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STONEHENGE AS A POSSIBLE LUNAR OBSERVATORY

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In a previous paper[1] we have given details of an accurate survey of the monument at Stonehenge and shown how the sarsen circle and the trilithons were set out. We also discussed the possibility that Stonehenge was the central point of a solar and lunar observatory. On a subsequent visit we examined in detail (as far as crops permitted) some of the postulated sight lines. We were using the same equipment as before, namely a Longines electronic watch, a Tavistock theodolite and other surveying gear. In only one detail do we wish to retract the views expressed in our previous paper, and that concerns the stone at Fargo Plantation. This is in fact a boundary stone and so presumably modern, but, as will be seen, this hardly affects any conclusion which may be drawn concerning the sight line which passes through this point.

The Lunar Hypothesis

The hypothesis that the site of the monument is a lunar observatory invites us to examine eight sight lines to find out if any of these could have carried distant foresights on the apparent horizon. The human eye can resolve two points about 20 seconds apart and so a foresight of 1 arc minute width would have been sufficient, that is, $1\frac{1}{2}$ ft for every mile. For the longer lines the foresight could well have been of brushwood, but as it was to be used only every nineteen years, its site would need to be marked in a permanent manner by a stone or a mound of earth. We had hoped that some trace of these mounds might still exist and indeed it might be claimed that there is evidence of this, but only archaeologists, by extensive digging, can settle the matter.

We set out to seek foresights for the eight limiting lunar rising and setting positions with declinations $\delta = \pm (\epsilon \pm i)$, where δ is the declination, ϵ the obliquity of the ecliptic, and i the inclination of the lunar orbit. We believe that the positions for four of these may have been located, if not accurately pinpointed: (1) Gibbet Knoll above Market Lavington; (2) near the mound inside Figsbury Ring; (3) near Hanging Langford camp; and (4) on Chain Hill. In addition there was probably a foresight at the position now occupied by the Coneybury tumulus.

It will be shown that, for each of the first three lines above, the ray grazes a ridge near Stonehenge, so perhaps only at night with cooling ground would the foresight be easily seen down to its base at ground level. During the day all three would have been visible (a) from the level of the lintels on the sarsen circle, or (b) if the foresights had been reasonably high.

Yet the monument could have been raised by moving it slightly to the north-west and there does not seem to be anything to have prevented the foresights being similarly moved. Why was this not done? It seems that it was of prime

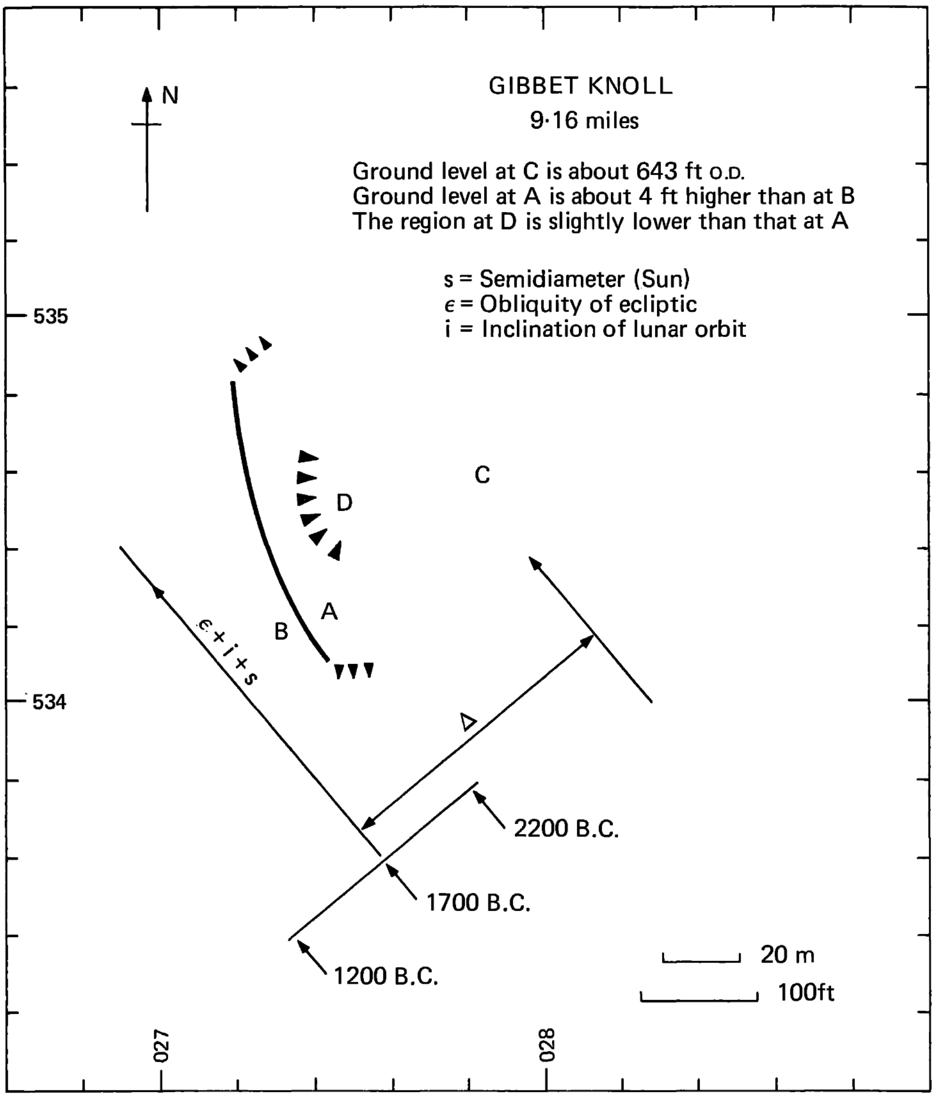

FIG. 1. Gibbet Knoll, near Market Lavington, showing the approximate positions for the Moon's upper limb setting at 2200, 1700 and 1200 B.C. at the major standstill. The measurement necessary for the perturbation Δ is also shown.

importance to use an artificial foresight for the rising solstitial Sun, and as C. A. Newham pointed out to us, if Stonehenge had been raised even by a few feet, the distant hills to the north-east would have come into view, thus destroying the usefulness of the foresight that we have called Peter's Mound.

There is plenty of room for side movement at the Heel Stone and hence it seems likely that the observing method for the solstitial Sun was as follows. One observer moved into such a position that the upper limb grazed the mound and another moved into position for the lower limb. The point midway between would be the position from which the Sun's centre passed over the mound. We have explained elsewhere[2] that this method of observing was almost certainly used for lunar work and there is no reason why it could not have been used at

Stonehenge for the Sun. Perhaps this is the reason why the declination of the mound is equal to the obliquity of the ecliptic at dates which agree with those shown by recent radio-carbon dating at the sarsen circle and at the Heel Stone.[3]

Gibbet Knoll

We shall now discuss the various foresights in detail. Scattered over the Wiltshire Downs we find numerous mysterious markings. There are ditches, banks without any apparent use, and peculiar shapes set in various places, some on the hilltops. Gibbet Knoll above Market Lavington may be merely another one of these and it is not a very impressive one (see Figure 1). It consists of what might be described as a long step in the otherwise flat ground; a step of about four feet in height, with the ground raised on the east side. Its importance for us is that it is in exactly the position that a lunar foresight for Stonehenge ought to occupy.

In some conditions it is difficult or impossible to see the ground at Gibbet Knoll from eye level at Stonehenge during the day. This could most easily be tested by heliograph. We mounted a spot lamp near *C* on the top section of a surveying staff so that it could be slid up and down from five feet to fourteen feet above the ground. The total length of the ray was about nine miles, and a mile and a quarter from Stonehenge it grazed a field of growing wheat at the end of Fargo plantation. Shortly after sunset the light was switched on at a height of fourteen feet and it was immediately visible from eye level at Stonehenge. There we measured its azimuth and altitude and by Morse code requested that the light be lowered. When it was nine feet above the ground the altitude was again measured, but when it was taken to five feet it could not be seen; probably the ray was then in the wheat or hidden by trees.

The Royal Artillery surveyors measured, in the field, the exact grid co-ordinates of the two ends of the Gibbet Knoll. As we knew the altitude and therefore the height above the theodolite level at Stonehenge we could calculate the refraction coefficient defined as

$$K = Bt^2/LP,$$

where B = refraction (arc seconds),
P = barometric pressure (inches of mercury),
t = absolute temperature °R (*i.e.* °F + 460),
and L = length of ray (feet).

It will be seen in Figure 3.2 of *Megalithic lunar observatories*[4] how this coefficient increases at sunset; but, during the experiments on which this figure was based, the coefficient seldom exceeded 12. On the Gibbet Knoll ray we found a coefficient of about 24 when the lamp was 14 ft above ground level and 27 when it was 9 ft above ground level. These very high values of refraction were almost certainly produced as the ray grazed over the cornfield. The ground was cooling rapidly by radiation to the sky, and producing a temperature gradient in the air immediately above it. This gradient is affected by a number of factors, such as the state of the sky, what has happened earlier in the day, and the amount of cloud and wind. A high wind, by reducing the temperature gradient, reduces the coefficient. This indicates how difficult it is to see a *low* foresight at

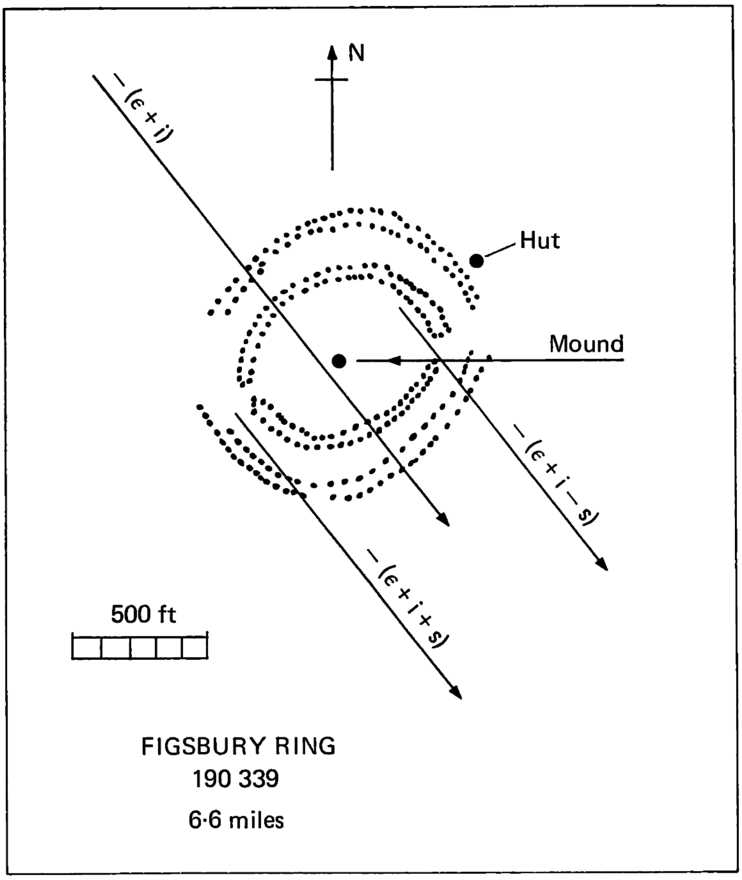

FIG. 2. Figsbury Ring, showing the position of the low mound and the estimated positions of possible foresights.

Gibbet Knoll, but it would always be visible from the level of the lintels. It will be seen that the same critical condition also applies to the Figsbury Ring and Hanging Langford foresights. Details of the measurements will be found in Table 1 which also gives the calculated declinations.

Gibbet Knoll represents the furthest possible north setting point of the Moon's upper limb. We do not know what type of foreight was used; perhaps it was a pile of brushwood on a mound of earth. This would be visible silhouetted on the Moon's disc provided it was some 15 ft wide, by no means an impossible size.

Figsbury Ring

This huge fortification is of course much more modern than Stonehenge, but in the middle of the flat area inside there is a clear indication of what has been an earth mound and we used this as a reference point (Figure 2). The grid coordinates are about 18838 33835. Using these and the known coordinates of Stonehenge we obtain a grid bearing of 141°46′ and so an azimuth of 141°54′.[5] Unfortunately there is a wood about 3000 ft from Stonehenge which prevents this azimuth being checked directly and behind the wood is a ridge which is grazed by the ray to Figsbury Ring. We could not find the Ordnance Survey bench mark at Figsbury Ring but by using several of the spot levels on the O.S.

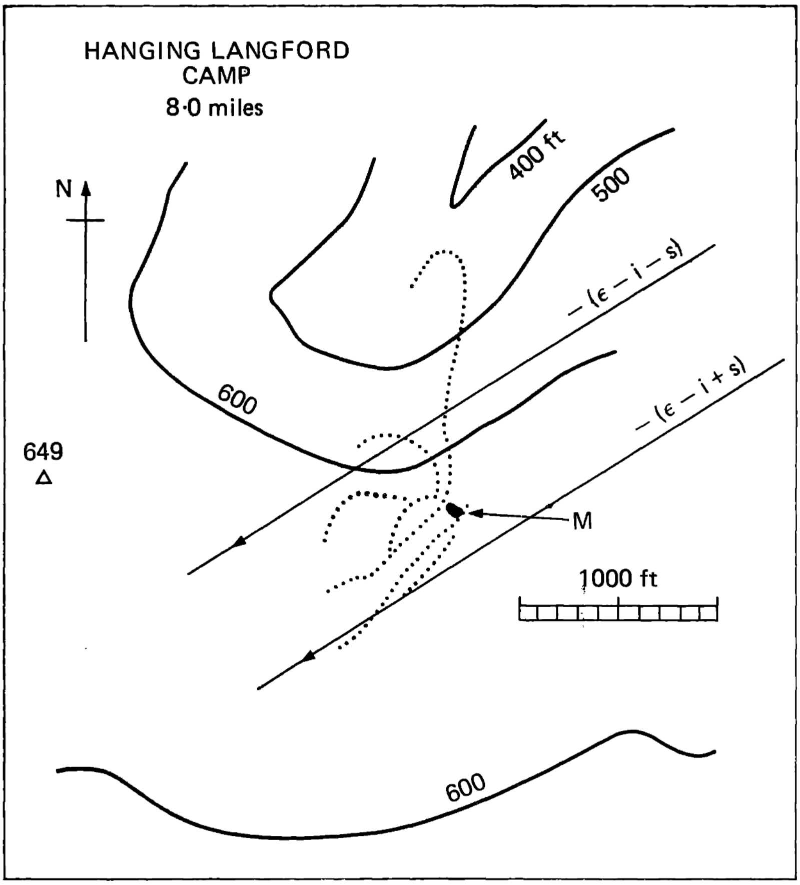

FIG. 3. Sketch plan of Hanging Langford Camp. The grid coordinates of the Trigonometric Station on the left are 400698·6, 135321·6. The dotted lines show the banks and ditches. The declinations are estimated values from Stonehenge centre. The positions of the arrows are considered correct to ± 100 ft.

maps we estimate the level of the mound to be 484 $\pm$ 2 ft O.D. and so the altitude from eye level at Stonehenge must be about 12′·0.

By reciprocal levelling from the bench marks at Stonehenge we found the level of the top of the tumulus at Coneybury to be 386ft (not 389 as shown on the O.S.). From there we ran a tacheometric traverse along the ridge and so found that the highest point on the line from Stonehenge to Figsbury is at a level of about 362ft, 5430ft from Stonehenge.

This implies that the altitude of the ridge where the ray crosses is about 11′·7. (We have assumed throughout that in Megalithic times eye-level at the centre of Stonehenge was about 343ft.) Thus a foresight placed near the position of the mound would be seen from Stonehenge silhouetted on the sky. Using the above values (and taking refraction as 32′·0) we obtain a lunar declination of $-29°00'$ which is within 2′ of $-(\epsilon + i)$.

Hanging Langford Camp

Figure 3 shows how the banks and ditches of this peculiar construction wind upwards to the crest of the long ridge along which runs the Roman road from

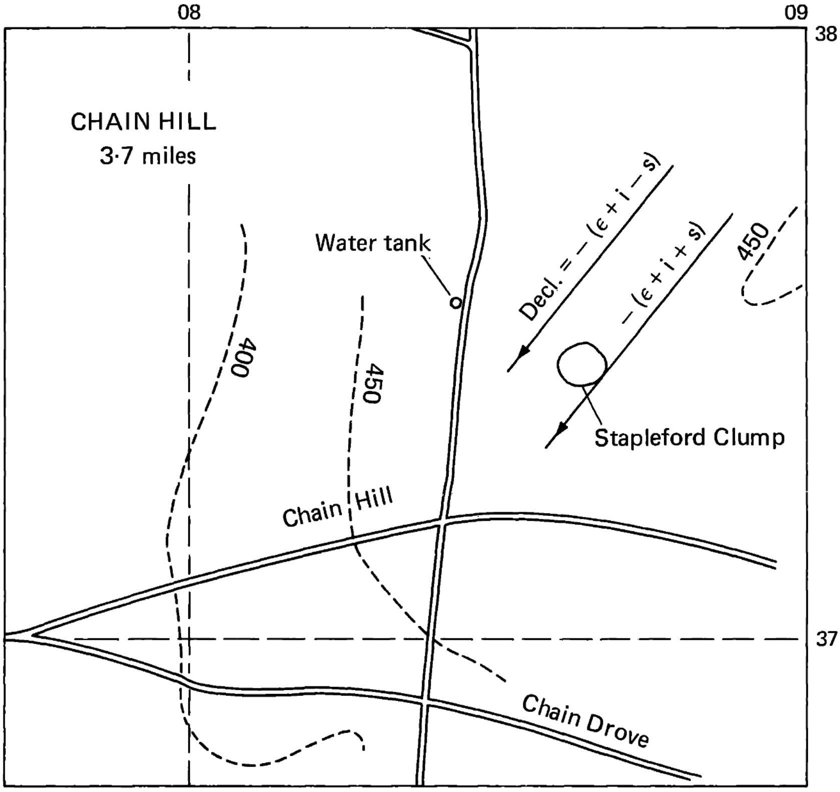

FIG. 4. Estimated position of possible foresights on Chain Hill.

Salisbury to the west. The figure also carries lines showing where on the ridge, as seen from Stonehenge, the lower and upper limb of the Moon would have set at the minor standstill about 2000 B.C. Growing wheat prevented a complete examination of the ridge and so we do not know exactly the height of the highest points on the rays, but we assumed them to graze at a height of 640ft. From this we obtain[6] the altitude from eye level at Stonehenge is about 21′·2. For this ray there is again an intervening ridge rather less than a mile from Stonehenge. The measured altitude of this ridge at the appropriate point, reduced to an assumed eye level of 343ft, is about 22′·2. It accordingly seems likely that in daylight conditions the ridge at Hanging Langford is just hidden by the nearer ground, but anything over some 8 or 10ft high would come into view. We have not had an opportunity of testing this ray at night with a lamp but conditions seem almost identical with those at Gibbet Knoll. The O.S. map contours indicate that at Hanging Langford the ray is near the ground for perhaps 2000ft so that one might expect night-time astronomical refraction to be raised considerably, thus raising the numerical value of the calculated declination. The effect would be that the arrows on Figure 3 would be slightly displaced to the north.

There is at or near the point marked *M* in the figure a mound about 50ft long, but this may be merely a part of the system of banks and ditches. We ran a traverse from the trigonometrical station to this mound and found its grid coordinates to be 401313 135270. With an altitude of 22′ this gives a declination of −18°52′. We do not consider it likely that this mound ever carried a foresight for Stonehenge but it gives a convenient point to use in any future work

Chain Hill

An ideal position for a foresight for $-(\epsilon + i)$ would be on the top of Chain Hill. All this area is cultivated which makes it unlikely that anything will be found here, but Figure 4 shows where one might look. The plantation known as Stapleford Clump has been examined without result. It is interesting that one of the old tracks which radiate from Stonehenge leads towards Chain Hill. It has slight deviations but it probably was straight at one time. It seems likely that it passed just in front of Druid Lodge where the road has the appearance of being old. Curiously, this very short part is at an azimuth of about 216°16′ from Stonehenge and, with the altitude of the top of the Chain Hill ridge behind, this azimuth gives a declination of about −29°24′ or very close to $-(\epsilon + i + s + \Delta)$, where s is the Moon's mean semidiameter and Δ is the mean perturbation of i.

Coneybury Tumulus

We give a sketch (Figure 5) showing the appearance of this tumulus from Stonehenge. It will be seen that if there ever was a Megalithic foresight here it could not have been very far from the position now occupied by the tumulus. The observed altitudes are such that there is no possibility of anything being seen further away than this ridge.

The Remaining Lines

We have discussed five of the eight lines which would make a complete set. Two remaining ones are more difficult to examine—those for the Moon rising in the north-east. The foresight for $(\epsilon + i)$ could only have been on the relatively

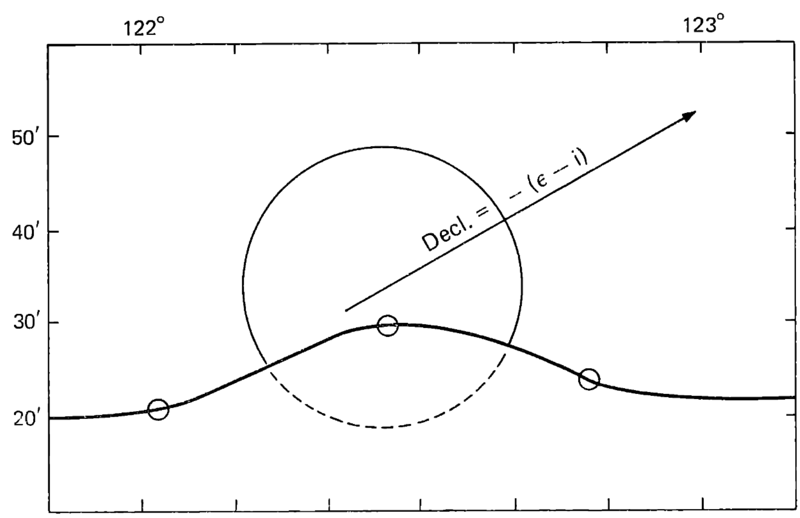

FIG. 5. Tumulus on Coneybury Hill. Sketch showing where the Moon rose in 2000 B.C. with declination $-(\epsilon - i)$, in relation to the position now occupied by Coneybury tumulus, distance 5000 ft.

TABLE 1. Particulars for foresights.

Foresight	Distance miles	Altitude	Azimuth	Declination	Compare value for 2000 B.C.
Gibbet Knoll	9·16	20′	319°56′	+29°21′	$+(\epsilon + i + s) = +29°20'$
Figsbury Ring, mound	6·6	12	141 54	−29 00	$-(\epsilon + i) = -29\ 04$
Hanging Langford Camp, mound	8·04	21	237 47	−18 52	$-(\epsilon - i) = -18\ 47$

Note: The mention of a particular mound or point in this table does not imply that this is considered to be the original Megalithic foresight, but it is used here simply to specify a reference point.

near high ground now built up at Durrington. The other, for ($\epsilon - i$), probably grazes the ridge among the houses and runs to the high ground at Dunch Hill. The difficulty which has to be overcome is that the ridge has a side slope so that accuracy is needed and somewhat difficult surveying through gardens and roads is required. But scrutiny of the contours on the existing 2½-inch Ordnance Survey indicates that a graze is very likely.

The Midwinter Setting Sun

In our first paper we have shown how the position of the mid-orb midsummer rising Sun would have been near the geometrical axis of the trilithons around 2000 B.C., the exact date depending on the assumed height of the observer's eye.

R. S. Newall suggested[8] that possibly the axis was also intended to be used looking to the south-west for the midwinter setting Sun. Unfortunately today a wood intervenes and so we have to estimate the altitude in this direction from

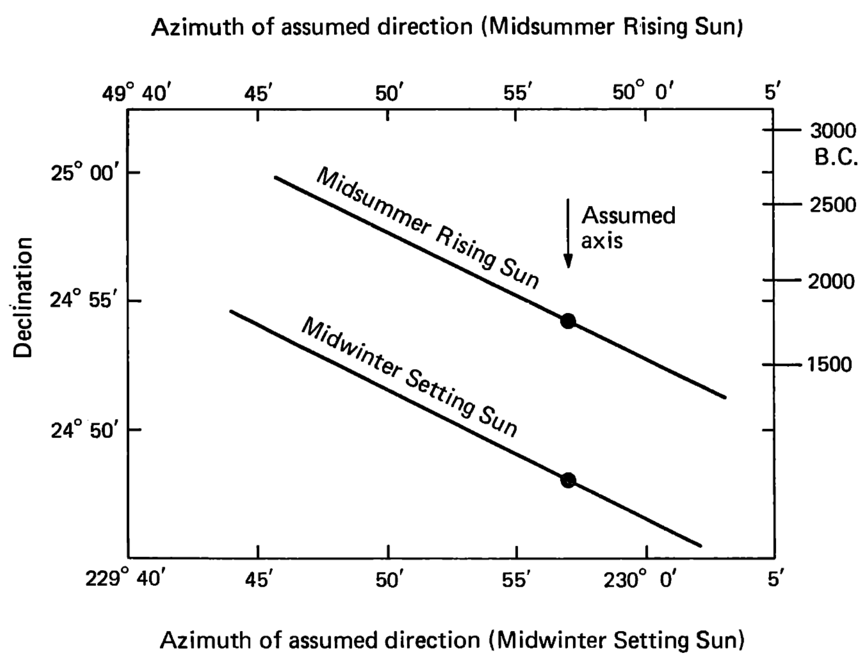

FIG. 6. To show how the declination of the indicated point on the horizon depends on the azimuth assumed for the axis. Values to north-east and south-west are both given.

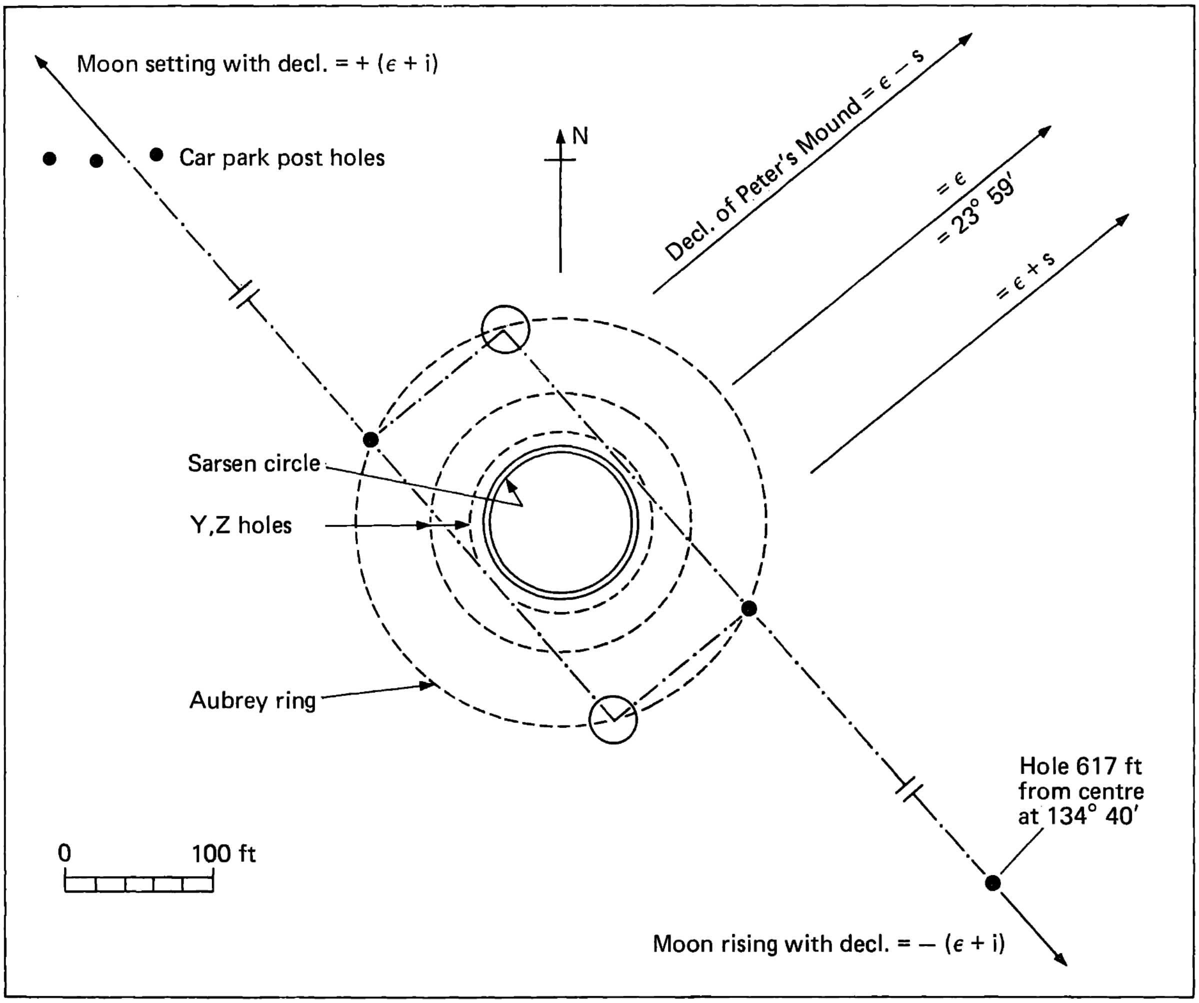

FIG. 7. Car park postholes and other features in relation to the rectangle formed by the two 'stations' and the two stones on the Aubrey ring.

the map contours. We consider that our estimate of $+29'$ is correct to perhaps $\pm 2'$. To do better than this it will be necessary to survey the line where it crosses the ridge between Asserton Farm and the site of a tumulus to the east, *i.e.*, near 090393. It is shown in Figure 6 that with an assumed axis azimuth of 49°57′ this line gives a declination too low numerically by about 6′ (unless indeed the upper limb was intended), and this would seem to indicate a date much too early for the trilithons.

The Position of the Backsights

In what has gone before we have assumed that the foresights were viewed from the centre of Stonehenge, but we must now consider if this was really so. If Stonehenge merely provided a backsight from which to make the simple kind of observations which must have preceded anything more elaborate, then perhaps after many decades of watching the observer would be able to place foresights showing the limits of the Moon's movement.

But now consider what would happen if Stonehenge was to be used as one, perhaps the principal one, of the kind of accurate observatories described in *Megalithic lunar observatories.* The observer had to be able to move rapidly transversely to get into such a position that the edge of the Moon's disc appeared to graze the foresight. He then marked his position by a stake in the ground. After two or three nights' observations straddling the time of the maximum declination he had the data necessary to enable him to extrapolate to the stake position for the maximum declination (which would in general have happened between two observing times).

Consider the conditions for observing Gibbet Knoll, for which a clear movement of several hundred feet was required. If the observer had to move further to his right than the Heel Stone, his eye level would have fallen more than three feet and Gibbet Knoll might have been hidden. Now suppose that M is the extreme left point on the line of movement, corresponding to the greatest possible numerical declination. Then all stake positions must lie to the *right* of M. This is true whether we are thinking of Gibbet Knoll in the north-west or Figsbury in the south-east; each will have its own M and it is desirable that each M should lie some distance to the left of the centre of the monument. The range of operations will then be kept at such a level that Gibbet Knoll will not be obscured. This perhaps explains the arrangement shown in Figure 7, where we see that if we stand on the mound of the south 'station' and look over the station stone to the north-west our line of sight is displaced to the left of the sarsen circle; and, similarly, if we use the other station and look towards Figsbury the line is again displaced to the left.

The line to the north-west passes through the car park post holes which we have already suggested may have contained posts tall enough to carry a platform on which temporary foresights could be placed. Shortly before he died in April 1974, C. A. Newham drew our attention to a hole or small depression in the ground near the Figsbury line which might have held a similar post for the south-east line. Until this hole is properly excavated there can of course be no proof that there ever was a post here.

If a raised platform was necessary for the Gibbet Knoll and Figsbury rays, then it was also necessary for the ray to the north-east for $(\epsilon - i)$, because here also the ground falls for the first several hundred yards. The position would, however, have been in land which has since been so much cultivated that there is little chance of finding anything by superficial examination.

We do not wish to say that Stonehenge *must* have been used in this way; but notice that the sides of the station rectangle do indicate the two foresights, Figsbury Ring and Gibbet Knoll, and remember that the accuracy attainable by the use of the station rectangle itself is not nearly sufficient to allow any scientific study of the lunar movements.

The long rays present two more problems. Why was it necessary to use a ray nine miles long when a shorter one was available? And how was the correct position for the distant foresight determined? In the fifteen or twenty seconds of available observing time there does not seem to be any direct method by which these people could have signalled to a party at the foresight to move right or move left. An intermediate pole would have helped because when the Moon was on the horizon this could have been placed exactly in position. The distant foresight could then have been ranged into place the next day with plenty of time available. This may explain why grazing rays were desirable. But the ridge which produces the graze is, in all important cases, at a distance of about a mile. This is beyond shouting distance, but one can think of ways whereby this could have been overcome.

The Roads Radiating from Stonehenge

We have already described the road running towards Chain Hill. There are however two other roads radiating from Stonehenge. A particularly straight track is that which runs off at an azimuth of 194°·6 towards the horizon where the altitude is about 20′·2. This gives a declination of −37°30′, which is that of α Centauri about 2640 B.C.[10] This star is one of the three brightest in the sky.

The track which radiated from the monument at an azimuth of 9°·1 gives a declination of about +38°·5, but there does not seem to be any obvious explanation of this value.

Note on Refraction

The measurement made of the bending of the ray to Gibbet Knoll raises some important points. We can calculate the refraction which would be expected under ordinary circumstances without a graze. Comparing this with the value actually found we obtain a bend in the ray of about 2′ with the lamp in the high position and rather more for the low.

The amount of the bend in any particular case will probably be proportional to the length of the part of the ray which runs near the ground. If we are interested in astronomical refraction only, then the amount of the bend (if known) should be added to the refraction, but the effect on terrestrial refraction depends on the position of the intervening ridge.[9]

Every lunar line for which we have published particulars passes at the foresight near the ground, and so it would seem that we ought to correct for the (as yet unknown) refraction produced by this graze in addition to that caused by any nearer ridge.

Conclusion

We have shown that Stonehenge may have been the central point of a lunar observatory of a size comparable to the Observatory which we believe was centred on Le Grand Menhir Brisé in Brittany. In the Breton observatory there was a central foresight to be observed from the surrounding backsights, whereas at Stonehenge the observations were made from the monument to distant foresights.

An interesting fact about the Stonehenge lines is that certainly three and possibly four graze the nearer ground one to two miles distant before reaching the foresight position. If this was intentional, perhaps it was to make it easier to establish the far-off foresight. Or was it to impress the populace by appearing to bring into view in the evening, foresights which during daylight may have been invisible? Or was it pure chance that when the site was chosen so that the solstitial ray to Peter's Mound was a grazing ray there were four other grazing rays for the Moon? Whatever the explanation, our work has shown that much research is necessary before we shall know exactly what really was visible from Stonehenge in different conditions. This will involve measuring the refraction of the grazing rays (as we did once only for Gibbet Knoll) at different times of day and under a variety of meteorological conditions.

Acknowledgements

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