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Astronomy and Stonehenge

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Introduction

THE PORTRAYAL OF STONEHENGE in the 1960s and 1970s as an astronomical observatory or computer forms one of the most notorious examples known to archaeologists of an age recreating the past in its own image (Hawkes 1966; Castleden 1993, 18–27; Chippindale 1994, 230–1). Despite persistent popular belief, detailed reassessments of the ideas of C.A. Newham, Gerald Hawkins, Fred Hoyle and others have shown that there is no convincing evidence that, at any stage, constructions at Stonehenge deliberately incorporated a great many precise astronomical alignments, or that they served as any sort of computing device to predict eclipses (Atkinson 1966; Burl 1981; Heggie 1981, 145–51, 195–206). In short, there is no reason whatsoever to suppose that at any stage the site functioned as an astronomical observatory—at least in any sense that would be meaningful to a modern astronomer.

Yet we would be unwise simply to dismiss all astronomical ideas relating to Stonehenge. People within human societies of a very wide range of types perceive certain celestial objects and integrate them into their view of the world, linking them inextricably into the realms of politics, economics, religion and ideology (Thorpe 1981; Ruggles and Saunders 1993a). The material record from Neolithic and Early Bronze Age Britain and Ireland suggests that astronomical symbolism, in the form of rough alignments upon certain horizon rising and setting positions of the sun or moon, was incorporated into a range of prehistoric ritual monuments at various places and times. Evidence comes from certain individual sites, most notably Newgrange with its spectacular midwinter sunrise phenomenon (O'Kelly 1982, 123–5), but most compellingly from trends observed in regional groups of small, similar Bronze Age ritual monuments such as the recumbent stone circles of north-eastern Scotland (Ruggles and Burl 1985) and the short stone rows of western Scotland (Ruggles 1988; Martlew and Ruggles 1996) and the south-west of Ireland (Ruggles 1994). 'Once we have accepted the reality of even the simplest observations . . . the question is no longer one of acceptance or rejection, but simply of degree' (Bradley 1984, 77).

Two questions immediately arise: what exactly do we mean by astronomy, and why should we be interested in it?

In order to assign a useful meaning to the term 'astronomy', it helps to focus on the distinction between the observation of celestial objects and phenomena, and their perception and use (Ruggles and Saunders 1993a, 2–4). The term 'astronomy' will be used here to describe the process of observation, whatever its context, despite the objections of some archaeologists who argue that the very word necessarily implies Western analytical science (e.g. Chippindale 1994, 230),[1] and despite the implicit overtones of twentieth-century Western science that have dogged archaeoastronomy[2] for many years. Perception, on the other hand, is the process of making sense of, and attaching meaning to, certain observations. Different groups or individuals may 'see' the same objects in the sky, but the significance that they attach to them will be influenced by their classification of the natural world and the various ways in which they interact with it. As is familiar to archaeologists, this broader world-view, cosmology, or *cosmovisión* (Broda 1982) will generally bear little resemblance to the principles of Linnaean classification that underlie modern, 'rational' scientific thought.

Why might astronomy be interesting? It is clear from the preceding discussion that evidence relating to what could have been observed, and to what was observed, is essential to the process of developing and improving theories relating to what was perceived. But why should the archaeologist, and in particular the student of Neolithic and Bronze Age Wessex, be interested in the perception of astronomical phenomena? A general answer is that in many, if not virtually all, non-Western world-views celestial phenomena are not separated from terrestrial ones but form part of an integral whole with complex interconnections. The association may often be viewed as closer in nature to modern astrology than modern astronomy. 'A basic feature of traditional rituals and cosmologies [is] their astrological insistence that good fortune on earth can be ensured only by keeping human action fundamentally in tune with observable astronomical events. "On earth as it is in heaven." Again and again, we find this belief that the template for the ancestral "Way" or "Law" lies in the skies' (Knight 1991, 294). Once we tackle questions of people's perceptions of their natural environment as a whole, it would be unreasonable not to consider their perceptions of objects and events in the sky.

An aspect of indigenous cosmologies that is currently receiving a good deal of attention is that of 'sacred geographies'. Many indigenous peoples have a world-view that

1. This objection might seem strange to many astronomers in view of the fact that the word 'cosmology', which is also used as the name of a branch of modern science, is freely used in their own sense by anthropologists without any such reservations.

2. Although to some archaeologists (e.g. Chippindale 1994, 220) the term 'archaeoastronomy' is inextricably linked with the ideas of Hawkins and Hoyle, the term was not even invented in the mid 1960s, but grew largely from reassessments in the late 1970s of the work of Alexander Thom. Modern archaeoastronomy has grown to encompass multidisciplinary studies of astronomical practice worldwide in the context of diverse social questions (Aveni 1989; Ruggles and Saunders 1993b) and to think less about natural phenomena in themselves and more about the impact of nature upon people (Aveni 1992).

expresses an intimate, spiritual connection between humans and their natural environment. By associating special places (such as prominent landmarks) with particular celestial features and with sacred and secular practices, through myth and oral tradition, the vitality and power of being in a particular place is reinforced. Sacred geographies are evidenced amongst groups as diverse as Aboriginal hunter-gatherers in Australia (Morphy 1991) and the Aztec state in the Valley of Mexico (Broda 1993). Archaeologists are becoming increasingly aware that patterns of human activity within the Neolithic and Bronze Age landscape, including the siting and orientation of public ritual monuments, may well have been structured according to symbolic or cosmological principles (Bradley 1993; Thomas 1991; Tilley 1994), ideas that also apply to the area around Stonehenge (Darvill, this volume). It is in the context of such ideas that astronomy assumes potential importance in the particular context of Stonehenge and its landscape.

Astronomy, then, is an integral part of cosmology, in the anthropological sense. To ignore it in attempts to understand people's perceptions of the Stonehenge landscape is to impose another twentieth-century agenda, one rooted in the backlash to astronomical overload in the 1960s and 1970s; an understandable one maybe, but an unreasonable one nonetheless.

It is not the aim of this paper to attempt new cosmological interpretations but rather to consider certain evidence on the nature of astronomical observations made at Stonehenge, encapsulated in some way in the material record, that may bear directly upon some broader issues of current interest. The available data are not generally of high precision, since they are mostly reconstructed from plans and maps rather than being obtained from first-hand surveys; but, as we shall see, in most cases this is quite adequate for our purposes. The data that will be presented here mostly involve orientations of structures and show how these relate to celestial objects or events visible at or close above the horizon. While the word 'alignment' is retained as a convenience, for example in phrases such as 'the Phase 3 axis is aligned upon midsummer sunrise', its use should not be taken to convey a restrictive view on the nature of use or meaning of such relationships, if any existed at all in prehistoric times (some correlations might, for example, have been meaningful in terms of shadow phenomena rather than direct sighting of the horizon) but rather to give an indication of what could have been seen in a certain direction of possible interest, either on the horizon or above it, or what other effects (such as shadows) might have occurred.

Prehistoric astronomy: the conceptual framework

Before examining the alignment evidence at Stonehenge it is necessary to clarify certain concepts and assumptions that underlie the critical framework within which we conduct the examination. One of the most fundamental of these is direction. Prehistoric people did not necessarily have a concept of direction as point-azimuth, analogous to ours. There are many examples of directions being perceived as regions (azimuth ranges) rather than points, from pre-Columbian Mesoamerica to Europe in the Middle Ages (Köhler 1989). Even if directions were conceived as point-azimuths, those directions that we consider of special significance, such as the cardinal directions, are not necessarily exactly reflected in other conceptual systems: the Chorti Maya of present-day Yucatan, for example, regard the rise-set directions of the sun on the day of zenith passage as 'east' and 'west', although these are actually several degrees from our cardinal points (Aveni 1980, 40). Thus when looking at alignment evidence it is important to think in terms of events within certain azimuth ranges as well as at particular azimuths.

In considering prehistoric astronomy it is common to apply a 'recipe book' of solar and lunar horizon targets which at minimum consists of the rising or setting sun at the solstices and the most northerly or southerly rising or setting moon at one of the lunar 'standstills' (Fig. 1). After these come the rising or setting sun at the equinoxes, and so on. However, the solar and lunar motions, and hence what might be perceived to be significant about them, have to be approached through concepts that might make sense within a non-Western world-view to someone making observations, very possibly not on any regular basis, and without the benefit of visualisation aids (such as graphs) or sophisticated recording techniques.

Thus in the case of the sun, the solstices are directly observable and their use is widely attested, although their main significance may be not as directions-as-points but as the limits of directions-as-ranges—this can still be seen, for example, amongst traditional Maya groups in modern Mexico (Sosa 1989, 132). The equinox, however, is a concept unlikely to have any meaning outside the viewpoint of modern Western science and its precursors. It is defined by modern astronomers as the time when the sun crosses the celestial equator (see below). Yet the position at which the sun rises or sets on the day of the equinox is inherently indistinguishable from adjacent days, its rising or setting position merely continuing to move rapidly north or south before and afterwards. It is often supposed that importance might have been attached to the mid-point between the solstices. This could either be determined spatially, by halving the distance between the directions (azimuths) of the two solstices, or temporally, by halving the time difference between successive solstices. To do the former with any precision would involve devising a method to mark the solstice positions (perhaps using natural markers on or below the horizon) and determining their mid-point; it also assumes a concept of point-direction. The latter would involve counting the days between two solstices, and then counting half the number of days, which implies the existence of a method of recording numbers up to more than 180 and of halving a large number. While it is not inherently implausible that some prehistoric people could do this if duly motivated—after all, someone was evidently capable of careful planning in order to calculate the number of bluestones and sarsens needing to be transported from afar so as to build Stonehenge 3—the question is whether the concept of a mid-point dividing something into two equal parts, either in space or time, was itself of particular significance or interest. This is far from self-evident.

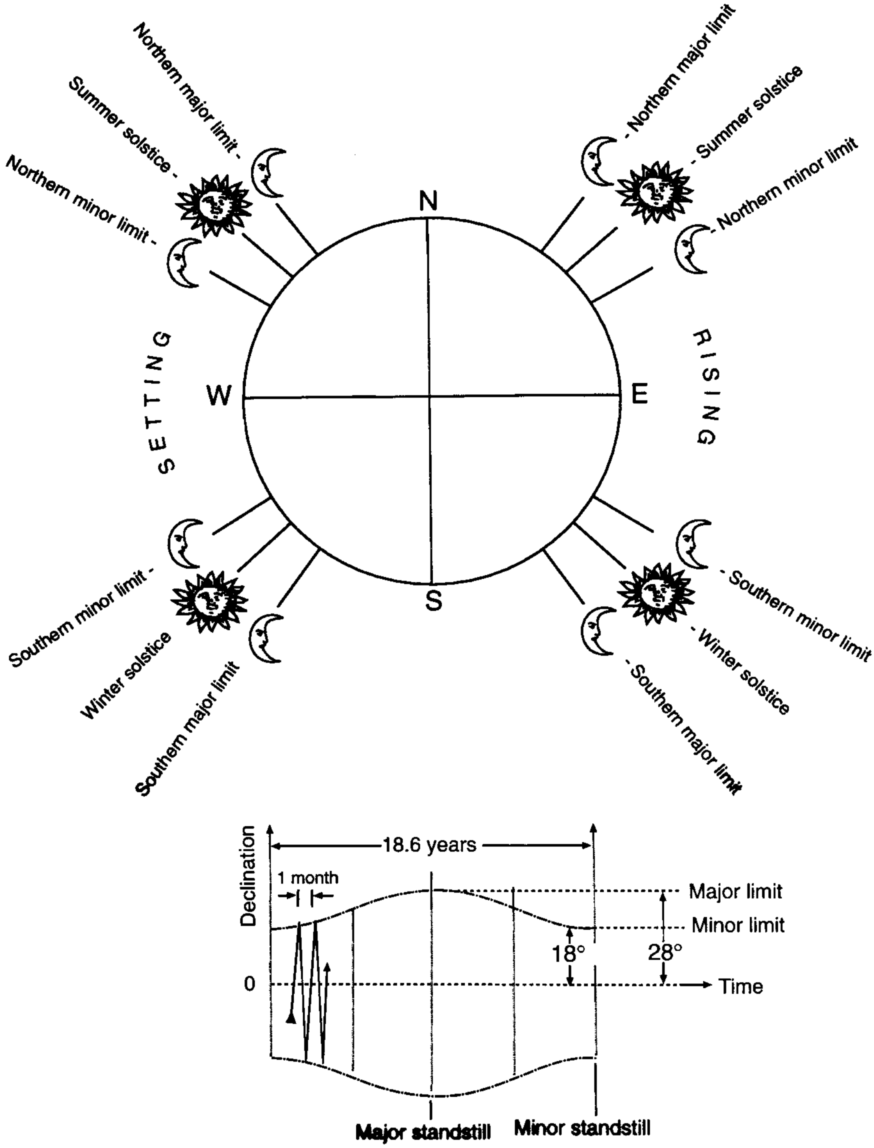

Figure 1. A schematic representation of the directions of the 'classic' solar and lunar horizon targets for an observer in southern Britain.
(a) Over the year, the sun rises and sets within the horizon arcs delimited by the solstices. Around the time of major standstill, which occurs every 18·6 years, the moon rises and sets within wider arcs delimited by what are here called the 'major limits', moving between these limits and back again once every month. Around minor standstill, mid-way between these times, the rising and setting positions are confined to the arcs between the 'minor limits'.
(b) The lunar standstills are defined as the times when the limits of the moon's monthly motions themselves reach a limit. After Thom (1971, fig. 2.2).

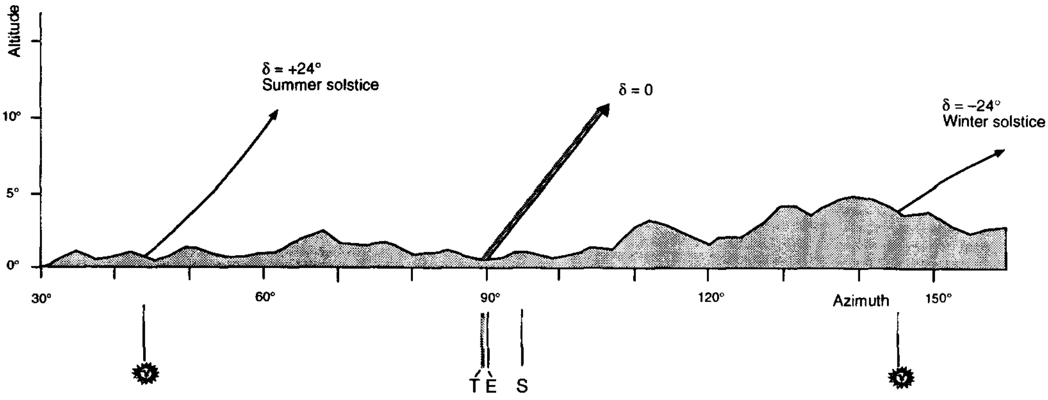

Figure 2. Possible 'mid-way' concepts yielding dates approximating to the modern concept of the equinox, for a hypothetical eastern horizon within the British Isles. The spatial mid-point between sunrise at the two solstices (sun symbol) is at *S*; while sunrise halfway in time between the solstices may be anywhere within the shaded area *T*. Sunrise on the day when the sun rises and sets in opposite directions will generally be different again, depending on the altitude of the western horizon. Sunrise at the equinox, corresponding to a declination of 0°, is *E*.

Furthermore, even if one of these mid-points was seen as important, it would not generally yield a date exactly corresponding to our equinox in any case (Fig. 2). A similar argument applies to the suggestion that significance might have been attached to the date when the sun rises and sets in opposite directions (see, e.g. Hoyle 1966, 271–2).

The fundamental point is that these concepts—the spatial mid-point between the solstices, the temporal mid-point between the solstices, and the day on which sunrise and sunset are opposite each other—bear no relationship whatsoever *on the conceptual level* to the modern astronomer's equinox. They have only been sought by modern investigators because they yield dates close to it. Even if any of these concepts was convincingly shown to have been of importance in prehistoric times, this would still not provide evidence that 'our' equinox was conceived and observed. The specificity of the equinox concept to Western science does not generally seem to be appreciated: this is evident, for example, in the remark 'The extremes were evidently what counted; the equinoxes were seemingly of lesser importance to early peoples' (North 1994, 2); and in the claims of equinoctial alignments that are still encountered quite frequently in the archaeoastronomical literature.[3]

The lunar standstills are another concept unlikely to have any meaning outside the framework of Western science. They represent the times when the limit curve of the moon's monthly motions itself reaches a limit, rather than anything directly observable;

[3] This does not, of course, preclude alignments upon sunrise or sunset at particular times of year, perhaps on the occasion of calendrical festivals, and such alignments are widely attested; the point is that our equinox would not occupy any special place in the range of possible festivals.

on the day when a standstill technically occurs the moon might actually rise or set anywhere on the horizon between the two corresponding limits, depending upon its position within the monthly cycle. What *might* be observable at major standstill is that (i) for a period of time, lasting some months, the moon can rise and set unusually far north and south; or (ii) the length of moonlight close to full moon is unusually long. (i) implies an awareness of the positions of the extremes but not necessarily of when the extremes will happen (Ellegård 1981, 105), and no corresponding observation can be made at minor standstill. (ii) may be more important for a community whose only effective illumination during the long winter nights was the moon (Thom 1967, 21). An awareness of this effect has been noted, for example, amongst a modern Irish farming community (Barber 1973, 37).

The northerly and southerly lunar limits have very different characteristics in pragmatic terms. The northerly limit corresponds to the full moon in midwinter, when the presence or absence of a near-full moon makes the difference between a long dark night and an illuminated night. The southerly limit is less consequential; whether or not there is a near-full moon on a short night close to midsummer, astronomical twilight ensures that the night is never very dark. Surprisingly, this important difference between the northern and southern lunar limits is rarely noted. Any symbolism relating to longer moonlit winter nights should relate to the northern major limit.

This discussion could be extended, but the point will already be clear that it may be very misleading indeed to use any 'recipe book' of astronomical targets that seem significant to us. Instead, in considering the possible astronomical significance of any alignment, it is better to quote a *declination* which defines a rising or setting line on the celestial sphere. The declination of any horizon point can be determined from the azimuth, altitude and latitude of the site, and the positions of any (periodic) celestial body at any time in the past can be calculated in terms of declination. By convention, the declination of the celestial north pole is +90°, that of the celestial equator is 0° and that of the celestial south pole is –90°. At the latitude of Stonehenge (51°·2), celestial objects with declinations between about –39° and +39° (the exact figures depend upon the horizon altitude in the north and south) will rise and set daily; those with higher declinations will circle in the northern sky, never setting, and those with lower declinations will never rise above the horizon.

In the literature on archaeoastronomy, declinations are often quoted to a precision of 0°·1 or even greater. However, the quality of the material evidence, together with the fact that the horizon around Stonehenge is relatively close (Cleal *et al.* 1995, 37) and devoid of prominent distant features interpretable as accurate foresights, do not justify considerations of declination to a precision much greater than the nearest degree, or approximately twice the apparent diameter of the sun or moon. To do otherwise is to risk obscuring any intentional, low-level astronomical effects with meaningless detail.

Tables 1–4 give the declinations of some prominent astronomical bodies and events, to aid discussion and interpretation. Table 1 gives the declinations of the solar and lunar

Table 1. Declinations of the solar solstices and lunar major and minor limits

Solar or lunar event	Declination (4000–1500 cal BC)
Moon: northern major limit	+28°
Sun: summer solstice	+24°
Moon: northern minor limit	+18°
Moon: southern minor limit	–20°
Sun: winter solstice	–24°
Moon: southern major limit	–30°

Table 2. Declination of the sun at intervals during the year

Days from summer solstice	Equivalent Julian calendar date, taking Jun 21 as the solstice	Approximate declination of sun (4000–1500 cal BC)
0	Jun 21	+24°
–27 / +30	May 25 / Jul 21	+21°
–59 / +61	Apr 23 / Aug 21	+12°
±92	Mar 21 / Sep 21	0°
–124 / +122	Feb 17 / Oct 21	–12°
–157 / +153	Jan 15 / Nov 21	–21°
–184 / +181	Dec 19	–24°

Table 3. Limiting declinations of the planets

Planet	Declination limits (4000–3000 cal BC)	Declination limits (2500–1500 cal BC)
Mercury	±31°	±31°
Venus	±27°	±27°
Mars	±26°	±26°
Jupiter	±25°	±25°
Saturn	±27°	±26°

limits already discussed. To a precision of 1° they do not change over the period 4000–1500 cal BC. Table 2 gives the declination of the sun at intervals during the year. Table 3 gives the limiting declinations of the planets; their motions are complex within these limits. Finally, Table 4 gives the approximate declinations of some of the brightest stars, which change significantly over the centuries owing to precession.

The list is not meant to be in any way exhaustive, but merely to give an idea of some of the possibilities. There are examples of people for whom other features in the sky are of greater importance than the brightest stars, such as dark or light patches in the Milky Way (e.g. Urton 1981). Non-periodic events such as novae and comets are not included. Stars at the latitude of Britain rise and set at a shallow angle and are generally not visible until they reach an altitude of several degrees (Schaefer 1993), so care must be taken in postulating stellar relationships.

Table 4. Approximate declinations of those of the 22 brightest stars in the sky (magnitude greater than 1·5) that were visible from the latitude of southern Britain at different dates between 4000 and 1500 cal BC, quoted to the nearest degree, and ordered by the declination in 2500 cal BC. Also included are two other formations prominent in northern hemisphere skies: Orion's belt (the declination given is for the centre star, ε Ori) and the Pleiades. Bracketed values represent stars not visible at the date in question

Star	Apparent magnitude	Brightness ordering	4000 cal BC	3000 cal BC	2500 cal BC	2000 cal BC	1500 cal BC	*AD 2000*
Arcturus (α Boo)	–0·1	4	+54°	+49°	+46°	+43°	+40°	*+19°*
Vega (α Lyr)	0·0	5	+47°	+44°	+43°	+41°	+40°	*+39°*
Deneb (α Cyg)	1·3	19	+37°	+36°	+36°	+36°	+37°	*+45°*
Capella (α Aur)	0·1	7	+20°	+26°	+29°	+31°	+34°	*+46°*
Pollux (β Gem)	1·2	17	+18°	+23°	+25°	+26°	+28°	*+28°*
Regulus (α Leo)	1·4	21	+22°	+24°	+24°	+24°	+24°	*+12°*
Spica (α Vir)	1·0	16	+19°	+15°	+13°	+11°	+8°	*–11°*
Altair (α Aql)	0·8	11	+13°	+10°	+9°	+7°	+7°	*+9°*
Procyon (α CMi)	0·4	8	–1°	+3°	+5°	+6°	+7°	*+5°*
Pleiades			–6°	0°	+3°	+5°	+8°	*+24°*
Aldebaran (α Tau)	0·8	12	–11°	–5°	–2°	0°	+3°	*+16°*
Betelgeuse (α Ori)	0·8	13	–13°	–8°	–5°	–3°	–1°	*+7°*
Antares (α Sco)	0·9	15	+2°	–4°	–7°	–10°	–12°	*–26°*
Orion's belt			–23°	–17°	–15°	–12°	–10°	*–1°*
Sirius (α CMa)	–1·5	1	–26°	–23°	–21°	–19°	–18°	*–17°*
Rigel (β Ori)	0·1	6	–31°	–26°	–23°	–21°	–18°	*–8°*
Adhara (ε CMa)	1·5	22	–37°	–34°	–32°	–31°	–30°	*–29°*
Mimosa (β Cru)	1·3	20	–30°	–34°	–36°	[–38°]	[–41°]	*[–59°]*
β Centauri	0·6	10	–29°	–34°	–36°	[–39°]	[–41°]	*[–60°]*
α Centauri	–0·1	3	–31°	–36°	–38°	[–41°]	[–43°]	*[–61°]*
Acrux (α Cru)	0·9	14	–34°	–38°	[–40°]	[–42°]	[–44°]	*[–63°]*

Evidence for astronomy at and around Stonehenge

Within the conceptual framework and with the background data just described, we can now proceed to evaluate some of the main evidence for astronomy in the archaeological record at and around Stonehenge.

The Early Neolithic

Long barrows have been claimed to provide evidence for symbolic astronomy during this period. Burl (1987, 26–8) has examined 65 examples on Salisbury Plain and finds that their orientations fall consistently between NNE and south. Some of these are shown in Fig. 3. Burl estimates that 52 examples lie within the solar arc, concluding that 'as no fewer than 13 of the 65 barrows face either to the north or south of this narrow arc, it is unlikely that their builders had aligned them on the sun' (ibid., 28). On the other hand, 59 examples lie within the wider lunar arc, from which Burl concludes that 'it seems quite probable that they were intentionally aligned on the rising moon' (ibid.). These conclusions are critically dependent upon the outermost orientations in the sample, and the distinction between 6 out of 65 outside the lunar range and 13 out of 65 outside the solar range seems too small to justify strong support for the lunar hypothesis and rejection of the solar one. Indeed, Castleden (1993, 42) concludes from the same data that the symbolism was solar.

North (1994, 2), on the other hand, suggests that the long barrows were aligned upon bright stars rather than the sun or moon, a theme that is to be developed in a new book on Stonehenge (pers. comm.). He also introduces 'three dimensionality', arguing that the height of a long barrow was important, perhaps acting as a false horizon. This idea may be appealing but the material record can give little support to it because of the state of the monuments that come down to us; there is already a great deal of room for manoeuvre in fitting bright stars to orientations when the date is uncertain (Cooke *et al.* 1977, 130), and the uncertainties in the original heights of the barrows as well as the uncertainties in their precise orientation simply compound this.

Nonetheless, it remains as a possibility that the five southerly-facing barrows that have no solar or lunar explanation might be oriented upon the Southern Cross and Pointers, which in the early fourth millennium cal BC hung a few degrees up in the southern sky (see Table 4) before dawn in early winter, and earlier in the night in late winter and spring, where they would have formed a prominent feature in the landscape. Another possibility, in view of the fact that only one barrow is oriented to the north of the lunar arc[4] and a relatively small number to the north of the solar arc, is that the important thing was to catch the sun or moon climbing in the sky rather than at its actual point of rising, a suggestion also put

[4]. The statement that only one barrow is oriented to the north of the lunar arc (Burl 1987, 28) is contradicted by the table (ibid., table 4) where four barrows are listed as being oriented NNE. The azimuth of the northern lunar limit is, by Burl's own estimate, 41°, yet NNE covers the azimuth range 11° to 34°, so at least four barrows would appear to be oriented to the north of the lunar limit. We assume here that the table is in error.

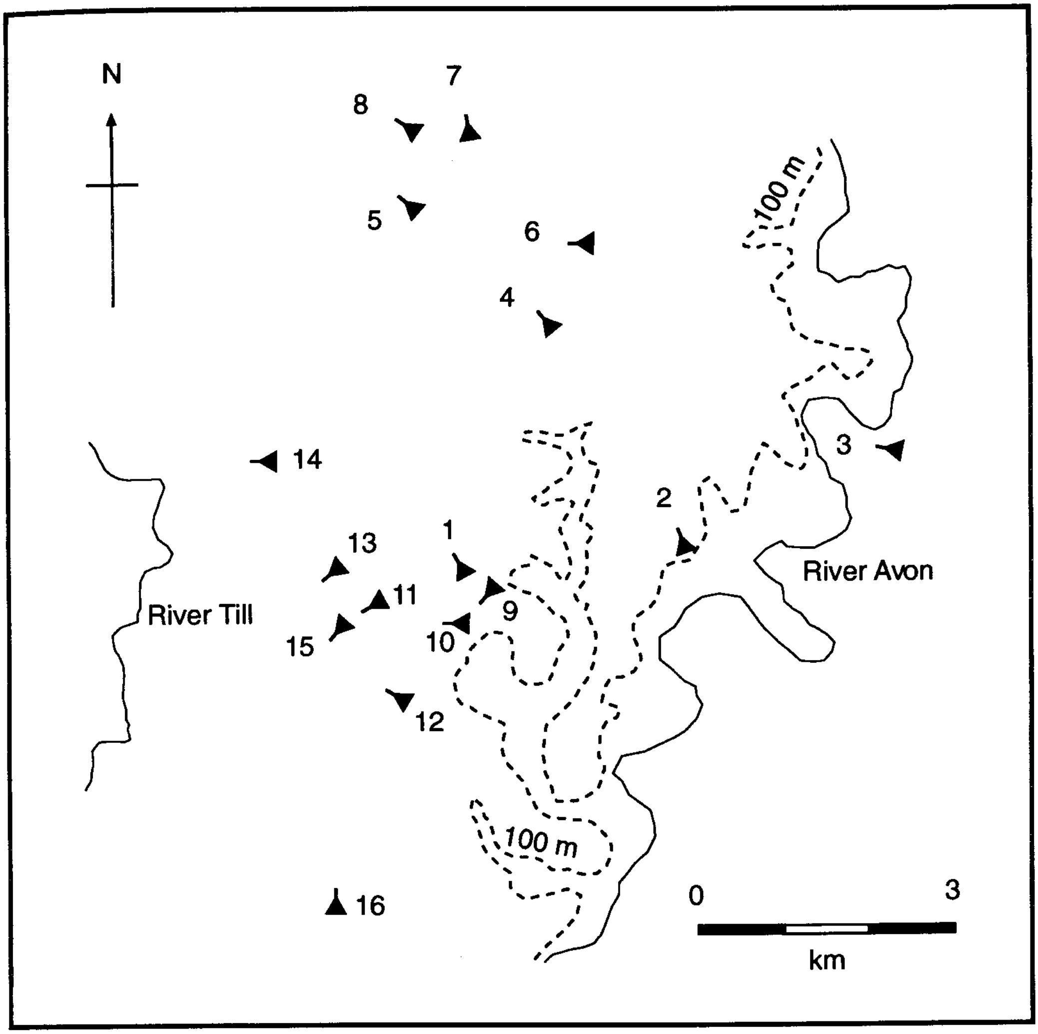

Figure 3. The distribution and orientation of long barrows in the vicinity of Stonehenge, after Burl (1987), fig. 3.

forward in the context of the orientations of certain groups of tombs in southern Europe (e.g. Hoskin *et al.* 1995).

Despite the uncertainties in its explanation, the orientation trend amongst the long barrows is unequivocal and further work is needed in order to move towards more convincing explanations. These may well feature the sun, moon or stars but might also invoke symbolism associated with sacred points and features in the natural landscape, the visibility of other long barrows and so on.

Stonehenge 1

The first question to arise in the Middle Neolithic is whether the choice of a site for Stonehenge 1 was influenced by any astronomical considerations. It has been suggested that the monument was placed so as to be viewable from a distance (Cleal *et al.* 1995, 476–7), yet its location has no obvious distinguishing features apart from the site itself (ibid., 37). It is possible that survey work might reveal special properties possessed by the actual site and not by other sites in the vicinity. None is known at present.

If the earth bank and ditch were the first features at Stonehenge, preceding the post-holes in the north-eastern entrance and elsewhere (ibid., 109), then the first recognisable orientations at the site were those of the ditch and bank entrances. The horizon declinations of the sides of the north-eastern entrance, and those of the southern causeways, as viewed from the centre, are shown in Fig. 4. The axis through the centre of the north-eastern entrance yields a declination (+27°) close to the northern lunar limit, but the left-hand side is well to the left of the northernmost possible lunar rising position. The sun is just shut out, at least as viewed from the centre of the site, so that Stonehenge 1 does not appear (cf. Burl 1987, 73) to reflect the practice found in the early stone circles of Cumbria (Burl 1988) of having two entrances, one in a cardinal direction and one defining a calendrical event by the rising or setting of the sun.

Stonehenge 2

One idea that has persisted since the 1960s and appears in recent literature (Burl 1987, 67–9; Castleden 1993, 54–8) is Newham's (1966; 1993, 20–3) that the entrance causeway post-holes were used to mark moonrises over several 18·6–year cycles, and hence to set up an exact orientation upon the northern lunar limit. Despite this, and despite two different possibilities for the detailed interpretation, the idea is untenable. Newham himself proposed that each of the six rows (across the entrance) represented observations within

Table 5. Orientations of entrances in Phase 1 and the possible post-holes in C44, probably attributable to Phase 2, from the centre of the site. The azimuths have been judged from Cleal *et al.* (1995, fig. 36) except for the post-holes in C44, for which ibid. (fig. 66) was used. In this and subsequent tables a horizon altitude of 0°·5 has been assumed throughout for convenience. The quoted declination should be within 0°·5 of the true value for any horizon between 0° and 1° in altitude, and Abney Level measurements taken in May 1996 confirmed that the relevant horizon altitudes vary between 0° 0' and 0° 50'

From	to	Az	Dec
Phase 1/2 centre	100 terminal	37	+30
	mid-line (axis)	43	+27
	1 terminal	49	+24
	Southern causeway (mid)	174	–39
	Blocked causeway (mid)	202	–36
	Post-holes in C44	138	–28

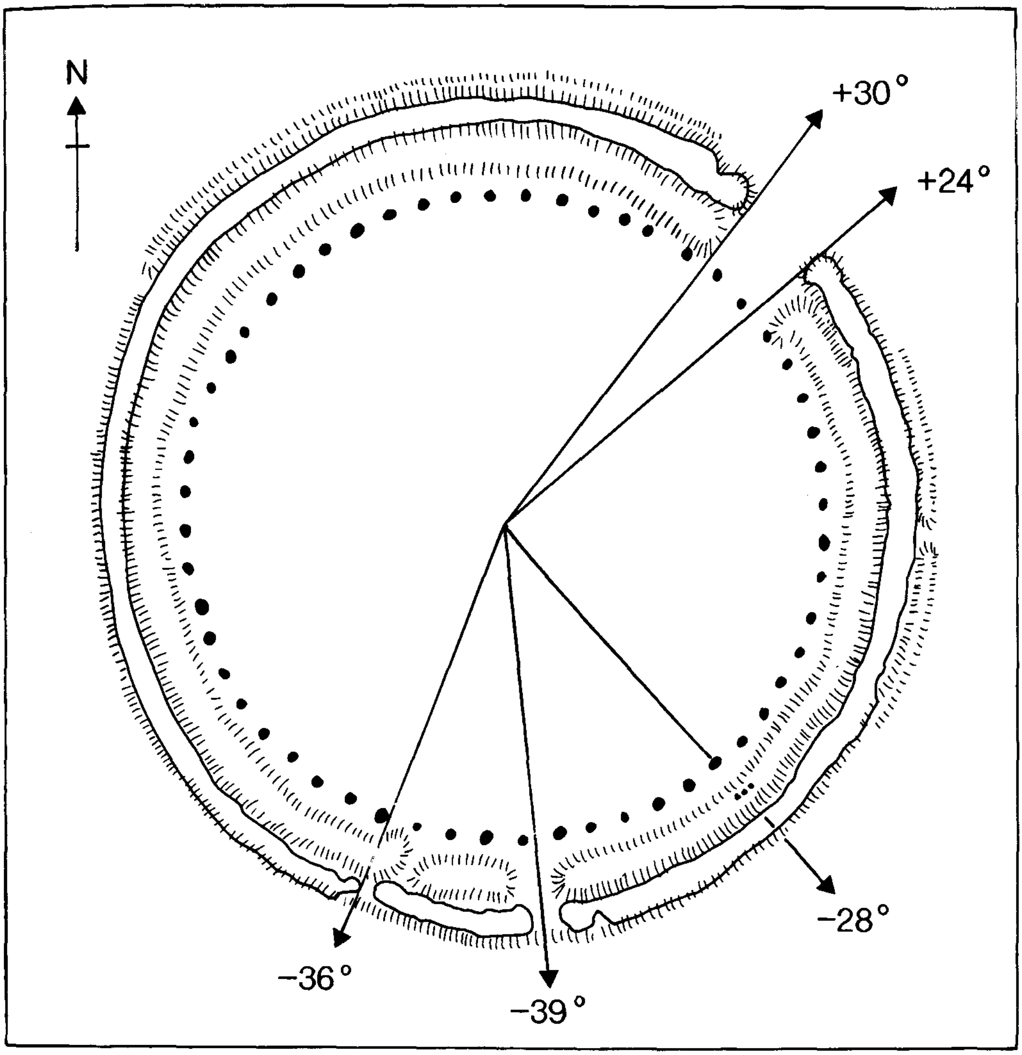

Figure 4. Stonehenge 1. Five of the orientations listed in Table 5 are shown together with the horizon declination estimated for a horizon at altitude 0°·5. The orientation of the post-holes in C44 is probably ascribable to Phase 2 but is included here for convenience. Based on Cleal *et al.* (1995, fig. 256). The arrows and 'indicated declinations' on this and later figures are merely intended to help the reader to assess the astronomical potential of a given direction, not to imply that observations were necessarily made of horizon phenomena, nor that they were made from a certain position along the arrow as 'sightline'.

one lunar cycle, of 'successive midwinter full moon risings'. The two problems with this explanation are that such observations should be clustered towards the left-hand (north-west) end, closest to the northern major limit (Heggie 1981, 202) and that the poles would have needed to stand for over 112 years, during which time they would inevitably have

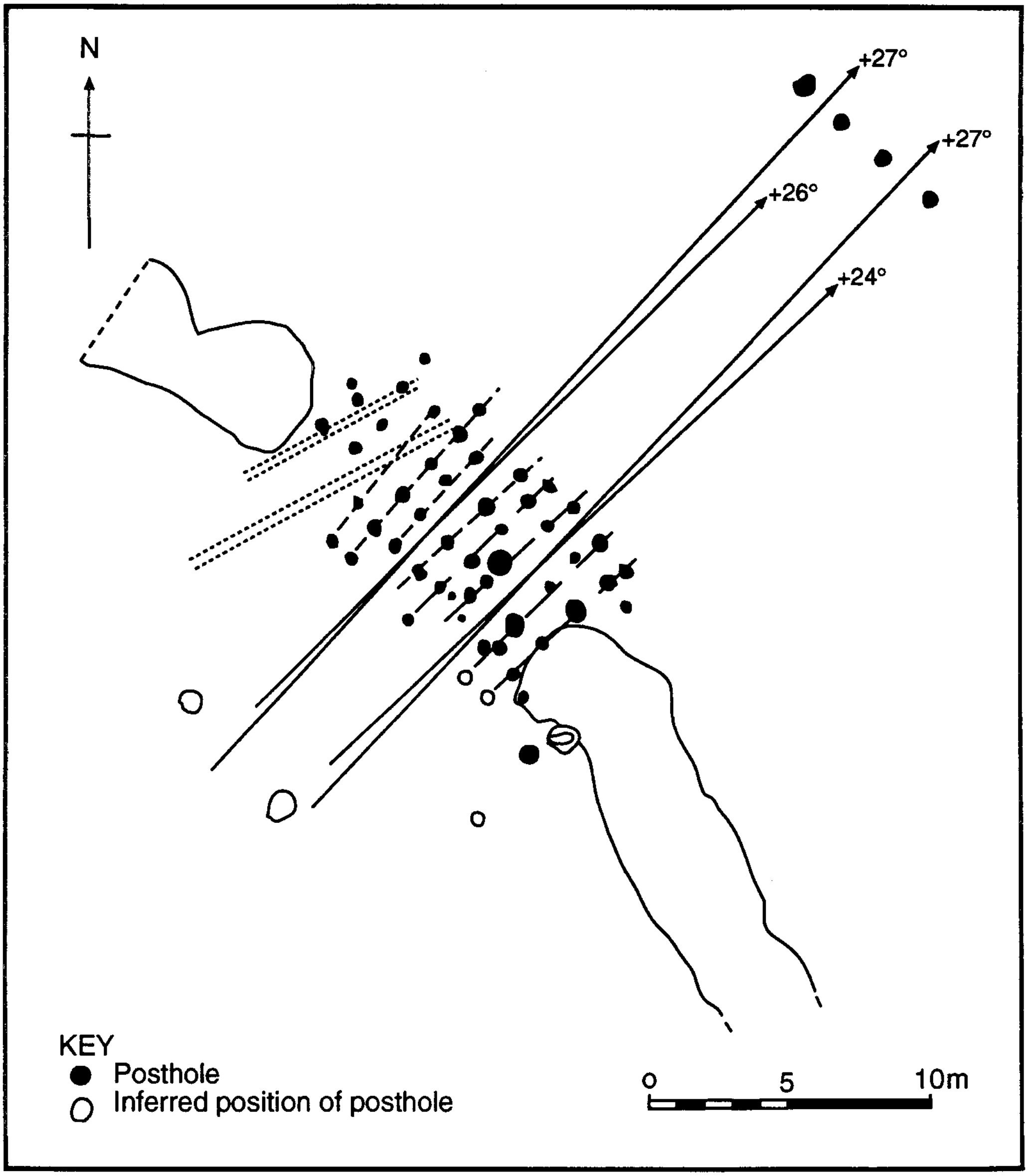

Figure 5. The north-eastern entrance during Phase 2. The entrance corridor orientations listed in Table 6 are shown together with the horizon declination estimated for a horizon at altitude 0°·5. Based on Cleal *et al.* (1995, fig. 68).

decayed. This problem forced Burl (1987, 68) to concede that 'perhaps exceptional accuracy was not an important consideration'. The other possible interpretation is that the posts were erected on successive nights or months around a single standstill, but here one runs into the sorts of problems widely discussed in regard to Alexander Thom's 'megalithic lunar observatories', such as the need for extrapolation (Ruggles 1981). Burl points out as confirmatory evidence that the holes on the left-hand (north-west) edge of the grid of post-holes line up with major northern moonrise and those on the right with midsummer sunrise, but the latter seems problematic rather than confirmatory for the lunar theory: why have such a sharp cut-off at midsummer sunrise? This is not 'as could be expected if that was where the observers began their sightings' (Burl 1987, 68), because at midsummer the moon is new, and hence invisible, when it rises in the NE.

The idea that the entrance post-holes represented attempts to fix the lunar orientation of the monument also depends on the assumption that the entrance post-holes pre-dated the north-eastern entrance of the ditch and bank (e.g. Castleden 1993, 54), a scenario that is now considered unlikely but which can not be ruled out (Cleal *et al.* 1995, 109). Castleden (1993, 55) suggests that the post structures blocked access through the north-eastern entrance, which was used for observations outwards, while people accessed the interior of the monument via the (remaining) southern entrance and causeway. Even if the entrance post-holes were not precise markers, and even if they did post-date the bank and ditch, it is still possible to argue that their lunar orientation did have significance and meaning, but possibly within the context of much less organised observations.

The prevailing view from the current archaeological evidence is that the post-holes represent structures that restricted access to the north-eastern entrance down to two narrow 'entrance corridors' (e.g. Cleal *et al.* 1995, 484) (Fig. 5).[5] If it is surmised that the earlier ditch and bank entrance was deliberately aligned upon the limiting moon, it is interesting to see whether any lunar symbolism was preserved in the later structures. The two proposed passageways line up with gaps between the 'A' post-holes further out, and are in the same orientation as the Phase 1 axis, yielding a horizon declination of +27°. These lines do not, however, pass through the centre of the monument, and viewing the passageways from the centre yields orientations further to the east, the right-hand one lining up on the midsummer sunrise. The details are given in Table 6.

Table 6. Orientations of the entrance corridors in Phase 2. The azimuths have been judged from Cleal *et al.* (1995, fig. 66)

From	to	Az	Dec
Phase 1/2 centre	Left corridor to left A-hole gap	43	+27
	Right corridor to right A-hole gap	43	+27
	Left corridor, from centre	45	+26
	Right corridor, from centre	49	+24

[5] Another possibility is that they represent no more than a planked bridging structure to protect the entrance while the sarsens were being dragged through prior to their construction (J. Richards and M. Whitby, this volume).

There is one item of evidence that may strengthen the now much weakened idea that the entrance post-holes did have significance in relation to the moon. Three small post-holes were reported under the bank on the south-east side of the monument, in section C44 (see Cleal *et al.* 1995, 94) (Fig. 4). They appear to date to Phase 2, but may date to Phase 1 or even before (ibid., 107). Their orientation from the centre of the Aubrey Hole ring yields a declination of –28°, which is close to southern major moonrise. It is still possible that the ring of Aubrey Holes, these three post-holes, and all the post-holes at the north-eastern entrance pre-date the enclosure (ibid., 107). The possibility that they had a function as markers against which the motions of the moon could be observed (which is different from saying that they functioned as precise markers of the rising positions themselves) is one that can not be entirely discounted.

Finally, Burl (1987) and Castleden (1993, 218–20) have argued that the spatial distribution of deposits of bone, antler and pottery and stone during Phases 1 and 2, in the Aubrey Holes and in the enclosure bank, reflects strong astronomical symbolism. For example, a cluster of nine cremations near Aubrey Hole 14 marks moonrise at the southern lunar limit. Burl (1987, 103) argues that such offerings demonstrate the transition from a lunar to a solar tradition; Castleden (1993, 282, note 78) considers that the moon and sun were worshipped together. Such interpretations are hampered more than most by the lack of evidence from unexcavated parts of the site, and now need to be reassessed in the light of the integrated primary data now published (Cleal *et al.* 1995, ch. 9).

Stonehenge 3i/3a

In relation to the equivocal evidence of lunar symbolism in Phases 1 and 2, the evidence of solar solstitial orientation in Phase 3 is relatively clear cut, at least in relation to the main axis.

Within the bluestone setting of Stonehenge 3i, the Altar Stone, placed on the south-west side, appears to have been the centre of attention. Whether it stood in feature WA 3639 (Cleal *et al.* 1995, 188) or WA 3359 (ibid., 268), or whether there was a pair, it was placed on an axis that yields a declination of +24° to the NE and –24° to the SW (Fig. 6). The axis, while not precisely defined, is precise enough that we can say for certain that stone 97 and the Heelstone straddle it and bracket the midsummer sunrise

Table 7. Orientations of the axis and station stone rectangle in Phase 3i/3a. The Phase 3i axis has been estimated from Cleal *et al.* 1995, fig. 80. The station rectangle orientations have been determined from Cleal *et al.* 1995, plan 1 together with fig. 164 (for stone 94) and fig. 165 (for stone 92)

From	to	Az	Dec
Phase 3 centre	Phase 3i axis to NE	49	+24
	Phase 3i axis to SW	229	–24
	Phase 3a: 93–94	49	+24
	Phase 3a: 93–91	116	–16
	Phase 3a: 93–92	140	–29
	Phase 3a: 92–91	50	+24

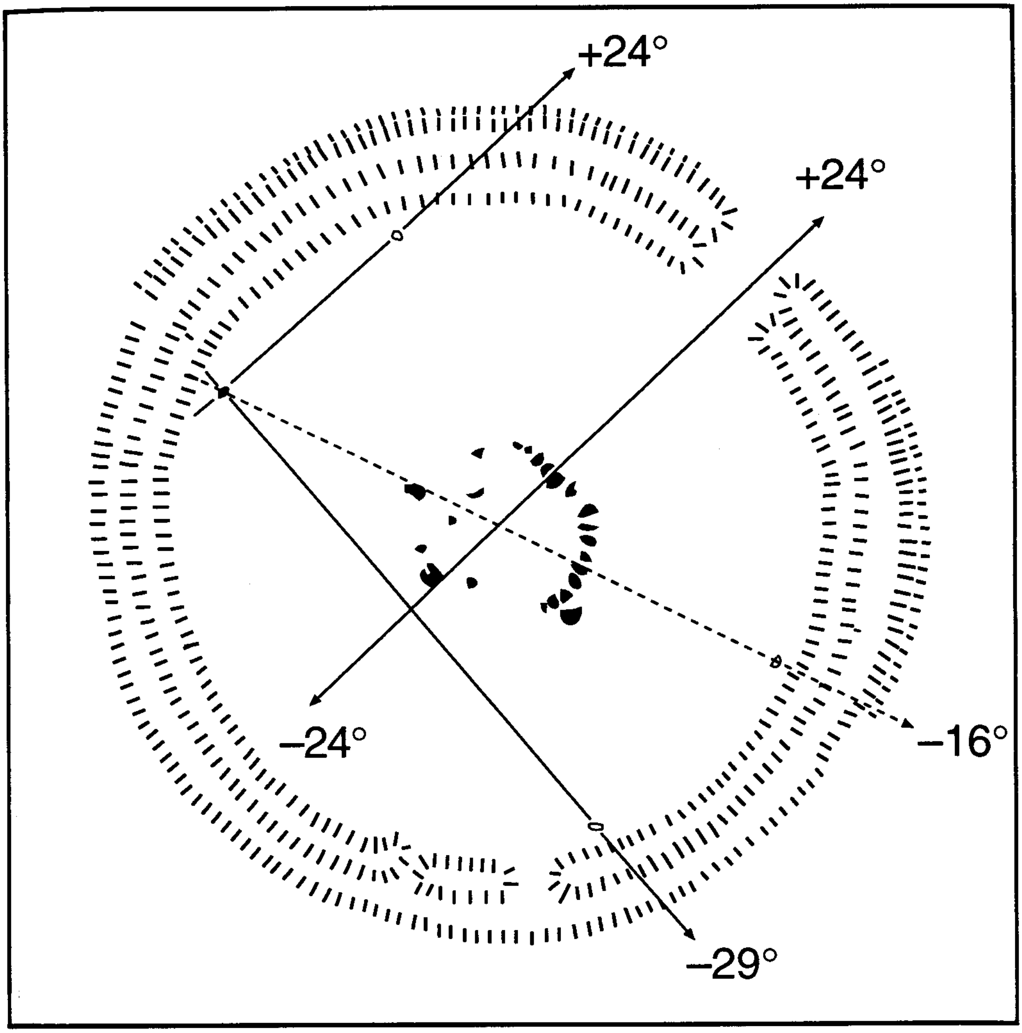

Figure 6. Stonehenge 3i/3a. Five of the orientations listed in Table 7 are shown together with the horizon declination estimated for a horizon at altitude 0°·5. They comprise the axis through the Altar Stone in both directions and various alignments between the station stones. Based on Cleal *et al.* (1995, fig. 256).

(Cleal *et al.* 1995, 268–70). The entrance from the NE now leads to a focus in the SW. It is possible that the significant association was the alignment of the Altar Stone in the direction of midwinter sunset, or the play of the light from the rising midsummer sun upon its north-east face, or both.

The station stone rectangle in one direction is aligned with the Phase 3i axis, but in the other direction, to the NW and SE, it is aligned upon declination ±29°, corresponding roughly to major limiting moon rising in the south (full in summer) or setting in the north (full in winter), a fact known since the 1960s. The question here, given that the solstitial axis is taken to be intentional, is whether the coincidence that the moon came very occasionally to rise or set in the direction at right angles to the axis simply passed unnoticed, or whether it was actively exploited. If so, then solar and lunar symbolism was being incorporated side by side.

The question of why the station stones were placed in a rectangle and not a square, has given rise in the past to the tentative suggestion that the WNW-ESE diagonal might have astronomical significance; however its declination, –16°, has no obvious explanation in terms of the sun or moon and in any case the diagonal passed across the centre of the site where it might have been partially obscured by the bluestones, and certainly would have been obscured by the later sarsens (Castleden 1993, 134).

The axis shift at the beginning of Phase 3 is generally assumed to represent a change to solar orientation,[6] but alternative explanations have been put forward. For example, North (priv. comm.) argues that the axis change was made because of precessional drift, which implies that it was the stars, rather than the sun or moon, that were of interest. Is it possible that bright stars were the cause of the axis shift? The question is important because of its bearing on the idea of continuity (see below). The only bright stars visible through the north-eastern entrance in 3000 cal BC were Deneb—which would already be at an altitude of 7° by the time it reached the left-hand side of the entrance, rising to 13° altitude by the time it reached the right-hand side—and Capella, which would rise within the entrance but would probably already have passed to the right before rising sufficiently to be visible. Deneb had only lost a degree in altitude by 2500 cal BC, and Capella would be becoming more visible rather than less so, rendering an axis shift unnecessary. Thus there is no evident reason why observations of bright stars, at least rising in line with the entrance, should motivate an axis change.

Further developments at Stonehenge 3

At the periphery, there are many uncertainties due to the lack of stratigraphic relationships and reliable sequencing; for example, it is not certain that the Heelstone and stone 97 actually stood together (Pitts 1982, 82). However, it seems reasonable to make the tacit assumption that they did (Cleal *et al.* 1995, 268).

A crucial question at this stage is whether the Slaughter Stone and its companion formed the middle two of a line of four stones placed across the entrance, as argued by Burl (1994, 90) on the basis of a postulated fourth stone to the south-east of the original position of the Slaughter Stone. Burl's argument is disputed by Cleal *et al.* (1995, 285–7).

6. On p. 20 of the 1995 edition of the English Heritage handbook on Stonehenge and Neighbouring Monuments is the statement that 'the entrance was ... reorientated slightly during the lifetime of Stonehenge to compensate for astronomical variation in the midsummer sunrise over many centuries'. This is erroneous. The variation in the solstice position is too small (only about 30 arc minutes, or the sun's own diameter, over 4000 years) and the axis shift is too great.

They also (ibid., 139) dispute Atkinson's (1979, 73) contention that some 7 m of the ditch to the south-east of the north-east entrance was deliberately backfilled, to bring the width of the earthwork entrance into line with the width of the avenue. Finally, they argue that the two gaps between stones *D* and *E*, and *E* and the Slaughter Stone, mimicked in stone the earlier two narrow passages through the entrance posts.

This new interpretation of the archaeological evidence does not affect the orientation of the 'solar corridor' passing between *E* and the Slaughter Stone, close to *C* and *B*, and between the Heelstone and its companion (Burl 1994, 91–3). It does, however, result in a considerable shift of emphasis, because the entrance along the solar corridor is now one of two (Fig. 7): the second entrance, to the NW, passes between *D* and *E* and has an orientation closer to the old lunar alignment, with declination +27°. Furthermore, the emphasis upon the 'solar corridor' as the central line of the avenue is countered by the fact that between a third and a half of the width of the avenue at its end by the entrance is still blocked by the ditch.

Yet the dramatic effect of midsummer sunrise (Burl 1994, 91) is unaffected. The sarsen circle and horseshoe having been constructed on the same axis as the earlier bluestone setting, the light of the rising midsummer sun would have passed between the Heelstone and its companion, between *E* and the Slaughter Stone, between stones 1 and 30 of the sarsen circle, and between stones 31 and 49 of the inner bluestone ring, into a space considerably more confined than at previous phases of the monument, in which much of the view of and from the outside world had been cut off by the large sarsens. The result must have been a very exclusive spectacle, in which light and shadow played an important part, the sun's light 'pouring down a thin tunnel of stone like the passage of a chambered tomb' (ibid.). The new archaeological interpretation does not affect this but implies that entrance to the interior was more restricted to people, perhaps emphasising the exclusivity of the spectacle.

One feature is worthy of comment in Phase 3iv: the anomalous, radial orientation of stone 33e (Cleal *et al.* 1995, figs 117 and 231), which appears to have provided some sort of additional access into the interior (Cleal *et al.* 1995, 486). Its azimuth from the centre is 137° and its declination –27°, close once again to the southern major limit of the moon.

The Bronze Age barrows

During the Early Bronze Age several dozen round barrows were built within sight of Stonehenge, many of them situated on a ridge forming a 'false horizon' a little over 1 km from the monument (Cleal *et al.* 1995, 35–7). If certain celestial bodies or events were of significance when viewed from Stonehenge, might not some of the most prestigious barrows be located in relation to those events as seen from Stonehenge? In Figure 8 we show the 'envelope of visibility' formed by this near horizon, together with the barrows, and add a few examples of orientations from Stonehenge to particular barrows showing the declinations of the horizon behind them. The declinations of intermediate

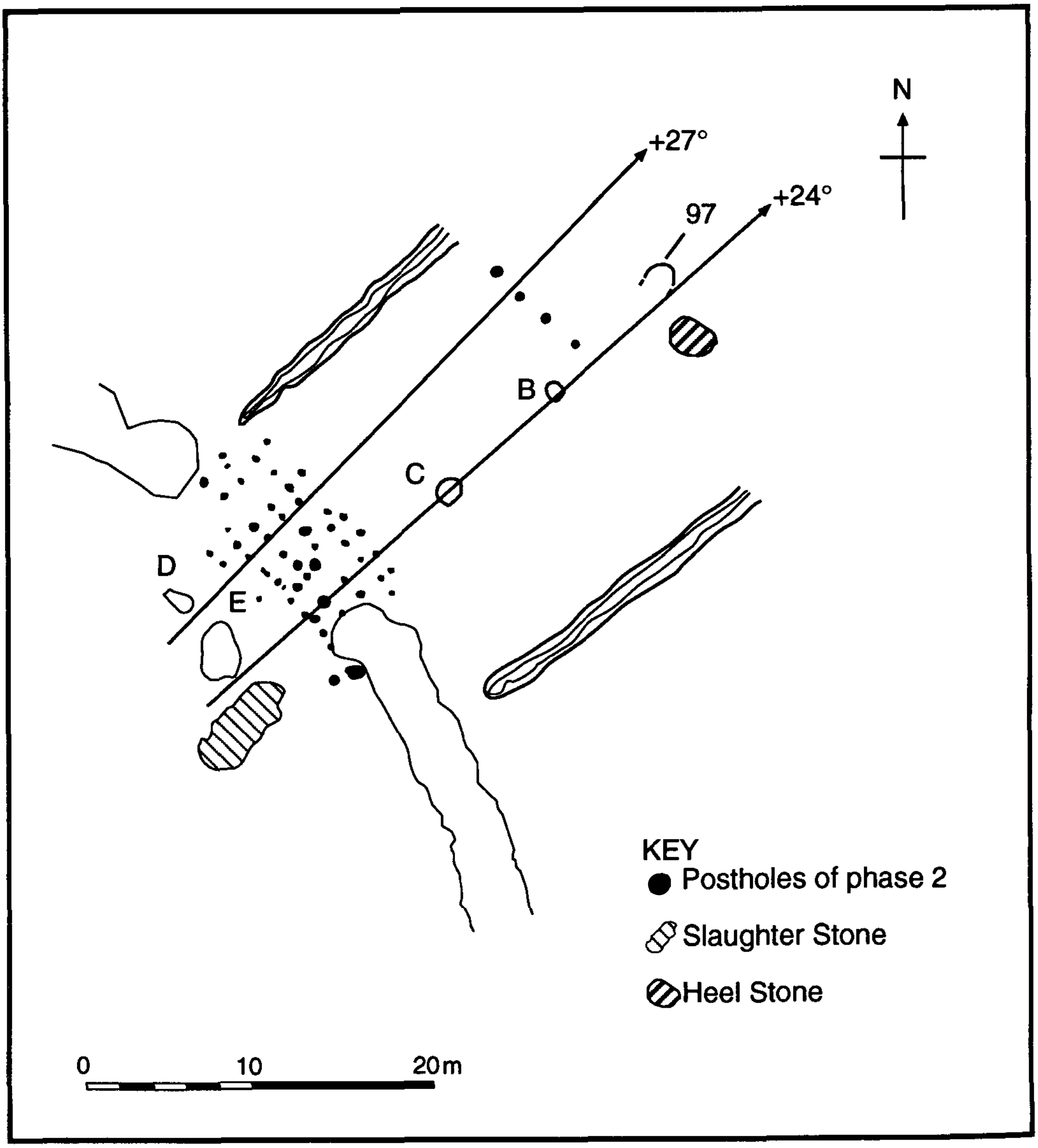

Figure 7. The north-eastern entrance during Phase 3. The orientations listed in Table 8 are shown together with the horizon declination estimated for a horizon at altitude 0°·5. They comprise the 'solar corridor' axis and the line through the gap between *D* and *E*. Based on Cleal *et al.* (1995, fig. 156).

barrows can be estimated by extrapolation. There is no obvious evidence that the stretches most thickly populated with barrows occupy particularly noteworthy declination ranges. Is there, then, any evidence that the most flamboyant examples were placed in particular spots that acquired special significance through being aligned with astronomical targets

Table 8. Orientations of the 'solar corridor' and other features in Phase 3a-b-c. The axis is determined from Cleal *et al.* 1995, fig. 79. The centre-to-D/E alignment is determined from this in combination with Plan 1

From	to	Az	Dec
Phase 3 centre	Centre to gap between D and E	43	+27
	'Solar corridor' axis	49	+24

beyond? The only one marked that has an astronomical correlation of obvious significance is G15, which aligns with the midwinter sunset, but whether this is because of the solstitial alignment, whether it was placed in line with the Stonehenge axis, or whether its position arose through the chance combination of other factors, is unknown.

Discussion

Stonehenge astronomy in context

The preceding discussion has tended to concentrate upon areas where the archaeological evidence bears upon astronomical ideas, in particular reinforcing or modifying existing ideas. But how does the astronomical evidence bear upon archaeological ideas? We briefly identify two areas of current debate where it may have some direct relevance, and then make some suggestions for future research.

The first area of debate is the extent to which Stonehenge emphasised continuity, representing slow-changing ritual practice during a time of otherwise rapid change (Bradley 1991; Cleal *et al.* 1995, 486–7). Can astronomy cast any light on this? It surely has the potential to do so, because authors such as Burl (1987) have emphasised a change from lunar symbolism to solar symbolism, and this could imply that some fundamental changes in ritual practice and tradition accompanied the transition from Stonehenge 2 to Stonehenge 3.

The evidence for intentional lunar orientation of Stonehenge 1 and 2 from the various structures does not seem strong, even if one is prepared to argue that the entrance post-holes preceded the ditch and bank, although the evidence from spatial patterns of deposition, when reassessed in the light of the new corpus from the twentieth-century excavations, may bear strongly upon this question. There is certainly no compelling evidence for solar orientation during this period, yet the evidence is quite convincing when we reach Stonehenge 3, especially with regard to the 'solar corridor' into the sarsen circle, despite the uncertainties in much of the archaeological evidence. This does seem to imply that a change in emphasis towards solar symbolism took place at the beginning of Stonehenge 3, and very probably that the change of axis is symptomatic of that change.

Yet there are also hints of continuity. The three post-holes under the bank in C44, the cluster of cremations near Aubrey Hole 14, the NW-SE orientation of the station stone rectangle, and possibly even the reorientation of bluestone 33e, do hint at a persistent

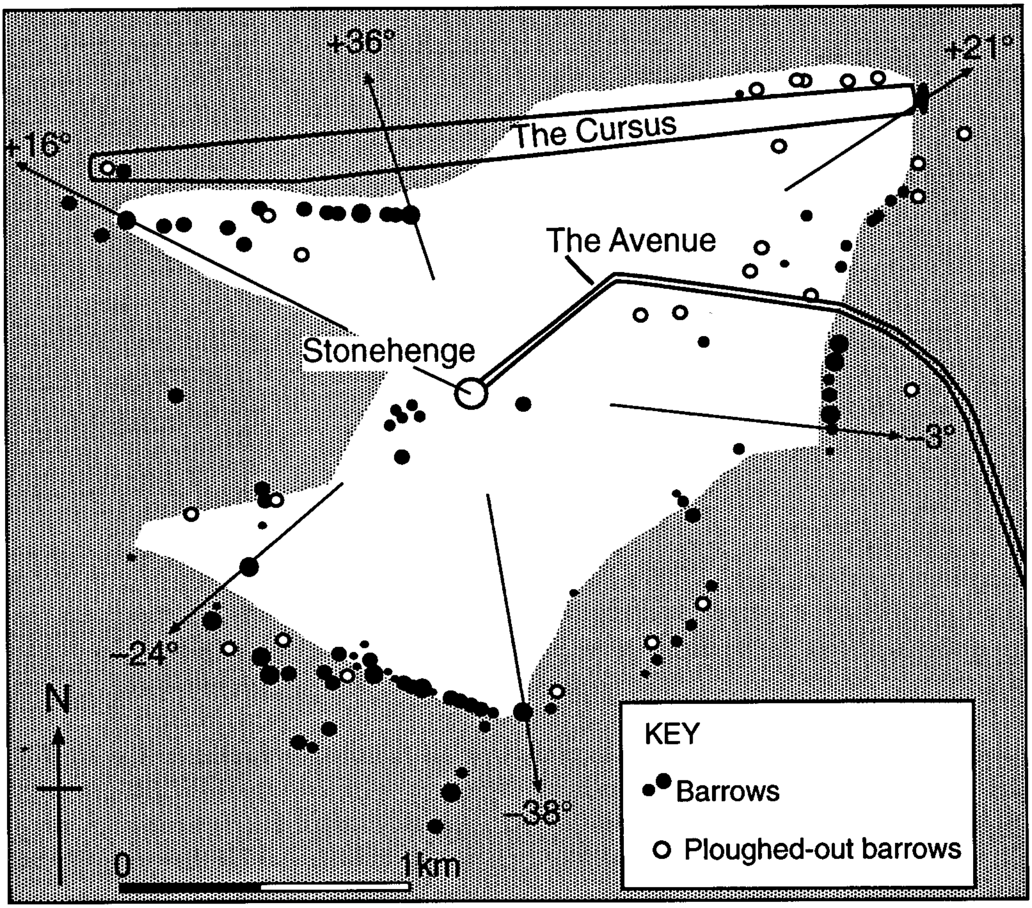

Figure 8. Stonehenge 3. The 'envelope of visibility' formed by the near horizon (unshaded) as seen from Stonehenge, showing barrows on and within the near horizon. The orientations listed in Table 9 are shown together with the horizon declination estimated for a horizon at altitude 0°·5. Based on Cleal *et al.* (1995, fig. 21).

interest in orientations aligned upon moonrise within two or three degrees of (and always to the north of, i.e. within the lunar arc) the southern major limit. Likewise, the orientation of the entrance of the Stonehenge 1 ditch and bank, the entrance post-holes with their two passages aligned upon gaps in the A holes, and possibly also the left-hand entrance gap in Phase 3, between stones *D* and *E*, are all aligned within two or three degrees of the northern major limit. Most convincing perhaps is the station stone rectangle, but perhaps also in stone 33e and stones *D* and *E*, come hints that lunar symbolism continued into the latter stages.

The second area of debate might clarify this. The question here is to what extent the later phases of Stonehenge were intended to restrict access, and the social implications of this. As far as astronomical observations are concerned, we can identify different degrees

Table 9. Orientations and declinations of selected round barrows as viewed from Stonehenge

From	to	Az	Dec
S/h centre	(S/h Cursus E end and earlier long barrow)	56	+21
	King Barrow Gp S end	95	–3
	Norm. Down Gp E end	168	–38
	Norm. Down Gp W end (G15)	230	–24
	Monarch of the Plain (G55)	296	+16
	Cursus barrows, E end (G43)	340	+36

of accessibility: a moonrise or sunrise, on a particular occasion such as the solstice, might be observable by many hundreds of people, not all within the enclosure. But moonrise or sunrise in relation to nearby markers—moonrise behind the entrance timber posts or sunrise between the Heelstone and its companion—might be directly viewable only by a few individuals inside the enclosure, within a fairly restricted space. And the privilege of witnessing phenomena such as the midsummer sun's light shining along the 'solar corridor' and into the centre of the sarsen monument, or shadow effects at midwinter sunset, might have been available to very few. It can be argued that the nature of astronomical observations gets gradually more exclusive, while access to the interior becomes more controlled (Burl 1987, 205; Cleal *et al.* 1995, 485).

Drawing these threads together suggests some tentative working hypotheses. First, there *was* lunar symbolism in Stonehenge 1 and 2, and there are hints that some of it may have carried through to Stonehenge 3. It was in the form of orientations upon the rising moon within two or three degrees of its major limits, both in the north and south. The posts in the north-eastern entrance did not function as precise markers of lunar rising positions, and they may have served to restrict access through the entrance, but they may also have served as markers against which the moon could be more casually observed.

Second, access to solar phenomena seems to have been restricted. Midsummer sunrise and midwinter sunset light and shadow effects would only have been visible to a privileged few in the interior. Third, this contrast between the generally more public access to lunar phenomena and more restricted access to solar ones is reminiscent of both the small, open ritual monuments such as the recumbent stone circles and short stone rows, built by the score in northern and western Britain and Ireland in the Early Bronze Age, where studies of groups of sites yield statistical evidence of preferential orientation upon the moon; as well as large chambered tombs such as Newgrange and Maes Howe, where solar light phenomena are confined within spaces with restricted access.

Concerning astronomy and Stonehenge, it will be clear that on the basis of the evidence currently available very little can be said with any great degree of confidence. Part of the problem is the nature of astronomical data, which either need to be collected from a large enough group of different cases for trends to be isolated statistically, or specifically to inform—and thereby to reinforce or weaken—a contextual argument. Most archaeologists are not in the habit of collecting declination data as part of field survey; yet any phenomenological study of the landscape is surely enriched by taking account of the appearance of the sky.

Future directions

In 1982 Richard Atkinson concluded a review of the astronomy of Stonehenge with the remark that 'only the alignment of the Avenue on the summer solstice sunrise . . . can be accepted with confidence. All other interpretations are open to doubt or to alternative explanations' (Atkinson 1982, 107). Despite a number of new ideas put forward in recent years, generally much more securely founded in the broader archaeological context than were those being reviewed by Atkinson, this remark remains true in broad terms.

Yet the preceding discussion suggests that investigations of astronomical potential could, and should, inform a number of important research questions relating to Stonehenge and its environs. The following programmes of work could be particularly enlightening.

1 *Monuments in the Early Neolithic landscape.* A systematic study of the siting and orientation of the long barrows, involving the collection of field data on horizon altitudes and declinations and their combination with data on the visibility of and relationship to other human-made and natural features in the terrestrial landscape, would help to establish the place of each monument within the terrestrial and celestial landscape surrounding it, and to determine whether certain astronomical bodies or events were of particular significance. Wider studies of long barrows in the vicinity of the Wessex causewayed enclosures other than Robin Hood's Ball could show whether similar considerations were important elsewhere.

2 *The siting of Stonehenge and the axial orientation of Stonehenge 1 and 2.* Theodolite surveys exploring the general astronomical potential of the site chosen and of other sites in the immediate vicinity would establish whether any special properties were possessed by the actual site, and if so to which astronomical bodies or events they might have related. This is relevant to the wider issue of whether the choice of location was influenced more by the 'view in' or the 'view out' (Cleal *et al.* 1995, 35). Comparison with the siting of the other circular enclosures and henges in the vicinity could help to establish whether there were any common patterns of preference. Comparison with the orientations of their axes and entrances could cast light on the question of whether the orientation of the north-eastern entrance at Stonehenge 1 and 2 was in fact astronomically influenced, and in particular whether it was related to the moon.

3 *The change in axis and the solstitial orientation of Stonehenge 3.* Further investigation of the zone outside the ditch in both directions along the Phase 1/2 and Phase 3 axes (the latter is already proposed in English Heritage's suggestions for a long-term programme of investigation—see Cleal *et al.* 1995, 493, item 4.2) could cast new light on the function and significance of the axial orientation, astronomical or otherwise, and the sequence of events marking the change from one to the other. It would also be enlightening to obtain new information from the south-east quadrant to clarify whether a south-easterly direction defined by the sun or moon (the latter hinted at by some of the evidence presented above), or indeed a NW-SE axis, was of particular significance.

4 *Astronomical factors in patterns of movement and approach.* What did the sky look like as people stood at certain points in the landscape, or moved around in certain ways? Was it important, perhaps, to be in a certain place, or to move in certain ways, at a particular time, when the celestial configuration was right? Was it important, perhaps, sometimes to approach Stonehenge along the avenue at night, when the stars in the sky would have been as prominent as earthly signs of ancestors during the day? Astronomical considerations should inform phenomenological studies. A pilot project might involve survey measurements to establish any prominent astronomical objects or events that could have accompanied an approach to Stonehenge along the avenue.

Throughout its history, and especially in Phase 3, Stonehenge was a focus of intense ceremonialism and is likely to have been imbued with significance and meaning at many levels and in many ways (Bender 1992; Whittle, this volume)—in its shape, form, and texture; in the materials used; in spatial patterns of deposition; in the symbolism of inclusion and exclusion; in patterns of experience and approach; and in notions of cyclical time. Astronomy surely has a place in contextual explanations exploring such meanings.

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meaning that underpinned those beliefs. Physical and celestial 'markers' were used at different periods to articulate meanings relative to the use and social significance of space, both within the monument and in the surrounding landscape. Four phases to these changes are proposed, each identified with a series of structuring principles: linear binary, linear quadruple, radial concentric, and linear concentric. All four phases are marked archaeologically by a re-design of Stonehenge and the restructuring of space around about.

CLIVE RUGGLES

Astronomy and Stonehenge

This paper begins by making some general observations about the perception and use of celestial phenomena in prehistoric times, what exactly is meant by 'astronomy', and why the prehistorian might be interested in it. We then proceed to establish a conceptual framework for studying prehistoric astronomy, identifying possible horizon 'targets' for symbolic alignments (which are less precise, fewer, and different in nature from those very often assumed), and explaining the significance of declination. This is followed by a critique of recent ideas about astronomy in and around Stonehenge, in the light of the newly published reports of twentieth-century excavations. The paper concludes with a summary of what we can begin to say with reasonable confidence about the nature and meaning of astronomy at Stonehenge, and presents some suggestions for the future research agenda at and around the site.

JULIAN RICHARDS and MARK WHITBY

The engineering of Stonehenge

A series of practical experiments, carried out at the instigation of the BBC, involved the transport and erection of the individual components of a full-scale replica of the Great Trilithon at Stonehenge. The use of a simple sledge running on a greased timber track demonstrated that a 40 tonne stone, representing one of the uprights, could be moved up a 1 in 20 slope using the motive power of 130 individuals. The raising of this stone to vertical was accomplished by rotating the stone over a solid pivot point with the assistance of a composite 6 tonne weight running along its length. An angle of 70 degrees to the horizontal was achieved by this method and the stone was hauled to vertical using a timber 'A' frame as a lever. The lintel was raised on a sledge running on rails up a ramp although a comparative experiment demonstrated that the orthodox timber 'crib' or platform provided a viable alternative method. For the purposes of all experiments a degree of proficiency in both woodworking and the manufacture of rope was assumed.

The overall labour requirements for the building of the sarsen structures at Stonehenge are recalculated from the newly available data. In addition, alternative interpretations of