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STONEHENGE

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Stonehenge, in Wiltshire in the south of England, is in many respects unique among Megalithic remains: most of its stones have been shaped and dressed in a manner which we find in no other stone circle; the large upright menhirs are capped by lintels; the main central part of the monument is an architectural entity carefully designed by an engineer/architect who seems to have had a well-developed sense of proportion and a sound grasp of the relevant mechanical principles. We must also realise that the total time interval throughout which work went on at Stonehenge was greater than the nine centuries which have elapsed since the Norman Conquest. The site is not on a hilltop or in a valley, but on a broad shoulder sloping gently down to the north-east. Just below the surface of the ground lies the chalk into which the foundations were cut. Avebury is larger than Stonehenge, but the more complicated design used

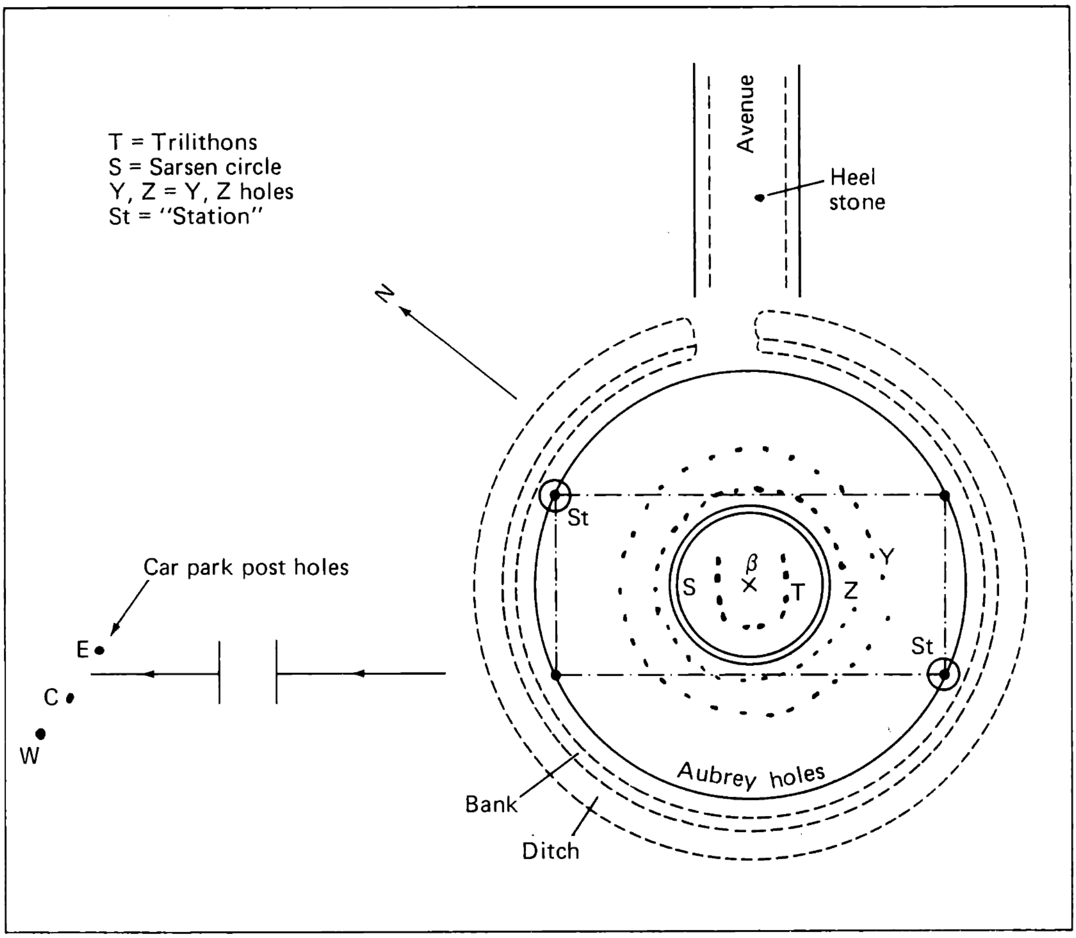


FIG. 1. Diagrammatic representation of Stonehenge.

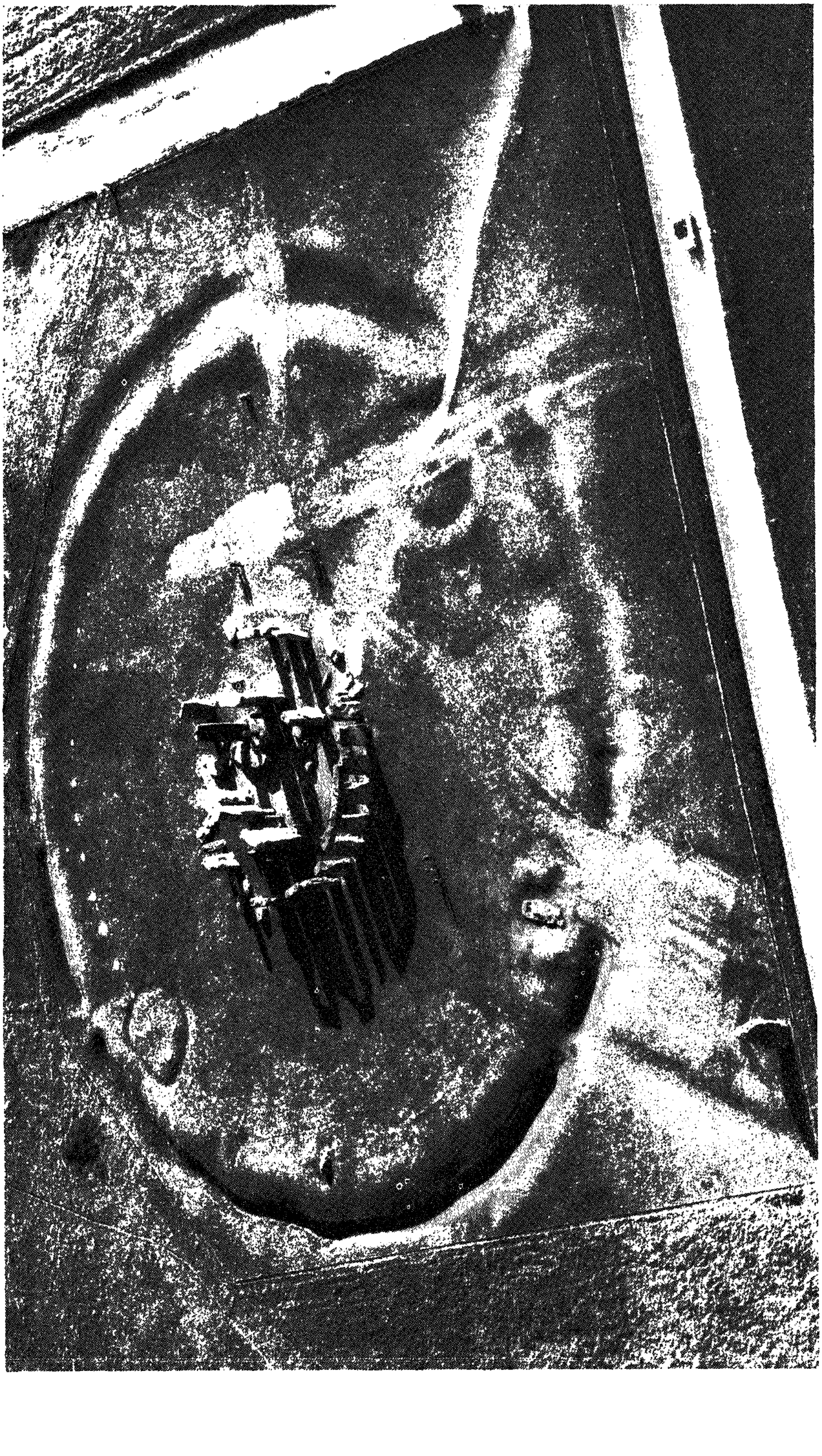


FIG. 2. Aerial view of Stonehenge (Cambridge University Collection, copyright reserved).

there spread the ring over such a wide area that its appeal now depends on its size rather than (as at Stonehenge) on the awe-inspiring feeling of perfection induced when one views Stonehenge from almost any position.

The earliest parts of the monument, probably constructed about 2,800 B.C., are the ditch and bank, the Aubrey holes, the Heel stone and perhaps the 'stations' (see Figure 1). The Aubrey holes cut down into the chalk (so called because John Aubrey in the seventeenth century noticed depressions and this clue when followed up by R. S. Newall led to their discovery) seem to have been filled and excavated several times and all that we see today are the concrete disks which have been placed flush with the ground to mark the positions. On the Aubrey ring there are (or were) two so-called stations, each of which consisted of a stone in the middle of a mound, the whole being surrounded by a ditch. The rectangle is completed by the two station stones; both are still to be seen, one upright and one almost prostrate. There are indications in the underlying chalk that two other stones existed between the Aubrey circle and the bank.[1] Placed off-centre in the beginning of the avenue is the Heel stone, a large undressed menhir with a surrounding ditch. Some trace of the banks which bounded the avenue are still to be seen in the field on the other side of the highway. We do not know what was inside the Aubrey ring when it was constructed, but from the very large number of holes which have been found in the chalk we know that, at a later date, the centre part was occupied by a ring or rings which were rebuilt more than once. An aerial view of the monument is shown in Figure 2.

When people think of Stonehenge they probably think of the two impressive rings which were eventually built in the centre of the monument about 2,100 B.C. The outer of these rings is the sarsen circle which originally consisted of 30 huge stones, capped by a complete ring of lintels. These lintels were cut to the curve of the circle in plan and were all at the same level. The method of attaching these to the uprights is shown in Figure 3. It is evident that so long as the

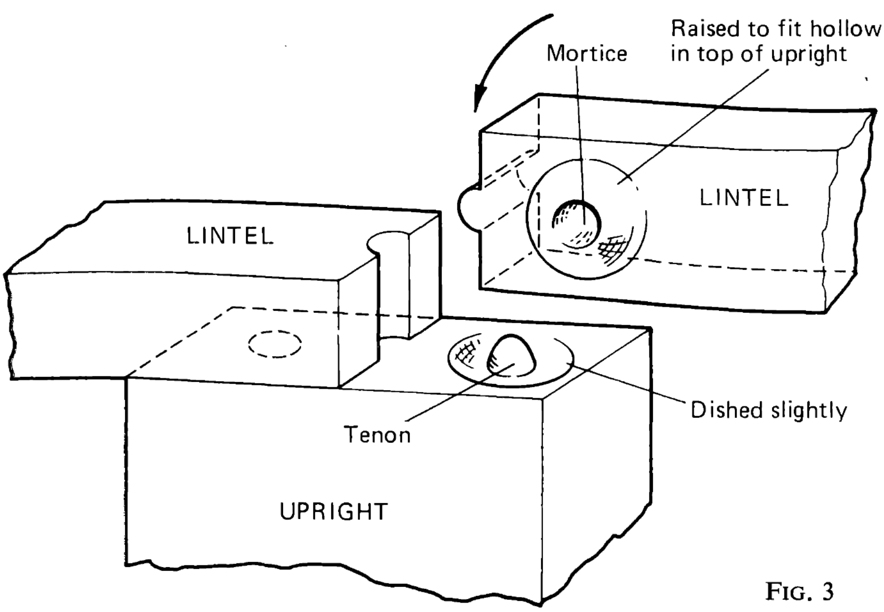


FIG. 3

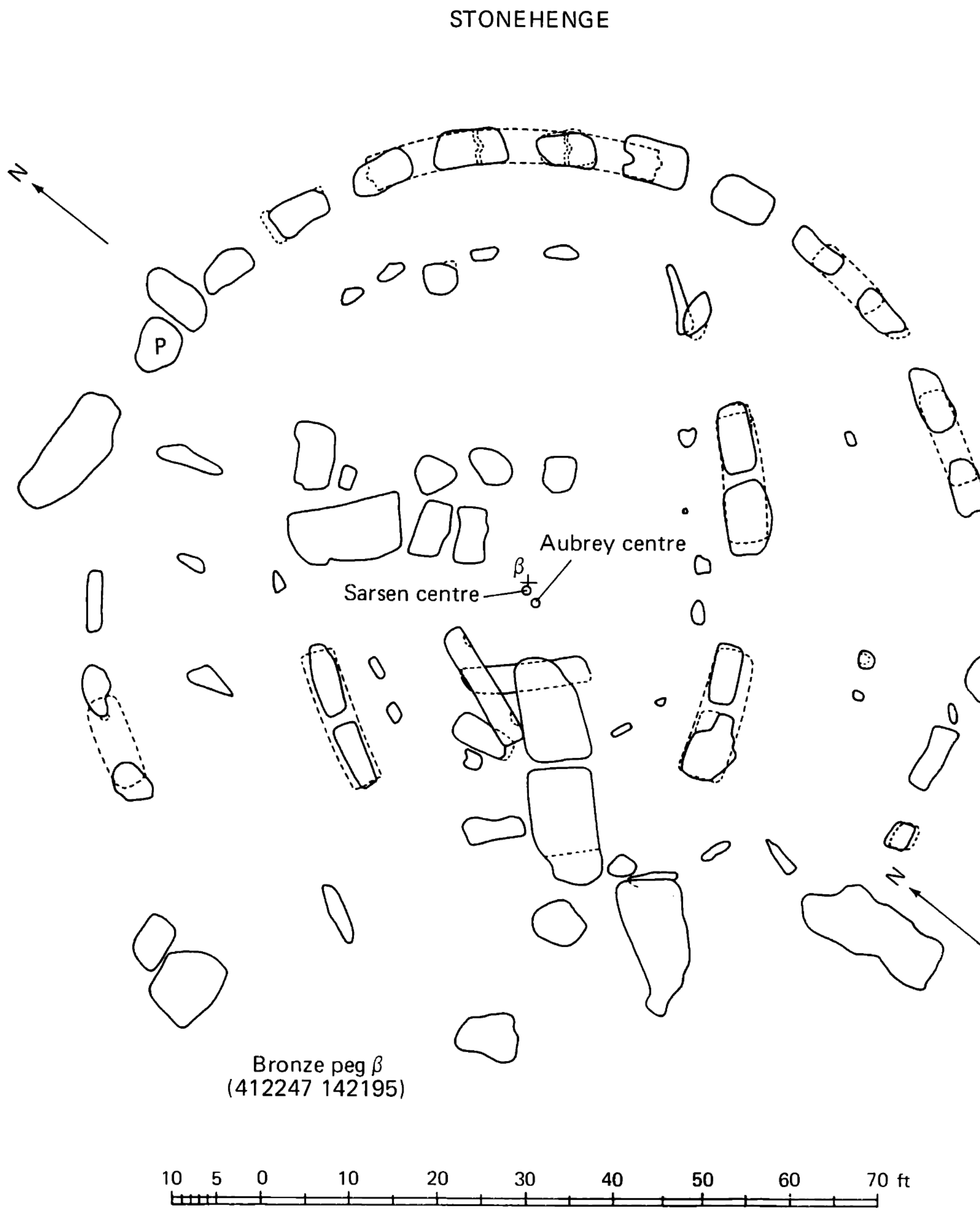


FIG. 4. The sarsen ring and its interior, based on the 1 : 84 plan.

STONEHENGE

Lat. 51° 10′ 42″ Long 1° 49′ 29″

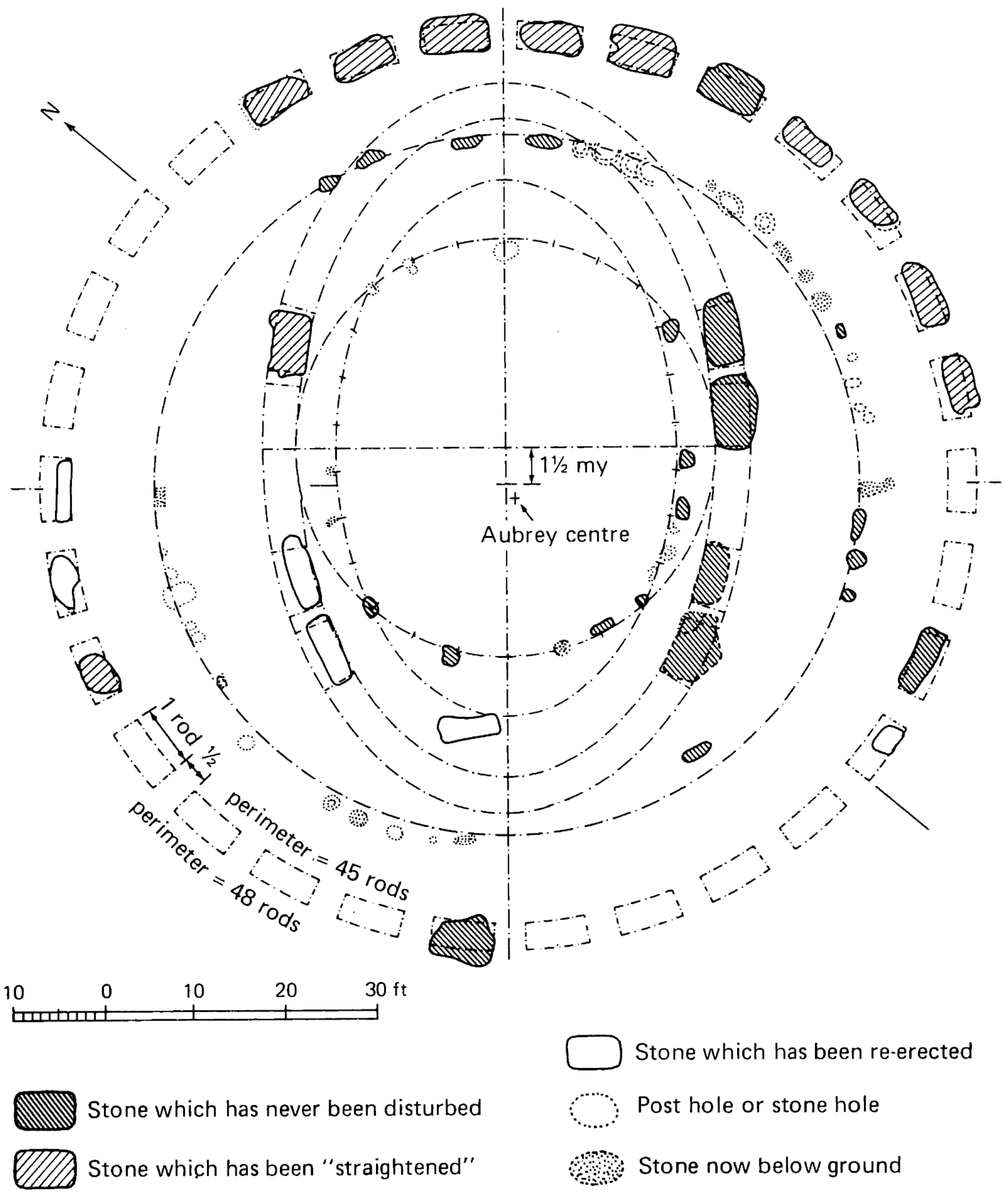
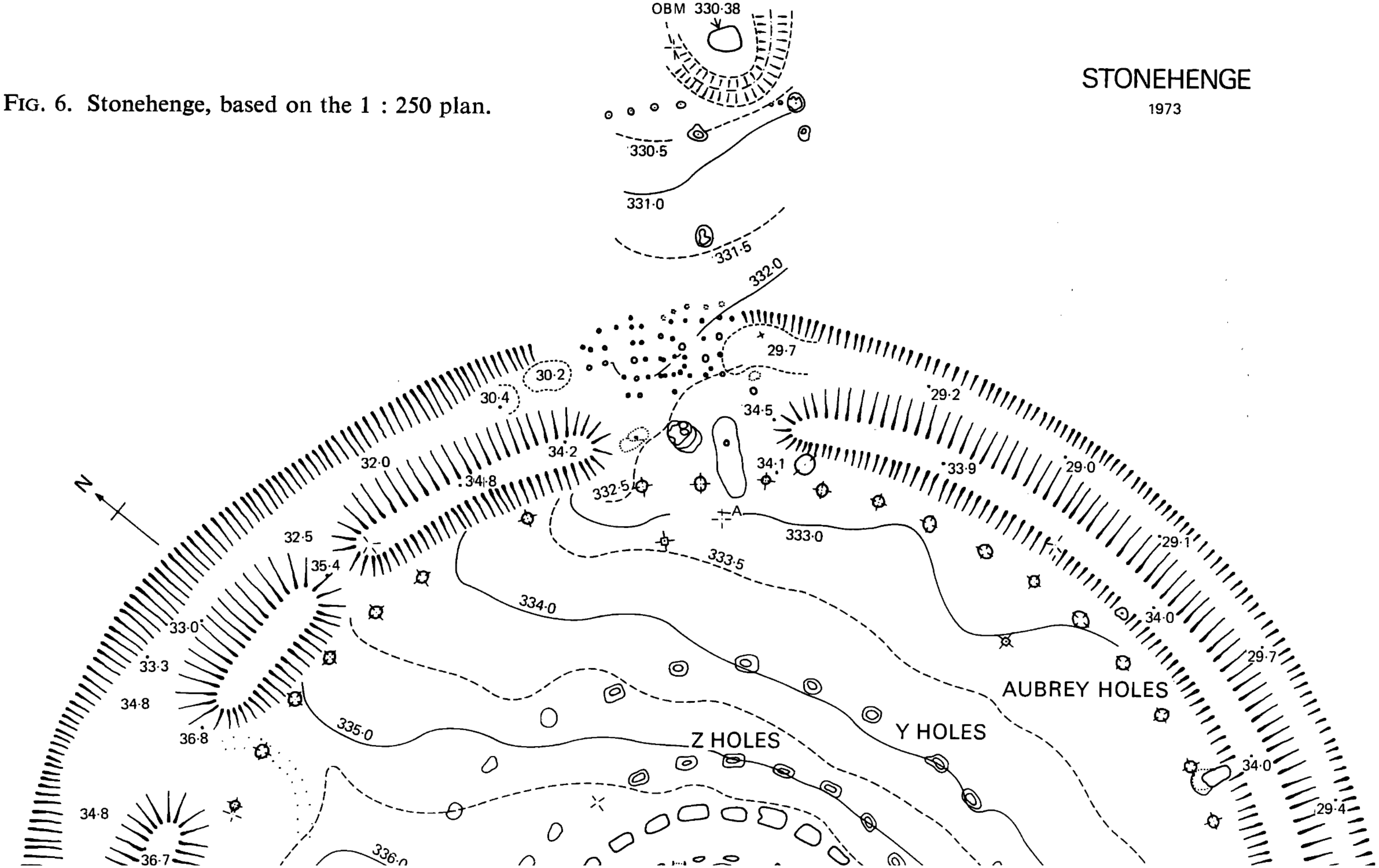
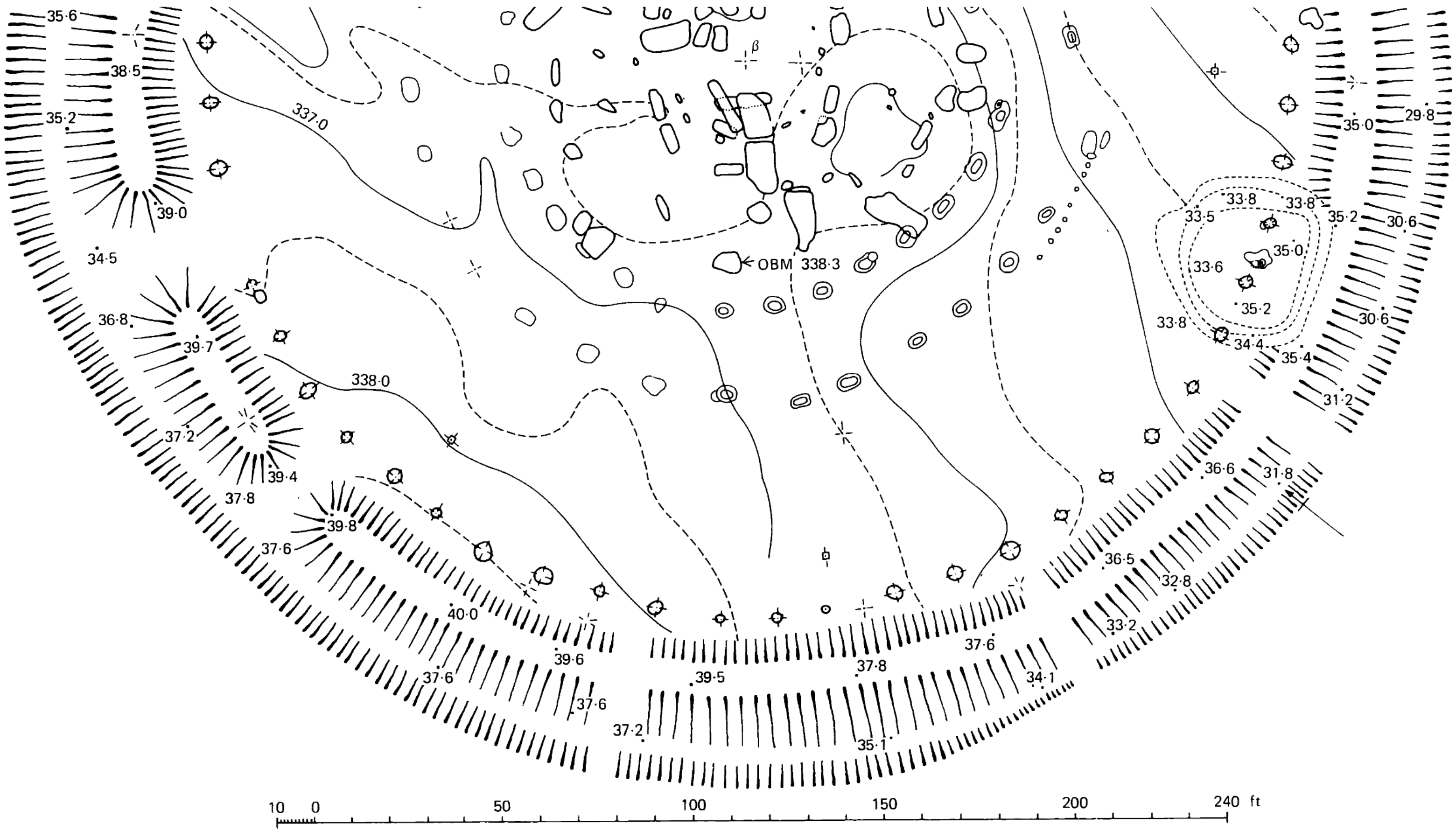


FIG. 5. The sarsen ring and its interior, with geometry imposed.

FIG. 6. Stonehenge, based on the 1 : 250 plan.





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35·2
30·6
30·6
35·0
29·8
10
0
50
100
150
200
240 ft

tenons do not fail, the ends of neighbouring lintels are held together so that distortion in a horizontal plane is prevented. We know that some of the uprights were longer than others and so go deeper into the ground. Any tendency of a shorter upright to tilt was prevented by the two lintels which rested on it. No serious study has ever been made of the stresses induced in the tenons in the event of the failure of one of the foundations. It is evident that the sheer stress in the tenon might be considerable and might have produced failure.

Inside of this circle stands the ring of trilithons. There are five pairs, and each pair originally carried a lintel attached in the same way as the lintels in the sarsen ring. Only one member of the southwest trilithon is today upright; it may be the tallest standing stone in Britain, but it is not the most massive. Between these two rings there are remains of the bluestone circle of shaped but smaller stones cut from an entirely different material. There are also remains of another bluestone ring inside the trilithons. Professor Atkinson has excavated enough of this area down to the chalk to show the complexity of the remains. Outside the sarsen circle there are two rings of holes, the *Y* and *Z* holes said by archaeologists never to have held posts or stones. These are not marked in any way, but some of them can be detected by stamping on the surface. When the car park on the other side of the highway was being excavated, three post holes were found; their positions are marked by white concrete disks in the tarmac. These had definitely contained tree trunks about $2\frac{1}{2}$ feet in diameter, and they suggest that much more may be hidden under the soil if only we knew where to look.[2]

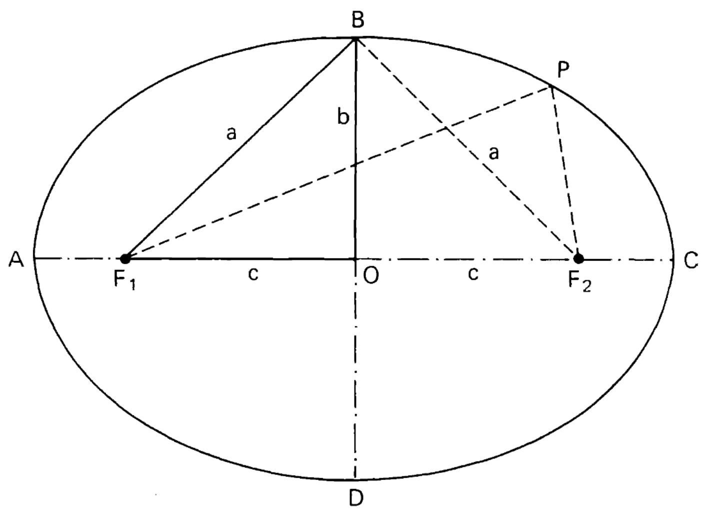
Before it is possible to make a study of the geometry to which the various rings were laid out, it is necessary to have an accurate survey. Existing surveys all seemed to have some distortion and accordingly in 1973 we undertook the survey of everything which was showing on the surface. Atkinson made available to us details of his more recent excavations inside the sarsen circle, but we have made use of only part of this material. We made a plan of the main ring and everything showing inside it to a scale of 1 in 84, and another to a scale of 1 in 250 extending to the ditch and including the Heel stone. The contours on this at 6″ intervals were surveyed by several staff members of the Survey Branch, Royal School of Artillery. Altitudes all round the visible horizon as seen from the monument were also measured. It is not possible to give the full surveys here, but we show small scale copies which illustrate our conclusions and the material on which these are based (Figures 4, 5 and 6).

Figure 4 shows the survey of the inner part. Measurements to the upright stones were made at heights of 6 inches and 2 feet above the present ground. (Atkinson states that originally the ground level was considerably higher than it is today.) Some of the stones have been re-erected in recent years and several full-sized stones and some broken stones still remain prostrate.

Figure 5 shows the same survey, but with the fallen stones omitted. Stone *P* has also been left out as it seems to have been inserted recently. The stones in the sarsen circle and in the trilithon ring have been divided into three classes. Firstly, those which are considered to be in their original position, hatching upwards to left; secondly, those which have been "straightened" in recent years, hatching upwards to right; and lastly, those which have been re-erected, shown in outline. The necessary information came from Atkinson. He suggested to us that as the south trilithon is inclined inwards and tapered, we ought to displace the outline slightly outwards to compensate. The amount was small, only three inches, but nevertheless we have shown these two stones in dotted outline. Details of the bluestone stumps now below ground were also provided by Atkinson, and these stones are shown stippled on the plan. Much of the area has at one time or another been excavated down to the chalk.

Post holes in the chalk are shown in dotted outline, but it should be pointed out that the whole area seems to have many such holes. To avoid confusion we have shown on Figure 5 only those which lie near one or other of the hypothetical rings which have been superimposed on the survey. Some of these perhaps did not belong to any ring but may have served other purposes. We would remind the reader that authorities are agreed that the best interpretation of the complicated evidence is that at different times there have been several rings or systems of rings in this area.

Atkinson has pointed out that the inner faces of the sarsens and trilithons were mostly worked flat and had been polished, whereas the outer faces had often been left rough or even rugged. Accordingly we decided to be guided primarily by the inner surfaces of these stones in determining the geometry of the rings to which they had been set. In Figure 5 it will be seen that it is a tenable hypothesis to assume that the intention was to contain the stones of the sarsen circle between concentric circles with circumferences of 45 and 48 Megalithic rods, the difference in radius being 0·48 rods.[3] The 45 dimension is built up by allowing exactly one rod for each of the 30 stones and exactly half a rod for each



Distance between foci $F_1 F_2 = 2c$
Major axis = $AC = 2F_1B = 2a$
Minor axis = $BD = 2BO = 2b$
$F_1BF_2 = F_1PF_2 = 2a$

FIG. 7. The geometry of the ellipse.

gap. On this basis, therefore, the theoretical diameter of the inside circle is $45/\pi$ rods or 97·41 ft (taking 1 rod = $2\frac{1}{2}$ Megalithic yards = 6·803 ft).

Ellipses

In *Megalithic sites in Britain*[4] particulars are given of 20 definite ellipses constructed by the Megalithic people, and several more have since come to light. These ellipses were presumably set out on the ground by use of a rope of length equal to the major axis ($2a$), the ends of the rope being attached to pegs driven into the ground at the foci ($2c$ apart). The ellipses would then be scribed with a movable stake in the loop or bight of the rope. In the position shown in full line in Figure 7 it is seen that $a^2 = b^2 + c^2$, or $(2a)^2 = (2b)^2 + (2c)^2$, where $2b$ is the minor axis.

In all Megalithic geometry we have so far found, it is evident that integral lengths were preferred so that the designers did not need to use graduated yard sticks. Straight lines were made integral in Megalithic yards, but perimeters (and most "long" lengths) were universally integral in Megalithic rods. The ideal "Megalithic ellipse" would have $2a$, $2b$, and $2c$ integral in Megalithic yards (my) and the perimeter integral in rods. This ideal is mathematically unattainable, but considering the resources available to these people it is surprising how often they found good approximations.

An examination of the data presented in Table 6.4 of *Megalithic sites in Britain* shows the importance attached by the erectors to perimeters. In practically every case these are close to multiples of one rod.

The Trilithons

It is shown in Figure 5 that four of the trilithons are accurately contained between two ellipses, 30 × 20 and 27 × 17 my. The inner of these ellipses is based on a triangle which nearly satisfies the Pythagorean condition in integers: $2a = 27$, $2b = 17$ and $2c = 21$. The square of the hypoteneuse is 729 and the sum of the other squares is 730. Since this is such an important site we shall examine the geometry in some detail by calculating the perimeter accurately. We assume that $2a$ is exactly integral in Megalithic rods and then take the two cases when either $2b$ or $2c$ is integral.

$2a$	$2b$	$2c$	Perimeter	Error
27	17	20·98	28·03 rods	0·03 rods or $2\frac{1}{2}$ inches
27	16·97	21	27·99 rods	0·014 rods or 1 inch

In either method the residual from the whole number 28 is so small that we may well ask how it was possible to measure round a perimeter about 200 feet long with an error of only an inch or two. Only one closer approximation is known and that is in the ellipse at Pennmaenmawr.[5]

After experiment it was decided that the centre of the ellipses was on the axis $1\frac{1}{2}$ my from the sarsen centre and so a precise representation of the suggested geometry of the sarsens and trilithons could be drawn on tracing paper and placed over the survey. In deciding on the final exact position, the greatest weight was given to the stones which are known to be in their original positions. The only stones which do not fit perfectly (radially and circumferentially) are those which have been straightened.

The above procedure automatically gives the position of the centre and azimuth of the axis. It appears that the latter is very close to 50°, perhaps 49° 57′ ± 3′. If it is assumed to be exactly 50° then the north-south line through the centre touches the edges of two of the 'boxes' or sections into which the sarsen stones were originally placed.

The intended width of the eight uprights in the trilithons seems to have been 1 rod and the spaces ¼ rod and 4 my, all measured on the inside ellipse. One edge is on the minor axis. These lengths have been carefully set out in Figure 5 and, when both sides are considered, it is seen how well the 'boxes' so provided fit the stones.

It will be seen that the four spaces between the five trilithons are all about 4 my, while the other dimensions are in rods. Other considerations, perhaps the aesthetics of the final result, probably decided these mixed dimensions.

The Bluestone Rings

Atkinson suggests that there were 60 stones in the larger ring, with the stone on the axis necessarily omitted. Like the majority of stone circles in Britain the spacing is not uniform, but if we take a mean interval of 1½ my the diameter becomes 28·65 my and a circle of this size has been drawn on the survey.

For the inner ring shown, a circle of diameter 17 my has been drawn and an ellipse with its foci on this circle is also shown. This ellipse is based on a triangle with sides 22, 14 and 17 my. The sums of the squares are satisfactory, being 485 *versus* 484. It will be noticed that the inner circle and inner ellipse produce a kind of oval with "corners". It has a calculated perimeter of 51·06 my which when divided into 26 parts produces a spacing of 1·96 my. (It is seen that two existing stones and one hole are in "corners".) The 26 evenly-spaced ticks marked round the ring on the survey appear to show approximately the positions of all the stones and holes near the ring. From the evidence we possess we cannot however be sure that we have correctly interpreted the designers' intentions in this ring. Here, as in the bluestone ring, things do not fit with the precision we found for the sarsens and trilithons. Reference should be made to Atkinson's book to appreciate the real complexity of the various rings which seem to have existed here.

The Great Trilithon

One of the members of the great southwest trilithon is fallen and broken. The other stone has been re-erected and so we cannot be certain of its exact original position. Atkinson points out that both faces of these two stones were finished and polished, perhaps because the position for observing the solstitial sunrise was here. This trilithon must have stood at right angles to the axis, possibly touching the inner ellipse. The upright member is about one rod wide, so it is rather surprising to find that its fallen neighbour is considerably wider.

The Aubrey Holes

In 1973 Atkinson and Vatcher by laborious prodding located accurately the outlines of all the Aubrey holes which were accessible. The centres of the shapes so marked out on the ground were indicated by metal stakes or by holes drilled in the disks of concrete previously placed to mark some of the holes and these stakes and drilled holes were surveyed accurately by us (Figure 6).

The statistical centre and radius of the Aubrey ring was then found by the method given in *Megalithic sites in Britain*.[6] The standard deviation of the radii to the holes is 0·56 ft and the mean radius is 141·80 ± 0·08 ft.

We might define the position of a hole in azimuth from the Aubrey centre as $\theta = Km + L$ degrees, where m takes all values from 1 to 56, and K is 360°/56.

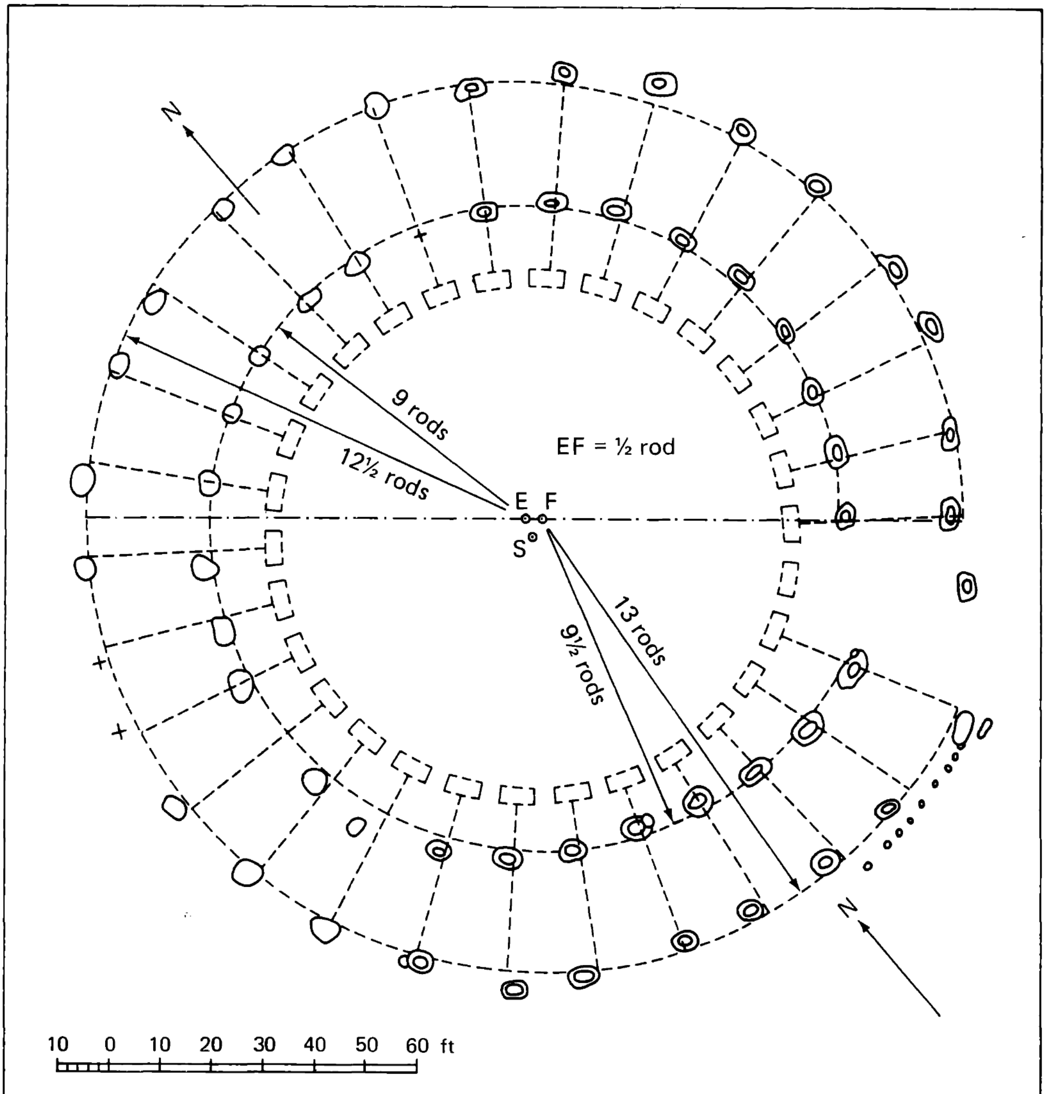


FIG. 8. The *Y* and *Z* holes at Stonehenge.

We find $L = 3°\cdot7$ and the standard deviation of the individual values to be $\pm\ 0°\cdot56$ which corresponds to $\pm\ 1\cdot4$ ft. It thus appears that the holes were more accurately placed radially than circumferentially.

The above value of the radius gives a figure for the circumference of 891·0 ft, *i.e.* almost precisely 131 rods. If we assume that the intention was to make the circumference *exactly* 131 rods then we obtain a value for the rod of 6·802 ft which can be compared with the value found in Carnac of 6·803 at Le Menec and 6·808 at Kermario.[7]

Since the position of the first Aubrey hole is $L = 3°\cdot7$ from geographical north and the mean spacing is $K = 6°\cdot429$, the north point is very nearly midway between two holes, and since there are 8×7 holes then all the cardinal points and the four intermediate points (NE, SE, etc.) lie midway between holes.

The Y and Z Holes

These holes in the underlying chalk are not visible but we have added them to Figure 6 as accurately as possible from a plan provided by Atkinson. Obviously they were never intended to be on complete circles, but Figure 8 shows that they lie on two spirals, each consisting of two semi-circles. Spirals of this kind with several whorls are found on petroglyphs or "cup and ring" marks in other parts of Britain.[8] The radii of the dotted semi-circles shown on the western half are $9\frac{1}{2}$ and 13 rods and since the separation of the centres is $\frac{1}{2}$ rod, it follows that the other two radii are 9 and $12\frac{1}{2}$. The best fit seems to be obtained by arranging to have the line of the centres, *i.e.* the line on which the two halves meet, at an azimuth of about 130°. It is evident that the position we have chosen for the centres cannot be substantially different from that used by the designers.

Figure 9 shows the central region to a larger scale. On it we see the relative positions of the six centres, namely

(i) The bronze underground pin on which our whole survey was based (β);

(ii) The centre (S) of the sarsen circle;

(iii) A centre (D) found approximately from the intersections of lines joining opposite pairs of $Y\ Z$ holes;

(iv, v) The chosen positions (E and F) of the centres of the semicircles drawn dotted in Figure 8; and

(vi) The Aubrey centre (A).

The positions of S and A are known relative to β to within an inch or two but the exact positions of D, E and F are less certain.

It might be an interesting exercise to find by a least squares method the most likely position for the spirals, but in view of the uncertainty of the exact positions of the intended hole centres this is not worthwhile attempting at present.

The fact that the Y and Z holes lie on radial lines drawn through the centres of the sarsen stones in the main ring shows how closely these holes were intended to be related to the ring.

We do not intend to make guesses about the use of these holes, but it seems that for some reason or another the intention was to place them on two spirals in such a position that the distance of the holes from the sarsens would not vary greatly round the ring.

THE ASTRONOMY OF STONEHENGE

The Solstitial Line

It is universally admitted that the axis of Stonehenge pointed to the rising solstitial Sun, but which part of the Sun's disk was intended? To settle this we need to know the altitude of the horizon and the azimuth of the axis. The altitude of the horizon from $5\frac{1}{2}$ ft above ground level in the centre of the monument was measured and found to be about 36 arc minutes, with an uncertainty of perhaps $0'\cdot5$ because of bushes, trees and vegetation. In 1901 Sir Norman Lockyer found $35'30''$ when perhaps there were fewer trees.[9]

We have seen that the azimuth of the axis is about $49° 57'$. When we take refraction $27'\cdot5$ and parallax $0'\cdot1$, the declination becomes $23° 53' \pm 3'$, which is the obliquity of the ecliptic at the date 1600 ± 450 B.C. Thus it would seem possible that the axis was orientated on the Sun when half of the orb was above the horizon about the date of the erection of the sarsens.

C. A. Newham drew our attention to a little mound, Peter's Mound, on the top of the high ground which forms the horizon from the centre of the rings. As this mound may well be of importance despite its small size, we made a contour plan of the ground and this is shown in Figure 10.

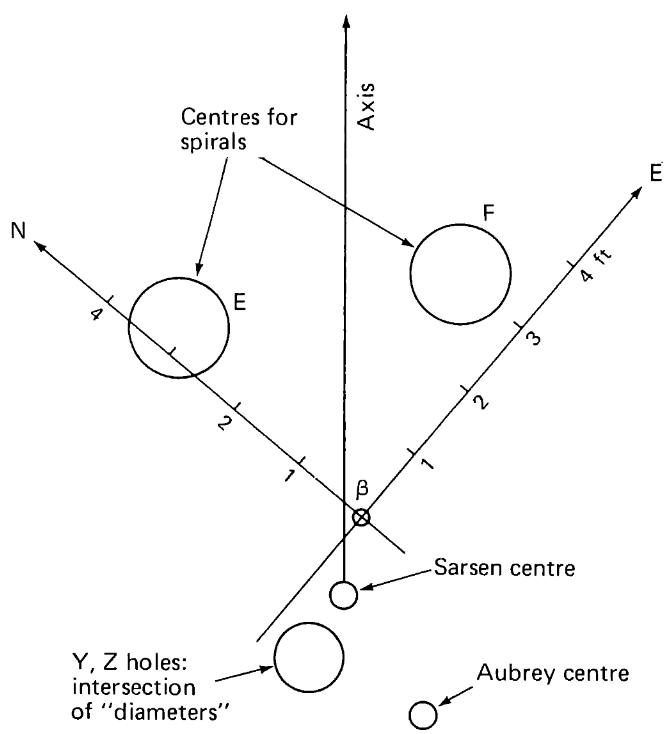


FIG. 9. The relative positions of the six centres at Stonehenge.

The azimuth of the mound was measured by us and found to be 49° 47′·6. The Royal School of Artillery surveyors provided us with the grid coordinates of the mound (14334 43967) and of the bronze pin at Stonehenge (12247·43 42195·20), and from the differences we find that the grid bearing is 49° 40′ and the azimuth 49° 48′, thus agreeing with the measured value. With the above values for refraction and parallax we find the following particulars:

From	Azimuth	Altitude	Decl.	Date
Aubrey centre	49° 47′·3	36′·0	23° 59′·8	2700 B.C. ± 400
Heel stone	49° 45′·5	38′·4	24° 03′·3	3300 B.C. ± 400

These dates happen to be close to the date now being given to the Aubrey ring, but they cannot be reliable because they are based on the Sun's centre and it is not clear how this could be estimated accurately when the lower half of the disk was hidden. An error of 2′ in estimating the centre would make a difference of 400 years in the date.

However, taking the above determinations at their face value we might say that, if the mound is Megalithic, it belongs to the same era as the Aubrey ring. Some 600 years later, when the sarsens and trilithons were being erected, the rising point of the mid orb had moved to the right and so the axis was put as we find it today, at an azimuth of 50° or slightly less. We are perhaps attaching too much importance to a few cubic feet of earth, but whether it is Megalithic or modern it has an important lesson for us: all this part of the ridge ought to be

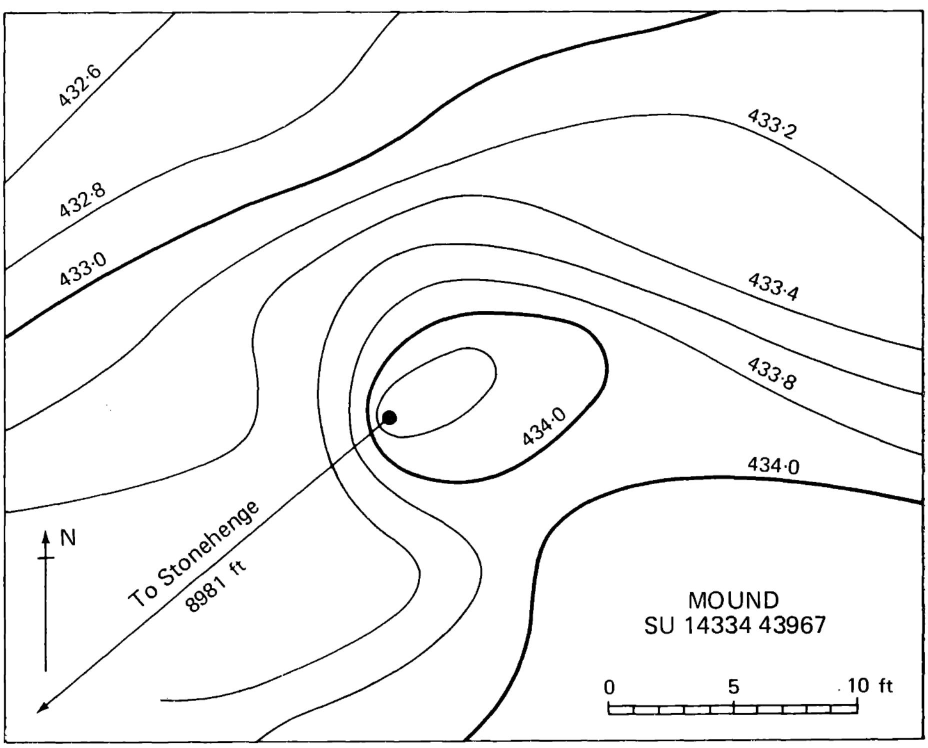


FIG. 10. Peter's Mound.

fully examined by competent archaeologists before the young trees recently planted grow and break up any relevant traces which may perchance still exist.

The Lunar Lines

Early in 1963 C. A. Newham drew attention to the fact that the long sides of the station rectangle (Figure 1) indicated the Moon setting in its extreme north position. It is reasonable to conclude that Stonehenge was a lunar as well as a solar observatory but no accuracy could have been possible if the backsights and foresights were confined to the monument itself. Further work still going on suggests however that Stonehenge may have been the centre of a huge accurate lunar observatory. Elsewhere[10] we have given reason to think that in Morbihan, Brittany, the huge menhir now called "Le Grand Menhir Brisé" was erected as a universal lunar *foresight*. Stonehenge, we now think, was perhaps a universal *backsight* from which distant marks on the horizon could be observed. As things stand at the date of writing, we are not prepared to go further than to say that there is a possibility that some traces of two or three of these foresights might still exist.

We were fortunate enough to obtain from Atkinson the original measurements made when the post holes near the Heel stone were excavated by Hawley in 1922. With these measurements we were able to plot the post holes on our survey. In view of the nature of Hawley's notes these cannot be considered to be entirely reliable positions, but they probably give a good idea of the holes which exist in the chalk below the ground. These holes are shown again in Figure 11. It is for the reader to decide for himself if the original intention was to set out a sector such as we have superimposed on the plan, bearing in mind that the posts need not have been in the centres of the holes in the chalk.

There are in Caithness and in Brittany numerous sectors of stones, and we have shown[11] that these were almost certainly for carrying out the necessary extrapolation when observing the Moon in its extreme positions, so perhaps we ought to consider the possibility that the Stonehenge sector was also for extrapolation. But we must also take into consideration Atkinson's remark that from the disposition of the holes "it seems certain that they are contemporary with the digging of the ditch and earlier than the construction of the avenue".[12] Hitherto we have not associated the advanced technique of using extrapolation sectors with as early a date as this (*c.* 2800 B.C.) and had in fact thought that it was not developed until the beginning of the second millenium. Nevertheless it seems desirable to put the following calculation on the record.

The radius of such a sector for use at the major standstill should be given by

$$\text{radius} = 4G = 80D\,\frac{\mathrm{d}A}{\mathrm{d}\delta},$$

where G is in feet, D is the distance to the foresight in miles, A is the azimuth and δ is the declination.[13] We can reverse the process and find the distance to the foresight, given the radius of the sector. The radius of the post hole sector is 188 ft and using the above formula we obtain a distance to the foresight of

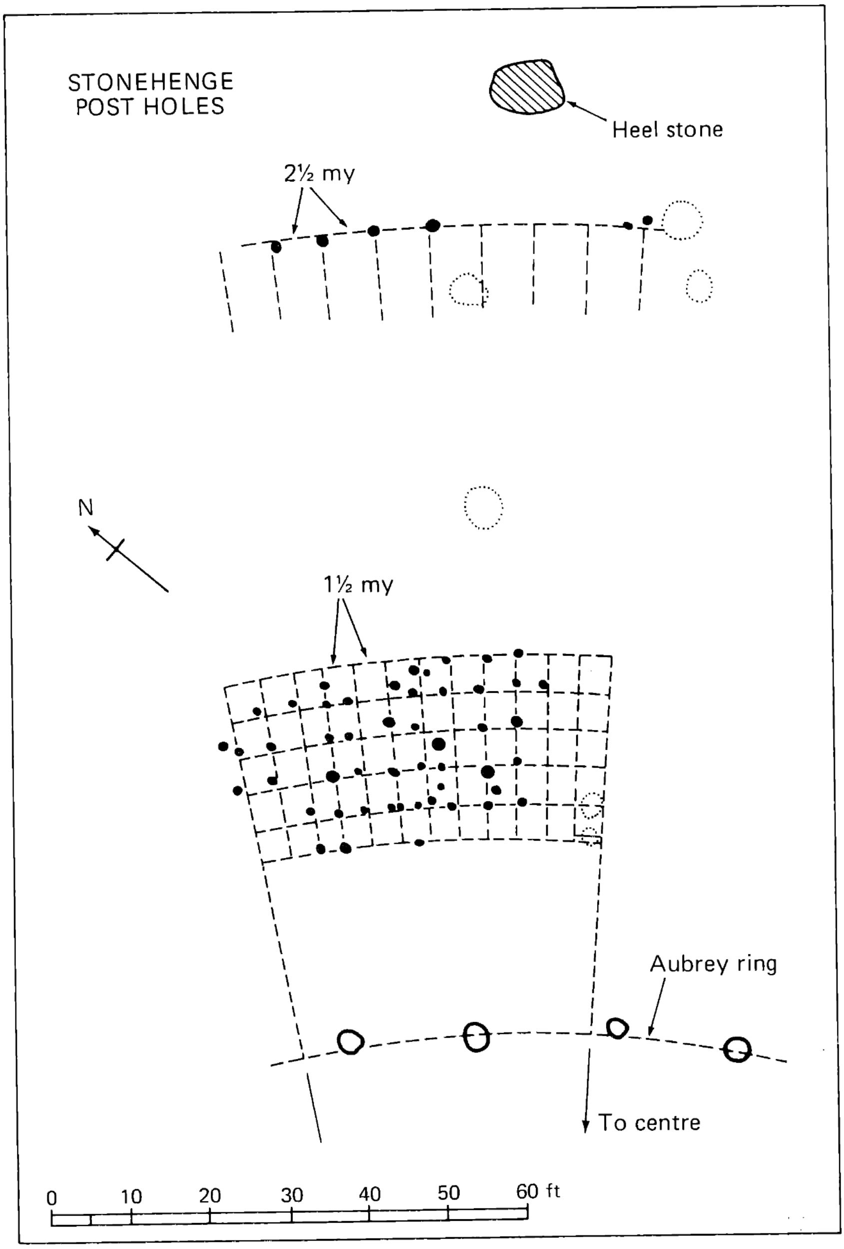


FIG. 11. The post holes between the Aubrey ring and the Heel stone.

about 1·1 miles. This is the distance to the broad ridge which forms the horizon in the direction of the Moon setting in its extreme northerly position.

On the large-scale Ordnance Survey maps there are several "stones" shown on the boundaries of Fargo Plantation which lies on this ridge. These "stones" are not shown in Old English characters and so were not considered by the surveyors to be antiquities. However, from the centre of the monument the stone at the NE corner of the plantation seems from its map coordinates to indicate the setting point of the Moon at its maximum declination. The azimuth has not yet been measured by theodolite but the observed altitude of the horizon is 18′·7 as viewed from 6 ft above ground level at the centre of the monument. Is it simply a coincidence that, on the same azimuth 9·16 miles distant, lies Gibbet Knoll on the flat high ground above Market Lavington? At this distance it is possible to calculate the azimuth and altitude to within an arc minute from the large scale Ordnance Survey. Allowing for night-time terrestrial refraction we find the altitude of the ground level at Gibbet Knoll is just over 18′ so perhaps the tip of the knoll was visible from Stonehenge, silhouetted on the Moon's disk. If it was, then we may note that the knoll gives a declination of 29° 18′ for its left end and 29° 22′ for its right end. It may also be noted that $\epsilon + i$ was about 29° 19′·5 in 1900 B.C., where ϵ is the obliquity of the ecliptic and i the inclination of the Moon's orbit.

If archaeologists did decide that this was the reason for erecting the Gibbet Knoll it could be used for dating only if we knew where on the top of this long mound the foresight was placed.

An arc of four post holes appears near the Heel stone (Figure 11) and at some time it *may* have formed part of another sector with a radius of 242 ft. Applying the above formula we find that the distance to the foresight is then 1·4 miles. If we assume that this was for the rising Moon in its extreme north position, then the necessary artificial foresight would have been on the high ground amongst the houses at Larkhill.

We hope to make a detailed examination of the above lines and some of the others necessary to complete a full set of eight. This will involve accurate surveying to decide exactly what could be seen if the obscuring trees were absent. Just as with the line to the Gibbet Knoll there are intervening ridges grazed by the rays, and the contours on the Ordnance Survey are not at close enough intervals to decide what is the highest (apparent) point along some of the lines. We experienced the same difficulty in the heavily wooded region in Carnac where we had to run many miles of accurate traverses with levels to show that the sight lines were clear and to determine their exact azimuths.

The Car Park Post Holes

When the car park on the north side of the main road was being made, three large post holes were found. The positions of the holes are shown by three white disks of concrete let in to the tarmac. We ran a traverse to these and so determined their positions. These are given in the table. They agree to within a few inches with values obtained by C. A. Newham from the Ministry of Public Buildings and Works.

Post hole positions from centre

Hole	Distance	Azimuth
West	855·5 ft	313° 24′
Centre	831·3 ft	314° 56′
East	807·3 ft	317° 08′

The azimuth of the line joining the South Station near the Aubrey ring to the stone at the NW corner is about 320° (Figure 1) and the line to Gibbet

Knoll (azimuth 320° 02′) passes between the centre and east holes. We shall give a *possible* reason for these peculiar posts. The car park is below the level of Stonehenge and so a high structure would be needed to cut the horizon. This explains why such massive posts were used. In Carnac when the backsights for Le Grand Menhir were being placed the observer moved sideways into position, but when the backsight is fixed as at Stonehenge, the observer has to communicate the orders to the people at the foresight telling them how to get into line with the edge of the fast-setting Moon. Communication must be instantaneous because there are available only a few seconds of observing time. To communicate with Gibbet Knoll was out of the question. Why not use an intermediate point at Fargo Plantation and then in daylight transfer the line forward? But perhaps even this distance was too great. It would take five seconds for a shout to reach the plantation and if it had to be relayed through two or three assistants the total time could well be nearly half a minute. They needed some position nearer but not too near; accordingly, they raised a platform on these posts. The ground is sloping down, and if a position much further away had been chosen it would have needed an impossibly high platform.

The Position of Stonehenge

On the assumption that Stonehenge was intended as a universal solar and lunar backsight let us consider the problems which faced the erectors. They had to have foresights silhouetted on the sky line, and for accuracy these had to be a reasonable distance away. Simply siting Stonehenge on a hilltop would have been useless because the visible horizon would then have been much too far away. On the other hand it could not have been too low down because then the distance to the horizon would probably have been severely limited by relatively high ground near at hand. Also, any location on a flat low plain with hills all round (if such a position exists) would probably have been heavily wooded and have had to be ruled out. It appears that the site chosen satisfies the necessarily stringent foresight conditions except that the horizon for the line needed for the Moon setting with declination $-(\epsilon - i)$ seems nearer than the ideal. However, any attempt to raise the site by more than a few feet would have brought up distant hills or ridges too far away for use; the midsummer Sun, for example, would then have risen on a horizon so far away that a very large artificial foresight would have been needed. The four lines for declination $\pm(\epsilon + i)$ all seem satisfactory, and to judge by the known lines at other sites[14] these declinations were used about four times as frequently as $\pm(\epsilon - i)$.

The foresights for the shorter lines may have been of stone but the larger targets needed for the long lines were perhaps of earth, wood, wattle or brushwood. As the foresights lay unused for 18 years between each lunar standstill, the positions of the perishable targets would have been marked in some permanent manner. When our survey is complete it is to be hoped that archaeologists will find time to make a detailed examination of the ground at the various suggested positions, but this in some cases may be difficult or impossible. Can anything be done, for example, at Chain Hill where the high ground is given over to agriculture? It will be noticed on the 1″ Ordnance Survey map that the downland track runs straight from Stonehenge towards this hill where the foresight would have been close to the little copse at 086 375.

The above suggestion, that Stonehenge was an accurate lunar observatory, presents a serious problem. Archaeologists now tell us that work on the site started early in the third millenium and all our work on accurate lunar sites has hitherto *indicated* dates in the second millenium. The explanation may be that work on studying the lunar movements began very early at Stonehenge and extended over several centuries. Possibly it was as a result of this work that other observatories in different parts of Britain were set up. It can be appreciated that at Stonehenge the definite and accurate location today of one or more of the foresights which may have existed for this, our most important British site, would be of first order importance.

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REFERENCES

1. R. J. C. Atkinson, *Stonehenge* (London, 1956; subsequently as paperback, Harmondsworth, 1960), 11. Other works on Stonehenge include Sir Norman Lockyer, *Stonehenge and other British stone monuments* (London, 1906), and C. A. Newham, *The enigma of Stonehenge* (Sedge Rise, Tadcaster, Yorks, 1964) and *The astronomical significance of Stonehenge* (Leeds, 1972).
2. Newham, *Astronomical significance of Stonehenge*, 23.
3. A. Thom, *Megalithic sites in Britain* (Oxford, 1967), chap. 5; A. Thom and A. S. Thom, "The Carnac Alignments", *Journal for the history of astronomy*, iii (1972), 11–26, p. 25.
4. *Op. cit.*, 77–82.
5. *Ibid.*, 78–79.
6. *Ibid.*, 35.
7. A. Thom and A. S. Thom, "The Kermario Alignments", *Journal for the history of astronomy*, v (1974), 30–47, p. 47.
8. A. Thom, "The Geometry of Cup-and-ring Marks", *Transactions of the Ancient Monument Society*, n.s., xvi (1968–69), 77–87.
9. Sir Norman Lockyer and F. C. Penrose, "An Attempt to Ascertain the Date of the Original Construction of Stonehenge from its Orientation", *Proceedings of the Royal Society*, lxix (1901), 137–47.
10. A. Thom and A. S. Thom, "The Astronomical Significance of the Large Carnac Menhirs", *Journal for the history of astronomy*, ii (1971), 147–160.
11. *Ibid.*, and A. Thom, *Megalithic lunar observatories* (Oxford, 1971), chap. 9.
12. Atkinson, *Stonehenge*, 11.
13. See ref. 11 above.
14. Thom, *Megalithic lunar observatories*, 76.