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The Prehistoric Solar Calendar: An Out-of-fashion Idea Revisited with New Evidence

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Abstract

The work of Alexander Thom on the geometrical and astronomical achievements of prehistoric Britain—depending as it does almost entirely on data gained from surveying and statistical analysis—is rarely referred to now by British archaeologists. Yet his idea of the prehistoric sixteen-"month" solar calendar—in which the year is divided successively into halves, quarters, eighths and sixteenths—can now be tested with evidence from other fields, including some spectacular archaeological artifacts and from excavations specifically designed to examine the hypothesis. This article reviews the origins of the idea and presents some new evidence which has emerged since Thom's time which bears on it. This material includes five sites which excavation and surveying

have shown to be probable accurate solar-calendar markers and three spectacular artifacts which, in their different ways, shed further light on the idea. These are the gold lozenge from Bush Barrow, Wiltshire, the "sky disc" from near Nebra in eastern Germany, and the fan-shaped design on stone K15 at the Knowth passage grave in Ireland. This diversity of evidence provides powerful support for Thom's hypothesis and, it is suggested, makes more likely the existence of intellectually skilled professional priesthoods in north-western Europe in the Neolithic period and the early Bronze Age.

Keywords: alignment, solar calendar, Thom, Knowth, Bush Barrow, Maeshowe, Nebra, prehistoric astronomy, priesthoods.

Introduction

Preamble

The history of Alexander Thom's work on the astronomical and geometrical properties of the British Neolithic standing stones and stone circles used to be familiar to archaeologists. Indeed there was a time in the early 1970s when it seemed that his primary conclusions might become absorbed into the mainstream of British prehistory, but for various reasons this did not happen and now his work is hardly referred to in archaeological periodicals (but see MacKie 1997, 1998). One reason is perhaps that his life and work has never been written about in a way that might appeal to academics and educated laymen; the original biography by his son A.S. Thom is rather chaotic and hard to read, a feature probably to be explained by its author's declining health—he died just before publication day (A.S. Thom 1995). However, a new biography has just appeared which is extremely readable and informative and—though it includes references to related, and controversial, areas which Thom never worked on—gives a good impression of the developing relationship between his work and mainstream British archaeological thought from 1967 to the 1990s (Heath 2007).

There are a number of reasons why Thom's work is no longer considered in British archaeology and why any mention of concepts like the megalithic yard and accurate celestial alignments tends to produce acute embarrassment and silence when raised with colleagues. At the risk of over-simplification there are four in particular which the author—having lived and worked in the field throughout this entire time—regards as of crucial importance.

First, since the late 1970s Clive Ruggles has systematically and skillfully questioned Thom's astronomical work, starting with a reassessment of three hundred of his claimed long celestial alignments on the Scottish west coast and in the Western Isles (Ruggles 1984). The conclusion of this critique was that there was no real evidence either for extreme accuracy or for the use of a detailed solar calendar in Neolithic times (broadly the period from 4000–2000 BC). It was accepted, however, that there was good evidence for low-level interest in certain solar and lunar cycles. This was followed up with a number of specialized papers on the same theme—including a chapter on Stonehenge—and finally with a book which systematically challenged all evidence from other workers which seemed to point to a contrary conclusion (Ruggles 1997, 1999).

In general, British prehistory has welcomed this authoritative down-grading of Thom's work by someone with similar surveying and mathematical skills.

The second reason involves the widespread belief among British (and probably other) prehistorians in what this author has termed "the false equation between accurate alignments and prehistoric science" (MacKie 2006: 344–5). In other words, to accept accurate alignments as defined by Thom is to accept something that no anthropologist has ever believed, and no sensible archaeoastronomer believes any more—that the modern Western concept of science as a rational search for knowledge explains what was going on in the Neolithic "observatories." Pitts provides a good example of this misunderstanding (2000: 222, etc.) while the occasional outburst elsewhere reveals that even the concept of a professional priesthood—well attested among chiefdoms (Renfrew 1973)—can inspire a similar alarm. Obviously anyone who can write "The ghastly specter of Euan MacKie's astronomer-priest missionaries (1997) should not deter others from pursuing the cosmological aspects."[1] is beyond the reach of rational argument on this topic but regrettably it seems likely that this attitude is widespread, if rarely articulated so revealingly.[2]

The third reason—which may explain the second—concerns training. With the fairly recent exception of the school of archaeology and ancient history in the University of Leicester, degree courses in British archaeology have never, to the author's knowledge, included instruction on the kind of survey and statistical methods that Thom used, or on basic observational astronomy; thus there are few overt signs that anyone currently working professionally in British prehistory is mentally equipped either to assesses independently Thom's evidence, or to go into the field and look for relevant evidence, or even to identify what that evidence might be. Moreover, the acceptance of Thom's hypotheses could result in a wholesale reappraisal of the structure of British Neolithic society and such revolutions tend not to be accepted easily if they go against the grain of received wisdom. Ruggles's downgraded version of the celestial alignment hypothesis is exactly what the profession needed in order to forget Alexander Thom's work and to assume that it was incompatible with the archaeological evidence.

This leads on to what is perhaps the greatest difficulty in getting Thom's work appreciated at present. This is the belief, strongly held by archaeologists who study prehistoric times, that the kind of society his conclusions seem to be pointing to—one with detailed knowledge of sophisticated astronomical and measuring techniques—is incompatible with what we know of recent and ancient preliterate societies. To be preserved over many generations, such bodies of arcane knowledge surely require two things—first a group of full-time professionals to study these subjects in detail and, second, writing to record the observations taken over many years. There is no evidence for writing in north-west Europe before the coming of the Romans and there is generally assumed to be no evidence for a professional priesthood in Neolithic times. In other words most archaeologists adopt a deductive approach to this whole problem; Thom's data does not fit with what we know of Neolithic society both through archaeological means and through anthropological analogy, therefore it cannot be right. Ruggles's refutation of Thom's claims of extreme accuracy is therefore seen as inevitable and right.

Despite all this, the present author—an archaeologist and prehistorian— is convinced that Thom's ideas have been unjustly dismissed (MacKie 1997, 1998, 2002, 2006). He also believes that Ruggles's basic 1984 criticisms of accurate long alignments contain a fundamental flaw based on a circular argument (MacKie 1984).[3] In particular, he is convinced that the concept of the sixteen-"month" solar calendar—derived from analysing the pattern of the accurate celestial alignments—is valid (MacKie 1988) and that an increasing amount of evidence from a variety of sources is supporting it. This in turn will surely require that we think again about the validity of Thom's work as a whole. If the long, reasonably accurate alignments which are part of the solar calendar are genuine, it then becomes easier to accept that the movements of the Moon were being marked too (although one can still argue about the level of interest shown here).

The author's approach is therefore the reverse of deductive, and assumes that the actual evidence—if tested and found solid—must always have priority. In Richard Atkinson's oft-quoted words "I myself have gone through the latter process [a deductive rejection of Thom's work] but I have come to the conclusion that to reject Thom's thesis because it does not conform to the model of prehistory on which I was brought up involves also the acceptance of improbabilities of an even higher order. I am prepared, in other words, to believe that my model of European prehistory is wrong, rather than the results presented by Thom are due to nothing but chance." (Atkinson 1975: 51).

The author has analysed the nature of archaeological evidence in some detail (MacKie 1977: 7ff.), concluding that it is simply not possible to make inferences about the intangible aspects of vanished societies—such as their social organization, religious beliefs, and so on—*directly* from that evidence; analogies with known modern or recent societies with a similar technological base have to be employed, and these by their nature are very lightly anchored to the evidence. It is therefore logically unjustifiable to maintain that an established reconstruction of British Neolithic society, for example, can be used *by itself* to cast doubt on the validity of new evidence which seems not to fit that scenario. It may be that a new reconstruction of Neolithic society—derived by analogy again—is required to explain the new evidence as well as the old.

This is what the author attempted in 1977 by considering whether a professional priesthood with a body of arcane knowledge may have existed in the British Isles in the fourth and third millennia BC. Renfrew (1973, chapter 11) had already suggested that the peoples of southern England were organized into chiefdoms at that time, pointing out that historically recorded chiefdoms often had a class of professional priests. The crux of the matter is whether the large henge monuments of southern England could have contained huge roofed wooden roundhouses and therefore have been the residences and training centres of such a priesthood rather than open-air temples. Analogies with recent chiefdoms with large roundhouses can also be found, and all this has recently been discussed again (MacKie 2002, Section 2). Moreover, historical evidence for similar learned orders in Britain and France in Iron Age times—the Druids—surely makes it more probable that something similar existed in the Neolithic period; furthermore, it is now clear that some Neolithic geometry and measuring survive in the brochs of western Scotland at least until the third century BC, when the Druidical orders were already in existence (MacKie forthcoming A). Thus the question really becomes one not of whether an alternative scenario is possible for Neolithic society, since it is possible, but of whether the evidence summarized in the body of this paper is sufficiently strong to require that this scenario be seriously considered.

Alexander Thom's work

It is useful at this point to summarize Thom's main conclusions, which can be broadly divided into two groups of hypotheses.

Accurate celestial alignments

The first hypothesis maintains that accurate observation of the sky took place in Britain in prehistoric times and this resulted in the construction of a precise solar calendar; there are also claims of a sophisticated understanding of the Moon's movements, and perhaps eclipse prediction, but these do not concern us here. Directly relevant to the main thrust of this paper is the nature of this calendar which appears to have been based on a simple sixteen-fold division of the solar year. Its peculiarity is that, because of the length of our year, these subdivisions obviously cannot contain whole numbers of days, so that alignments pointing at the sunrises and sunsets on pairs of these intermediate dates (one in each half of the year) have to be compromises between two slightly different positions (see Fig 1 below, p.00). In addition, the Sun's daily rising and setting positions start to change rather rapidly when the solstices are more than about forty days away and most rapidly at the equinoxes; this adds to the difficulty of marking specific dates precisely.

The primary subdivision into quarters is of course at the solstices and equinoxes; only the former are directly observable and the horizon markers for all the others have to be set up by counting the days. The dates of the "eighths" of the year follow by working out the halfway positions between solstices and equinoxes, and it is surely not a coincidence that the four major ancient Celtic festivals fell near these times—at the beginning of February, May, August, and November (MacKie 1988). The histogram of alignments strongly suggests that the calendar was subdivided further into sixteen "months" of mostly 22 or 23 days and there are hints of a further subdivision into thirty-two short time periods of 11 or 12 days, like long weeks.

Geometry and the use of a standard measure

Thom's second group of hypotheses proposes a knowledge of exact measurement and geometry which is to be seen in the design of the stone circles of the period. The use of a standard unit—the "megalithic yard" (MY) of 0.829m—is inferred mathematically from this data (essentially from the computed best-fitting radii for the true circles), and a one-fortieth subdivision of this—the megalithic inch—was inferred quite independently from the cup-and-ring rock carvings (Thom and Thom 1978, chap. 5 and fig 5.1). Perfect Pythagorean triangles were used as a basis for the geometry used to lay out the noncircular stone rings.

The importance of diversity in the evidence

We are enquiring here whether the solar-calendar hypothesis of 1967 has been supported by discoveries by others since that time, preferably from a variety of fields. Are there new sites, new artifacts, which are more easily interpreted in terms of the solar calendar? The situation is rather like that described by Whewell more than 160 years ago (Whewell 1840): "The Consilience of Inductions takes place when an Induction, obtained from one class of facts, coincides with an Induction, obtained from another class. This Consilience is a test of the truth of the Theory in which it occurs." As Ruse, discussing the Darwinian theory of evolution, explains: "The idea is that somehow, if an hypothesis is true—tells us about the real world—then various facts or other claims follow from it and will keep doing so. And there is a kind of feedback process here. As the hypothesis leads to new information, so its derivations themselves confer a kind of probability upon the hypothesis. A false hypothesis would simply not keep working as well. At the least you would have to keep adding to it, and thus lose the elegance and simplicity that scientists prize so much." (Ruse 2006: 38). There is a basic simplicity and elegance in Thom's primary hypothesis—that accurate long alignments toward the sun at the horizon at important points in the annual solar cycle were marked in Neolithic time, with standing stones, and that with these the year was subdivided into sixteen (or thirty-two) more or less equal parts.

However, as noted, the hypothesis has been challenged many times and this is the reason the author has repeatedly sought independent verification over the years. He hopes to show that a steadily increasing number and variety of new sites and artifacts, as well as historical evidence—mostly unknown to Thom— are neatly explained by the solar-calendar hypothesis and that there is therefore a "convergence of consiliences" in this field. The active defenders of the archaeological status quo (Ruggles 1999, Ruggles and Barclay 2000, Barclay and Ruggles 2002) continue to deny the relevance of all new evidence but have to dismiss each new fragment in isolation; they have no constructive alternative hypothesis to offer which does not discount whole swathes of evidence. Its passive defenders presumably simply ignore the whole debate. There is unfortunately no space here to summarize the author's counterarguments, or the attempts to refute them, which have been attempted in the past (MacKie 2002, 2006: 344–9); it is hoped that the quantity and diversity of the new evidence in favour of the solar calendar will be sufficiently convincing.

Cognitive archaeology

It is often maintained now that the future of interpretive archaeology lies in an attempt to understand the thought processes of prehistoric peoples, insofar as these can be inferred from the mute and fragmentary material record (Renfrew et al. 1993). Clearly most of these thought processes vanished with the societies concerned but there may be ways at getting at a few of them which do not depend entirely on analogy. For example, the qualities of flint have been the same throughout the ages, so to reconstruct experimentally techniques of flint-knapping is to come to understand the qualities of flint in much the same way as a prehistoric knapper knew them; to perfect the skills of pressure-flaking, for instance, is to go through the same process of trial-and-error as prehistoric flint workers did. Obviously this cannot necessarily lead on to an understanding of the worker's religious beliefs or his social network but it is a start.

Likewise the apparent movements of the Sun, Moon, planets, and stars through the sky as the Earth turns have presumably been the same for many thousands of years. A few years ago the author wrote: "Tracking celestial bodies accurately with primitive equipment involves—no less than flint-knapping—technical problems for which there are a limited number of practical solutions. When the facts fit together in an unequivocal way—as they seem to at Maeshowe—there is the same sense of having crossed over the centuries and of having, however briefly, entered the mind of the architect and designer …" (MacKie 1997: 340). Although what is being constructed is the *technology* of ancient astronomical observations rather than the religious reasons for them, merely discovering what was being done could partially open a window to the understanding of why. It is therefore nothing less than a tragedy that British archaeology seems to have turned its collective back on this potentially valuable way into cognitive archaeological research.

Nature of this work

Much of this paper consists of a summary of evidence which the author has collected, or noted, over the years and which has been published in a variety of places. There are two completely new elements, however—namely, the section on Kerbstone K15 from Knowth in Ireland and the section on the Station Stone rectangle at Stonehenge. It is hoped that these two fragments of evidence will prove to be a major leap forward in the campaign for the general acceptance of the Thom prehistoric solar calendar.

Some New Solar Alignments

Thom's histogram

Thom's prehistoric solar calendar is particularly important because it appears to be the only hypothesis about how the year was systematically subdivided in ancient times which has been derived entirely from analysing mute archaeological evidence; the author is aware of no direct historical or traditional evidence for its existence. Even the important feast and other ceremonial days which now look like survivals from it were not inferred to be based on the solar cycle until Thom presented his hypothesis in book form in 1967; he himself referred only to Anglo-Saxon and Christian festivals like Lammas, Michaelmas, and Candlemas.

Alexander Thom spent many years identifying and surveying standing stones and stone circles throughout the British Isles, and in particular in testing his hypothesis that many if not most of these were carefully set up in positions from which distant horizon features could be used to detect important dates in the year fairly exactly; *it is important to note that only those sites with some in-*

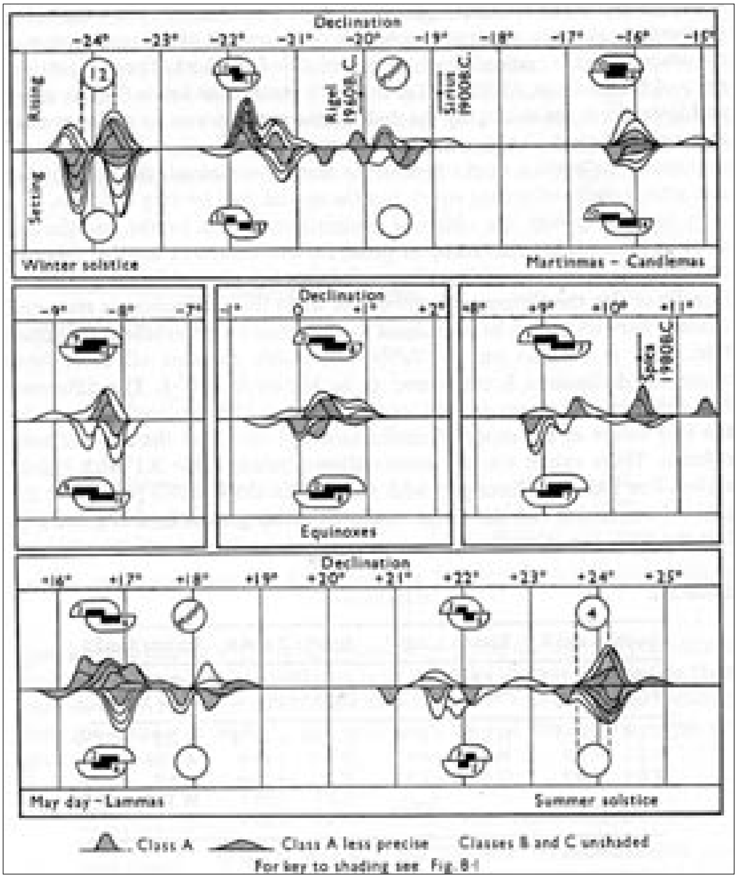


Fig 1 Histogram prepared by A. Thom of those of his surveyed standing stone alignments which fit the sixteen-"month" solar calendar (Thom 1967, figs 8.1 and 9.2). The horizontal scale is in astronomical declinations rather than in azimuths (bearings from true north), with midwinter at top left at –24° and midsummer at bottom right at +24°. Each indicated alignment—its position above or below the median line indicating either sunrise or sunset—is shown by its shading as either precise or less precise and, when unshaded, imprecise, and each is shown as a small Gaussian area at the declination concerned, the more accurate alignments being shown with steeper, narrower curves. The advantage of this method is that it is easier to see where the alignments cluster. At the solstices there are two peaks which may suggest that both the upper and lower limb of the Sun were observed against the horizon marks. The equinoctial positions tend to cluster at about +0.5°, suggesting—as explained in the main text—that these dates were fixed by counting from the solstices. The small black rectangles mark the fourteen calendar declinations (between the solstices) which the Sun passes twice a year, "the width of each rectangle showing the unavoidable spread of the declination in the four years of the leap-year cycle" (Thom 1967: 113–14) (© Oxford University Press, reproduced courtesy of Oxford University Press).

built indication of the direction concerned were included. Of course only a proportion of these "indicated alignments" could be linked to the Sun's movements; when all the astronomical declinations indicated by the standing stones were plotted as a histogram (Thom 1967, fig 8.1), a large number clustered at positions (declinations) which seemed to correspond with the Moon's movements (marked with shaded circles on the histogram), and also at the declinations of many bright stars. There were indeed clear clusters marking the obvious solar dates like the solstices (midwinter and midsummer days) and the equinoxes (around 21 March and 21 September) but also others not so easily explained at first. Some seemed to be aimed at the midway dates between those events (the beginning of February, May, August, and November), usually known as the Quarter Days although they mark eighths of the year; a logical conclusion was that the year was divided into eight equal parts and all these are marked on the histogram by white circles. However "As the author collected more and more reliable lines from the sites certain groups of declinations began gradually to appear in positions on the histogram which were difficult to explain. These were at or near (declinations) –22º, –8º, +9º and +22º. The group at +9º might be ascribed to (the star) Spica at 1700 BC but there were no convenient stars to explain the others" (Thom 1967: 109). The conclusion was that the year was actually further divided into sixteen parts (Fig 1).

Subsequent discoveries

Since 1970 the author has investigated a number of sites in order to test Thom's solar-alignment hypothesis. Most of this work has been published in detail and the sites are only described briefly here.

Solstitial and quarter day alignments

Figs 2a and 2b Kintraw standing stone, Argyll. *Top:* view of the emerging platform on the hill slope during the author's excavations in 1970/71. *Bottom:* view of the standing stone and the solstitial mountain notch beyond, taken from the hill platform in 1970 (both photographs by the author).

Kintraw standing stone and hill platform, mid Argyll (winter solstice)

In 1970 and 1971 this site provided the first independent test of Thom's long alignment hypothesis (MacKie 1974, 1977: 84–92). The standing stone is at a spot in a level field from which it is very hard to see the distant (and very conspicuous) horizon notch marking midwinter sunset in about 1800 BC (Fig 2a). A slightly higher position is needed and on the steep hill slope north-east of the stone an almost certainly artificial rubble platform was found at the appropriate spot. Unfortunately it could not be independently dated (Fig 2b). The criticism that the topography of the area means that there is not enough space to the left of the platform (looking south-west) for observations to be taken on several days before the solstice assumes that at each site the date of the solstice had to be discovered afresh; however, the solar calendar seems to have been in use by the middle of the fourth millennium BC (see 'Knowth' below) so it is much more likely that it was just a question of finding a long alignment which accurately marked sunset on an already known date.

Fig 3 Kintraw: view of the small standing stone 100 ft higher up the hill from the observing platform—supposedly marking a position from which to warn the observer below of the imminent midwinter sunset (photograph by the author).

A "warning stone" was identified by the Thoms about 30m further up the slope from the platform which, they assumed, was designed to give advanced warning to an observer on the platform that the Sun was approaching the notch (Fig 3) (Thom and Thom 1971: 36–8 and fig 4.3). Despite the fact that the Thoms described this as an upright stone and as two and a half feet high, the author somehow assumed that it was just another of the boulders which lie about the slope and did not visit it until 2007.[4] It is however quite clearly a miniature standing stone, firmly set into a very steep slope, and its nature surely transforms the interpretation of the hill platform, giving it a clear archaeological link with the large standing stone in the field below. The hypothesis that the whole site is an accurate marker for midwinter sunset thus becomes very much more plausible.

Cultoon stone circle, Islay, Argyllshire (winter solstice)

"An important example (of an elliptical ring with a solstitial alignment) is ... Cultoon ... whose major axis is aligned upon the midwinter sunset; and it may not be a coincidence that it is also aligned on a distant peak in Ireland." (Ruggles 1999: 133). The circumstances in which this excavation, and the resulting research, were carried out make this site particularly interesting (Figs 7 and 8). It was done at the request of a local organization which wished to restore the ruined ring and make it more interesting for visitors; an archaeological exploration obviously had to be carried out first but there was no particular expectation of what specific discoveries might be made.

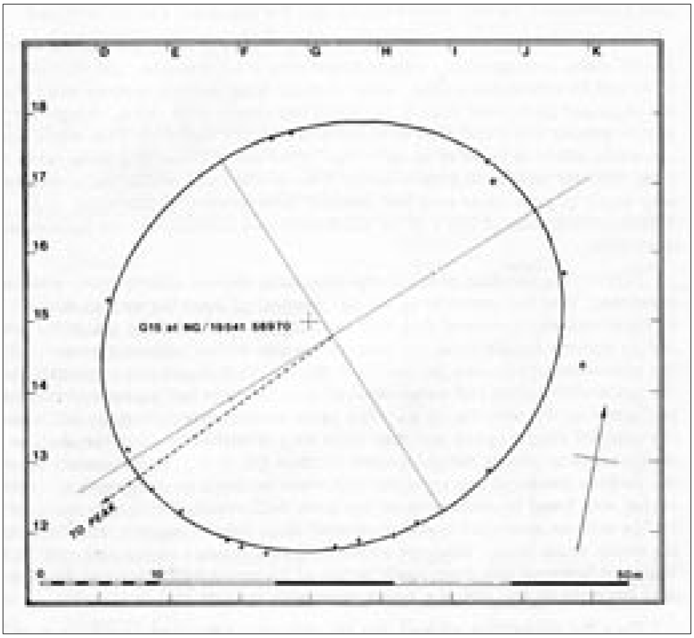


Fig 4 Cultoon stone circle, Islay: plan showing the three standing stones and the thirteen stone sockets in relation to the site 3m grid: the superimposed ellipse—the long axis of which points to the south-west and very close to a peak in Donegal—has an eccentricity of one half and a long axis of 50 megalithic yards.

The excavation mainly involved removing a layer of peat which had accumulated on the Neolithic ground surface. Exposure of this showed that the ring was not ruined but unfinished; only three monoliths had been erected and ten more lay around in a rough oval waiting to be put up. Moreover, thirteen empty sockets were found next to or near these stones and these had gradually filled with silt before the peat grew. Thus whereas before excavation the stone ring seemed to fit only approximately around an ellipse, afterward the sixteen standing stones and sockets fitted exactly around one with a long axis of 40.716 m and a short axis of 35.10m; the average difference from the actual perimeter is 20.6 cm (MacKie 1981, tables 3.1 and 3.2) (Fig 7). Two extra sockets were found which did not fit the ellipse. One was discovered by chance outside the ring and had been deliberately filled (showing that there may be more such), while the other had supported a standing stone (no. X) just inside the ring which had been evidently raised at a later time; it had fallen over on to one of the unerected monoliths (no. XI).

The likeliest construction of this ellipse seems to be one based on an equilateral triangle with sides of 25 MY, giving it an eccentricity of one half. It is interesting that the computed ellipse has an eccentricity of 4.98; the closeness to 0.5 may mean that at this site a shorter megalithic yard of 0.816m was used, 13mm less than the claimed national average of 0.829. A comparable ellipse measured in the latter would run round just outside the centres of the stones and sockets.

The computer programme which determined the size and proportions of the

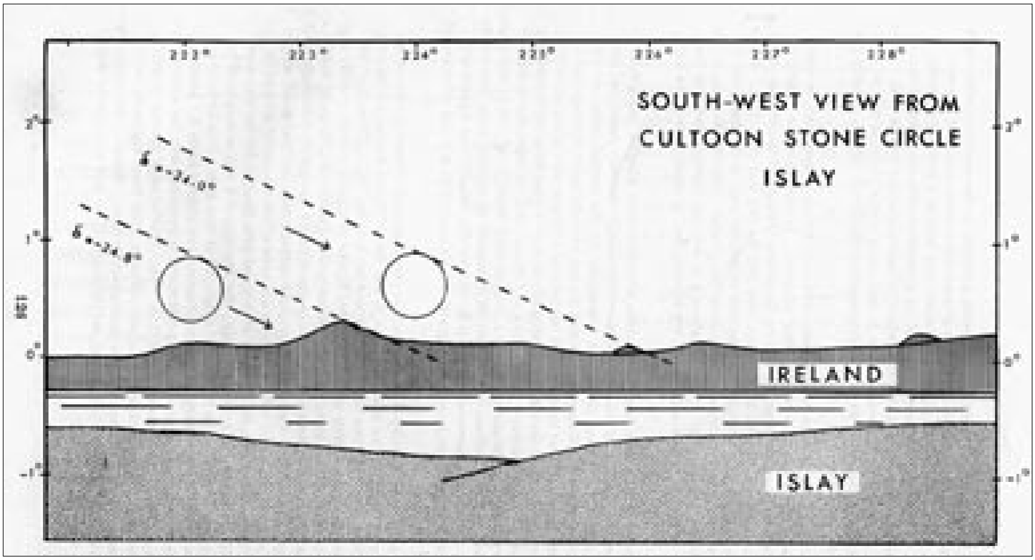
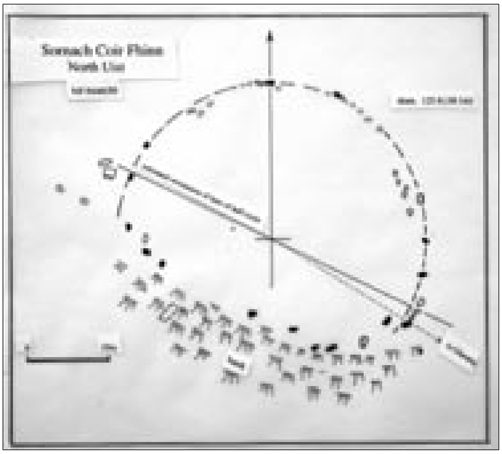


Fig 5 Cultoon stone circle, Islay: the south-west horizon showing the position of the prehistoric midwinter sunset as indicated by the long axis of the ellipse.

ellipse also gave the orientation of its long axis—presumably to within an accuracy of a very few degrees—which points almost exactly north-east/south-west, just north of Slieve Snaght, a peak fifty miles away in north Donegal (Fig 8). A smaller peak indicated by the axis has a declination of –24.0°, suitable for midwinter sunset at the end of the third millennium BC. Cultoon ring is thus a striking example of a superficially unpromising site which unexpectedly revealed a close link between geometry and the solar calendar. The site could not be directly dated but the base of the peat which subsequently grew over the long-abandoned stone holes—and which signifies the advent of a wetter climate—gave a C14 date with a corrected time span of between 933 and 802 BC.[5]

Sornach Coir Finn, North Uist (Quarter Day)
A few years ago the author visited by chance the stone circle Sornach Coir Finn in North Uist (Figs 4a, 4b) (Thom, Thom, and Burl 1980, 310–11). The site stands on a levelled platform dug out of the slope above Loch Langass and, though it was surveyed by both Thom and Ruggles and examined by Burl, no one had considered previously that the diameter of the flattened circle, pointing to the south-east (and the north-west) on a bearing of about 118°, might be pointing at something. (It is intriguing that a completely different geometrical construction for the ring produced a similar axis pointing to 119°: Macaulay 2006, fig 32). The landscape in the south-east shows some low ground between two low hills and framed between these are



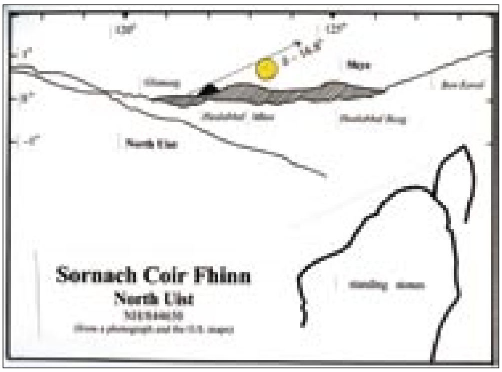


Fig 6 Sornach Coir Fhinn stone circle, North Uist. *Top:* plan, redrawn by the author, of the stone circle (after Thom, Thom, and Burl 1980, fig on p. 310: the site is wrongly named Pobull Fhinn there) with the suggested north-west/south-east axis of the half circle marked. *Bottom:* drawing by the author of the south-east horizon as seen from the circle with the visible mountains on Skye, with the rising Sun on the first and last Quarter Days marked.

three distant peaks on Skye. At 47 miles the furthest is conical Glamaig which marks sunrise at a declination of about –16.7° (on an azimuth of close to 122°), that is on the first Quarter Day before and after midwinter, at the beginnings of November and February respectively.[6] This peak was very faint when the author arrived and had vanished by the time he left. (If such long alignments are figments of the imagination, what are the odds in favour of such a precise one being found by chance—and in a direction to which both the landscape and the geometry of the flattened circle seem to take your eye—during a half hour visit to a site chosen simply because a signposted path has been made to it?) That it is not illusory is suggested by several other convincing, long, Quarter Day alignments which can be seen in Ruggles's own data (Fig 5).[7] This site also shows how important it is to make a note of the weather conditions when carrying out research on potential long alignments; there may be many which have been missed even on fine days because of haze.

Maeshowe, Orkney (Quarter day and Sixteenth)
This famous and architecturally sophisticated Neolithic passage grave has long been known for the fact that the setting Sun at midwinter shines down its lintelled entrance passage. Research by the author in the early 1990s (MacKie 1997) established that in addition there is a clear sight line—defined by the straight inner part of the entrance and also by the outlying Barnhouse standing stone—toward the right slope of Ward Hill on Hoy about ten miles away. This marks sunset on the first sixteenth of the year before and after the winter solstice (Fig 6) and is a rare example of a very obvious alignment in a major structure being directed toward one of the minor divisions in the solar calendar. Unmarked by the structure

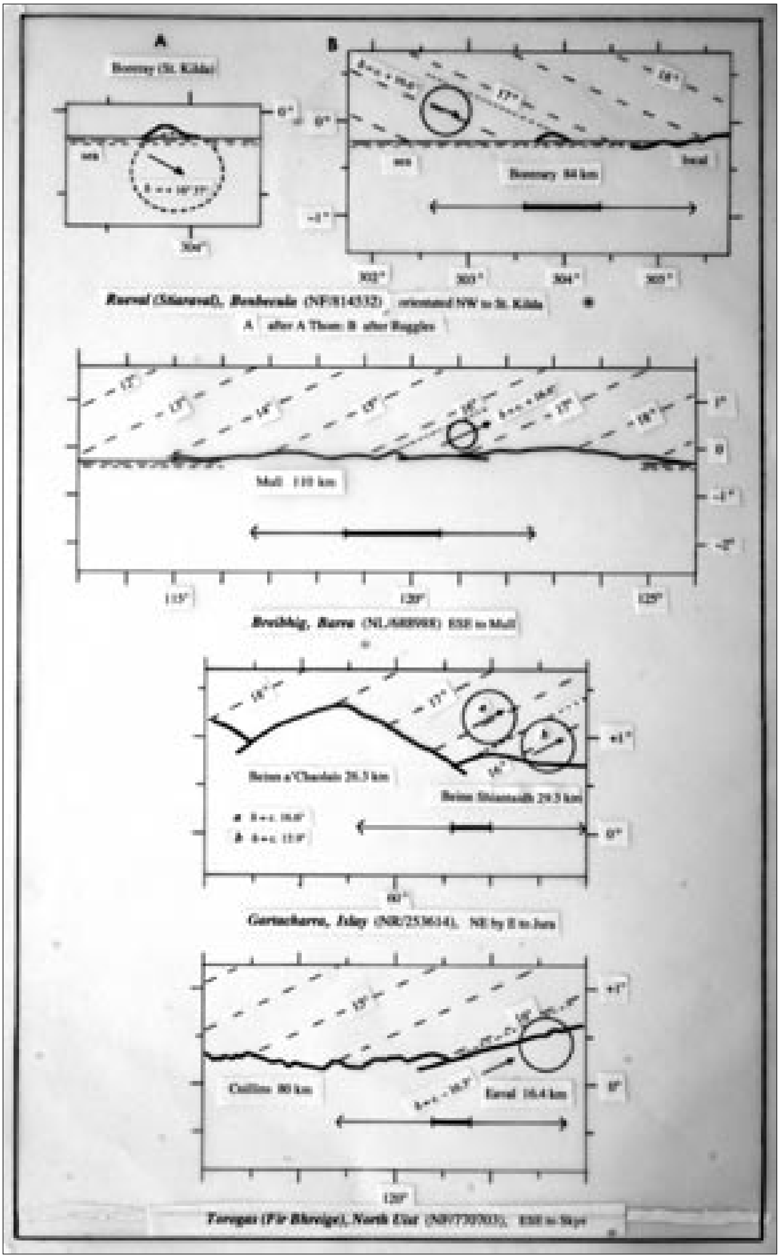


Fig 7 Examples of long, standing stone alignments to Quarter Day sunsets from the Outer Hebrides. *Top:* from Stiaraval stone to Boreray, A being Thom's survey (1967, Fig 11.5) and B the same site recorded by Ruggles (1984). C—three more similar sites surveyed by Ruggles. Redrawn by the author, with the solar discs added.

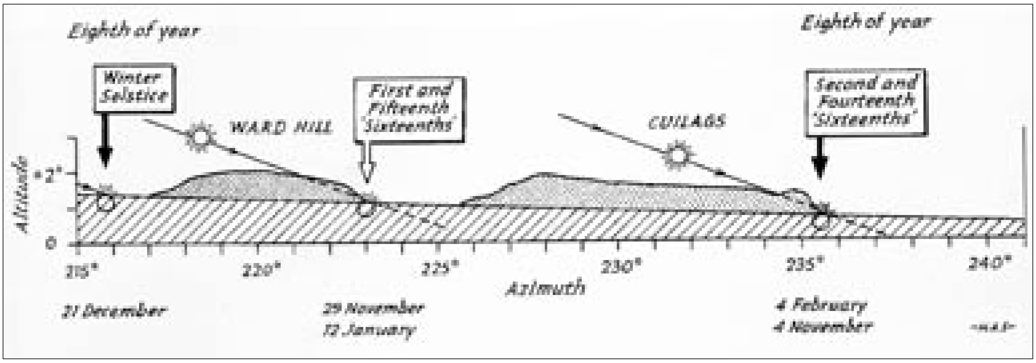


Fig 8 Maeshowe chambered tomb, Orkney. Drawing of the south-west horizon as seen from the entrance to the tomb, showing the position of the prehistoric midwinter sunset and the two other calendrical alignments identified by the author (MacKie 1997). The two to the left are indicated by the angled entrance passage (© Antiquity Publications, Ltd, reproduced courtesy of Antiquity Publications, Ltd).

now but very obvious is the right end of Cuilags, also on Hoy, which marks sunset on the first Quarter Day before and after midwinter (the beginning of November and February respectively). There seems little doubt that the position of Maeshowe was chosen in relation to the landscape to fit these two precise solar alignments as well as one imprecise but visually spectacular orientation—namely the outer part of the entrance which approximately indicates midwinter sunset.

An interesting further point that emerged from this research is that the entrance passage of Maeshowe is only about half the length now that it was when first exposed in the 1860s, and that it very probably also then had some kind of "light box" above the present doorway through which the setting midwinter Sun shone into the chamber, in the same way as still happens at Newgrange in Ireland. Unfortunately subsequent restoration and conservation has destroyed all traces of it and of the lower, outer half of the passage.

Equinoctial alignments

Defining the date of the equinox is clearly an essential part of the construction of the prehistoric calendar, especially as setting out an accurate east/west line would have been a relatively easy task for prehistoric man;[8] indeed it might be said that, if there is no evidence for such alignments, then the existence of the calendar itself become problematic. In his discussion on the equinox Ruggles rightly points out that the equinox is a modern astronomical concept (Ruggles 1997: 206–7); we define it as the time that the Sun reaches δ 0°[9] (directly above the equator) in its annual passage across the stars from the Tropics of Capricon (δ –23° 27') to Cancer (δ +23° 27') and back south again. This is the halfway point between the solstices (midwinter and midsummer) in the Sun's annual journey. However, unlike the solstices this intermediate date cannot be detected directly with long alignments because at these times (at around 21 March and 21 September) the position of the Sun's rising and setting is moving at its most rapidly along the horizon, in the same direction.

Thom's critics use this sophisticated modern astronomical definition to imply that the idea that a prehistoric people would have wished to define a date near the equinox is fanciful; why should they, since—without knowledge of the Earth as a sphere and hanging in space—the idea of an *astronomical* equinox must have been inconceivable to them? Yet it is perfectly possible to define a midway point between midwinter and midsummer—and with no knowledge of the modern astronomical facts—if all one wants is a calendar and if one can count the days between midwinter and midsummer and divide the total in half (Ruggles 1997, Fig 2). The resulting "equinoctial" alignment would then be set up to indicate the *average* of this halfway point in the spring and autumn. Because of the slightly elliptical shape of Earth's orbit, such a counting exercise must produce a mid-point date slightly later than the true astronomical equinox (δ 0°) in spring and slightly earlier than the same point in the autumn. This is exactly what Thom's histogram of solar-calendar alignments shows (Fig 2) and this evidence from standing stone alignments is surely one of the most striking confirmations of the reliability of his work in this area. In addition, and since Thom's work, a convincing equinoctial alignment has been discovered at Brainport Bay in mid Argyll.

Brainport Bay, mid Argyll

Fig 9 Brainport Bay midsummer sunrise alignment, Argyll: a view of the midsummer Sun in 1976 rising behind a small artificial notch on the alignment and behind distant peaks near Tyndrum (photograph by the author).

This is an unusual site and was thought at first (by the late Col. P.F. Gladwin) to be some kind of ancient settlement. It lies on the west shore of Loch Fyne, Argyllshire, not far from the village of Minard. The astronomical interpretations advanced (MacKie 1981: 128–37: MacKie, Roy, and Gladwin 1985) have been criticized (Ruggles 1999: 29–34) and responses have been offered (MacKie 2002). This description of the discoveries is therefore brief except for one aspect of the finds—a cache of thirty-three quartz pebbles—discussed here for the first time. Ruggles claims that the astronomical explanations offered for this site were a series of ad hoc, and increasingly dubious, attempts to make the evidence fit such hypotheses.[10] The author prefers to think that the process was one of proposing

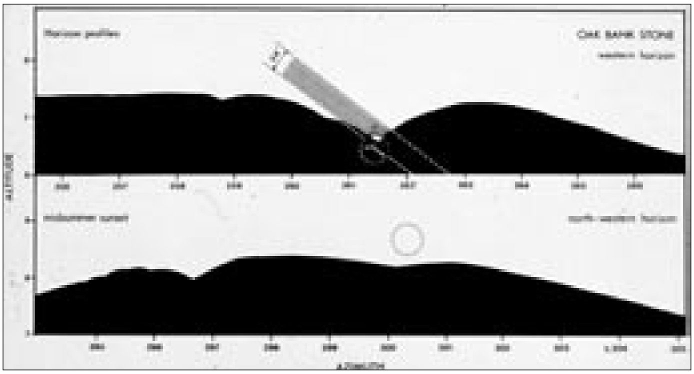


Fig 10 Brainport Bay, Argyll: diagram of the equinoctial sunset notch—indicated by the two cups and one of the lines in the cup-and-line rock carvings—identified by trial and error on higher ground 400 meters south-west of the main alignment.

a series of hypotheses, several of which were tested by further excavations and survey and found wanting until, finally, a new, unexpected, and convincing alignment was found at the end of this process. (This seems like a reasonable approximation to the scientific method!)

Essentially the main long alignment—directed toward midsummer sunrise behind distant peaks (Fig 9)—was found to be a result of the chance occurrence of natural features some of which had been modified to make an impressive ceremonial site. Because it was not a standard Thom long alignment, another, simpler one nearby would add to the credibility of the site. One was eventually located, through a process of trial and error, on higher ground to the south-west, and consisted of two small cup-and-line rock carvings in a clearing in a fir plantation. The two cup-marks, and one of the lines, pointed east/west and after clearance of some tree branches the western horizon was exposed, revealing a conspicuous notch about 1.5 miles away. This turned out to be the place of sunset at the equinoxes (Figs 10, 11). This result —as well as providing a convincing new solar calendar alignment (MacKie, Roy, and Gladwin 1985)—surely adds plausibility to the idea that the main

Fig 11 Brainport Bay, Argyll: view of cup-and-line rock carving no. 2 (golf ball in the cup and the line chalked) pointing toward the equinoctial sunset notch revealed by clearing vegetation (photograph by the author).

site was for the ceremonial observance of dawn at midsummer (though the date of that event could have been foretold with some accuracy, granting knowledge of the "splitting the difference" technique: MacKie 1988: 213–24).

Then we come to the cache of thirty-three quartz pebbles. Soon after the author first visited Brainport Bay in 1976, Peter Gladwin told him of the discovery of a cache of thirty-three white quartz pebbles; many broken quartz fragments had been found scattered around all over the site but these formed a distinct group of whole pebbles which had evidently been hidden under a flat stone on the north-east end of the main alignment (Gladwin 1985: 14). No reason for this number occurred to the author until many years later when he read an account of the possible significance of the number (Heath 2001: 38–40).[11] This depends on the fact that the year is just under 365.25 days in length (a modern estimate being 365.242199 days).

We can suppose that an equinoctial alignment like that at Brainport Bay has been set up by counting the days from the solstices and so arranged that, at its first sighting (assumed to be at the beginning of a four-year leap-year cycle), the Sun sets in the notch exactly—its upper limb just flashing at the base of the V-shape as it slides diagonally down to the right and behind the left half of the notch (Fig 10). After an interval of 365 days it will not be at the same point until 5.8 hours *after* sunset so will be completely hidden behind the hill forming the left side of the notch. In the following year it will slip back another 5.8 hours and so on until the fourth year when, after 366 days, it is almost exactly back in the notch, reaching the originally marked position 45 minutes after sunset. This would have been easily observable and would have made clear the need for a leap year to anyone using such an alignment and capable of recording day counts of up to 356 (see section 3 below).

However, assuming careful observations over many years as well as a suitable sight-line, our observer would find that after thirty-three years the Sun was the closest to its original position at the base of the notch, being only ten minutes out. Thus the thirty-three pebbles may have been a counting device to record this cycle, assuming that this relatively short alignment was capable of detecting such fine changes in the Sun's position. The evidence of the Brainport Bay pebble cache is perhaps not enough on its own to support the solar-calendar hypothesis significantly but it is another example of a strange and unique find which acquires meaning, and sheds light on the archaeological site at which it was found, when interpreted by that hypothesis.

A Rock Carving from the Late Fourth Millennium bc

The Fan-shaped design at Knowth

The great Neolithic passage grave at Knowth probably dates, like its neighbour Newgrange, to the end of the third millennium BC (Eogan 1986: 170–2). Also like Newgrange, the perimeter of the huge mound is defined by large, prone kerbstones but many more of these are elaborately decorated with pecked designs. Kerbstone K15 is unique in having, among a mass of other symbols, a fan-shaped pattern which has been controversially interpreted as an exact representation on stone of the sixteen-"month" solar calendar

Fig 12 Knowth passage grave, Ireland, dating from about 3100 BC. The fan-shaped pattern on K15, lit by sunshine, which seems well explained as a graphic representation of the Thom solar calendar (reproduced with the permission of the Department of the Environment, Heritage and Local Government, Ireland, with whom copyright remains).

with all its details (Fig 12) (Thomas 1988: 4–7 and one plate and two figures). The pecked design on this stone is another quite distinct and unique artifact which is hard to interpret convincingly without some external clue. Does it indeed make more sense when interpreted by the solar-calendar hypothesis? If it does it is particularly important because of its early date.

Thomas's interpretation does not acknowledge the prior discovery of the solar calendar in British standing-stone alignments by A. Thom, and suffers from this omission. It is also unclear both how reliable his drawing is and also how unequivocal is his interpretation of the "day symbols." The author therefore visited the site in March 2008 to inspect the stone at first hand, but the design is difficult to see now unless the sun is slanting across the surface.[12] Fig 12 shows a clearer, older view of the pattern taken in sunlight with most of the details well seen.

The fan-shaped pattern could be a realistic representation of the solar phenomenon; the small cup-mark at top center looks like the Sun and is shown with nineteen, perhaps twenty, pecked rays radiating from it. Below the wider ends of these rays is an arc of sixteen more or less rectangular symbols which have been claimed to represent the "months" of the solar calendar; each rectangle would then represent twenty-two days. This totals 336 days which leaves a shortage of twenty-nine days—or thirty in a leap year. Next to the rectangular symbols are varying numbers of small dash-like symbols which are held to be the extra days in each of these short "months." Thomas's drawing shows all these "month" and "day" symbols unambiguously and they seem to add up to 365 very satisfactorily. However, there are two problems. The first is that the design is damaged at the lower left of the fan and "month" ten has completely disappeared; there is therefore room for debate about exactly how many day dashes, if any, there are in this part of the design. The second problem is that Thomas's interpretation

Table 1 Comparison of the distribution of the days in the sixteen-"month" solar calendar in (*top*) as originally calculated by A Thom and (*bottom*) as seen recently by the author on kerbstone K15 at Knowth. The numbers in bold are uncertain and could be the other way round.

'Month'	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
								starting at spring equinox								
Thom (alignments):	23	23	24	23	23	23	23	22	22	22	22	23	23	23	23	23
(quarters)		93			91			89		92						
								starting at right end (spring equinox?)								
MacKie (Knowth):	23	23	23	23	23	23	23	23	23	**21**	**22**	23	23	23	23	23
(quarters)			92				92				89				92	

includes an intermediate short dash or tick—at right angles to the rest—between "months" 1 and 2 and another between 5 and 6; however there are two other similar ones (including another at right angles) which are not shown in his drawing at all, though they can be plainly seen on the photograph. Clearly the pattern is not the unambiguous one that the published drawing suggests.

The details of this reassessment of the fan-shaped pattern on K15—which ignores the four irregularly placed "ticks"—are being published elsewhere (MacKie forthcoming A)[12] but the results are summarized in Table 1. If the sixteen "month" symbols are divided into four quarters, the damaged and obliterated symbols—"months" 10–12—all fall in the third of these. All the other thirteen "months" are clearly composed of a rectangle and two dashes—twenty-three days each, totalling 299—so it seems to follow that the number of days in the third quarter can only be 89. That the same happens in Thom's calendar can surely not be a coincidence and allows one to infer that the Knowth fan-shaped pattern is designed to be read from right to left and to start at the spring equinox. It also provides striking confirmation that the summer half of the calendar year ("months" 1–8) is longer by three days than the winter half, thus confirming Thom's hypothesis that—the Earth's orbit being slightly elliptical—it would have to be so if everything bar the solstices was arranged by counting the days (Thom 1967: 107). It remains unclear whether there is anything in the pattern to indicate leap years.

Early Bronze Age Artifacts

The Nebra "Sky Disc" from Eastern Germany

In 2001, a bronze disc (Fig 13, left) with gold leaf ornament was recovered from thieves in a police operation in Switzerland.[14] Almost certainly it was found on the Mittelberg, a hilltop site in Saxony Anhalt in eastern Germany, as part of a hoard of bronze artifacts. These other objects are all of early Bronze Age type and they appear to give a good stylistic date for the disc of approximately 1600 BC. The disc and its likely significance have been described often in German newspapers and periodicals, but for some time the discovery was scarcely noticed in the English-speaking world[15] apart from a popular article which appeared in *The National Geographic* for January 2004 (Meller 2004). Recently, there has appeared a detailed discussion of the disc which argues that it is a piece of a village shaman's equipment (Pásztor and Roslund 2007); the German scholars' astronomical interpretations are barely referred to here.

The main archaeological description is by its discoverer, Dr Harald Meller of the Landesmuseum in Halle, East Germany (Meller 2002, 2003). The bronze disc itself is about 30 cm in diameter and the symbols in gold leaf include a Sun disc (or perhaps a full Moon), a crescent Moon with its points unrealistically facing the "Sun," a long, crescent-shaped "boat" at the bottom with fine dashes along the edges, two opposed long "arcs" along the sides (one having lost its gold leaf) and thirty-two small spots which are presumably stars. The cluster of seven spots near the top was immediately assumed to be the Pleiades, a hypothesis which has generated much speculation. The design on the disc evidently went through various stages; for example the gold of the right-hand "arc" covers two of the "star" spots and X-ray analysis has apparently shown that the "boat" was added after the "arcs." The perforations round the edge were obviously added last as some of them penetrate the gold "arcs."

By a fine piece of archaeological detective work the disc and the other metal items associated with it were determined to have originally been buried under an ancient stone mound on the Mittelberg Hill near the town of Nebra.[16] This was enclosed by a ring-ditch on the hilltop, about 75 meters in diameter. These enclosures are widespread in northern Europe and are thought to have been prehistoric ceremonial or holy places. Heavily forested though the area is now it seems likely that in the Early Bronze Age the hilltop was bare and, with its wide views in every direction, could if necessary have served as a celestial observation point.

An astronomical element in the design was inferred by Professor Wolfhard Schlosser of the University of the Ruhr (Schlosser 2002, 2003). Here it is not necessary to discuss the inferences he makes about the Pleiades and the star pattern, or what has been surmised about the boat image, or whether the golden disc is the Sun, the full Moon or the Moon in a total eclipse. All these symbols except for the boat (images of which are widespread in Bronze Age Europe—Meller 2002) are unique, and therefore their purposes must remain somewhat speculative until good parallels are found. However, there are aspects of the disc which could be related directly to the British prehistoric solar calendar and here some definite progress can be made.

Schlosser recognized that the two golden arcs each subtend angles of about 82° from the center of the disc and suggested that this could relate to the fact that, in this part of Germany, the difference in azimuth (degrees clockwise from true North) between the Sun on the horizon at midwinter and at midsummer is also 82°. (Mittelberg lies at a latitude of about 51.3° north.) The disc could therefore be a representation of the annual solar sunrise and sunset cycle as seen from near Nebra. However, when the angles are plotted on the disc (Fig 13) it becomes obvious that—unlike the astonishingly accurate pattern inscribed on the lozenge (below)—the two "horizon arcs" are not on the same axis; the midpoint of one arc is a few degrees away from that of the other. This relative crudity could confirm that the Nebra disc was a symbolic rather than a functional artifact (Pásztor and Roslund 2007).

The western horizon seen from the hilltop is fairly level but includes several peaks in the Harz mountain range many miles away in the north-west.[17] An isolated peak called Brocken marks sunset on the longest day in the north-west, but the midwinter Sun sets in the south-west on a level horizon. However, at the north end of the range is the peak Kyffhäuser, which marks sunset on 1 May. The Germans drew a parallel with the local May Day festival of *Walpurgisnacht* which is still celebrated in the Harz Mountains and is thought to be a survival of the ancient spring festival. It seems possible to go further and draw a parallel between these phenomena and the Thom prehistoric solar calendar in the UK, with its primary eight-fold subdivision of the year and its four Quarter Days which survive in major Celtic festivals halfway between the equinoxes and solstices. In this scheme the sunset at Kyffhäuser at the beginning of May marks the continental equivalent of Beltane (*Bealltuinne*) and it must also mark sunset at the beginning of August—the ancient harvest festival of *Lùnasdal*, or the Anglo-Saxon Lammas.

The golden "star" spots are probably relevant here too, though not just as constellations. When the disc was first seen no one noticed that two of the "star spots" (an original feature) were hidden under one of the golden arcs (which were added later) and that a third had lost its gold leaf.[18] There was natural speculation that the twenty-nine spots first seen represented the lunar month. This being now irrelevant, what is left? As noted earlier there is a 33-year solar cycle, but what can thirty-two signify? Quite possibly the finest subdivision of Thom's calendar in which the sixteen "months" of twenty-two or twenty-three days are further split and for which a few signs were seen in the solar alignments in the British standing stones (but see Note 9). The Nebra disc may thus be providing us with valuable tangible evidence of an entirely new kind in favour of Thom's interpretation. This would be pure speculation, not mentioned were it not for the powerful hint of solar-year tracking provided by the 82° "horizon arcs" on the disc, the evidence of the same in the long solar alignments seen from the Mittelberg and the comparable evidence from Bush Barrow, Wiltshire, about to be described.

The Gold Lozenge from Bush Barrow

The diamond-shaped gold plaque (Fig 13, right) found with an early Bronze Age burial under Bush Barrow in Wiltshire, southern England, at first sight bears no resemblance whatever to the Nebra disc. The large round mound is less than a mile from Stonehenge and was explored in 1808 by Sir Richard Colt Hoare and William Cunnington (Ashbee 1960). The extended skeleton of the middle-aged man under it was accompanied by a remarkable array of high-quality objects which put the burial into the Early Bronze Age, early in the second millennium BC. The diamond-shaped, decorated gold object known as the lozenge was on his chest, and may have been attached to wood. The extraordinarily high quality and great

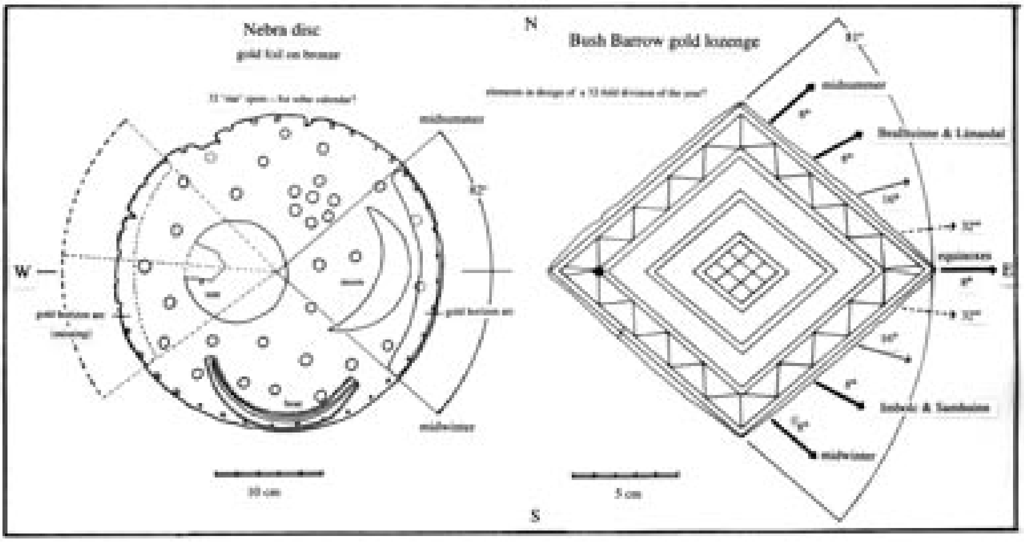


Fig 13 Drawing by the author of (*left*) the bronze and gold "heavens' disc" almost certainly from Mittelberg near Nebra in Saxony-Anhalt, Germany, and (*right*) the large golden lozenge from Bush Barrow near Stonehenge. It illustrates how both artifacts can be interpreted as relating to a latitude of about 51° N—where the Sun travels along about 82° of the horizon each year—and to a solar calendar with sixteen, possibly thirty-two, subdivisions. In the case of the lozenge, the calendar dates are marked by lines starting at the black diamond and passing through the inner points of the zig-zag pattern.

regularity and precision of the engraved geometrical pattern on the thin gold have often been noted (Taylor 1980; Kinnes et al. 1988) and excellent color photographs have been published (Kinnes et al. 1988). The craftsman must have used a measuring scale of some kind in addition to a precise straight edge, and of course a very fine metal scriber.

A new interpretation of the geometrical pattern on the lozenge which relates directly to Alexander Thom's ideas was originally conceived by J.M.D. Ker in 1977 (Thom, Ker, and Burrows 1988) (Fig 13), yet in his wide-ranging survey Ruggles passes over this possible significance of the plaque in barely a sentence (Ruggles 1999: 139).[19] British archaeology in general has completely ignored it. One reason for this must be that it was until recently unique;[20] the usual—and fair—argument being that a single example of a "significant" design may have arisen by chance.

Ker and his colleagues found the pair of acute angles of the basic diamond pattern to be 81°.[21] They realized that this was the angle between midsummer and midwinter sunrises (and sunsets of course) on a low horizon at the latitude of Stonehenge (51.17° N) four thousand years ago.[22] They further suggested that the lozenge is a record in gold of a larger, probably wooden, surveying device which could have been used in southern England to help with setting out long sight-lines marking the main points of the prehistoric solar calendar. The long axis of the pattern, when oriented east/west, must point to the equinoctial sunrise or sunset; the two sides of the diamond must then point to those at midwinter and midsummer. In fact the authors claim that all the "Eighth" subdivisions of the solar calendar are clearly shown by lines running from a point on the left (marked by the black diamond here) through the inner points of the zig-zag pattern opposite (Fig 13, right). These include, in addition to the four just mentioned, the halfway points between the solstices and equinoxes—"May Day and Lammas" (now 1 May and 1 August) and "Martinmas and Candlemas" (now 11 November and 2 February). The "best-fitting" date for the engraved angles is evidently about 1900 BC.

The pattern on the lozenge, being symmetrical, cannot show all the subdivisions claimed for the solar calendar with the restricted number of points used. The Sun's daily rate of movement along the horizon varies—slowest at the solstices and fastest at the equinoxes—and therefore the sixteen points of sunrise and sunset are more bunched around midwinter and midsummer and are much farther apart around the equinoxes. The four "Sixteenth" dates nearest the solstices cannot be fitted in but the four half-"month" or "Thirty-second" divisions closest to the equinoxes can be shown. If the basic hypothesis is correct, this could be more valuable evidence for the division of the prehistoric solar year into thirty-two parts. This inability of the regular diamond-shaped pattern to show every irregularly spaced point on the horizon of the Thom solar calendar has been held to make the whole hypothesis implausible (North 1996: 511–13). Presumably one has to decide whether the craftsman and his employer would have been more likely to want a simple design to reflect the calendar points exactly and obviously, or whether a more elegant, regular pattern was desired, the real meaning of which was hidden.

As noted, the geometrical pattern on the gold lozenge must have been exactly and skilfully scribed using a standard measure of some kind, and one could argue that the mere existence of the Bush Barrow lozenge means that an exact measuring system was in use in the early Bronze Age. Thom, Ker, and Burrows looked for multiples of the Megalithic Inch (MI) discovered in an analysis by A. Thom of the prehistoric cup-and-ring rock carvings in the UK; this unit turned out to have a length of 2.0725 cm, or one fortieth of the Megalithic Yard (0.829 m). They found forty-two distances the mean length of which is 4.08+0.03 inches, equivalent to almost exactly 5MI. The problem here of course is that these distances do not run along actual inscribed lines but are a function of the geometrical pattern; nevertheless it is hard to believe that they emerged by chance. It is worth mentioning that a radius of 5MI (one eighth of the MY) was particularly common in the radii of the rings of the British rock carvings (Thom and Thom 1978, Fig 5.1).

North quite reasonably contends that one should only measure actual lines, and he found that some of these were in multiples of one one-hundredth of an MY (North 1996: 511). The central lozenge has diamond shapes one one-hundredth of an MY in length and the lines of the outer zig-zag measure exactly two hundredths. As North says, Thom thought he had evidence for a Megalithic Fathom made up of 2.5 MY, so a small unit 2.5 of which make up a MI is a reasonable hypothesis.

Latitude of the find spots (Fig 14)
Each of the two metal artifacts just discussed was found in or near a major circular sanctuary at about the same latitude, and each—if interpreted correctly—was designed to be used near that latitude.[23] When one considers the wide range of latitudes which mainland Europe covers it does seem rather remarkable that the most convincing archaeoastronomical artefact ever found should have come from about the same latitude as Stonehenge—the most spectacular of the prehistoric circular 'holy places'—even though it is in eastern Germany and far away across the sea from the Wiltshire site. The centre of Stonehenge is at 51.15° N (Thom and Thom 1978, Fig 11.6) and the summit of the Mittelberg at 51.28° N.[24] This represents a latitudinal distance apart of only about 11 km and is another remarkable coincidence (in the literal sense of the word) to which attention is only now being drawn (MacKie 2006: 357).

Can there have been some important reason for the establishment of the two sanctuaries at this latitude, which would partly explain the deposition in or near them of two elaborate metal artifacts which, though completely different in form and design, seem to have had similar links with the solar calendar? Is it really possible plausibly to infer such a reason at this distance in time? To answer this we have to try to unravel two more difficult problems: (1) could the Station Stone rectangle have specific geometrical properties, and a specific orientation, so that it marked rising and setting positions unique to its latitude and (2) could the Station Stones, or at least their positions, belong to the very beginning of the site's history, as they must if the answer to the first question is "yes"? If the qualities of geometry and astronomy which have been claimed for the Station Stones are plausible then Stonehenge, which—in terms of its architecture and the engineering skills needed to build its most spectacular sarsen elements—is the most important Neolithic ceremonial site in Europe, will provide convincing evidence in support of the Thom solar calendar early in the third millennium BC.

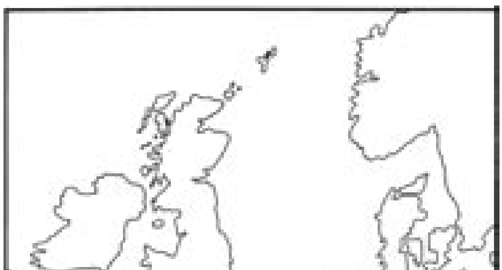


Fig 14 Outline map of central and north-western Europe drawn by the author and showing how the Mittelberg (with the Nebra disc) and Stonehenge (close to the burial with the golden lozenge) are on almost exactly the same latitude—just north of 51° N.

Some space is being devoted to this subject here, partly for the reason just explained but also because the geometrical and astronomical evidence from the site tends not to be discussed seriously by modern investigators (Ruggles 1997: 203, 218–20), although a new paper on solstice alignments in the area has just appeared (Ruggles 2006).[25]

Stonehenge

The Station Stones: archaeology and early views

This name is given to the well-known rectangular formation of four sarsen standing stones (nos 91–94), two of which (94 and 92) have disappeared although their stone-holes have been located and explored (Fig 15) (Atkinson 1978; Cleal et al. 1995, figs 164 and 165). Although direct evidence was lacking, the Station Stone rectangle was assigned by Atkinson to his phase IIIa—the time of the construction of the sarsen circle and horseshoe—although he accepted that the undressed nature of the two surviving stones, similar to that of the Heel Stone, could mean that the formation actually belonged to Phase 1, or even earlier (Atkinson 1961: 77). After an extensive reassessment of the results of all the twentieth-century excavations, the later dating has been upheld and the Rectangle has been tentatively assigned to an early period of the new Phase 3, also when the sarsen circle and horseshoe were erected; it is still accepted however that there is no radiocarbon or stratigraphical evidence for this conclusion (Cleal et al. 1995: 468).

C.A. Newham was the first to suggest that the Rectangle had significant astronomical properties.[26] He showed that the short sides are oriented toward δ+24°—to midsummer sunrise and midwinter sunset about 4,000 years ago—and are parallel to the main axis of the site along the center line of the Avenue; the long sides by contrast indicate δ+29°—approximately the extremes of maximum moonset and moonrise. (Fig 15). A few months later, and after analysing potential alignments on a plan of the site with a computer, Hawkins made the same claim in *Nature* and then in his book (Hawkins 1963; 1965, Fig 11); in addition, he suggested that the diagonals of the Rectangle point to δ+19°, the extremes of minimum moonrise and moonset. Hawkins was also the first to point out that there is only a short span of latitudes—covering a few miles—where these solar and lunar risings and settings occur at right angles to one another; further north or south any quadrilateral with these qualities would have to be progressively more diamond-shaped.

Another example of this "right-angle" phenomenon can be seen in the rectangular setting of stones at Crucuno in Brittany, which is based on a perfect Pythagorean triangle with sides of 30, 40, and 50 MY with its short sides orientated due north-south. It is at the right latitude (47° 37.5' N) for the two diagonals to indicate sunrise and sunset at both solstices (with the Sun just touching the horizon) and simultaneously for the long sides to indicate sunset at the equinoxes in the same way (Thom and Thom 1978: 175–6 and Fig 3.2).

The argument that it was this property—having a right-angle between these two pairs of solar and lunar sight-lines—that determined the location of Stonehenge in the first place obviously does not require the four stones to be positioned in any particular rectangular figure; a square would do just as well. However the proportions of the Station Stone rectangle are close to those of a perfect Pythagorean triangle with sides 5, 12, and 13 (Dibble 1976) and, if deliberate, this could be important. It would obviously have been much harder, within the constraints of such a rectangle, to pin down a location where not only did the long and short sides point at the significant solar and lunar risings and settings mentioned, but where one diagonal also pointed at more of these (the 92/94 diagonal is too close to the north-south line to be usable). To try to unravel these problems, and to determine what geometrical and astronomical claims about the Rectangle are plausible, we have to ask about the shape, size, and orientation of this figure, as well as about its date. Clearly, if Stonehenge was built where it was because of the astronomical phenomenon referred to then the Rectangle must have been established at the start of the site's history, though not necessarily with standing stones at its corners. As noted, this is not the current view.

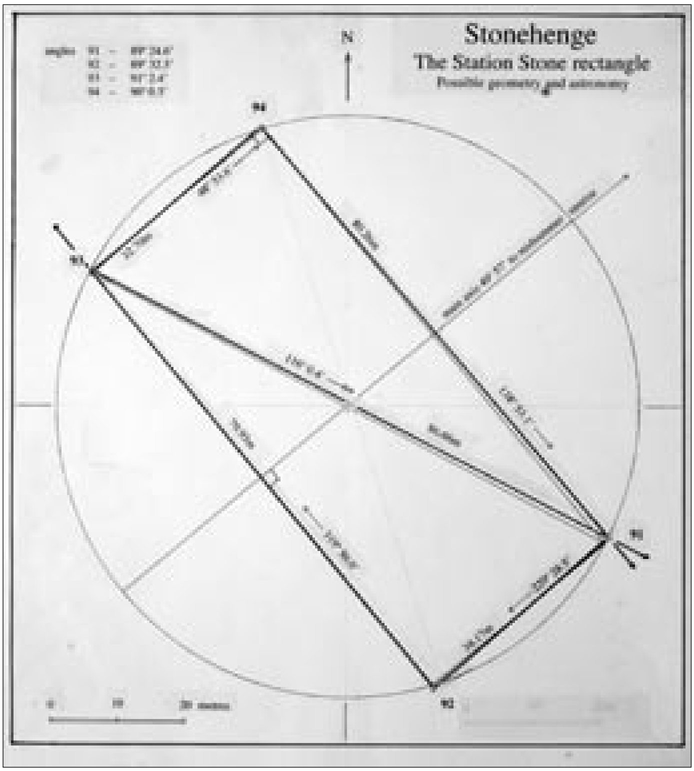


Fig 15 Stonehenge, Wiltshire. Schematic plan at 1:250 by the author of the actual position of the Station Stone rectangle (thick lines) superimposed on the "ideal" geometry of the rectangle and the Aubrey hole circle as a unit. The significant azimuths are marked.

Reliable data on the station stones

Geometry

All previous surveys of the Station Stones were rendered redundant by Atkinson's new fieldwork and excavation at the site in 1978, when he not only identified and excavated for the first time the socket of stone 94 but also accurately measured the distances along the sides of the Rectangle, the angles at the corners and the azimuths of the sides (Atkinson 1978). The information is shown in Fig 15 which is a plot of the actual rectangle in thick lines superimposed on the ideal geometry (in thin lines) of this and the Aubrey circle. This "ideal" construction assumes that the Rectangle has the same centre as the Aubrey circle with a diameter of 104 MY, with its corners on that circle, and that the long sides are oriented on an azimuth of 50°. The dimensions of the actual Rectangle, in megalithic yards and clockwise from stone 91, are 41.22, 96.42, 39.45 and 96.82, with the 93/91 diagonal at 104.64 MY. The real Rectangle is obviously extremely close to the hypothetical "ideal" one in every way (North 1996, figs 184 and 192).[27]

The proposed link between the Rectangle and the Aubrey ring in the "ideal" geometrical construction is supported by an earlier survey. In the early 1970s, A. Thom and R.J.C. Atkinson mapped the Aubrey holes exactly and found that the centers of the fifty-six pits lay on the perimeter of an accurately drawn circle with a mean radius of 141.80+0.08 ft, or 43.22+0.024m (Thom and Thom 1978: 146). The diameter (86.44m) is so close to the known lengths of the diagonals of the Rectangle (the corners of which are in fact very close to the Aubrey circle—Cleal et al. 1995, Plan 1) as to make it difficult to doubt that the ring was planned so that a 5:12:13 rectangle of this size could be marked out on to it. Even if the actual Station Stones were set up at a later date (Phase 3), the same rectangle could have been marked with posts when the Aubrey holes were laid out at the start of Phase 1 and near the beginning of the third millennium BC. The circle of fifty-six holes must have been marked out, with a peg-and-string "compass," just inside the surrounding bank and at the beginning of the site's history, and might have had a variety of diameters; it can hardly be doubted that, since it can contain exactly the Pythagorean Station Stone rectangle, the two geometrical figures were set out together, as a unit (Fig 15).

Reliable Azimuths

Atkinson also established in 1978 the azimuths of the long and short sides of the Rectangle and these are also shown in Fig 15. They provide the necessary information to calculate the astronomical positions on the horizon indicated by pairs of Station Stones. Before explaining this diagram further it is necessary to consider the only other independent evidence for the azimuths of the main axis of the site (excluding Lockyer's earlier work on the main axis, which is not entirely satisfactory—Atkinson 1961). The angle that the rectangle makes with this axis could provide further clues about the astronomical qualities underlying the original design of the site.

The orientation of main axis of the site has been deduced from two independent measurements—from the central axis of the straight part of the Avenue (leading north-east from the circular site) and also from the geometry of the Phase 3 sarsen circle and horseshoe, the axis of which appears to point in the same direction. A fresh survey of the former was carried out in 1978 and produced an azimuth of 49.89° (Atkinson 1978: 50). The geometry of the sarsen circle and the enclosed horseshoe of trilithons was worked out by the Thoms (Thom and Thom 1971, 141–5 and Fig 11.5), who assumed that the axis must run through the center of that circle and through the centers of the spaces between stones 30 and 1 and the opposed 15 and 16 (of which the former is missing—Atkinson 1963). By computing the geometry of these thirty stones from the survivors they established that this axis has an azimuth 49.95° and is thus extremely close to the mid-line of the Avenue. The Thoms also inferred that the five trilithons lie around an ellipse and that the long axis of this lies along the same azimuth (Thom and Thom 1971, Fig 11.5).[28]

The other reliable azimuths are those of the four sides of the Station Stone rectangle established in 1978 (Atkinson 1978, Table 3). The angle at 94 is almost exactly 90° so, in a true 5:12:13 Pythagorean triangle, the angle 94-93-91 should be 67.38° whereas it is in fact 67.84°. Bearing in mind the possibilities for error in measuring angles set out nearly five thousand years ago this seems close enough to allow one to accept that the Rectangle was laid out with sides close to 40 and 96 MY. It is also plain that there are two almost exact right angles in the Rectangle; the first is, as noted, at stone 94 and the second is between the long side 92/93 and the main site axis. The latter surely cannot be a coincidence and should confirm that the Rectangle and site axis are part of the same geometrical construction. The diagram also shows how close the Rectangle is to one based on Pythagorean triangles of 40, 96 and 104 megalithic yards. The "ideal" Aubrey ring is so close to the actual one that on the figure the latter is omitted for clarity.

Nevertheless the Rectangle is obviously slightly skewed. The corner at stone 91 is furthest off, with long side 94/91 slightly more than a degree away from the ideal alignment. Likewise it is hard to understand why the short sides 93/94 and 91/92 are slightly skewed away from the site axis—in the former case by just over a degree and in the latter about half a degree—when side 93/94 shows that a line at exactly right angle to this axis could be laid out. It remains to consider whether these irregularities are the result of errors in surveying (or in the subsequent placement of the markers) or whether they can be explained by the calendar requirements of the formation. The diagonal 93/91 on the "ideal" Rectangle has an azimuth of 117.38° [29] whereas because of the distortions mentioned the actual diagonal is 116.07°.

Astronomy

Do these irregularities make sense in terms of the astronomical positions (azimuths and declinations) pointed at by the four sides and the one relevant diagonal? Table 2 shows a set of azimuths for midwinter sunset and midsummer sunrise at the middle of, and at the beginning of, the third millennium BC, and compared with the actual azimuths of the Rectangle. It is obvious, first, that there is no significant difference between the positions of the solstitial Sun at either date. It is equally obvious that the solstitial Sun when risen and just touching the horizon matches the direction of the site axis best. These may be said to be reasonably precise alignments (though hard to use as such, since there is no useful horizon mark), as the rising Sun stays in about the same place for several days at these times. The short sides of the Rectangle, as noted, do not match the main axis exactly, both being skewed slightly toward the north. However, 92/91 points close to the half-risen solstitial Sun at 3000 BC and 93/94 points nearer to, but slightly short of, its first appearance then. Here again the slight skewing of the Rectangle may be explicable in astronomical terms.

In the case of the long sides of the Rectangle, again it is not easy to distinguish whether positions at the beginning or middle of the third millennium are most likely to have been indicated. One would expect, however, that if the Rectangle was deliberately skewed from the "ideal" position, then side 94/91, being furthest "off," would fit the lunar extremes best, but this is not obviously the case. For example the "regular" side 93/92 (exactly at right angles to the main site axis) fits very well the first and last appearances of the lunar disc at the maxima at *c.*2900 BC, but the other long side fits the disc resting on the horizon at the same epoch very neatly. Perhaps this is the explanation, and the two lines were aimed at two distinct positions of the same moonrise or moonset. Although the purpose of such an arrangement is not clear it cannot be doubted that the lunar alignments in general are remarkably good.

Table 2 shows rather neatly how the "ideal" diagonal would have pointed as closely as feasible to the Quarter Day rises and sets concerned but that the actual line does not because of the slight shifting of the long side 94/91 more toward the north. Even

Table 2 The main axis of Stonehenge and related azimuths

	First or last flash	half risen or set	on horizon
a. Sun at 2400 BC	48.78°	49.61°	50.01°
(δ = 23.97°)	228.78°	229.61°	230.01°
b. Sun at 3000 BC	48.67°	48.49°	49.90°
(δ = 24.03°)	228.02°	228.49°	229.90°
c. Site axis	*'ideal'*	*actual (sarsen circle)*	
	50.0°	49.95°	
	230.0°	229.95°	
d. S S Rectangle azimuths	*'ideal'*	*actual*	
93/94	50.0°	48.86°	
	230.0°	28.86°	
92/91	50.0°	49.48°	
	230.0°	229.48°	

Table 3 Azimuths of maximum lunar positions and of the long sides of the Station Stone rectangle

		on horizon	half risen or set	first or last flash
a. Maximum northern moonset & rise		318.72	319.19	320.14
2900 BC (decl. 29.165° (ε + i))		138.72	139.19	140.14
b. Maximum northern moonset & rise		318.62	319.08	320.03
2400 BC (decl. 29.12° (ε + i)		138.62	139.08	140.03
c. S S Rectangle azimuths	*'ideal'*	*actual*		
94/91	140.00°	138.89°		
	320.00°	318.89°		
93/92	140.00°	139.94°		
	320.00 °	319.94°		

Note: In both tables the horizon altitudes are assumed to be about +0.5°. In general terms it is thought that the solstitial sunrises (and sunsets) have been gradually moving toward each other over the last few millennia but this does not appear in the table of solar azimuths above. I am assured that there is a good reason for this.

so line 93/91 marks the four Quarter Days reasonably satisfactorily—or would have done before the sarsen circle and horseshoe were erected in the middle of the Rectangle. For the reasons explained it would have marked them better in some years than in others. One might conclude that—if the skewing of the Rectangle is deliberate rather than the result of incompetence—getting good sightings of the Moon at its maxima was thought more important than getting the best Quarter Day lines.

Conclusions

After this brief review of the archaeological, geometrical and astronomical data about the Station Stone rectangle at Stonehenge there are several points to consider.

Date of the rectangle

There is no compelling archaeological reason to assign the Rectangle to Phase 3, the period when the sarsen circle and horseshoe setting was installed, at around 2400 BC. On the other hand, if one accepts the geometry of the Rectangle and of the Aubrey circle as genuine (below), there is a very good reason to interpret the former with the latter as a single geometrical construction laid out at the very beginning of the site's history, in Phase 1 (below). This view is also supported by the undressed nature of the surviving sarsen Station Stones (and of the Heel stone).

Geometry

When the actual shape of the Rectangle is compared with the ideal shape—based on a Pythagorean triangle of 40, 96, and 104 megalithic yards, exactly contained within the Aubrey circle and tilted away from due north on an azimuth of 50° (Fig 15)— it is difficult to doubt that the Station Stones were intended to mark out a figure very close to that. The contrary view—denying all geometrical and astronomical qualities (apart, presumably, from the midsummer sunrise line)—must assume that this close resemblance has come about entirely by chance.

Astronomy and latitude

The correspondence between the most accurately determined azimuths of the sides of the Rectangle and those of the solstices and lunar maxima at the beginning of the third millennium BC is extremely good, provided that one accepts that the rising and setting sun was marked when the disc was just touching the horizon instead of, as is more usual, by its first or last flash. In particular, we can now see that one long side of the Rectangle (93/92) is almost exactly at right angles to the main site axis and that it also marks nearly exactly the first and last appearances of the Moon on the horizon at the lunar maxima.[30] The other long side fits the same extreme moonrises and sets but when the disc is sitting on the horizon. As a result of this skewing of the Rectangle the four Quarter Day sunrises and sunsets are not marked as well as they could be but were even so probably quite adequate. If, as seems likely, all these alignments were set out at the beginning of the history of the circular site, Stonehenge may well have been placed where it is because of the ability of a rectangular formation, based on a 5:12:13 Pythagorean triangle, to mark all these celestial positions reasonably accurately. This hypothesis would have to be tentative if only Stonehenge is considered, but the discovery of the Mittelberg on almost exactly the same latitude, and with a remarkable astronomical artifact also designed to mark points in the solar calendar—and with at least an indication in its design that the Moon was important—surely makes it far more plausible.

Two site axes?

One last point has to be made about Stonehenge. The recent compendium of archaeological research on the site argues that there was a major change in the orientation of the site between Phases 1 and 3; the Phase 1 axis is taken to be the line from the center of the site out through the mid-point of the entrance to the henge monument and has an azimuth of about 55° (Cleal et al. 1995: 170 and Fig 79). The change to the present site axis of almost 50° is assumed to have occurred at the start of Phase 3, with the construction of the sarsen monument, and to have marked a major change toward a solar religion. However, if the arguments advanced here are valid the 'Phase 3' axis was established in Phase 1, and the orientation of the entrance to the henge is of little significance. Perhaps it was placed at about 55° so that it was roughly in line with the midsummer sunrise but so that people coming in and out of the site would not get in the way of the real alignment. In any case, Stonehenge evidently combined lunar and solar orientations from the very start of its existence.

General Discussion

At the start it was asked whether Thom's solar-calendar hypothesis has been supported by the variety of relevant evidence which has accumulated since 1967, and it surely has been. The original idea was based *solely* on a statistical analysis of long alignments marked by standing stones.

Now, however, we have much new data—so much and so varied that the author now believes that any doubts about individual items are being laid to rest by the support from other sources. For example, both the existence of the megalithic yard and of accurate geometry underlying stone circles has been unexpectedly supported by the Cultoon stone circle, the exact shape of which was invisible until the excavations there. (It also surely cannot be a coincidence that the megalithic rod (2.5 MY) is exactly represented by the outstretched arms on the metrological lintel from Samos, which is equal to seven of the Greek foot also depicted on the slab—Fernie 1981.) Moreover, the newly discovered long axis of the Cultoon ellipse points to a distant midwinter horizon marker. Another potential accurate solstice alignment (at Kintraw) received independent support from the excavation of a predicted platform on a hillside behind the standing stone, and a small, genuine standing stone is now known to be a possible warning marker higher up the hill. Alignments pointing at the intermediate dates of the calendar have been found at Maeshowe (Quarter days and sixteenths), by chance at Sornach Coir Fhinn (Quarter days), and by a process of trial and error at Brainport Bay (the equinox).

Evidence from actual artifacts now supports the existence of the calendar—particularly the Knowth rock carving which seems to be a 5,000-year-old prehistoric representation of a calendar very close to that inferred by Thom through the careful surveying of the wreckage of the standing stone part of the system 5,000 years later—an outstanding achievement. The Nebra disc and the Bush Barrow lozenge both seem to be designed to reflect the annual solar cycle at about latitude 51° north, and both have elements in their design which could refer specifically to the solar calendar. The close similarity of the latitudes of their find spots drew attention again to the idea that Stonehenge might have been built where it is for a specific calendrical or astronomical reason, and a fresh look at the Station Stone rectangle—the structure which best reflects this reason—seems to confirm that it is built round a 5:12:13 Pythagorean triangle, is integral with the Aubrey hole circle, and has three kinds of celestial alignment built into its sides. It can also belong to the very beginning of the site's history, as the latitude hypothesis demands.

Moreover, if the similar latitudes of the two key sites discussed here are the result of similar astronomical interests in Wiltshire and Saxony-Anhalt in the third millennium BC, it should follow that each group of priests—hundreds of miles apart and with a sea in between—was able to define this important latitude independently to within five miles of each other. Alternatively a more ambitious hypothesis may be proposed. If a same solar calendar was indeed in use in the early Bronze Age in eastern Germany and in the UK and Ireland, then the entire body of arcane knowledge unravelled by Thom—concerning sky observation, the solar calendar, and exact measuring and geometry—could have been in the possession of priesthoods throughout northern, central, and western Europe in the Neolithic period. Moreover, the evidence from Knowth suggests that this knowledge was fully developed by the end of the fourth millennium BC, and is linked firmly with the emergence and spread of the passage grave building cultures of Iberia and Atlantic

Europe. Whether the Neolithic priesthoods inherited this knowledge from earlier local cultures, devised it themselves, or acquired it from elsewhere is a subject for future research.

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I am grateful to David Hughes for various discussions about astronomy and Stonehenge and much indebted to Robin Heath for undertaking some calculations about Stonehenge for me. I also owe a great debt to Anthony Murphy for supplying excellent photographs of the Knowth kerb stone for a preliminary analysis, and also for much help during my visit to Knowth. The staff of Bu na Boinne visitor centre, especially the manager Clare Tuffy, were unfailing helpful during that visit. Antiquity Publications, Ltd., gave permission to reproduce Fig 6, and Oxford University Press permission to reproduce Fig 1; the respective copyrights remain with their institutions. The fine photograph of stone K15 was supplied by the Department of the Environment, Heritage and Local Government, Ireland, with whom copyright remains.

Notes

1 Alison Sheridan in a book review, and referring to the author's 1997 paper on Maeshowe, Orkney—at http://www.ucl.ac.uk/prehistoric/reviews/03_08_grooved.htm.

2 One must not forget either the powerful fear of guilt by association. A distorted version of astronomical alignments fits in with "New Age" ideas and, worse, they were of interest to Heinrich Himmler's SS in the 1930s (Michell 2001: 58 ff.).

3 Essentially the author's position—argued in detail in this review—is that Ruggles devised a method of resurveying Thom's sites which, though it had the praiseworthy aim of being objective (avoiding identifying standing-stone-indicated horizon markers in astronomically "suitable" positions), nevertheless also by its nature prevented the identification of accurate long alignments. Thus his conclusion that long alignments did not exist was based on an a priori assumption, not on independent fieldwork and a large part of his subsequent campaign against Thom's conclusions is based on this error. See note 7.

4 I am very grateful to Thomas Gough for drawing my attention to the nature of this stone in 2007.

5 The raw date is 2715 + 40 bp (SRR–500): see https://C14.arch.ox.ac.uk/oxcal/OxCalPlot.html.

6 Euan W MacKie in *Discovery and Excavation in Scotland in 2007*, pp. 204–5.

7 Drawings A and B on Fig 5 well illustrate how Ruggles's survey method cannot reveal an accurate long alignment even when one exists. Despite the fact that the foresight is the tip of a small island far out to sea, and therefore can mark a sunset precisely, Ruggles's diagram marks with horizontal arrows only the minimum and maximum spans of the horizon indicated by the standing stone itself. Thus a potentially exact alignment is arbitrarily reduced to a more approximate one.

8 I am grateful to David Hughes for his suggestions as to how this was probably done.

9 The Greek letter Delta means "astronomical declination" in this context.

10 He is mistaken in saying "Yet the increasingly attractive alternative, that the astronomy of the main alignment was of lower precision … is never considered." (Ruggles 1999: 34); this was more or less the conclusion reached by the author in a book edited by Ruggles (MacKie 1988: 215).

11 See also Duncan 1999: 190: the Arab poet and astronomer Omar Khayyám (c. 1048–1131) apparently proposed a 33-year cycle of leap years as a calendar reform. Thomas (1988: 82–3) also refers to the symbolism of 33 but without acknowledging any connection with the Sun. However it is also possible that the numbers 33 and 32 refer to the relationship between the solar and the lunar years, the lengths of which are almost exactly in that proportion; the solar year of 365.242/33 = 11.07 days, and the lunar year of 13 months of 27.32 days = 355.16/32 = 11.09 days. Alternatively 33 lunar years = 11,720.3 days and 32 solar years = 11,687.7 days, a difference of 32.6 days. It has been claimed that the Nebra disc, with its 32 "star"' spots, is an aide-mémoire for synchronizing the solar and lunar calendars.

12 The decorated kerbstones are now under a sort of shelf to protect them from the weather; the photograph Thomas uses shows a sunlit design and was evidently taken before the shelf was built (1988: 42). The author hopes to have an expanded version of this section published in an Irish archaeological journal.

13 It may be noted that if "month" 11 does have 22 days then "month" 1 cannot have more than 23.

14 See the *National Geographic* for January 2004 for a racy description of the "sting" by Dr Meller.

15 A major international symposium to discuss its significance was held in Halle in February 2005.

16 Careful excavation found the missing fragment of the gold leaf on the solar disc in the fill of the looted burial pit.

17 The author has not yet obtained a full translation of Schlosser's articles describing these astronomical alignments so cannot judge their plausibility and potential accuracy; the available data comes from the *National Geographic* article. However there is an article by Erich Buhmann et al. on http://www.masterla.de/conf/pdf/conf2005/61buhmann-c.pdf describing an analysis of the terrain once visible from the Mittelberg (now obscured by forests) using 3D GIS.

18 The disc went through several phases of alteration, as follows. *Phase 1*. The only decoration was the Sun and Moon and the thirty two "star spots." *Phase 2.* The two horizon arcs were added on opposite sides of the disc, the one on the right covering two star spots; on the left side one star spot was moved slightly inward to make way for the band, a new ring having been incised into the bronze first. *Phase 3.* The boat symbol was added at the bottom. *Phase 4*. Many holes were punched through the bronze around the edge of the disc, some going through the gold leaf. *Phase 5.* One of the "horizon bands" was deliberately removed, and no trace of it was found in the burial pit.

19 His footnote 189 (ibid.: 248) objects, quite reasonably, that the calendar hypothesis for the Bush Barrow gold lozenge was then untestable. However, the author maintains that the Nebra disc and the Knowth "calendar stone" now provide such tests, in the sense that they are completely different artifacts the designs on which can be understood better with the same hypothesis.

20 There was a second smaller diamond-shaped plaque somewhat more crudely engraved.

21 Actually 82° on the accompanying drawings.

22 These sunrises then occurred 47° 48' apart on a sea horizon at the equator (Earth's axis then being tilted 23° 54' from the vertical) and that the angle increases as one goes north or south and the path of the Sun's daily motion tilts downward from a right angle in relation to the horizon. In the Orkney Islands, at Maeshowe for example (MacKie 1997), it was about 110°.

23 There are reports in the German press of the excavation and reconstruction of another circular sanctuary at Goseck, only 20 km from Nebra, which apparently has clear solar-calendar orientations built into it.

24 See http://www.megalithic.co.uk/article.php?sid=10863.

25 The author has not yet been able to secure a copy of this paper.

26 In *The Yorkshire Post* for 16 March 1963. Also C.A. Newham, *The Enigma of Stonehenge*. 1964.

27 He argues something very similar, but the text has so much detail about so many aspects of Stonehenge that it is sometimes hard to identify the essential points. Nevertheless his work should be consulted for a much more detailed analysis of some of the problems briefly described here.

28 Atkinson (1978) argued that the slight inward tilt of the second trilithon means that the axis of the hypothetical ellipse round which they were set should be rotated anti-clockwise by 25–30', giving an azimuth for the axis of about 49.50°—about half a degree away from that of the straight part of the Avenue. However this conflicts with the much more plausible idea that the north-east/south-west axis has to run through the middle of the gaps between opposed pairs of stones in the sarsen circle already mentioned, so Thom's azimuth is preferred here.

29 This is so close to Thatcher's earlier result of 117.35° (1976) that one has to wonder if he derived this figure by calculation from the hypothetical geometry rather than from an on-site survey.

30 These are the extreme moonrises and moonsets—equivalent to the solstices but occurring once a month instead of annually, and for several months in succession—which occur furthest south and north respectively twice in the 18.6-year cycle.

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