Megalithic Observatories in Britain: Real or Imagined?

R. P. Norris, Division of Radiophysics, CSIRO, Sydney

Abstract
Over the last two decades there has been an accumulation of exciting evidence that appears to show that, as early as 5000 years ago, people in Britain were making precise observations of the Sun, Moon, and stars, and studying small perturbations in the lunar motion. Structures such as Stonehenge, and the thousands of other megalithic sites in Britain, are then seen as prehistoric observations. Within these, data would be accumulated to enable the prediction of celestial phenomena such as eclipses, and allow the construction of a calendar. Recently however a small number of rigorous statistical studies of the sites have cast doubt on the astronomical hypotheses, and have posed the question of whether some of the support for these hypotheses has been generated by well-intentioned but over-enthusiastic selections of chance alignments. In this review, the arguments and counter arguments are presented and examined, and we see what can be salvaged from the astronomical hypotheses after the statistical smoke has cleared.

Introduction
Of all the megalithic sites in Britain, Stonehenge is undoubtedly the most famous, and yet it is often not generally appreciated that Stonehenge is only one, albeit one of the most impressive, of at least a thousand megalithic sites in Britain. These exhibit a wide range of forms, from the single standing stones, or menhirs, to carefully laid-out circles of stones, and long stone rows up to 3.6 km long. Most of these were built in the third or second millenium BC, and are frequently associated with cremations or burials. The quantities of manpower expended on these monuments bear testimony to their importance to those who built them, and they must have played a major role in the lives of those who used them, and yet we know little else of their purpose or function.

The fame of Stonehenge usually embraces a notion that it had something to do with astronomy. It is certainly true that the main axes of Stonehenge (the Avenue, the 'Station Stones', the Heel Stone) roughly indicate the position of the mid-summer sunrise. In addition, it has been postulated that there are accurate alignments indicating the positions of significant rising and setting places of the Sun and Moon, which could have been used to study small perturbations in their motions, and perhaps construct a calendar or predict eclipses. Sadly, concrete evidence for these speculations is absent.

Stonehenge is not alone however in being the subject of astronomical hypotheses. Indeed, as a guide to the practices and capabilities of the society who built it, it may be regarded as atypical and therefore misleading. It has the further disadvantage that, given a sample of one such site, one cannot tell statistically whether any proposed alignments are significant. However, hundreds of other sites in Britain have been carefully surveyed, mainly by Professor A. Thom and his son Dr. A. S. Thom, who have constructed from their substantial data a group of hypotheses which propose that:

(a) The megalithic sites were laid out using accurate measuring techniques and a unit length (the megalithic yard) which was defined to an accuracy of about 1 mm and whose value was kept within this range throughout Britain.
(b) The sites were laid out in many cases using elaborate geometrical constructions which involved knowledge of Pythagorean triangles.
(c) Many of the sites were set up to indicate the rising or setting position of the Sun, Moon, or a star, at a particularly significant date, and with minute-of-arc accuracy.

The current status of all three of these hypotheses is that they have an ardent following of believers, an equally ardent band of disbelievers, and a rather smaller number of people who consider that Thom’s data appear to show a prima facie case, and warrant further investigation. However, this group of agnostics would also insist that more data, and better ways of analysing those data, are necessary before any firm conclusion can be reached. It is perhaps unfortunate that, because nearly all the data have been collected by the Thoms, any evaluation of the astronomical hypothesis is necessarily an examination of their methodology.

There are clearly elements common to all three hypotheses, so that ideally they should be studied together. However, testing the first two hypotheses has proved extremely difficult, requiring a sophisticated mathematical approach which is still under development (Patrick 1978). The third hypothesis, whilst still presenting a thorny statistical problem, is rather more tractable and is one that has recently been tackled by a number of workers. It is this astronomical hypothesis with which I will deal in this review.

This review is strictly limited to the sites in Britain, and so omits the culturally unrelated sites of the Americas, on which there is a rapidly growing body of archaeoastronomical evidence, and the megalithic monuments in Brittany. Because of the large volume of literature on British archaeoastronomy, this review traces the main threads of the archaeoastronomical
debate, rather than attempting to cover the rich variety of arguments from both sides.

**Megalithic Sites in Britain**

This section shares its title with that of A. Thom's first book (Thom 1967; hereafter called MSB), in which he first presented his ideas, previously scattered throughout several journals, as a coherent whole. In MSB Thom lists and describes several hundred sites, of various shapes and sizes, and here I describe some of the types of megalithic monument encompassed within the astronomical hypothesis.

The largest group to be described are the stone circles, most of which have diameters between 4 and 30 m. However, there are a few large circles over 100 m in diameter, including the spectacular circle at Avebury (330 m in diameter). The stone circles are extremely common in the unspoilt areas of Britain, often constructed in high areas with unobstructed or panoramic views. Burl (1976) has also suggested that they are preferentially situated near a source of water.

Also prolific are the stone rows. Most of those considered by Thom are a few tens of metres long, and consist of standing stones up to 4 m high. They occur both as single, isolated rows (e.g. at Swincombe; see Section 7), as single rows associated with burials (e.g. at Ballochry, see Section 7) or with circles (e.g. Eleven Shearers, MSB p. 149), and as multiple rows (e.g. Mid Clyth, MSB p. 152). There also appears to be a distinct class of long (up to 3.6 km) rows consisting of short (usually less than 1 m) stones, found mainly in south-west England. These have not been considered by the Thorns, although Lockyer (1906) and Wood and Penny (1975) have proposed them as astronomical indicators. However, Emmett (1979) has shown that these long rows are generally ill-suited for astronomical use.

The simplest class of megalithic monument, and that attracting the most scepticism, consists of the single standing stones. A single stone cannot on its own define an azimuth with any great accuracy, even if flattened on one side. There is the additional problem that, on a roughly hewn rock now weathered and covered with lichens, one man's flat side is another man's cylindrical surface. Nevertheless, the MSB data include several alignments which depend on such flattened surfaces, and which therefore need to be treated with caution.

**What Does Archaeology Tell Us?**

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The Implications of the Astronomical Hypothesis

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(b) Who built them? It has been argued that these primitive people scratching an existence from the soil could not have had the organization skills, or continuity of society, to build the larger sites, even if they had the manpower available. This argument leads to the idea that there may have been an elite class of priests or wise men, who ruled and organized the commoners.

(c) Why are there so many megaliths? Many are within sight of one other, so that some groups probably built more than one megalithic monument. Could they have been status symbols?

(d) Why did the builders expend so much labour on their construction? For example, Avebury cost an estimated 400 man-years, whilst the related Silbury Hill cost an estimated 7500 man years. When compared to a total British population of perhaps only a few thousand (Atkinson 1972), it is clear that the construction of these sites was a project of major importance at the time.

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(a) There must have been a stable society, since for the lunar alignments observations would have been necessary over centuries.

(b) The work force for the construction and operation of the observatories must have been highly organized, perhaps by the elite class mentioned above.

(c) Most controversial of all, there must have been a degree of mathematical and scientific skill that seems totally incompatible with the current view of a primitive, barely agricultural, society.

These implications do seem to be accommodated in a model devised by MacKie (1977) consisting of a peasant society ruled and dominated by an elite class of highly educated priests. Some support for this view comes from sites like Skara Brae, in the Orkney islands, where a settlement dated to the third millennium BC contains stone furniture (beds, querns, shellfish-tanks,
To build a megalithic observatory therefore it is necessary to erect a structure which not only defines the observing position, but also a horizon feature may have more to do with the prejudices of an archaeoastronomer than with the intentions of the megalith builders. It is therefore advantageous to the builder to erect a structure which not only defines the observing position, but also indicates which horizon feature is to be used (an indicated foresight). Analogously, any statistical study of these sites must also concentrate on those sites with indicated foresights, in order to reduce the personal bias of the investigator.

The actual construction of a megalithic observatory appears straightforward. Suppose, for example, that an indicator of the winter solstice is desired. Having selected their foresight (a distant mountain peak, say), the megalith builders then watch the setting Sun each day, and push a stick into the ground at the position from where it is just possible to see the Sun setting behind the foresight. Each day the Sun sets a little further to the south, and the sticks are pushed in a little further to the right, until one day the sticks get very close together, and then on subsequent days have to be placed to the left of the existing sticks. The solstice has then passed, and a megalith may be erected at the position of the extreme righthand stick. A stone row may also be erected to indicate which mountain-top is the correct foresight. We may also conjecture that the whole ceremony would not have been performed with the disinterested objectivity with which modern-day astronomers conduct all their research (1), but would have been surrounded with a great deal of religious ritual, perhaps with sacrifices being offered so that the Sun would return to drive away the miseries of winter.

In practice, the celebrations might well be dampened, for example by heavy cloud on the day of the solstice, necessitating either an interpolation between the available data sticks, or a re-observation the next year. In general, we can expect that the setting up of a solar observatory might take a few years. The setting up of a lunar observatory, considering the Moon's 18.6-year cycle, might take several generations. A further complication is the variable lunar parallax (Morrison 1980) requiring even longer periods of observation.

**The Case for Prehistoric Astronomical Observations**

IN MSB, Thom presented his results of surveys of some 600 sites. In the cases where a site appeared to indicate an alignment Thom measured the azimuth of the alignment, converted it to declination and plotted it on a histogram, which is reproduced in Figure 1. The histogram, which contains over 250 sightlines, appears decidedly non-random, and in fact the peaks appear to cluster around the extreme declinations of the Sun, Moon, and a few bright stars. In addition, there are some peaks corresponding to the Sun's declination on the days half-way between the solstices and equinoxes (Martinmas, Candlemas, May Day, and Lammas), and on the days half-way between these and the solstices and equinoxes (the so-called calendar dates). Thom interpreted this histogram as indicating that not only were the megalith builders marking out the extreme declinations of the Sun, Moon and stars, which might have indicated some ritual, but were also subdividing the year to make a calendar. This level of the astronomical hypothesis, which maintains simply that there exist astronomical alignments accurate to half a degree or so, is labelled by Ruggles (1981) as 'level 1'.

Thom then plotted (MSB p. 120) the lunar data from the four extremes as a histogram of (observed-calculated) declination. If the alignments indeed had a precision of half a degree or so, then a smooth Gaussian curve would have been obtained. Instead, a bimodal distribution resulted, with a separation between the peaks of about 0°.5 (the apparent lunar diameter). This implies that observations were not made roughly of the centre of the Moon, but that rather more accurate observations were made of the lunar limbs. This level of the hypothesis is labelled 'level 2' by Ruggles (1981).

Subsequent analysis of the lunar lines by Thom (1971) appeared to show an even more significant relationship (Ruggles' level 3). When only the 'most reliable' lunar lines were plotted on a histogram of (observed-calculated) declination, they seemed to show definite peaks corresponding to the sum and difference of the lunar semi-diameter with the small perturbation term (9°.4 arc) of the lunar orbit (Fig. 5a). This implied that not only...
did the megalith builders construct alignments directed at the limbs of the Moon, but they did so to a precision sufficient both for the detection of the small perturbation in the lunar orbit, and for the alignment of monuments to the Moon at the maximum and minimum values of this perturbation.

A further level of sophistication, level 4, is demonstrated in three further papers (Thom and Thom 1978, 1980; Thom 1981) in which various small corrections are made to the data, and only the most reliable data are included. The resulting histogram implies a precision in the alignments of better than 1° arc. Because of the variable lunar parallax (Morrison 1980), such a precision could only be achieved by averaging observed positions of the Moon over a period of 180 years.

Taken at face value, these data appear very persuasive. However, there is clearly ample room for selection effects to corrupt the data. For example, how do you select the alignments at a site? Given a site of, say, 10 standing stones, there are 90 possible alignments, and several of these are likely to hit astronomically significant declinations, purely by chance. If all 10 are in a straight line however we can ignore all except the two alignments along the line, and if these hit an astronomical declination it can be regarded as a significant result. In practice, real sites tend not to be so clear-cut, and it is essential to use objectively defined selection criteria in order to avoid unintentional bias when selecting the most ‘obvious’ alignment at a site.

To test these data therefore it is necessary to establish a body of data comparable in size to that of the Thoms, but selected according to rigidly defined criteria. The difficulty of doing so is illustrated by the decades that Thom has spent in collecting his data.

Examples of Possible Megalithic Observatories

Swincombe

This previously unpublished site is listed first because it has just one clearly defined alignment, which unambiguously indicates a single distant notch in the horizon, and because it has not been included in the Thom data. On Thom’s hypothesis this single alignment should indicate an astronomical declination. For the same reasons, it is a good illustration of a typical site, and of the techniques and problems associated with archaeoastronomical investigation.

The row of three carefully tooled stones (Figure 2), each about 1 m high, is above the River Swincombe (SX631722) on Dartmoor, in south-west England. The regularity of the stones, atypical of Dartmoor rows, led to their tentative classification by the Ordnance Survey as tethering posts.
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To indicated notch

Figure 2 Plan at ground level of the Swincombe stone row. Filled circles indicate points surveyed using the theodolite. Remaining faces were surveyed using a steel tape and magnetic compass.

However, R. Burnard in 1894 regarded them as true menhirs of considerable antiquity, and they are similar to many authenticated standing stones elsewhere in Britain. Without further data, there seems little reason to doubt that they are associated with the prehistoric hut circles and small standing stones that surround them.

All three stones have flat faces, and the line along their faces indicates accurately ($\pm 1^\circ$) a notch in the horizon about 10 km away (Figure 3). The site was surveyed using a 1" arc theodolite, and due north was determined by timed observations of the Sun. The survey of the horizon was used to calibrate a photograph taken from the theodolite position, giving an estimated uncertainty of 20" arc. The resulting declination of the notch, corrected for refraction, is 16°33', which is similar to the declination of 16°32' of the lower limb of the rising Sun on Lammas Day in 1800 BC. Although this result therefore supports the astronomical hypothesis, it should be regarded more as an illustration of the available data than as a positive confirmation of the astronomical hypothesis. Many more such sites need to be surveyed before a definite result can be claimed.

Ballochroy

Ballochroy is a row of three stones in Kintyre, west Scotland, and is remarkable for showing two accurate solar alignments. Thom (1971) showed that a line along the row indicated the setting mid-winter Sun over Cara Island 12 km away, whilst a line along the central flat stone indicated the setting midsummer Sun over Corra Bheinn, Jura, some 30 km distant. This site attracted attention because both alignments were accurate to a few minutes of arc, and so it would be difficult to explain such a site as due to chance alone. The site was independently surveyed by Bailey et al. (1975), who agreed with Thom's data. However, more recently it has been suggested that the mid-winter alignment would have been obscured at the time of construction by an intervening cairn, and that the mid-summer alignment is not necessarily the most obvious alignment along the central flat stone.

Kintraw

Of all sites, Kintraw (MSB p. 141; Thom 1971 p. 37) probably supports the astronomical hypothesis more than any other. This is because it is here that, in the tradition of the scientific method, Thom's hypothesis was used to make a prediction that could be tested by conventional archaeology. Kintraw, in Kintyre west Scotland, consists of an impressive 3.6 m-high menhir, together with a ruined cairn, a small circle, and a small standing stone, all in a line. This line indicates a notch between two mountains 45 km away, at which the mid-winter Sun makes a brief appearance as it sets, thus providing an accurate solstitial indicator.

The problem with this site was that an intervening hillside actually prevented an observer from seeing the foresight from the backsight. Professor Thom suggested that an observer could climb up the steep hillside behind the site, in order to see over the obstruction, and actually found what appeared to be a sheep track in the required observing position. Thom suggested that the ledge was not a sheep track but was man-made. The ledge was subsequently excavated, and petrofabric analysis indicated that the ledge was indeed manmade (MacKie 1977, and references therein).

Thus a prediction based on the astronomical hypothesis has been borne out by independent archaeological investigation. Although there has since been some debate on the significance of this result (e.g. McCreery et al. 1982), it probably remains as the strongest independent support for the astronomical hypothesis.

The statistical approach

Selected samples of alignments

Since opportunities for testing a prediction in the manner of the Kintraw investigation are rare, an alternative approach is to look at the statistics of the indicated astronomical alignments, and see if there are significantly more of them than are expected by chance. The main difficulty with this approach is that there are few sets of data which are sufficiently free of selection effects to be amenable to statistical treatment. A previous difficulty, that there existed no rigorous statistical technique for analysing

Figure 3 Profile of the indicated horizon at Swincombe. Surveyed points are indicated by arrows. Drawn above the horizon is the path of the rising Lammas Day Sun in 1800 BC.
Figure 4 Example of a rough alignment, from the Barbrook I stone circle in Derbyshire (from Norris et al. 1982). At the bottom are shown two standing stones, and at the top left is shown the path of the setting mid-winter Sun in 1800 BC.

The accurate lunar lines

The most controversial aspect of the astronomical hypothesis is the high accuracy with which Thom claims the alignments are established. In order to test this, Ruggles (1982a; 1983) has investigated the sample of lunar lines in some detail. He has visited and resurveyed every site in Thom’s sample, and has evaluated both the alignments proposed by Thom, and those which seem at least as feasible. His conclusions are illustrated by Figure 5, which shows a reassessment of Thom’s level 3 data. Ruggles has shown that a few of Thom’s alignments are clearly faulty (e.g. foresight invisible from backsight, non-archaeological site) and so they have been rejected. The remaining lines have been resurveyed and have had their uncertainties reassessed. The result, shown in Figure 5(b), is that there appears to be no evidence for the accurate lunar lines.

The nature of the disagreement

The results discussed above pose the question: How is it that different sets of data produce such different answers? Although occasionally a survey by the Thoms has been found to be faulty (e.g. Ruggles and Norris 1980), such errors are insufficient to explain the discrepancy. The cause of the disagreement for level 1 alignments appears instead to be the method of selecting the data, has been removed by the construction of such a technique by Freeman and Elmore (1979).

The Freeman and Elmore (1979) test was applied to a selection of data collected by Barber (1973), who had surveyed a number of circles in Cork and Kerry, Ireland, and to a survey (Cooke et al. 1977) of the alignments associated with the Callanish group of sites, in the island of Lewis, Outer Hebrides. In each case the test showed no more alignments than might be expected by chance. However, the data of Barber were subsequently found to be faulty, and when the test was repeated on corrected data (Patrick and Freeman 1983) marginal evidence was found for rough (level 1) alignments. Another set of data was obtained by Norris et al. (1982), on the Barbrook group of sites in the Peak District of England. Again, the test showed no evidence for accurate alignments, but did show some marginal evidence for rough alignments. An example of such an alignment is given in Figure 4. These rough alignments would have been of little use for studying the motion of heavenly bodies, or for the construction of a calendar, but could have been used for some ritual associated with the solstices.

Despite these setbacks for the astronomical hypotheses, it must be stressed that the quantities of data referred to above are small compared to the Thoms’ data, and do not in themselves offer a refutation. The only way of tackling this problem is to survey many more sites, using rigorously defined selection criteria. Such a project, concentrating on the Western Isles of Scotland, has been in progress for the past few years, and although the first results will soon be available (Ruggles et al. 1984) a thorough evaluation of these data is likely to take some time to complete.
alignments. This is not to say that the Thoms have deliberately chosen to publish only those alignments which fit their theories, but instead emphasizes how easily subjective bias may unintentionally influence data. When surveying a site, the Thoms appear to have been guided by astronomical considerations when choosing their alignments. Only selection criteria, such as those of Cooke et al. (1977), which have been rigorously defined prior to the first visit to the site, can ensure freedom from this bias.

The cause for the discrepancy in levels 2 to 4 is more puzzling, since no one can estimate positions to minute-of-arc accuracy, and so it is difficult to see how subjective bias can influence the data. Perhaps we should accept that such distributions can occasionally arise purely through chance.

What is Left of the Astronomy?
The previous section might give the impression that the astronomical hypotheses have disappeared in a puff of statistics. However, it is only on the accurate lunar lines that a definite conclusion has so far been reached. No attempt has yet been made to subject the solar lines to a similar treatment. This is largely because the astronomical protagonists have not formally advanced the theory that a large number of solar alignments are defined to minute-of-arc accuracy, even though the examples given in this review indicate that there may be grounds for examining this idea.

In addition, two of the rigorous tests have shown marginal evidence of rough alignments, and it may be argued that two marginal results constitute one somewhat less marginal result. Only more data will serve to test adequately whether or not these rough alignments were indeed intended by the megalith builders.

More important than the quantity of data is the quality of data. The work of Ruggles and others has highlighted the real problem of British archaeoastronomy and shown it to be one of methodology. The nature of the problem is such that different methodologies give different results. It is unlikely that we have yet found the optimum methodology which although free from subjective bias cannot accidentally discriminate against a type of alignment favoured by the megalith builders.

In conclusion: Whilst some of the most extreme claims of archaeoastronomy seem supported by recent work reviewed herein, there are areas not yet fully investigated, and other areas (the rough alignments) where the evidence may even show signs of accumulating in favour of archaeoastronomy. The case remains open, and the debate continues.

Acknowledgements
I would like to record my appreciation to Professor Alexander Thom, who, regardless of the eventual outcome of this debate, has drawn public attention to the rich culture represented by the megaliths, thereby ensuring their conservation. I would also like to thank Mr. M. Derrington, of the Simon Engineering Laboratories, University of Manchester, for the loan of surveying equipment, and Lady S. Sayer for her help in dating the Swincombe site. Finally, I thank Phil Appleton, Roger Few, and Clive Ruggles for fruitful collaboration, stimulating discussions, and exchange of software, and I thank my wife, Cilla, for her help with the surveys.

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