. Smith which also gives a full description of the site as it is today.

But the kind of survey necessary for our present purpose was lacking and so the author, assisted by Brigadier A. Prain and Miss E. M. Pickard, made an accurate survey of the upright stones and of the concrete posts which now mark the positions of many of the destroyed stones. The traverse necessary, about 3000 ft long, was checked at three points by astronomical determination of azimuth and closed to 0.6 ft. Thus the survey can be accepted as sufficiently accurate. It is shown on a reduced scale in the Frontispiece.

The geometrical design to which the stones in the outer ring are set out differs from anything so far discussed in that the arcs forming the ring meet at definite corners not appreciably rounded off. Without a knowledge of the exact length of the Megalithic yard and of the simpler designs it is doubtful if the construction could have been discovered. The basis of the design is a 3, 4, 5 triangle set out in units of exactly 25 MY so that the sides are $AB = 75$, $AC = 100$, and $BC = 125$. The main centre for the whole design is a point (D) inside this triangle exactly 60 MY from C and so placed that a perpendicular dropped from D to CA is 15 MY. The peculiarity of this position of D is that if DC is produced 140 MY to S , so that DS is 200, the distance SB is 259.97 MY, which was certainly thought to be 260. Now draw the main circle with centre D and radius 200 and draw a line parallel to AB through D to meet the circle at E .

The next stage is to draw three arcs all of radius 260, each centred on one of the corners of the basic triangle. To be specific, with centre B draw the arc HG where H is on BC produced, with centre B draw the arc GF , and with centre C draw the arc ML . This last arc will run into the main circle tangentially at L on CD produced. Now passing through E draw the arc FEM with centre 750 MY from E on ED produced. So far we can be perfectly certain of the geometry. This half of the ring has been excavated, but in the other half the suggested construction is less certain, there being only a few stones with only one now upright. But there are some depressions which probably show the positions of the burning-pits dug to assist in the destruction of some of the stones. These would be near the base of the upright stones and so offer some guidance. Nevertheless the suggestion cannot have the same weight as what has gone before. From H to J draw an

arc centred on CB produced and having a radius of 750 MY. Drop a perpendicular to CB from D and produce it to P making $PQ = QD$. As in the egg-shaped constructions there may have been a mirror image of the triangle ABC mirrored about BC , in which case P would occupy the position corresponding to D . Produce PD to meet the main circle at K and from K draw the arc KJ with centre at P . Probably from K to L the stones followed the main circle.

The whole design was set out on tracing paper with the greatest possible accuracy. When this was superimposed on the large-scale survey the manner in which the outline passed through the stones and stone positions was remarkable. The yard was taken as 2.720 ft. Had, say, 2.730 ft been used, the ring would have been too large by some 5 ft and would have passed outside the stones, a striking proof of the value of the yard and of the precision with which the builders set out the ring.

When the tracing paper was adjusted to the best fit with the stones it appeared that the point S of the construction fell inside the plan of the largest stone on the site, that is the stone to the west of the road leading north from the village. The most likely position is under the overhang of the west end of the stone. It will be seen that E is also marked by a stone and that the two large stones at the south entrance are placed one on the main circle and one on the ring.

The detailed trigonometrical calculation of all the dimensions would occupy several pages and is much too long to give here, but the results throw some light on the reasons for the peculiar design. The calculated lengths of the arcs are as follows.

ME	97.23 MY	perhaps	accepted	as	97.5
EF	117.43	"	"		117.5
FG	199.87	"	"		200
GH	129.68	"	"		130
HJ	150.09	"	"		150
$JKLM$	608.10	"	"		607.5
	-----				-----
Total	1302.40	"	"		1302.5

It is seen that all arcs in the portion where we have definite evidence that the assumptions are correct are close to being multiples of $2\frac{1}{2}$, a rule which we have seen is almost universal for perimeters. Here we find it applying to the portions of the perimeters between the 'corners'. If the total perimeter was intended to be 1300 the error was only about 1 in 550, but it is unjustifiable to accept this until excavation on the east side has gone far enough to prove the assumed geometry.

The two inner circles have a diameter of 125 MY, which curiously is exactly 340 ft. Taking $\pi = 3.140$ makes the circumference 392.5, again a multiple of $2\frac{1}{2}$. This is one of

the best rational approximations to π left us by these people. It was used in the large circle at Brodgar in Orkney. Note the theme of 25 and 2·5 running through all the Avebury dimensions.

The line joining the two inner circles is 145 MY long and lies at an azimuth of about $340^\circ\cdot2$. The meaning of this azimuth will be discussed later. The only indication of a connexion between the inner circles and the main ring comes from the fact that the line joining the stump of the ring stone R and the main centre D shows the same azimuth and so is parallel to the line of the inner circles. Keiller's excavations showed the depth of the hole under the ring stone, which had apparently been considered important.

Chapter 7: The Compound Rings. Thom, A. *Megalithic Sites in Britain*,
Clarendon Press, Oxford 1971:84-91.

8

MEGALITHIC ASTRONOMY

(Thom 1971:92-106)

THE conclusions in previous chapters regarding Megalithic metrology rest on a sound statistical basis: the probability levels are such as to leave no doubt about the reality of the units. But it is much more difficult to deal with astronomical hypotheses in the same rigid manner. In 1955 the author published a statistical examination (Thom, 1955) which showed a high degree of probability that many of the sites contained lines with an astronomical meaning. Since then much additional information and knowledge has been obtained. The calendar hypothesis has been set up as an explanation of many previously puzzling lines. Other lines group themselves unmistakably round four lunar limiting declinations. These advances have come about by the gradual accumulation of observed declinations at certain values demanding explanations. As we saw in the chapter on astronomy there are definite limitations to the magnitude of solar and lunar declinations. So any definite group of declinations with a value beyond these limits demands a stellar explanation. Any group inside the limits may be solar, lunar, or stellar. It would be very difficult to devise a rigid statistical method of handling the material in this important part of the declination range which would be universally acceptable. Accordingly it is proposed to adopt the simple visual demonstration of plotting histograms of the observed declinations and to present these in such a manner that they can be compared with (1) calendar declinations, (2) lunar declinations, and (3) the declinations of first magnitude stars between 2000 and 1600 B.C.

The difficulty of laying down working terms of reference to assist in the objective selection of the lines to be included makes it perhaps impossible to put the demonstration on a perfectly sound basis, but although other workers might discard this line and include that, it is considered that the material presented is sufficiently representative to give a correct over-all picture. It is hoped that in the future other workers will find many other sites here and in Ireland and will produce more accurate surveys of sites already included. Then with much new material it ought to be possible to make a complete analysis using only first-class lines, but even then a certain degree of subjectivity will remain. In the meantime it is hoped that the scheme adopted of dividing the lines into classes of different reliability will allow any serious student to decide for himself whether or not to reject the various hypotheses put forward.

The azimuths

It is desirable for the reader to be familiar with what is meant by the terms *outlier*, *alignment*, and *indicated foresight*. An outlier is an upright stone near a circle or other well-defined site. An alignment is a row of upright stones. Two stones can be considered as an alignment when one (or both) is an upright slab set up on the line to the next stone. In some places a row of boulders can be accepted provided the row occurs in association with other remains. A look through the figures will show examples. An *indicated foresight* is a prominent natural feature on or near the horizon indicated by a slab, an alignment, or an outlier. All these three arrangements can be used to define an azimuth.

Let us think of the possible uses of an azimuth. Apart from ritualistic purposes there are three- time indication, calendar purposes, and studying the moon's movements. To use the rising or setting of a star to show the time of night the star must be identified. To the question 'where will it rise?' the obvious answer is to point with the finger and not much greater accuracy is in general necessary. So a slab set on edge will do as a minimum requirement. But the sun controls the calendar and it is no longer a matter of identification but of indicating precisely where the sun will rise or set on the specified days of the year. The moon is most useful as a giver of light in those years when it is highest in the midnight sky (and therefore longest above the horizon), but to discover the cycles controlling the changes demands accurate definition of azimuth. Today an astronomer uses a transit circle to measure the positions of the stars as they cross the great circle of the meridian. Megalithic man had to use another great circle, namely the horizon. To obtain accuracy a slab is not enough. There must be a backsight and a foresight. The backsight might be a stone, a hole in a stone, a gap between two stones, or a staff at the centre of a circle. The foresight may be a distant stone or a pole at the centre of a circle. It can most effectively be a distant mountain peak, a distant notch in the horizon, or, when a sea horizon is involved, it can be a rock far out at sea or the fall of a steep island. If the foresight is artificial then perhaps it needs no pointer. If it is a natural feature there ought to be something to distinguish it, but the indicator need only provide enough accuracy to avoid confusion.

In these latitudes the rising point of the sun at the equinoxes moves along the horizon about 0.7 degrees per day, so a method of indicating azimuth to about $\frac{1}{4}$ degree will make possible the definition of any required day in the spring or autumn, but as we get nearer the solstices the accuracy necessary becomes progressively greater. The precision which can be obtained by a suitably chosen natural foresight is very much greater than is commonly recognized. Think of the right-hand slope of a distant mountain running down to form a notch in the horizon. Suppose that the slope is a little flatter than the apparent path of the setting sun. Then we can choose a viewpoint from which the upper edge of the sun will appear to vanish half-way down the slope. Had the viewpoint been slightly to the right the sun's edge would have reached the bottom of the slope before it

vanished. In this way very small changes of declination can be detected. Vegetation such as heather will have very little effect. For example, at ten miles a foot subtends an angle of about 4 seconds of arc or about 0.001 degree.

When the sun sets behind a clean-cut horizon in a clear sky the last vestige of the disk appears momentarily as a brilliant emerald green point of light. The author has watched the phenomenon countless times. Once when we were lying anchored in the Outer Hebrides the horizon to the west consisted of low hills not very far away. It so happened that the upper edge of the setting sun did run down such a slope as has just been discussed. When it vanished it was only necessary to step along the deck a few feet to bring it again into view. By moving quickly my son and I were able to see the small emerald flash three times before the sun finally vanished. We shall see later that there are several places on the west coast where such a foresight was used. The erectors of the backsights must have been well acquainted with the phenomenon and probably made use of it at the solstices. The point is made here that the backsight had to be marked and some rough indicator used to identify the particular slope to be used.

It is evident that such foresights were only useful for the sun or moon. For a star the indicator had to be near enough to be seen in starlight. If it was, say, half a mile away it could be illuminated by a fire but it would in general be impossible to arrange for a fire ten or twenty miles away.

To summarize, we might expect to find as azimuthal indicator for a star:

- (1) a slab,
 - (2) two or more stones not too far apart,
 - (3) a circle and a close outlier,
- or (4) two circles.

For the sun or moon we must have as a minimum:

- (1) a long alignment,
 - (2) two well separated stones,
 - (3) a circle with an outlier some hundreds of feet distant,
- or (4) a natural foresight identified by some simple indicator.

It follows that when we find a circle or even an isolated stone we ought to look round the horizon. If there is a suitable natural foresight which gives a commonly found solar or lunar declination exactly then we are entitled to suspect that there had been a secondary indicator which would have identified the foresight but that it has vanished. Such a line could only be given a low classification and would not be put on a general histogram. Similarly a short alignment incapable of giving the accuracy necessary for a solar or lunar line may have had a distant extension now removed.

The problem of knowing in which direction to use an alignment is an interesting one. If local high ground blocks one view then no problem arises, but when the alignment stands in open ground then there are two possible declinations. There seem to be a number of alignments in which both the declinations are significant. This is, in general, only possible where the varying heights of the surrounding hills allowed the builders to move about on the flat until they found a position which would allow a line to be laid out having hill altitudes giving the required declinations. Obviously years of work would be necessary to find a suitable line if one or both of the declinations were solar or lunar, so it is not surprising that they were well marked when found. An outstanding example is the line *AB* across the circle at Castle Rigg where both declinations are solar, but others will be found listed. This arrangement perhaps explains why a long line is used sometimes for a star. The line may have had to be long for the solar or lunar declination given by the other direction. It is too much to expect a natural foresight to be found at both ends of such a line. This would seem to be almost impossible.

Indications of the meridian

There are a great many sites with very definite indications of a north/south line. Many circles have one of the stones in the ring placed at the north point. This happens oftener than would be expected on a random distribution. Merrivale circle (S 2/2) has a large outlier at $181^{\circ}\cdot5$. The Seven Brethren circle (G 7/2) has an outlier at $358^{\circ}\cdot9$ and Mitchel's Fold (D 2/1) has one at $178^{\circ}\cdot5$. Remains of a north/south passage can be seen in the circles at B 7/17, B 7/18, and B 7/19. Several of the flattened circles Type B and of the egg-shaped rings have either the axis of symmetry or the transverse axis in the meridian.

Perhaps the most interesting meridional sites are the alignments listed below.

SITE	AZIMUTH	REMARKS
Tobermory	$3^{\circ}\cdot5$	3 stones, one fallen
Loeb Stornoway	$357^{\circ}\cdot0$	2 slabs
Laggangarn	$1^{\circ}\cdot8$	2 slabs
Callanish I	$0^{\circ}\cdot1$	Natural rock and alignment
Mid Clyth	$358^{\circ}\cdot6$	Axis of alignments

It is possible today to use the first three or four as indicators of local apparent noon by watching the shadow of the south stone fall on the stone to the north. At many places throughout the country there are single flat slabs with the flat face in the meridian. A notable example is the large slab at Dalarran G 5/1, where the face is so flat that the glancing shadow can be used to obtain the time to within a few minutes.

In a few places we find two circles on a north/south line, e.g. Carnoussie House (B 4/1), the Grey Wethers (S 2/1), and Burnmoor (L 1/6).

It is not clear how these lines were determined. There was no pole-star to show the north point. The method using the shadow cast by a vertical pole on a horizontal plane surface could not be used in country where flat sand does not exist. The method of bisecting the angle between the rising and setting points of the solstitial sun is only applicable in perfectly flat country, whereas most of these sites are in hilly country. For the kind of accuracy attained at Callanish a more sophisticated method must have been used. The most likely seems to be the bisection of the angle between the east and west elongations of a circumpolar star. This would involve the use of a plumb-line hung from a high pole or frame. Stakes or smaller plumb-lines would be used to mark the two backsights from which the two elongations were observed. The point midway between the stakes and the foot of the main plumb-line would then give the required direction. This method could only be used in winter, since roughly twelve hours elapse between the elongations. It may be noted that today Polaris is about 50' from the pole and this, if the observation were made when the star is at elongation, would produce an error of $50'/\cos$ latitude or about $1\frac{1}{2}^\circ$. If we observe the star on the meridian the long plumb-line is still necessary. It will be seen that the determination of the north/ south line at Callanish correct to $0^\circ\cdot 1$ is no mean feat.

The observed lines showing declinations

The most difficult part of the whole investigation is to decide when to include a line and when to exclude it. The decision must always be a matter of personal opinion and is influenced by the viewpoint and the other lines with which, at the time, it is being compared. An attempt to get some measure of objectivity, however small, in the material presented in Table 8.1 has been made by dividing the lines into three classes, A, B, and C.

Class A contains those lines which it is considered would be accepted by any unbiased observer.

Class B contains borderline cases which some people might accept and others discard.

Class C contains lines which would be excluded from a statistical analysis. For example, a line from a site to an impressive natural foresight is marked C when its only claim is that it gives one of the declinations in which we are interested. If the hypothesis on which the declination depends is later accepted then some importance attaches to the line. These lines are naturally excluded from the main declination histogram in Fig. 8.1.

Table 8.1 contains all lines which seem worthy of consideration. No line has been excluded which appeared impressive except one or two for which the azimuth or horizon

Table 8.1. *List of observed lines*

Description of lines		Class A — Definitely indicated line		" B — Poorer indication		" C — Little or no indication				
Type	CC Site to site	Type	OS Orientated stone to stone							
	CO Site to outlier		SO Stone to orientated stone							
	CS Site to stone		P Line along tumulus passage							
	OC Outlier to circle		IF Indicated foresight							
	A Alignment		COIF IF indicated by outlier							
	A3 Alignment with three stones		SSIF IF indicated by two stones							
	SSS Three stones in line		AIF IF indicated by alignment							
Az—Azimuth		h—horizon altitude		h _B —extinction angle						
Site		Class	Type	Az	h	h _B	Decl.	Star	Date	Remarks
A 1/2	Loch Nell	A	CO	147.5	6.6		-21°.8	Sun		
A 1/4	Loch Seil	A	AIF	146.8	6.9		-21.3	Sun		
"	"	A	AIF	326.1	5.3		+32.1	Capella	1870	
A 2/1	Inveraray	C	IF	23.7	11.1		+41.2	Vega	1900	Or Arcturus 1750
A 2/5	Kintraw	B	IF	223.9	0.5		-23.6	Sun		
"	"	B	IF	307.5	2.7		+21.9	Sun		
A 2/8	Temple Wood	A	SSS	206.1	0.3		-30.3	Moon		S ₃ S ₁ S ₄
"	"	A	SSS	26.1	2.6		+32.3	Capella	1830	S ₄ S ₁ S ₃
"	"	A	SSS	21.0	1.8		+32.7	"	1760	S ₃ S ₁ S ₂
"	"	A	CC	136.6	4.4		-20.1	Moon		Circle to group
"	"	A	CC	135.0	3.7		-20.1	or Rigel		Circle to S ₁
"	"	A	CO	115.9	7.1		-8.2	Sun		Circle to S ₄
"	"	B	AC	321.2	4.5		+29.7	Castor	1730	S ₃ S ₄ to circle
"	"	B	CA	141.2	1.8		-24.4	Sun		Circle to S ₄ S ₃
"	"	A	AS	329.6	5.8		+34.0			S ₃ S ₂ S ₄
"	"	A	SA	149.6	2.0		-27.1			S ₃ S ₂ S ₃
A 2/19	Achnabreck	B	SS	159.5	2.1		-29.9	Moon		One fallen
A 2/12	Duncraigaig	A	A4	140.7	2.3		-23.7	Sun		Large stones
"	"	A	"	320.7	3.1		+28.2	Moon		" "
"	"	B	A2	151.9	1.1±		-28.8	Moon		" "
"	"	B	"	331.9	3.1		+32.2	Capella	1850	
"	"	A	IF	42.3	9.2		+32.5	"	1790	Through holystone
A 2/6	Carnasserrie	A	A	169±	2.4±		-30.9±	Moon (?)		
A 2/14	Dunamuck South	A	A2	138.2	3.4		-21.7	Sun		
"	"	A	A2	318.2	1.9		+26.4	Pollux	2000	
"	"	C	—	339.4	1.3		+32.5	Capella	1790	To A 2/21
A 2/21	Dunamuck North	A	A3	346.1	3.0		+35.6			
A 3/4	Tayvallich	A	CA	32.8	1.9		+29.5	Castor	1800	
A 3/4	"	A	IF	27.7	1.3		+30.4			
A 3/4	"	A	IF	34.1	2.1		+29.3	Castor	1860	
A 4/1	Escart Fm	B	AIF	206.5	0.9		-29.7	Moon		Foresight not checked
A 4/4	Ballochroy	A	IF	315.5	0.9		+24.2	Sun		Ben Cora
"	"	A	AIF	44.2	6.2		+29.4	Castor	1820	
"	"	B	AIF	226	-0.1		-23.6	Sun		Cara fall
A 6/1	Camus an Stacca	C	—	340.6	4.8		+36.6	Deneb		Poor or.
"	"	C	—	213.7	4.2		-24.2	Sun		No or.
A 6/2	Strone, Jura	B	AIF	298.3?	7.5		+21.6	Sun		One stone fallen
A 6/4	Knockrome	A	SSS	73.7	1.9		+10.4	Spica	1970	
"	"	A	IF	203.4	1.0		-30.4	Moon		Crackaig Hill
A 6/5	Tarbert, Jura	B	SS	106.7	1.5		-8.1	Sun		
A 6/6	Carragh a Chlinne	A	IF	228.0	2.6		-20.0	Moon		Dip
A 8/1	Mid Sannox	A	IF	229.3	6.2		-16.3	Sun		Col
A 9/7	Stravannan Bay	A	AIF	136.0	2.7		-21.7	Sun		Peak
"	"	A	A	311.5	0.7		+22.1	Sun		
A 10/2	Lachlan Bay	A	IF	43.0	0.6		+24.2	Sun		
A 10/3	Ballimore	B	PS	228.2	1.8		-20.6	Rigel	1950	
A 10/4	Kilfinnan	B	IF	333.5	6.8		+36.5	Deneb		
							± 0.4			

Table 8.1 (cont.)

Site		Class	Type	Az	<i>h</i>	<i>h_E</i>	Decl.	Star	Date	Remarks	
A 10/6	Stillaig	A	OSIF	325.5	0.8		+27.9	Moon			
A 11/2	Blanefield	A	A4	56.7	+7.2		+24.0±	Sun			
B 1/8	Sheldon of Bourtie	A	CO	119.7	-0.2		-16.0	Sun			
"	"	A	CO	55.9	0.0		+17.1±	Sun			
B 1/18	Ardlair	A	CSSS	116.0	+1.1		-13.4	—			
B 1/26	Loanhead	B	CC	41.6	+0.7		+24.0	Sun			
"	"	A	CSS	144.0	0		-26.4	—			
"	"	A	CSS	139.0	0.2		-24.3	Sun			
B 2/4	Esslie (S)	A	CC	43.1	1.1		+24.1	Sun		To B 2/5	
"	"	A	CS	306.2	0.2		+18.4±	Moon			
B 2/5	Esslie (N)	A	CC	223.1	2.7		-21.2	Sun		To B 2/4	
B 3/3	Raedykes	B	CS	259.2	0.8	1.7	-4.4	Bellatrix	1670		
"	"	B	CC	314.2	2.1		+23.9	Sun			
B 3/5	Kempston Hill	B	SS	231.4	0.6		-19.8	Moon			
B 7/1	Clava	A	PP	216.5	1.7		-24.3	Sun			
B 7/3	Dulnanbridge	A	AS	230.9	0.9		-19.5	Moon			
B 7/10	Easter Delfour	A	CO	219	2.0		-23.6	Sun			
D 1/7	Barbrook	A	CO	284.8	2.3		+10.5	Spica	2000		
"	"	B	CO	118.6	2.2		-15.1			Below grass hor.	
G 1/4	Ballantrae	A	SSS	11.8	+2.7		+36.5	Deneb			
G 3/3	Laggangarn	B	CS	296	2.1		+16.2				
"	"	B	CS	106.2	0.7		-9.0	Sun		Long stone	
"	"	B	CS	105.4	0.7		-8.5	Sun			
"	"	B	CS	150.3	0		-30.4	Moon			
"	"	B	CS	124.8	0		-19.6	Moon			
"	"	B	CC	133.8	0.2		-23.7	Sun			
G 3/12	Drumtroddan	A	A3	43.3	+0.4		+24.8	Sun		Re-erected (?)	
G 3/13	Wren's Egg	B	—	227.5	-0.2		-23.6	Sun		To Big Scare	
G 3/17	Whithorn	B	SS	254.3	+0.9		-8.5	Sun			
G 4/1	Carsphairn	B	CO	100.4	+3.2		-3.5				
G 4/2	The Thieves	C	SS	228	-0.4		-23.4	Sun		Axis of ring	
"	"	C	SS	48	+6.7		+28.5	Moon		" "	
G 4/13	Kirkmabreck	B	SSS	5.9	3.1		+37.7			Meridian (?)	
G 4/12	Cambret	A	CCC	296.7	0.2		+14.7				
"	"	A	CCC	116.7	5.7		-10.3	Antares	1860		
"	"	B	CS	254.3	4.3		-5.4	Bellatrix	1870	Stone on skyline	
G 4/14	Cauldside	A	CSSC	156.8	8.7		-23.9				
"	"	A	IF	59.5	0.3		+16.8	Sun		Peak	
"	"	B	IF	78.2	+0.3		+6.6				
"	"	"	"	"	"	0.9	+7.2	Altair	1900		
G 6/2	Auldgirth	B	COIF	281.2	+3.3		+8.9	Sun		Reported fake	
G 7/4	Loupin Stanes	A	CC	306.5±	5.1		+24.1	Sun			
"	"	B	CSS	201.2	1.5		-31.0				
G 8/8	Dere Street IV	B	SSC	276.7	2.3		+5.4			To Dere St. II	
G 8/9	Eleven Shearers	A	A18	94.7	4.1		+0.5	Sun			
"	"	A	A	109.2	3.1±		-8.3	Sun		Estimated <i>h</i>	
G 9/10	Borrowston Rig	A	CSS	333.3	2.0		+31.8	Capella	1930		
G 9/13	Kell Burn	A	A	129.8	1.8		-19.7	Moon			
"	"	A	A	309.8	2.9		+23.5	Sun			
H 1/1	Callanish I	A	CA	9.2	1.5		+32.5	Capella	1790		
"	"	A	CA	10.6	1.6		+32.5	"	"		
"	"	A	AC	190.6	1.3		-30.2	Moon			
"	"	A	AC	189.2	1.5		-30.2	"			
"	"	A	CA	270.9	0.5		+0.3	Sun			
"	"	A	CA	77.8	0.9		+6.9	Altair	1760		
"	"	B	CC	142	+0.5		-24.5	Sun?		To V	
H 1/2	"	II	B	CC	129.5	+0.3		-19.7	Moon		To VI
H 1/3	"	III	B	CC	280	0.6		+5.4	Sun		To I
"	"	III	B	CC	249	+1.7		-10.2	Antares?	1880	To II
H 1/4	"	IV	B	CC	89	+1.0		+1.0	Sun		To VI
"	"	IV	B	CC	135	+1.4		-22.8	Sun		To V
H 1/5	"	V	B	CC	64	+0.7		+13.6	Sun		To VI
"	"	V	B	CC	332.8	+0.3		+27.8	Moon		To II
"	"	V	B	CC	322	-0.2		+23.8	Sun		To I
H 1/6	"	VI	B	CC	304.9	-0.2		+16.9	Sun		To I
"	"	VI	B	CC	269.0	+1.0		0.0	Sun		To IV
"	"	VI	B	CC	244	+0.9		-12.9	Sun		To V

Table 8.1 (cont.)

Site		Class	Type	Az	<i>h</i>	<i>hg</i>	Decl.	Star	Date	Remarks
H 1/7	Gt. Bernera	B	IF	236	1.7		-16	Sun		Dip
"	"	B	IF	83			+6±			Cairn
"	"	B	IF	90	0.7		0.3	Sun		Cairn
H 1/10	Steinacleit	B	CO	89.1	0.7±		+0.7±	Sun		Too close
H 1/12	Clach an Trushel	B	AC	77.9	0.9		+6.8	Altair	1700	To H 1/10
H 1/14	Clach Stein	A	CC	24.8	0.4		+28.5	Moon		To H 1/15
"	"	A	IF	98.3	0.4		-4.5	Sun		To Suilven
H 1/15	Dursainean	A	SC	227.9	2.0		-19.3	Moon		H 1/15 on hor.
H 2/1	Clach an Teampuill	B	CC	138	1.9		-21.8	Sun		To Hill
H 2/2	Clach Mhic Leoid	A	IF	271.0	-0.1		0.0	Sun		To Boreray
H 2/3	Borvemore	B	IF	317.2	-0.1		+22.3	Sun		To Gasgier
H 3/1	Cladh Maolrithe	A	IF	296.6	-0.2		+13.2			To Spuir Islet
H 3/2	Clach ant Sagairt	A	IF	287.6	-0.0		+8.8	Sun		To Boreray
H 3/3	Clettraval	C	SC	126.5	-0.1		-19.2	Moon		To H 3/11
H 3/5	Fir Bhreige	B		121.8	0±		-16.0	Sun		To H 3/9
H 3/6	Barpanan Feannag	C		160.7±	0.7		-29.8±	Moon		Az. doubtful; stone on hor.
"	"	C	CC	220.0±	0.6		-24.2±	Sun		To Tigh Chloiche
H 3/8	Na Fir Bhreige	B	SSS	288.9	2.3		+11.7			Perhaps reverse
"	"	A	IF	271.8±	0.4		+0.8±	Sun		To H 3/6 and hill
"	"	C	IF	253.2	1.3		-8.2	Sun		To Marrival
H 3/9	Ben a Charra	B	IF	255.7	-0.3		-8.1	Sun		To Deasgeir
H 3/11	Leacach an Tigh Chloiche	C	IF	304.1	-0.2		+17.0	Sun		To Haskeir
"	Leacach an Tigh Chloiche	A	CCC	131.8	-0.3		-21.7	Sun		To H 3/20
H 3/12	Clach Mhor à Ché	A	IF	281.9	+0.4	0.9	+6.8	Altair	1700	To Craig Hasten
"	"	A	IF	281.9	+0.4	0.5	+6.4	Procyon	1750	" "
H 3/15	Claddach illeray	C		288.3	0.0		+9.3	Sun		" "
H 3/18	Sornach Coir Fhinn	A	IF	303.2	+0.6		+21.6	Sun		To Cringraval
"	"	A	IF	318.5	+0.8		+24.0			To H 3/11
H 3/20	Craonaval	A	CCC	311.8	+0.6		+20.9			To H 3/11
H 4/2	Gramisdale (S)	C	CC	120.7	+0.3		-16.2	Sun		To Hacklet
H 4/4	Rueval Stone	A	IF	303.8	-0.1		+16.9	Sun		To Boreray
H 5/1	An Carra	C		315.4	-0.1		+21.9	Sun		"
H 5/9	Pollachar Inn	C		227.6	-0.1		-22.1	Sun		Not visited
H 6/3	Brevig, Barra	A	A	135.0	-0.3		-23.6	Sun		
H 6/5	Berneray	C	CS	342	4.8		+35.9	Deneb		To Hecla
L 1/1	Castle Rigg	A	CO	251.5	3.2		-8.1	Sun		Good outlier
"	"	A	SS	127.0	5.2		-16.0	Sun		Diameter
"	"	A	SS	307.0	4.6		+24.3			"
"	"	A	SS	157.1	2.8		-29.8	Moon		Cross axis
L 1/3	Sunkenkirk	B		128.8	+0.5		-21.5	Sun		'Entrance'
L 1/6	Burnmoor	A	CC	348.0	+7.5		+42.1	Arcturus	1900	E to A
"	"	A	CC	343.5	7.7		+41.5	"	1800	E to B
"	"	B	CC	292.3	6.2		+17.9	Moon		
"	"	B	CC	311.9	+5.5		+27.6	Pollux (?)	1600	E to D
"	"	B	CC	243.6	-0.5		-16.0	Sun		D to C
"	"	B	CC	131.9	+1.6		-21.6	Sun		D to E
"	"	B	CC	63.6	4.3		+18.5	Moon		C to D
"	"	B	CC	112.3	2.6		-10.8	Antares	1700	C to E
"	"		CC	358.7				Meridian		C to B
L 1/7	Long Meg, etc.	A	CO	223.4	1.1		-24.2	Sun		To Long Meg
"	"	A	CC	65.1	3.4		+16.7	Sun		To Little Meg
"	"	B	SS	86.0	3.7		+5.2			Cross axis
L 1/10	Seascale	A	CO	354.0	1.0	1.3	+36.3	Deneb		Good outlier
L 1/11	Giants' Graves	A	SSS	30.8	2.1		+31.8	Capella	1920	
"	"	B	SSS	210.8	0.5		-30.2	Moon (?)		<i>h</i> guessed
L 3/3	Five Kings	B	A4	252	4.5±		-6.5			Uncertain
"	"	A	IF	312.6	21.3		+41.1	Vega	1820	Stone on hor.
L 6/1	Devil's Arrows	B	A3	331.2±	0.7		+31.2	Capella?		Re-erected (?)
"	"	B	A3	151.2±	0.4		-30.7	Moon?		Trees?
M 1/4	Dervaig (A)	A	A4	342.0	0.0	0.5	+31.7	Capella	1930	One fallen
M 1/5	Dervaig (B)	B	A7	334.0	0.7±		+29.9	Castor	1700	Poor <i>h</i>
"	"	B	A7	154.0	1.6±		-28.4			"
M 1/9	Ardnacross	B	A	339±	2.0		+32.7	Capella	1750	Fallen alignment
M 2/6	Ross of Mull	A	IF	59.9	1.5		+17.1	Sun		Peak

Table 8.1 (cont.)

Site		Class	Type	Az	<i>h</i>	<i>h_G</i>	Decl.	Star	Date	Remarks
M 2/8	Bunessan	B	IF	330.7	0.2		+28.6	Moon		St. on hor.
M 2/9	Ardlanish	B	CS	282.4	2.6		+ 9.0	Sun		From ring
M 2/10	Uisken	B	IF	229.6	0.3		-21.3	Sun		
M 2/14	Loch Buie	A	CO	123.4	6.8		-12.0			
"	" "	A	CO	223.6	0.4		-23.7	Sun		
"	" "	A	CO	237.0	2.1		-16.0	Sun		
"	" "	B	CO	330.8	14.1		+42.1	Arcturus	1740	
"	" "	B	CC	297.9	9.0±		+23.2±	Sun (?)		To small circle
"	" "	A	SSIF	348.5	10.3		+42.9	Arcturus	1980	Stone on hor.
"	" "	C	SS	65.7	+6.2		+18.2	Moon		
"	" "	A	OS	245.1	3.5		-10.4	Antares	1850	
"	" "	B	SCIF	324.7	16.8		+42.4	Arcturus	1900	Peak
"	" "	C	SC	150.8	5.1		-24.2	Sun		
M 4/2	Tiree S	B	IF	190.2	2.8		-30.4	Moon		Flat hill top
M 8/2	Barcaldine	A	IF	319.5	2.3		+26.6	Pollux	1930	Double stone
N 1/8	Loch of Yarrows	B	SS	343.0	0.0		+29.6	Castor	1800	Reverse?
N 1/13	Latheron Wheel	A	CO	196.1	1.0±		-29.7	Moon		
N 2/1	Learable Hill	A	A	92.8	2.4		+ 0.3	Sun		Multiple rows
"	" "	A	A	61.6	2.4		+16.6	"		" "
"	" "	A	AIF	75.0	2.2		+ 9.5	"		Single row
P 1/1	Muthill	A	A3	57.3	1.8		+18.7	Moon (?)		
"	" "	A	A3	237.3	5.6		-12.7	Sun		
P 1/2	Doune	A	A3	13.5±	0.5		+32.7	Capella	1760	
P 1/8	Comrie	A	SS	296.8	5.3		+18.2	Moon		
"	" "	B	SS	116.8	2.3		-12.3	Sun		
P 1/10	Fowlis Wester	B	CS	30.9	0.6		+29.4			
P 1/13	Monzie	B	CS	305.5	4.8		+22.8			
P 1/14	Tullybeagles	B	CC	264±	3.7		- 0.5±	Sun		
P 1/19	Croftmoraig	B	CO	101.7	8.9±		+ 0.8±	Sun		Close outlier
P 2/8	Shianbank	A	CC	137.5	2.6		-21.9	Sun		
"	" "	A	CC	317.5	0.6		+24.2	Sun		
P 2/12	Dunkeld	B	A2	310±	3.7		+24±	Sun		
P 2/17	Dowally	B	SS	106.4	6.2		- 3.9	Sun		
P 3/1	Glen Prosen	A	A4	198.1	1.9		-29.9	Moon		
P 7/2	Galabraes	B	SO	86.8	5.6		+ 6.2	Procyon	1840	
S 1/1	The Hurlers	B	A4	76.3	0.8		+ 9.0	Sun		Far uprights
"	" "	B	A4	256.3	0.5		- 8.6	Sun		" "
"	" "	B	SCC	16.5	3.4		+40.7	Vega		& Arcturus
"	" "	B	CC	12.4	3.3		+41.5	Arcturus	1800	Trees (?)
"	" "	B	CC	10.1	2.4		+41.9	"	1860	"
S 1/2	Nine Stones	A	CA	63.5	1.5		+17.5	Moon		
S 1/5	Treswigger	B	CS	317.2	1.9		+29.3	Castor	1840	Poor
S 1/6	Leaze	A	CS	59.1	1.7		+16.3	Sun		
S 1/7	Rough Tor	B	CS	351.5	5.1		+43.7			
S 1/9	Nine Maidens	A	A9	26.1	2.0		+36.5	Deneb		Good line
S 1/11	Nine Maidens	B	CSS	332.7	0.5		+34.4			
S 2/2	Merrivale	A	CO	70.4	3.5		+14.9			
S 3/1	Stanton Drew	B	CC	232.7	1.6±		-21.2±	Sun		Trees
"	" "	B	CC	52.7	1.3±		+22.9±			" "
"	" "	B	CC	211.4	1.7±		-30.9±	Moon (?)		<i>h</i> unknown
S 5/2	The Sanctuary	A	IF	320.0	0.3		+28.4	Moon		
S 5/3	Avebury	A	CC	339.2	0.5	1.3	+36.5	Deneb		
S 5/4	Woodhenge	A	CS	31.0	0.4	0.5	+32.5	Capella	1790	
S 6/1	Rollright	A	CO	29.0	0.0	0.5	+32.7	Capella	1750	
"	" "	A	CC	95.0	-0.2		- 3.8	Sun		The Whispering Knights
W 2/1	Penmaen-Mawr	A	CC	60.9	-0.2		+16.4	Sun		Large to small
"	" "	A	CC	240.9	+3.7		-14.1			Small to large
"	" "	B	A3	18.6		1.3	+35.5	Deneb		? reverse
W 5/1	Moel ty Ucha	B	IF	256.7	0.1		- 7.6			
"	" "	A	CS	17.3	-0.2	1.3	+36.1	Deneb		
"	" "	B	CC	298.6	0.6		+16.9	Sun		To W 5/2
W 5/2	Twyfos	A	CC	118.6	5.0		-12.7	Sun		To W 5/1
W 6/2	Rhos y Beddau	A	CA	79.1	5.0		+10.5	Spica	2000	
"	" "	B	AC	259.1	3.8±		- 3.7	Sun		
"	" "	B	CA	72.7	5.5±		+15.0			
W 8/1	Rhosygelynnen	A	A	82.1	0.6		+ 4.9	Sun		
"	" "	A	A	262.1	2.2		- 3.3			

Table 8.1 (cont.)

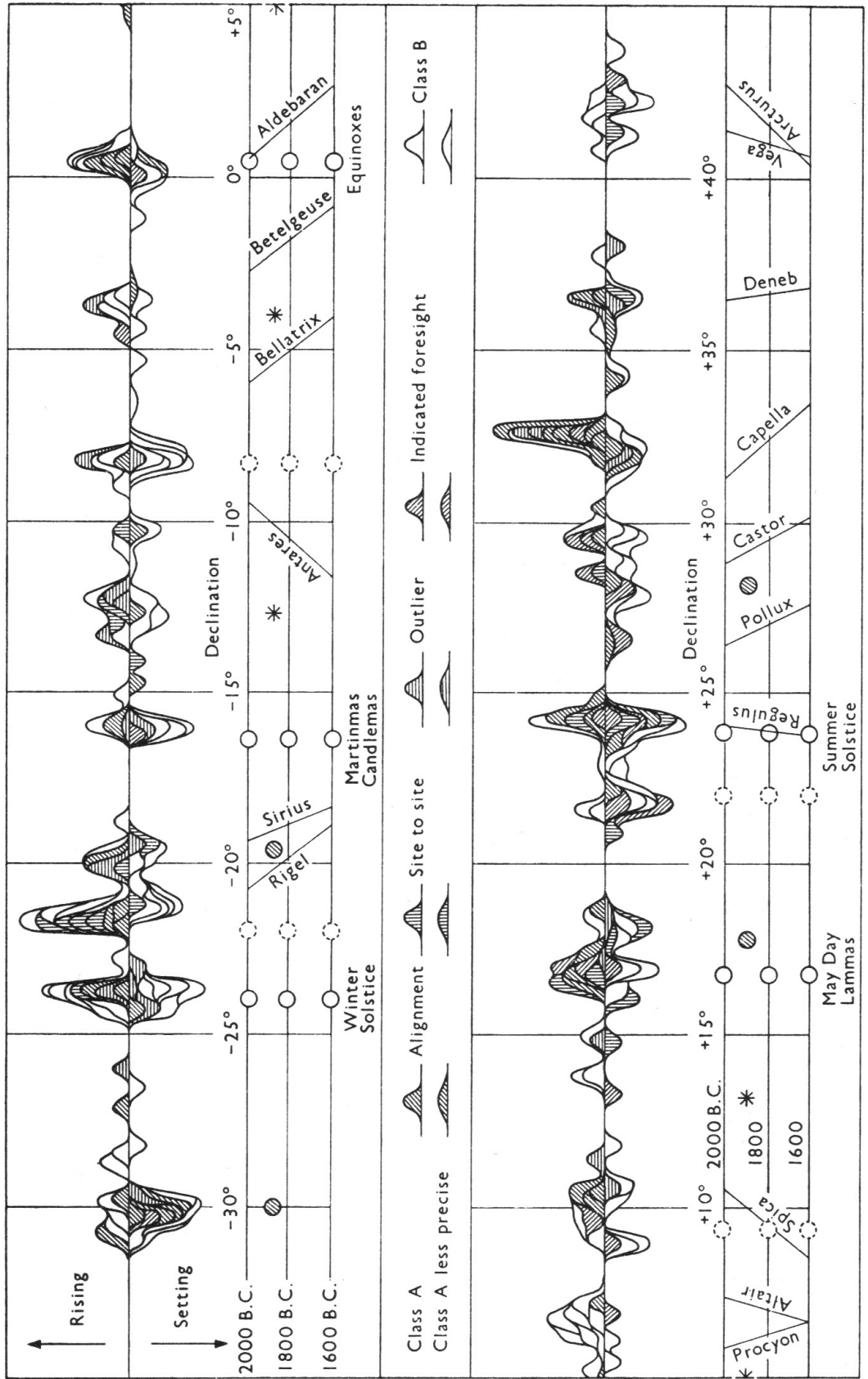
Site	Class	Type	Az	h	h_E	Decl.	Star	Date	Remarks
W 9/2	Gors Fawr	A	A4	49.6	1.3	+24.3	Sun		
"	" "	A	A4	229.6	-0.2	-24.2	Sun		
W 9/4	Castell-Garw	A	CCSS	214.3	0.0±	-31.2±	Moon (?)		Trees
W 9/5	St. Nicholas	A	CSS	71.0	0.3	+11.4	—		
W 9/7	Parc-y-meirw	A	A4	301.4	-0.4	+17.8	Moon		
W 11/1	Saeth-maen	B	A8	83.5	3.6	+ 6.6	Procyon	1660	
W 11/2	Y Pigwn	B	CC	53.3	0.4	+21.5	Sun		Stone on horizon
"	"	B	CC	233.3	1.0±	-21.0±	"		
"	"	B	CS	131.0	0.9	-23.5	"		
W 11/3	Maen Mawr	A	CO	335.2	4.3	+38.0			
"	" "	B	CS	4.5	4.6	+42.4	Arcturus	1950	
W 11/4	Usk River	B	CO	285.0	1.5	+10.1	Spica	1900	
"	" "	B	A3	78±	3.3	+ 9.7±	Sun		
"	" "	A	CC	295.3	1.2	+16.0	Sun		
"	" "	A	CC	115.3	2.9	-13.1	Sun		
W 11/5	Ynys Hir	B	IF	126.5	0.2	+21.7	Sun		Vis. unchecked
W 8/3	Four Stones	B	COO	67.5	0.9	+13.9			Distant outliers

altitude was not measured and could not be estimated with sufficient accuracy. A few lines from an outlier to a circle have been included but these have been given a low classification. This may be a wrong decision, but only an entirely new investigation can show if this method of defining a line is admissible.

Bad weather occasionally prevented an astronomical determination of azimuth and once or twice mist and rain prevented complete verification of the intervisibility of sites. Many of the horizon altitudes given in column 5 were measured on the site, but a number were calculated from the O.S. contours and these may be inaccurate where the horizon is near. Trees often prevented a measurement being made and it must be remembered that horizons which are clear today may have carried trees when the stones were erected. This is particularly true of many English circles sited in flat level country. The effect of trees, by raising the horizon, is to increase the calculated declination algebraically whether the declination is positive (N) or negative (S).

The extinction angle (pp. 15 and 160) given in column 6 is that of the star named in column 8, on the assumption that the line belongs to the star. The declination was calculated as shown on p. 17 or taken from a table similar to Table 3.1 but with a closer tabulation interval. For this h or h_E was used, whichever was larger.

It is generally agreed that the date of the erection of standing stones lies between 2100 and 1500 B.C. Accordingly when a star is shown in column 8 it is the star which had the tabulated declination at a date some time in this range. The date given is not necessarily the date of the erection; it is simply the exact time when the star named attained the tabulated declination. Assuming that the intention was really to indicate this particular star, there may still be uncertainty (1) in the survey and (2) in the hill horizon, which may have been affected by scrub or even trees when the line was set out.



○ Sun's declination at 16 calendar dates * Sun at intermediate dates ● Moon at 4 limiting declinations

Fig. 8.1. Histogram of observed declinations.

A statistical analysis would give a mean date for all the lines brought in and it would give a probability level, but as the author pointed out in 1955 (Thom) these figures would not be reliable unless we are sure that we are taking into account every possible explanation. The date obtained in the paper just mentioned was unreliable because the intermediate calendar dates were not taken into account. As a result declinations in the group around -21° were all assigned to Rigel, whereas, as we shall see, the majority were solar. A second source of error was failure to take account of extinction angle. It so happened that both of these factors tended to make the apparent date earlier than would now be obtained.

The over-all picture of the declinations will be found in Figure 8.1, which uses the same method of presentation as was used for the circle diameters. Each line is represented by a small gaussian area placed at the corresponding declination. The more precise lines have a higher, narrower area than the less precise. The key to the shapes and shading of the areas used will be found in the middle of the figure. Only Class A lines are shaded, so in forming a first opinion the unshaded areas can be ignored. It will be obvious without statistical analysis that the manner in which the shaded areas tend to form definite groups cannot be explained on the assumption that the observed lines got there by accident. The fact that the lines only group in this way when we plot on declination shows that a large majority of these lines must have an astronomical explanation. The gaussians are arranged to show whether any given declination was obtained from an azimuth between 0° and 180° (rising) or between 180° and 360° (setting). The rising cases are shown above the base line and the setting cases below.

Below the declination distribution will be found plotted: (1) the declinations of all first-magnitude stars in the range, (2) the sun's declination at certain calendar dates, and (3) the declination of the moon in four limiting positions. The sun's declination at the solstices was about $+23^\circ\cdot91$. But the declination of the upper limb of the rising sun when it first appeared on a level horizon would be about $0^\circ\cdot22$ greater (algebraically) than this and the declination of the lower limb on the horizon $0^\circ\cdot22$ smaller. Accordingly, the various positions of the sun are shown by a circle with this radius. If the lines were intended to show, for example, the upper limb on the horizon, then the gaussians ought to pile up to a maximum above the right-hand edge of the circle, as in fact they are seen to do at both solstices. Discussion of these and the other solar and lunar lines will be found in Chapters 9 and 10.

In looking at the histogram it must be remembered that it inevitably carries a number of spurious lines. An arrangement of stones which appears to indicate intentionally an azimuth may be entirely accidental. A line may have been disturbed or we may be looking along it in the wrong direction. An apparently good outlier may have belonged to another circle of which there is now no trace.

But accidental intrusive lines cannot explain the concentration of rising gaussians peaking at $+32^{\circ} \cdot 5$. One or two of these lines taken the other way certainly are lunar, but not all, and we conclude that the majority belong to Capella, c. 1800. It will be seen that several of the other first-magnitude stars appear to carry concentrations for a date between 2000 and 1800 B.C., but no group is so outstanding as that ascribed to Capella.

The stars as time-keepers

The times of lower transit of the four first-magnitude stars which were circumpolar as seen from the north of Scotland were as follows for the four seasons of the year.

	Vernal equinox	Midsummer	Autumnal equinox	Midwinter
Capella	1 a.m.	7 p.m.	1 p.m.	7 a.m.
Deneb	6.30 p.m.	12.30 p.m.	6.30 a.m.	12.30 a.m.
Vega	4.30 p.m.	10.30 a.m.	4.30 a.m.	10.30 p.m.
Arcturus	11 a.m.	5 a.m.	11 p.m.	5 p.m.

Unless on an elevated horizon the setting and rising of the last three would not differ by more than an hour or two from the times given for lower transit. From some parts of England, Deneb, with a nearly constant declination of $36\frac{1}{2}^{\circ}$, would set only in the sense that it would fall below its extinction angle.

Figs. 8.2 and 8.3 have been prepared to give approximate times of rising and setting for first-magnitude stars in latitude 56° at about 2000 B.C. The rising and setting times of the sun are shown on both figures by a full line, while dotted lines show the times when the sun was 5° and 10° below the horizon. It is thus possible to see at a glance the time of year throughout which the star risings or settings would have been visible. The times will be affected by latitude, by the height of the horizon, or by extinction angle, so for any particular site these figures give only a rough idea. The difficulty of seeing fainter stars at all at midsummer in the north is shown by the very short times of darkness at that time of year when twilight lasted nearly all night.

As an example of the use of these figures note that in Scotland Castor was the only star which had a good chance of being seen rising at the summer solstice. It will be seen on the histogram (Fig. 8.1) that Castor has only three Class A lines, all rising, and all three are in the northern part of the country.

Capella's usefulness at setting is seen to begin in the late autumn and thereafter either at setting or rising it was available until just before midsummer.

From the above list it is seen that Deneb transited below the pole about midnight at midwinter and so had about as long a run of usefulness as was possible for any star. Its setting was indicated by the line joining the two large inner circles at Avebury (S 5/3) and by the outlier at Seascale (L 1/10). Its rising is shown by an alignment at Ballantrae (G 1/4) but much more impressively by the very fine alignment the Nine Maidens (Fig. 12.15).

Perhaps the explanation of the precise nature of the indications of Deneb's rising and setting is that Deneb is not in itself a very impressive star and other stars in the constellation are nearly as bright. This would not, however, explain the necessity for erecting so many stones as there are in the Nine Maidens' alignment.

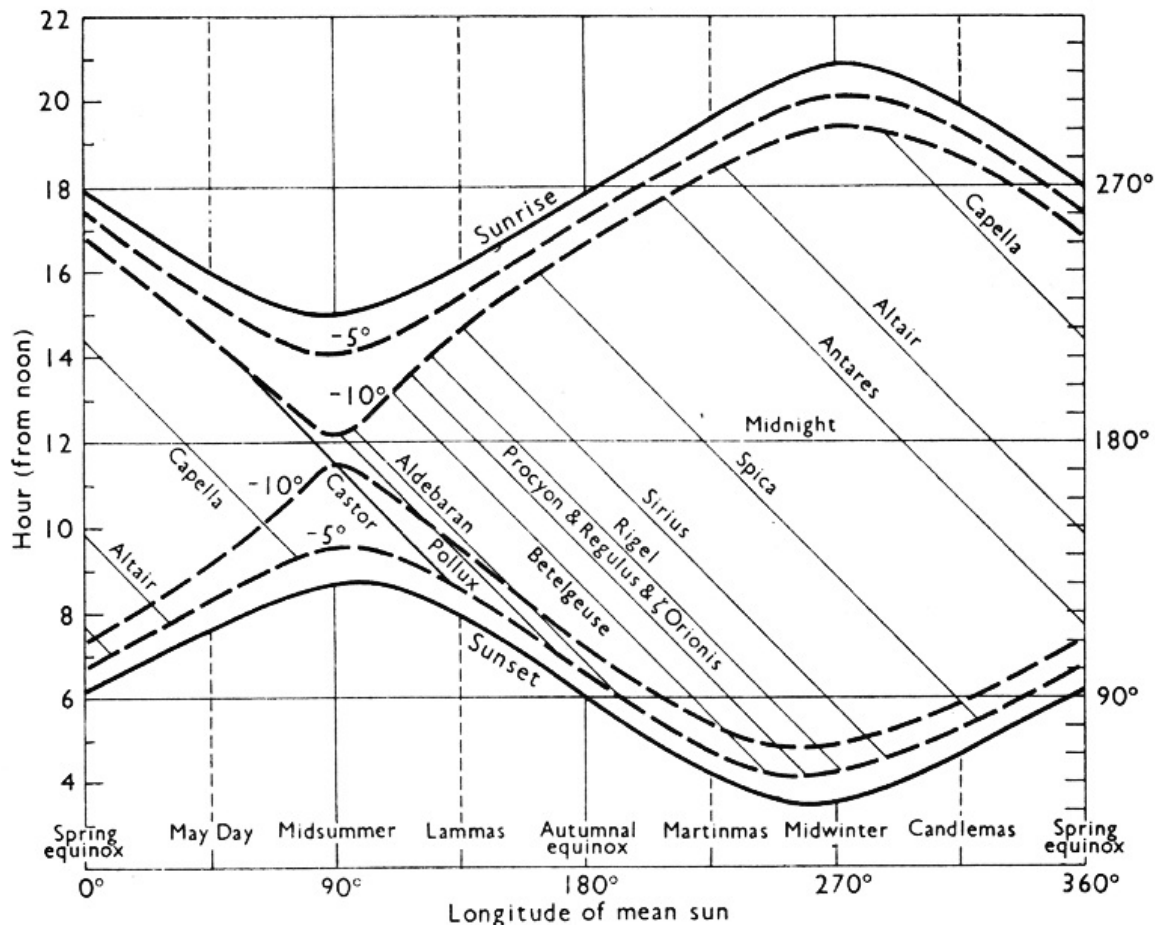


FIG. 8.2. Rising time of stars; sun at alt. 0° , -5° , and -10° . 2000 B.C., lat. 56°N .

It is interesting that there is a complete sequence marking the early morning hours at midwinter, when in the long winter night any community wants to have a method of knowing the time. We have then:

Sirius setting	2 a.m.
Altair rising	4 a.m.
Capella setting	5½ a.m.
Pollux setting	7 a.m.
Dawn	7-8 a.m.

Sirius has no indicators, but with Orion's belt to show where it would rise or set no other identification would be necessary. The other three stars all have azimuthal indicators at one site or another. The sequence given gets earlier by four minutes every day but is soon joined by Capella rising and Regulus setting. It will be seen that Regulus needs no special indicators. Its declination throughout the period in which we are interested was that of the midsummer sun and many sites contain solstitial lines.

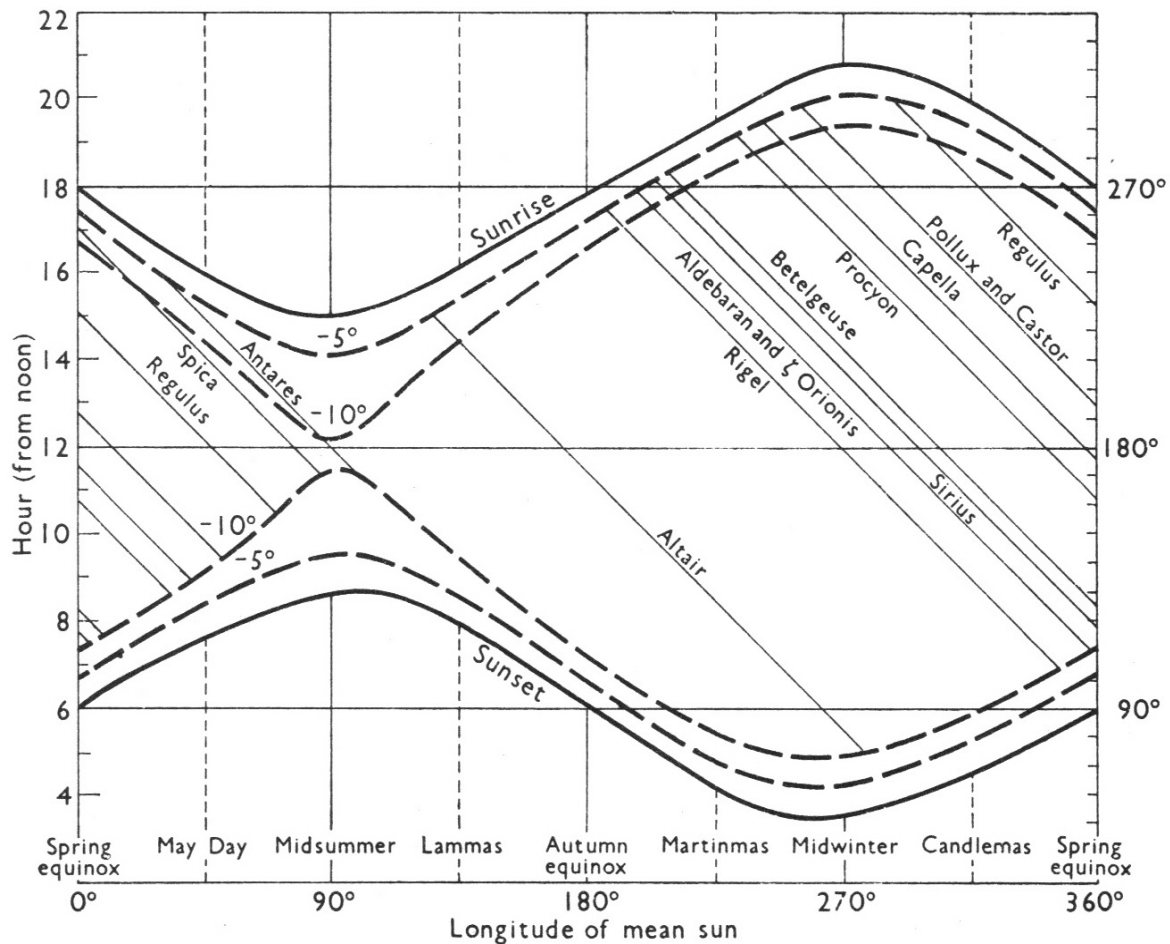


FIG. 8.3. Setting time of stars; sun at alt. 0° , -5° , and -10° . 2000 B.C., lat. 56° N.

It will also be seen that at 2000 B.C. the declination of Aldebaran was that of the equinoctial sun. These two coincidences must have appeared significant to a culture which about 2000 B.C. was presumably beginning to take a close interest in astronomical phenomena.

Chapter 6: Megalithic Astronomy, A. Thom, *Megalithic Sites in Britain*, Clarendon Press, Oxford, 1971:92-106.

Further selections from *Megalithic Sites in Britain*:

1. [Introduction, Statistical Methodology, Requisite Tools, The Megalithic Yard, Conclusions](#)
2. Circles, Rings, Megalithic Astronomy [current selection]
3. [The Calendar, Indications of Lunar Declinations](#)
4. [The Outer Hebrides; Variety of Sites](#)