

# The British Sundial Society

## BULLETIN



VOLUME 23(ii)

June 2011

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**Front cover:** *The 17<sup>th</sup>-century Scottish polyhedral dial boss found at Great Amwell and recently auctioned by Christie's for £16,250. For the full story, see the article on page 52. Photo courtesy of Christie's.*

**Back cover:** *Jackie Jones' entry 'Christmas Time' for the Photographic Competition, judged to be one of the 'top ten'. Jackie designed and made the dial (with Rob Stephenson) as well as photographing it. See page 33 for the other results.*

# BULLETIN

## OF THE BRITISH SUNDIAL SOCIETY

ISDN 0958-4315

VOLUME 23(ii) - June 2011

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### EDITORIAL

The 'themed' issue of the last *Bulletin*, featuring several articles on polyhedral dials, seems to have been popular with members. As promised, another article on the same topic appears in this issue. I would like to produce some further themed issues occasionally in future. It is, though, quite difficult to organise as I don't have much control over what articles authors offer me. Still, if you have ideas for particular topics in dialling which you would like to see—especially if they can be approached from a number of viewpoints—I will see what I can do.

By the time you get this issue, the 2011 BSS Conference will have been and gone. It is always a rush to prepare the conference report in time for the June issue and, with this year's meeting being later than usual, it has been necessary to hold it over to September. That issue will also have the second parts of several articles which have begun in this one. The point of splitting the longer articles is so that there is a variety of topics in each issue. I hope this meets with general approval.

### Erratum

The BSS 2010 Sundial Design Competition article *BSS Bulletin 22(iv)*, December 2010 p.45, should have included H. Thiessen as Highly Commended in the Amateur Class. The omission was my error and I apologise for any inconvenience it caused to the entrants or BSS members.

His equatorial dial consists of two brass hemispheres the top one of which is slotted and can be rotated allowing a shaft of light to indicate the apparent time. The top hemisphere can also be turned so that when the set time arrives a chime is activated electronically. The dial was shown as Fig. 8.

*Tony Belk*

# THE RAINBOW AS A SOLAR TIMEKEEPER

ALLAN MILLS

*My heart leaps up when I behold  
A rainbow in the sky.*

**Wordsworth**



Wiki Commons

Fig. 1. A fine example of a rainbow in Alaska.

## Introduction

In principle, we define time-of-day from the position of the Sun in the celestial sphere. But it is too bright to look at directly, and there are no calibration marks in the blue sky. So, long ago, mankind discovered that shadows were the key to accurate and convenient solar timekeeping.

But are there other solar-related natural phenomena that could be utilised to derive its position in the celestial sphere and thereby furnish alternatives to the shadow-casting sundial? It should be borne in mind that great accuracy is no longer important: clocks and watches are better at fulfilling this function. Possibilities are:

- Radio emission from the Sun. Not very practical.
- Polarization pattern in the blue sky. Half-shade polarimeters allow time to be determined to 5 minutes.
- The position of the rainbow. This is the subject of this article.

## Observation of the Rainbow

There can be few people who have not admired the beauty of the rainbow (Fig. 1), and wondered about how and why it is produced and its possible significance as an omen for the future. There is therefore a rich folklore about the phenomenon in almost every age and culture.<sup>1</sup>

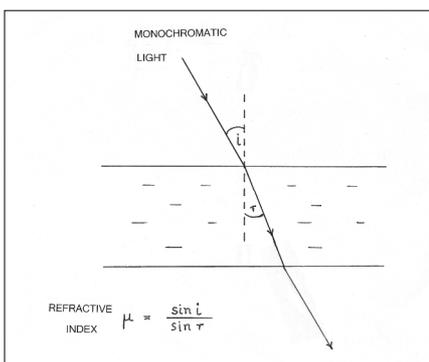


Fig. 2. Refraction of monochromatic light.

The rainbow requires the simultaneous presence of direct sunlight (just like a normal sundial) and rain. The latter does not have to be falling on the observer: it may well be a mile away. The rainbow is a much more complex phenomenon than is commonly realised, for looking carefully at Fig. 1 we can see:

- **PRIMARY BOW:** An arc of colours crossing the sky in a direction away from the Sun. It is part of a circle about  $42^\circ$  in radius, but we can never normally see more than a semicircle. The colours are those of the spectrum, with red on the outside and blue on the inside. The sky is comparatively brighter within the bow.
- **SECONDARY BOW:** A second, fainter, arc exterior to the primary bow with red on the inside. This is just visible in the upper corners of the illustration.
- **ALEXANDER'S DARK SPACE:** A comparatively dark region between the primary and secondary arcs. It is named after Alexander of Aphrodisias, c.200 A.D.
- **SUPERNUMARY ARCS:** Faint arcs on the inside of the primary bow. Their vague pink and green colours hint at an origin in the interference of light.
- **VARYING BRIGHTNESS WITH ALTITUDE:** Sometimes one section of the arc (e.g. the lower ends) will be brighter than elsewhere. This is due to the non-spherical shape that is induced when raindrops larger than a few tenths of a mm in diameter fall through the resistive atmosphere.

The overall gamut of variations is so large that it has been said that no two rainbows are identical. Colour photographs are therefore collected, although a wide-angle lens is required.

The first scientific attempt to understand the rainbow was the application of geometric optics by Descartes in 1637, but the entire phenomenon is so complex that it took centuries before the application of advanced calculus (Airy's 'rainbow integral'<sup>2</sup>) described it completely and quantitatively. A general treatment is given in Minnaert's perennially intriguing little book,<sup>3</sup> while Tricker,<sup>4</sup> Walker<sup>5</sup>, Nussenzweig<sup>6</sup> and Greenler<sup>7</sup> give more extensive modern explanations. I shall attempt no more than a non-mathematical overview using geometric optics.

## Refraction in General

It is generally known that when a beam of light goes from air into a transparent liquid it is bent towards the normal, in the manner shown diagrammatically in Fig.2. This is a result of the velocity of light being less in the liquid than in air, and is described quantitatively by the *refractive index*  $\mu$

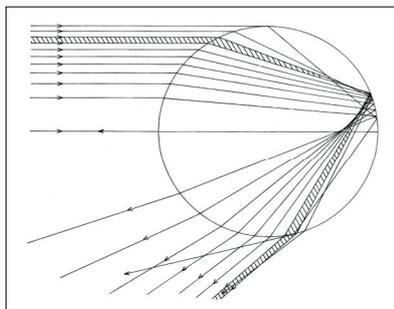


Fig. 3. Descartes' scheme for the refraction of light in a raindrop.

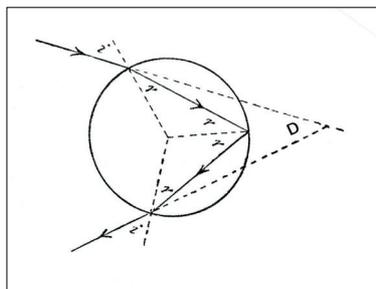


Fig. 4. Refracted boundary rays in a raindrop generating the primary bow.

of the medium, where according to Snell's law:

$$\mu = \sin i / \sin r \quad (1)$$

For water,  $\mu = 1.33$ , less than that of any other common liquid. For soda glass  $\mu$  is about 1.5, the exact value depending on the composition of the glass.

### Refraction in Spheres

In a shower of rain, pure water occurs in the form of more-or-less spherical drops – never the teardrop shape beloved of cartoons! If the Sun is shining, then some of its parallel incident light will enter droplets and undergo refraction followed by one, two (or even more) internal incomplete reflections. The simplest scheme is for one reflection of an imaginary monochromatic beam, and by accurately drawing many rays in a parallel incident beam Descartes produced the diagram summarised in Fig. 3. He showed that the deviations were very considerable, with many rays leaving the lower half of the drop in a direction back towards the source. These produce the brighter sky within the bow. However, near the position of minimum deviation the angle of incidence can vary over an appreciable range with little effect on the deviation. The exit rays therefore tend to concentrate in this region, bunching up to define a sharp boundary at the angle of minimum deviation. This behaviour is clearly shown by thick lenses and strongly curved mirrors, with the resulting bright band known as a *caustic*.<sup>6</sup>

Figure 4 is confined to these *Cartesian rays*, and it will be seen that an incident ray undergoes a deviation  $D$  (measured with respect to the incoming direction) given by:

$$\begin{aligned} D &= (i - r) + (180^\circ - 2r) + (i - r) \\ &= 180^\circ + 2i - 4r \end{aligned} \quad (2)$$

This stationary value of the deviation may be evaluated more accurately by differentiating (2) and setting it to zero, then using (1) to give:

$$\cos i = \sqrt{(\mu^2 - 1)} / 3 \quad (3)$$

$$\sin i = \sqrt{(4 - \mu^2)} / 3 \quad (4)$$

Note that these values are independent of the size of the raindrop. (In practice, very tiny droplets give a white 'fog-bow'.)

For rain water, with  $\mu = 1.33$ , this gives  $i = 59^\circ$ . Substituting back into (1) and (2) gives  $D$  as  $42^\circ$ . To an observer on

the ground, the incoming solar radiation is parallel to an imaginary line joining the Sun with the observer's eye, which if continued downwards goes towards the *anti-solar point* (Fig. 5). (If you turn your back on the Sun and look at your shadow on the ground, then the imaginary line joining your dominant eye with the position of the shadow's 'eye' marks the direction towards the antisolar point.) So, as shown by Fig. 5, the brightest rays from an illuminated raindrop come in at  $42^\circ$  to the direction towards the line joining the Sun to the antisolar point – the *solar axis*.

This angle is purely a direction: the bow is not a structure in the sky, so it is not possible to walk to the end of a rainbow! And it does not change its shape to part of an ellipse or hyperbola as one moves about! The rain is falling, so the drop represented in the diagrams is continually being replaced by new droplets in the indicated positions.

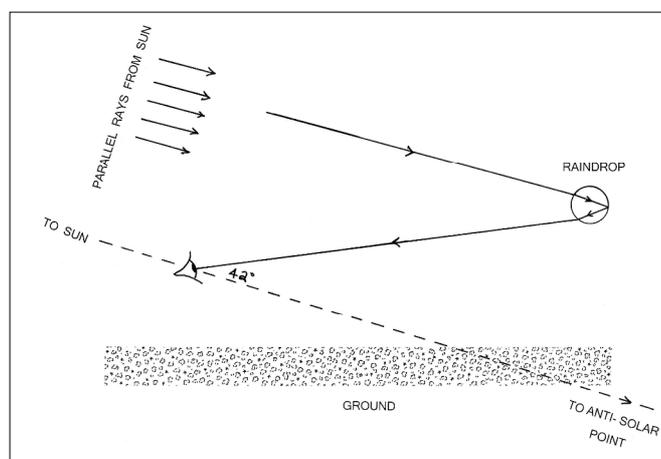


Fig. 5. Planar diagram of the natural situation.

### Formation of the Primary Bow

The diagram of Fig. 5 is not confined to the plane of the page, for any raindrop in the shower that is temporarily at  $42^\circ$  to the solar axis will send a bright beam to the observer's eye. This defines a *cone* of semi-apex angle  $42^\circ$ , and we see part of a circular *arc* in the direction away from the Sun. The solid model shown in Fig. 6 may make the situation clearer. It will also be appreciated that:

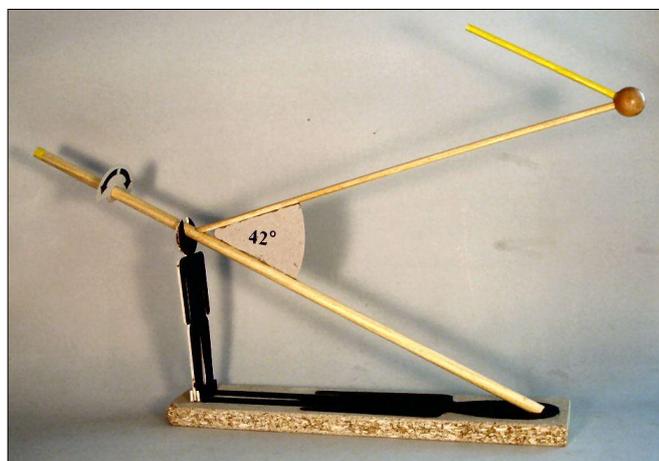


Fig. 6. Solid model to show how a bow would be formed in monochromatic light.

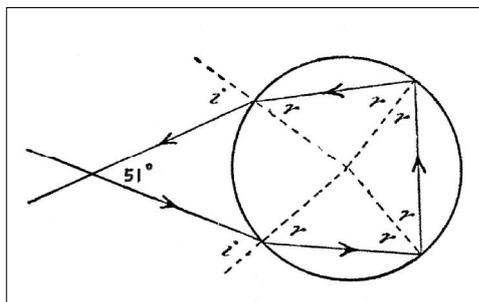
- a) The higher the Sun, the lower the bow.
- b) No normal rainbow may be seen when the Sun is higher than  $42^\circ$ .
- c) When the Sun is rising or setting it is at its lowest point relative to the observer, and the solar axis is parallel to the horizon. The bow is then at its highest in the sky, with an altitude of  $42^\circ$ , and we see a complete semicircle.
- d) Everyone sees their own personal rainbow, as does each eye!

**Formation of the Secondary Bow**

Two reflections of the Cartesian rays in a spherical raindrop are shown in Fig. 7. Exactly the same concentration of the emerging light into a caustic occurs, but this time at the minimum deviation of  $51^\circ$ . A second bow therefore appears in this direction encircling the primary arc (Fig. 1). However, as the light has been weakened by two reflections (which are not total internal reflections) it is of lesser intensity than the primary bow.

A greater number of internal reflections are possible, and in theory each should give rise to an additional bow. However, they are of such low intensity (and in the case of the third and fourth situated towards the Sun) that they may only be seen in drops of water suspended from a waxed fibre replacing the prism at the centre of a student spectrometer.<sup>5</sup>

Fig. 7. Formation of a secondary bow. (Boundary rays in monochromatic light.)



**Dispersion: the Colours of the Rainbow**

The diagrams we have seen so far are for light of just one wavelength, sodium yellow for example. However, white light from the Sun is made up of a range of frequencies, which we see as colours in a range from red to violet. Following Newton, these are traditionally quoted as red, orange, yellow, green, blue, indigo, violet; but in reality the human eye can distinguish between hundreds of shades. (Hence the common difficulty in matching socks!) Separation of light into its constituent frequencies is called *dispersion*.

Dispersion commonly accompanies refraction, so for an incident beam of white light Fig. 2 should be replaced by Fig. 8. The refractive index of water is somewhat greater for blue light (1.35) than for red light (1.33), so the beam is spread into the fan of colours named a *spectrum* ('appearance') by Newton. The dispersion accompanying deviation of sunlight in raindrops therefore gives rise to coloured beams, as shown in Fig. 9. Separate and ever-changing individual raindrops give rise to each colour! Ro-

Fig. 8. Dispersion accompanying the refraction of white light.

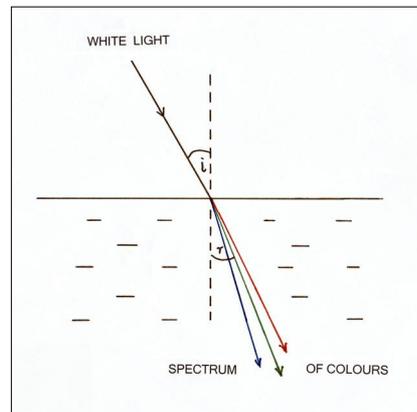
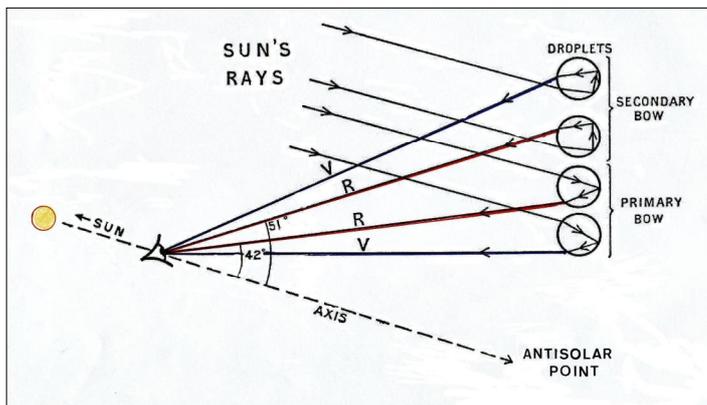


Fig. 9 (below). Formation of coloured primary and secondary rainbows.



tation about the solar axis then gives the familiar primary and secondary rainbows (Fig. 10). Note how the sequence of colours is reversed in the secondary bow. There is a near infra-red arc outside the red primary bow,<sup>7</sup> but our eyes are unable to detect it.

The Moon can give rise to a lunar rainbow when it is bright enough – usually this means when it is around full. Even then, the intensity of the bow is so low that it is difficult for us to perceive colours, so it appears off-white.



Fig. 10. Solid model to show how bows are formed by incoming parallel rays of sunlight.

**Polarization**

If reflection occurs, then some degree of linear polarization will usually appear. One or more reflections are involved in the generation of rainbows, so we would expect polarization to be associated with them. Viewing through a piece of Polaroid, or polarizing spectacles, will soon confirm the presence of very strong linear polarization in both the primary and secondary bows.<sup>8</sup> The plane of polarization is

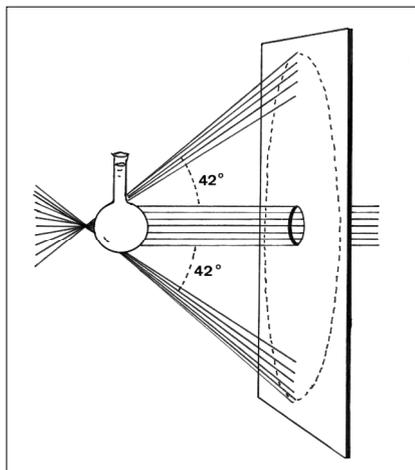


Fig. 11. Refraction of parallel light in a spherical flask filled with water.



Fig. 12 (left). Practical realisation of Fig. 11.

Fig. 13 (right). Circular coloured fringes surrounding a refracted beam of sunlight in apparatus of Fig. 12.

parallel to the horizon at the apex of the bow, so a sector around the apex will disappear when viewed through a piece of Polaroid with its polarizing direction oriented vertically. The missing sector will appear to rotate around the bows as the Polaroid is turned in the hand.

### The Spherical Flask Demonstration

A classic demonstration of the formation of rainbows by refraction in a water-filled spherical flask<sup>3</sup> is shown in Fig. 11. (Chemical flasks are difficult and expensive to obtain nowadays: I used a Christmas tree ornament of thin clear glass.<sup>9</sup>) This apparatus enables the full circular primary bow to be seen (Figs. 12 and 13).

Theory suggests that a liquid of higher refractive index than pure water should produce a rainbow of lesser angular diameter. This may be confirmed by comparing the size of rainbows produced by organic liquids or salt water in the flask. An increase in temperature lowers the refractive index of water, so in theory the angular diameter of a natural rainbow is not entirely constant – but the effect is hard to discern. A solid soda glass sphere gives the much reduced value for  $D$  of about  $21^\circ$ .

This demonstration suggests one way in which a ‘rainbow’ may be produced in the garden whenever the Sun is shining. All that is additionally required is a means of measuring direction when set to produce a circular halo, and to



Fig. 14. Rainbow in spray from a garden hose.

translate this directly into time of day. A mounting similar to that described below would be suitable, but somehow a rainbow with no raindrops seems incomplete. This idea was therefore not pursued.

### Rainbows in Spray

Rainbows sometimes seen in spray produced by waterfalls and fountains prove that droplets generated in ways other than rain can give rise to a coloured bow. Also, it will be remembered that the phenomenon is a *direction*, so the cloud of droplets can be quite close to the observer. A hose-pipe fitted with an adjustable spray nozzle screwed-up nearly to closure will therefore produce quite an intense bow if the cloud of droplets is viewed in a direction away from the Sun (Fig. 14).

Spray in this demonstration is generated by violent turbulence in the high pressure jet leaving the restricted nozzle. A row of small holes (as in many patterns of garden sprinkler) produces streams that are inherently unstable and soon ‘pinch off’ into individual droplets. However, these are larger than those generated by a nozzle, so there are fewer droplets per unit volume in the spray. Consequently, although rainbows are produced, they are of lower intensity than those produced by the spray nozzle. An ordinary attachment made for garden use produces a cone of droplets of some  $35^\circ$  apex angle, but three nozzles connected together reduce the water pressure too much for efficient atomization. An elevated single nozzle adjustable in elevation, and directed more-or-less at right angles to the line of sight, appears best. It must either be hand held or mounted



Fig. 15. Clamp to hold spray nozzle. Adjustable in height, direction and angle.

Fig. 15. Clamp to hold spray nozzle. Adjustable in height, direction and angle.

An array of commercially-produced nozzles fed by a pump would be required in a large installation.

### Artificial Light Sources

The theory given above shows that a closely-parallel beam of intense white light of width exceeding the chord of any rainbow is required for its generation. Only the Sun produces this, so quartz-halogen lamps, slide projectors and the like do not give rainbows when directed upon a curtain of spray droplets. We do not see rainbows generated by street lamps when walking on a rainy night! The much smaller coloured circular rings sometimes seen surrounding lamps in misty conditions are called *halos* or *glories*, and are a completely different diffraction phenomenon.<sup>7</sup>

### Rainbows Greater than Semicircles

If one stands with one's back to a fairly low Sun, and holds a hose nozzle high up at arm's length so as to direct a fine spray more-or-less horizontally about two feet in front of the face, then one can see most of a circular rainbow. A dark background (e.g. foliage) is advantageous, and it may be necessary to adjust the positions of eyes and nozzle to see the entire circumference. Similarly, a rainbow extending over more than 180° of arc may occasionally be seen

from an aircraft or cliff top. Photography would require a wide-angle lens.

It would appear that a very large plane mirror, placed flat on the ground in the light from a high Sun, should reflect a broad parallel beam in an upwards direction. Combined with nearby sprays of water, this too might allow most of a complete circular rainbow to be seen. Two full sheets of hardboard covered with aluminized Mylar sheet might suffice, but I have not been able to test this hypothesis.

### The 'Rainbow Catcher'

The centre of the natural rainbow is not marked in any way, so it is not possible to aim upon it with a device incorporating gun-like sights. In addition, an angular diameter of 84° is greater than can be covered by the human eye in one view: we unconsciously move our eyes and head to encompass the entire phenomenon. It has already been explained that the rainbow is a direction in space, and may appear to be anywhere along a cone stretching from the eye to a distant circular base effectively at infinity.

It seemed to me that a 'rainbow catcher' might take the form of a wire frame incorporating an arc curved to the same angular radius as a rainbow, and able to be superimposed upon part of the latter. The normal eye is unable to clearly define an object closer than about 10 inches (the 'near point'), so this distance represents the minimum separation between frame and dominant eye. I chose a rather greater separation, a 42° arc being developed as part of a circle of radius 10.8 inches held at a baseline distance of 12 inches from a small hole in a plate positioned at the end of a rod equivalent to the solar axis (Fig. 16). The length between hole and arc is the hypotenuse of the triangle, and is equal to 16.1 inches. The frame was constructed from steel (coathanger) wire held together with silver solder.

### The Rainbow Dial

It would be possible to mount the above frame in an instrument containing two mutually perpendicular calibrated axes, rather like a theodolite. Setting the arc on a rainbow would then enable the altitude and azimuth of its centre to be determined, enabling the corresponding time on any given date to be calculated by spherical trigonometry. However, this mathematical chore may be eliminated by employing a version of the equatorial mounting commonly used for astronomical telescopes. It acts as a mechanical analogue computer when the solar axis of the rainbow catcher takes the place of the usual telescope.

This ancestry may be recognized in Fig. 16, the sloping polar axis carrying an equatorial hour dial. It is divided into two sets of equal hours, with midnight and noon on the meridian. This construction also facilitates orientation, for a rod fitted with sights may be fixed temporarily in the polar axis and lined-up on *Polaris* (Fig. 17). Alternatively, the base may be set with a good magnetic compass, taking account of the fact that true north is currently about 2° east of magnetic north in central England.<sup>10</sup>

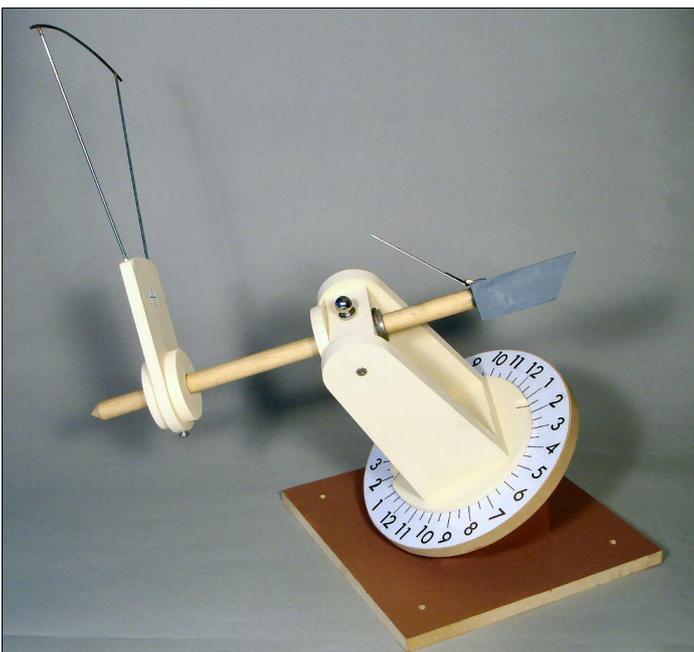


Fig. 16. The 'rainbow dial'.



Fig. 17. Temporary polar axis to aid alignment with the Pole Star.



Fig. 18. Rainbow in spray generated by nozzle shown in figure 16.



Fig. 19. 'Rainbow catcher' in action.

Once the base has been set against pre-set marks, the solar axis may be manipulated until the arc of the rainbow catcher is superimposed upon part of a rainbow generated by rain or spray (Figs. 18 & 19). The time is then indicated by either index on the hour dial. It will be obvious that corrections for Summer Time, longitude and the equation of time must be made, just as with standard dials.

It is not claimed that clock time may be determined with great accuracy: perhaps to plus or minus 10 minutes.

It will also be apparent that the instrument may be inoperative around the middle of the day, when the Sun is too high to generate a natural rainbow if its altitude exceeds  $42^\circ$ . However, it may be possible to use a nearby spray to generate the lower part of a circular arc. Alternatively, the hinged plate visible in Fig. 16 may be raised until it is at right angles to the solar axis. A small hole in it then throws an image of the Sun upon a cross at the same height (Fig. 20).

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Fig. 20. Image of a high Sun caught upon a screen painted on lower portion of the 'rainbow catcher'.

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10. Google 'magnetic declination' for the exact figure for a given location and date.

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# A HORIZONTAL QUADRANT OF 1658 BY HENRY SUTTON

## Part 1

MICHAEL LOWNE and JOHN DAVIS

### Introduction

This quadrant (Figs. 1 & 2) is the only known surviving representative of its type. It has been described by the present authors<sup>1</sup> and allocated the serial number HQ-2. Details of the delineation and method of use have also been given.<sup>2,3</sup> These do not exhaust the properties of the instrument and this article explains some of the further details. It is fully described (with some differences) by John Collins in his 1658 book<sup>4</sup> and appears to have been made by Henry Sutton in close collaboration with him; in fact the book can be regarded as a handbook for the instrument. Note that this instrument is different from the type which is generally known as *Sutton's quadrant* and was described in a second book<sup>5</sup> by Collins a year later. From the text of the first book it appears that the horizontal quadrant, among its other uses, was intended to show that the scales appearing on a sector (specifically Gunter's sector) could be accommodated on a quadrant. The instrument is formed from paper prints pasted on wood (which has shrunk and split) and coated

with varnish, now discoloured. It would originally have been fitted with two sighting apertures and a weighted cord for finding the altitude of a body when viewed by the sights. One aperture and the cord are now missing.

### Of Horizontal Quadrants in General

In this application the term 'horizontal quadrant' refers to an instrument using the projection of the sky upon a horizontal plane, using the stereographic projection.<sup>6</sup> The projection is folded along the meridian so that it represents both halves of the sky (for a specific latitude) on the same diagram. It can solve many of the problems concerned with the diurnal motion of the sun by measuring its altitude. From this, the time and the sun's azimuth can be found. The times of sunrise, sunset and twilight for given dates can be determined. Some quadrants carry perpetual calendars; others provide star places to enable time to be found at night.

### The 1658 Quadrant by Henry Sutton

The two faces of this quadrant are shown in Fig. 1 (the fore-side) and Fig. 2 (the reverse side). The radius is eleven inches (280 mm). The stereographic projection upon it is called by Collins 'the horizontal projection inverted'<sup>3,4</sup> in which the view is taken from the zenith so that the centre represents the nadir. Distinguishing features from the more usual zenith-centred projection are that the positions of the declination arcs are reversed with those for northern declinations appearing furthest from the centre, and the hour lines are convex to the meridian, not concave.

The instrument bears many other scales and lines, as can be seen from Figs. 1 & 2. The various tables and rulings may be briefly described and the uses of some of them explained later.

*Fig. 1. The fore-side of the quadrant. Photo by JD, courtesy Oxford MHS.*



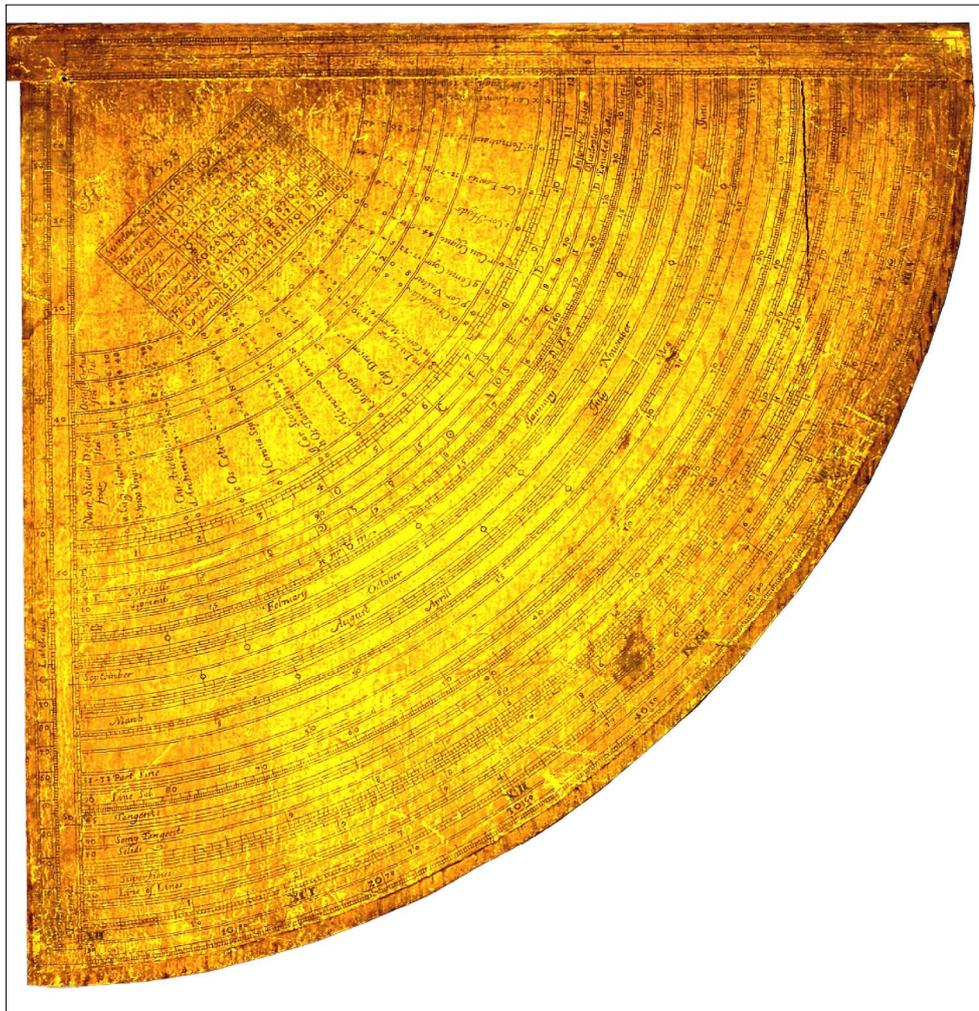


Fig. 2. The reverse side of the quadrant.

d. Scales of 'shadows' and 'quadrants'.

Values of trigonometric functions are extracted as chords from the curved scales with dividers, setting one point on the zero and the other on the required angle.

Rectilinear rulings surround the projection. With the meridian uppermost as in Fig 1 and reading downwards, the rulings encountered are:

e. Sines  $23\frac{1}{2}$ - $0$ - $62^\circ$  labelled *Declin. for ye Azimuth* and *Alt for ye Houre*.

f. Versines of angles  $0$ - $180^\circ$  outwards from centre.

g. Scale for altitude setting of a bead on the cord,  $30$ - $0$ - $62^\circ$  outwards from centre. This is at a slight angle to the noon line and overlaps the projection.

Parallel to those scales, on the opposite edge of the projection:

h. Versines, calibrated both in hours  $12$ ,  $11\frac{1}{4}$  to  $4\frac{1}{8}$  in two-minute intervals and in degrees  $0$ - $140^\circ$  with half-degrees readable from the two-minute scale.

i. Discontinued tangent,  $0$ - $60^\circ$  in  $10$ s, divided in half degrees.

j. Panicle sine,  $0$ - $90^\circ$  in single degrees, drawn with short strokes radial from the centre. (In botanical use, 'panicle' describes a flower which has small flowerets depending from a central stem. The scale has a resemblance to this. In fact the scale is not of sines, the calibration appears to be versines).

Between this last and the curved trigonometric scales are Sutton's advertisement and a perpetual calendar to be used with another table on the reverse side.

The main feature of the fore-side is the stereographic projection, with declination lines at degree intervals and hour lines numbered in Roman numerals for the morning hours and Arabic for those of the afternoon, divided in five-minute intervals. Collins gives detailed instructions for drawing this. The prominent curved line on the stereographic projection is attributed by Collins to "Mr Dary" (Michael Dary, see Biographies, in part 2). It has degrees and halves, numbered in tens but running from  $23\frac{1}{2}$  at the left end to  $62^\circ$  at the right and operates in conjunction with two other scales. The delineation and use will be explained later.

The numerous other scales are:

Scales concentric with the curved limb:

- The outermost is an equally-spaced dotted time scale with hours numbered XII, XI/1 to VI and divided to single minutes.
- Next inward is the altitude and azimuth scale, divided to degrees and sixths (10 arc-minutes) numbered both ways  $0$ - $90^\circ$ .
- Trigonometric scales for sines ( $0$ - $90^\circ$ ) continued as secants ( $0$ - $59^\circ$ ), tangents ( $0$ - $62^\circ$ ) and sines ( $0$ - $75^\circ$ ), all divided to degrees and quarters except where too crowded.

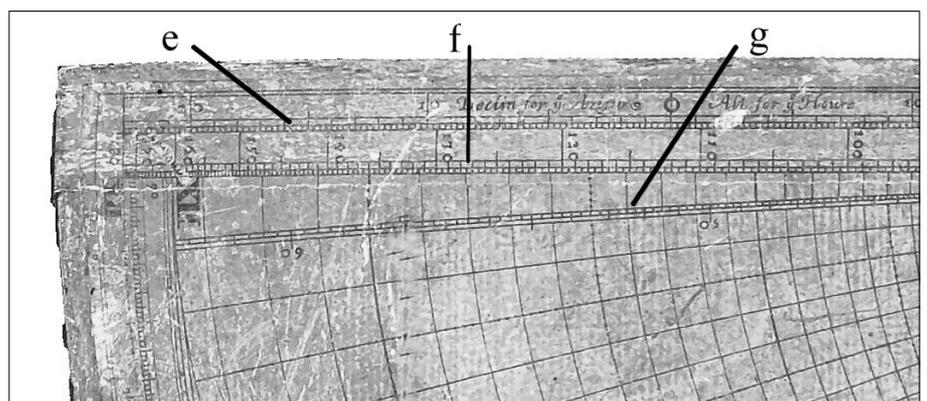


Fig. 3. Identification of some fore-side scales.

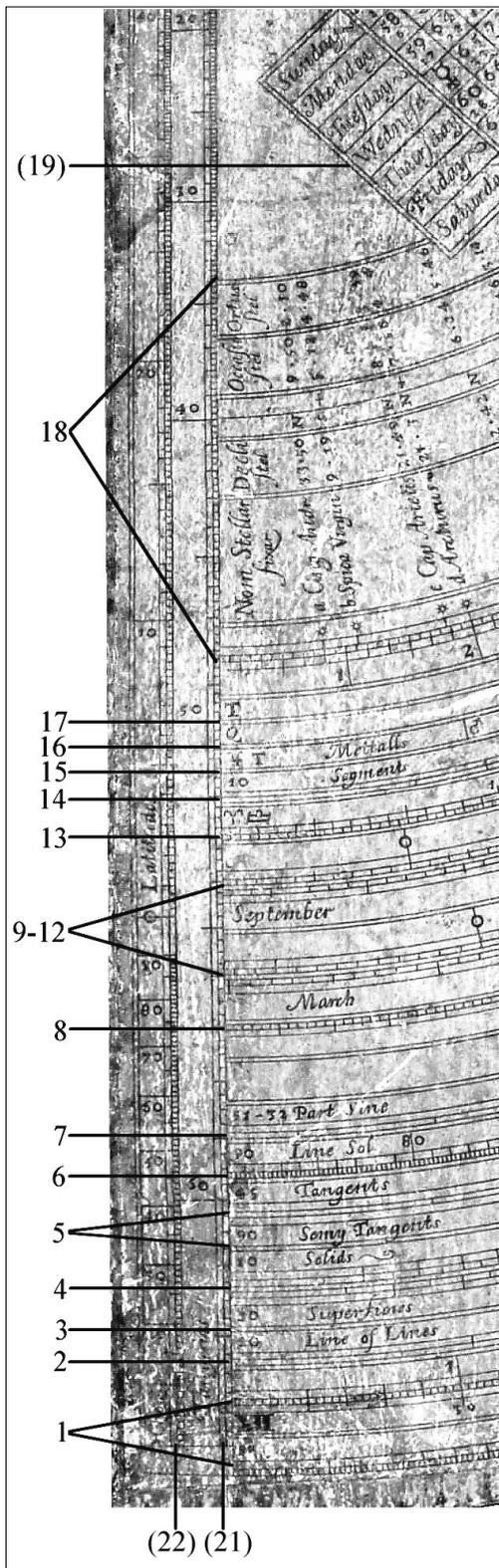


Fig. 4. (Parts of some reverse side scales identified.)

On the vertical edge:

- k. Sines 0-90° reading outwards, also numbered in reverse to serve as a cosine scale, divided degrees with 10 arc-minute intervals.
- 1. Scale of sines divided to degrees and halves, matched to a scale of tangents (divided to degrees and quarters) with the

same zero point position but multiplied by the tangent of the latitude (51° 32') so that the scale value of the co-latitude (38° 28') matches 90° on the sine scale.

The design latitude 51° 32' is noted in a small area between the centre and the projection. Parts of scales e, f and g are identified in Fig. 3.

The reverse of the instrument is completely covered with engraving, some of which has no relation to dialling. Collins admits this and makes no attempt to explain the uses of some of the scales. They are, he says, 'added to fill up spare room and to show that whatever can be done on a sector may be performed by them on a quadrant'. Fortunately he lists the scales, otherwise it would be difficult to deduce what some of them represent. Scales 1-18 are concentric with the curved limb and are numbered working inwards from this. The unnumbered scales are parallel to the edges. Collins' descriptions are, with modern spellings:

1. The equal limb divided into degrees, as also into hours and halves, and the quarters pricked to serve for a nocturnal.
2. A line of equal parts.
3. A line of superficieses or squares.
4. A line of solids or cubes.
5. A tangent of 45 degrees double divided to serve for a dialling tangent, and a semitangent for projections.
6. The line Sol, *alias* a line of proportional sines.
7. A tangent of 51 degrees 32' throughout the whole limb.
8. A line of declinations for the sun to 23 deg. 31'.
- 9, 10, 11, 12. Four quadrants with the days of the month.
13. The sun's true place, with the characters of the 12 signs.
14. The line of segments, with a chord before they begin.
15. The line of metals and equated bodies.
16. The line of quadrature.
17. The line of inscribed bodies.
18. A line of 12 hours of ascension with star names, declinations and ascensional differences.

Above all these a table to know the epact and what day of the week the first day of March happens upon, by inspection continued to the year 1700.

On the right edge a line of equal parts from the centre decimally divided, being a line of 10 inches; also a dialling tangent or scale of 6 hours, the whole length of the quadrant not issuing from the centre.

On the left edge a tangent of 63 deg 26' from the centre.

Also a scale of latitudes fitted to the former scale of hours not issuing from the centre, and below it a small chord.

Some scales are partly shown and identified in Fig. 4.

### The Uses of the Quadrant

In the following sections symbols are used for astronomical angles: latitude ( $\phi$ ), declination ( $\delta$ ), hour-angle ( $h$ ), altitude ( $a$ ) and azimuth ( $A$ ).

The sun's declination for the day is found from the quarter-circle date scales (9-11) on the reverse of the instrument. The cord is stretched through the date and the declination read off on scale 8, calibrated 0-23.5°. It is necessary for the user to supply the sense of the declination (north or south of the celestial equator), depending on the sun's position relative to the equinoxes. The sun's true longitude (position in the ecliptic relative to the zodiacal signs) can be read from scale 13. As the dial was made before the 1752 change to the Gregorian calendar in Britain, the dates are relevant to the Julian calendar. In the book, Collins provides a table of the daily position of the sun in right ascension and declination, calculated by Sutton. The declinations are average values over the leap year cycle and a table gives corrections to derive the

Fig. 5. “Mr Dary’s curve”.

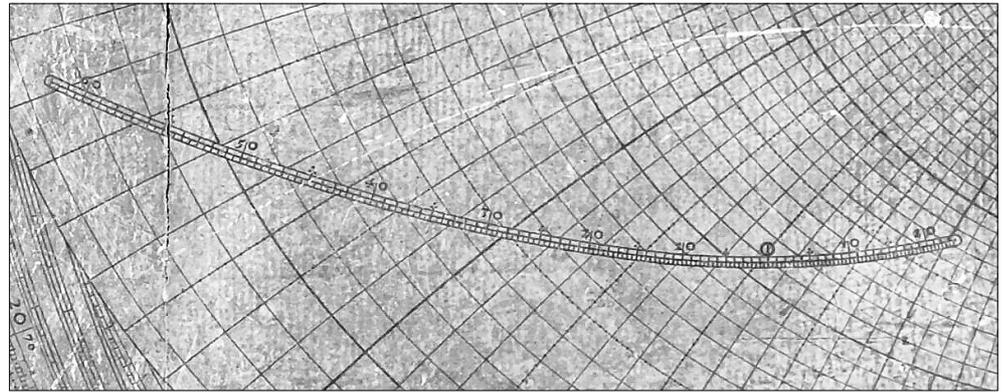


Fig. 6. (below right). Method of constructing Dary’s curve.

appropriate values for years 1657 to 1676.

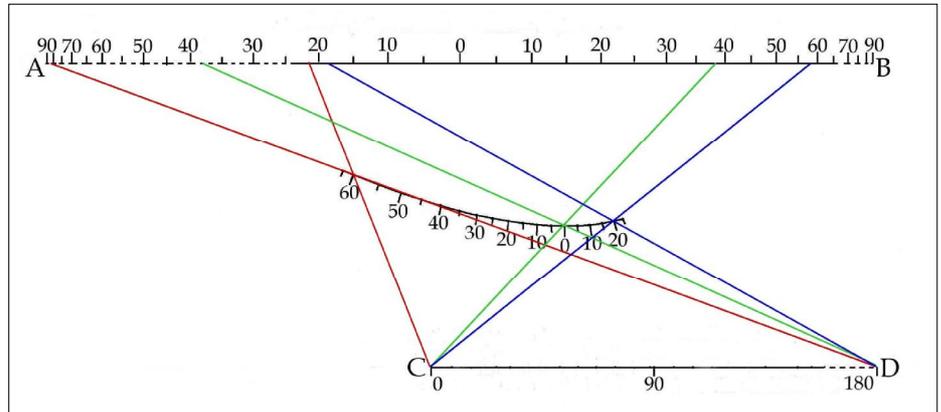
The use of the quadrant to find the time follows the same procedure as that for a zenith-centred projection.<sup>2</sup> The altitude of the sun is measured by sighting through the two apertures and the weighted cord is allowed to hang freely to indicate the altitude on scale b. The altitude reading is transferred to a small sliding bead on the cord from the separate altitude scale g (this is called ‘rectifying the bead’). By moving the cord around until the bead rests on the declination line for that day the time will be shown by its position among the hour lines, taking the Roman numerals for morning hours and Arabic for those of the afternoon. If stretched out to the limb, the sun’s azimuth can be read on scale b. By reading the time scale where the day’s declination line meets the horizon, times and the azimuths of sunrise and sunset can be found.

A complication is that, being restricted to a quarter-circle, the projection cannot show those times in the summer months when the sun is north of the east or west points of the horizon. Collins overcomes this by means of what he calls the ‘reverted tail’ which occupies that part of the projection which is not used in the winter months because the sun is then below the horizon.<sup>3</sup> The scale of altitudes is continued on either side of zero, and the method of using the reverted tail is that if the bead when set on the cord will not provide a reading on the projection, it is instead set on the side of the altitude scale nearest the centre, when it should give a reading on the tail.

#### “Mr Dary’s curve”

The curve appears to duplicate many of the functions of the stereographic projection, and is latitude-specific (51° 32’ for London). Details are shown in Fig. 5, from which it is apparent that the curve was drawn before the stereo grid lines were inserted. (This is also true of the altitude scale g). The uses include finding the time, sunrise, sunset and twilight times, and the sun’s azimuth from the altitude and declination for the date.

As shown in Fig. 5, the curve runs from 0 to 62° on the left and 0 to 23½° on the right, labelled in 10s. Two scales are used with it, the upper (scale e) is of sines from 0 to 23½° at



left and 0 to 62° at right, numbered in 10s and labelled ‘Declin for ye Azimuth’ and ‘Altitude for ye Houre’. The lower (scale h) is immediately below the projection and is called ‘Versed sines for ye curve’, dually numbered with hours IV-XII and I-VIII on the top, and degrees 0-140° below. The versed sine (abbreviated versine, vers) of an angle is  $(1 - \cosine)$ . The calibrations of the upper line and the curve are limited to 23½° and 62° to cover the maximum values of the sun’s declination and meridian altitude, and the lower line restricted to the limits of solar time and the sun’s azimuth at the summer solstice. Full-length 180° scales are however needed to draw the curve.

Fig. 6 shows how to derive the curve from the two parallel lines of the upper and lower scales. Collins says: “It matters not whether of the same radius or no, nor how posited.” Following this precept, Sutton has fitted the scales into the most suitable space available. The upper line carries scales of sines 0-90° drawn either way from the centre as zero and labelled A, B at the ends. The lower line requires no calibration at this stage: the ends are labelled C, D. For each angle point  $\beta$  on the curve in the range  $-23\frac{1}{2}$  to 62°, form the sum and difference of  $\beta$  and the colatitude,  $\{\beta + (90 - \varphi)\}$  and  $\{\beta - (90 - \varphi)\}$ , and plot them on the upper sine scale. Positive values are plotted to left of centre towards A, subtracting from 180° if it exceeds 90°, and negative values to right of centre towards B. Join  $\{\beta + (90 - \varphi)\}$  to end D of the lower line and  $\{\beta - (90 - \varphi)\}$  to C with straight lines. The intersection of each pair of lines is the curve point for  $\beta$ . The construction lines for values of  $\beta = 60, 0$  and  $-20$  are shown in red, green and blue. The point for  $\beta = 0$  falls on the line joining the centres of the parallel lines. Points for other values of  $\beta$  were calculated, not found by drawing!

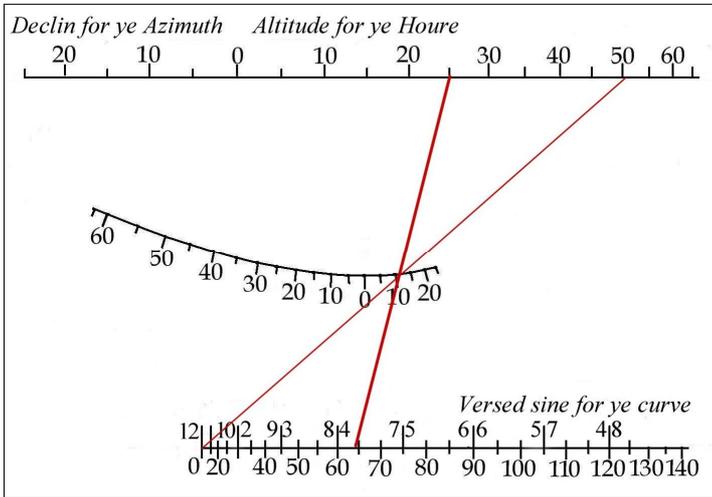


Fig. 7. Finding the time from the altitude and declination.

From the properties of intersecting lines between parallels this construction forms two similar triangles meeting at each point  $\beta$ . It follows that the base of one triangle is at a certain ratio to that of the other. As the lower line is effectively  $180^\circ$  long (vers = 2) the proportion of the bases (with respect to the calibrations, not their lengths) is:

$$[\sin\{\beta + (90 - \varphi)\} - \sin\{\beta - (90 - \varphi)\}] : 2$$

which is equivalent to:

$$\cos \varphi : \sec \beta$$

The bases of any pair of triangles drawn through a point  $\beta$  will have the same proportion.

To use the curve to find the time from the sun's altitude and declination, the altitude measured by the plumb-bob and cord is located on the upper scale to the right of the zero. The declination is located on the curve, to the right of zero towards centre if positive and left if negative. A straight line from the altitude through the declination indicates the time on the lower scale. Declinations are found from the scales on the reverse, as before.

Throughout the book Collins gives all his formulae in the form of proportions. That from which the curve operates to find the time is:

*As the cosine of the Latitude is to the secant of the declination, So is the difference between the sine(s) of the Suns proposed and Meridian Altitude, to the versed sine of the houre from noone.*

In modern terms:

$$\cos \varphi : \sec \delta = [\sin\{(90 - \varphi) + \delta\} - \sin a] : \text{vers } h \quad (1)$$

The expression  $\cos \varphi : \sec \beta$  becomes  $\cos \varphi : \sec \delta$ . The meridian altitude  $\sin(90 - \varphi + \delta)$  is located on the upper scale by a line drawn from the left end of the lower scale through the current declination of the sun on the curve. Fig. 7 is a simplified version of the curve and scales as they appear on the quadrant. The line for  $\delta = +12^\circ$  is shown on Fig. 7 by a narrow red line: this indicates that the meridian altitude is  $50\frac{1}{2}^\circ$ . Suppose the measured altitude is  $25^\circ$ : a loose cord or a straight-edge is set at that point on the upper scale, through  $\delta = +12^\circ$  on the curve (the broad red line) to meet the lower scale. Then the difference between the

meridian and observed altitudes  $[\sin\{(90 - \varphi) + \delta\} - \sin a]$  is given by the distance between the locations on the upper scale. On the lower scale the distance from the 12 noon mark to the intersection of the altitude line is proportional to vers  $h$ . The construction is therefore equivalent to Eq. 1 and the broad red line shows the time to be about 7:42 am or 4:18 pm. The narrow noon altitude line is drawn just for explanation: there is of course no need to include it in practical use.

The same construction is used to find the times of sunrise, sunset and twilight. On Fig. 8 the red line shows the times of sunrise and sunset by setting the cord or straight-edge at  $0^\circ$  altitude on the upper scale and through  $\delta = +12^\circ$  on the curve to meet the lower scale. To be clever, the altitude could be taken as  $-0.8^\circ$ , thus allowing for refraction and the semidiameter! For twilight times (sun below the horizon) the depression is read to the left of zero. The green line gives the times of twilight for the same values of declination and for a depression of the sun at  $6^\circ$  (civil twilight), plotted as  $-6^\circ$  altitude. Collins recommends taking the altitude as positive, reversing the signs of  $\delta$ , and reading the times on opposite hour scales. This gives the same result, but is only necessary when the twilight time exceeds the

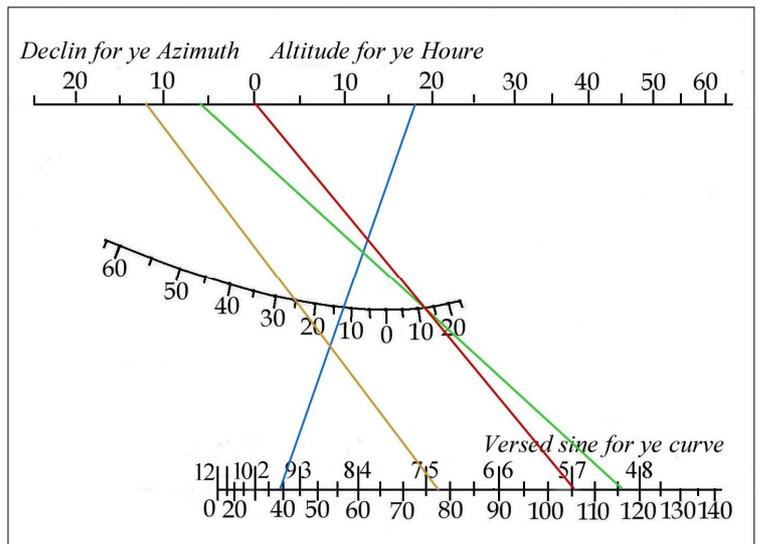


Fig. 8. Finding times of sunrise, sunset and twilight, and the azimuth.

hour scale calibration. The blue line shows this condition, drawn for a depression of  $18^\circ$ , astronomical twilight.

The azimuth of the sun from the south is found from a modification of the versine proportion in which the altitude and declination are interchanged:

$$\cos \varphi : \sec a = [\sin\{(90 - \varphi) - a\} + \sin \delta] : \text{vers } A \quad (2)$$

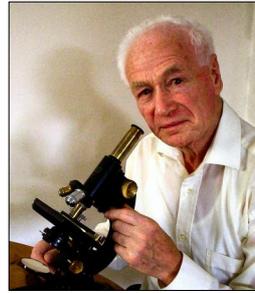
The sun's declination is taken on the upper scale, positive to the left and negative to the right of zero, and the cord placed through the altitude on the curve to left of zero. The azimuth can then be read on the lower degree scale. The orange line on Fig. 7 shows the use for the same conditions of declination and altitude as before.

As with all altitude dials, times and azimuths near the meridian are poorly determined and very susceptible to

errors in altitude and declination. In Figs. 7 and 8 the compression of the versine scale near noon is very noticeable.

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**John Davis** spent his career at the BT Research Centre near



Ipswich, working initially on the physics and engineering of semiconductor devices and latterly on the development of advanced mobile networks. In 'retirement' he makes bespoke sundials, mainly in brass, and researches the history of dialling. Formerly the BSS Treasurer, he is now the Editor and can be contacted at [john.davis@btinternet.com](mailto:john.davis@btinternet.com).

*To be continued*

# WAR MEMORIAL DIALS

## TONY WOOD

The recent discovery of the Youlbury War Memorial dial in Oxfordshire prompted an enquiry to the Imperial War Museum National Inventory of War Memorials for further information. They had indeed details of the Memorial and were also able to follow up our request for a listing of war memorials with sundials.

The Imperial War Museum (IWM) produced no less than 53, which was a big increase compared with the twelve produced in 1999 in response to a similar request when the Inventory was in its early days. The Sundial Register can be interrogated similarly for 'war memorials' and produced 14 dials. Quite a difference! How come? The two lists had eleven dials in common.

Before examining the reasons for the large difference, it is interesting to look at a probability theorem which predicts how many memorial dials are out there to be found. Basically, if the BSS find  $B$  dials and the IWM find  $W$  dials AND there are  $C$  dials in common, the number of dials still to be found ( $U$ ) is:



*SRN 1323 at Wootton, Oxon, is in both the BSS and IWM lists.*

$$U = \{(B - C) \times (W - C)\} / C$$

Which gives us  $3 \times 42 / 11$  or  $11+$ ; say between 11 and 12 war memorial dials still to be found and a possible total of:

$$11 \text{ (or 12)} + 53 + 14 - 11 = 67 \text{ (or 68)}$$

Examination of the IWM listing revealed that many were in fact registered with us but no comment about any memorial was included in the records.

On checking churches in particular as relatively easy sites to find and access, it was found that seven were claimed to have war memorial dials but they did not appear in the Register 2010. They are as follows:

|                            |                 |
|----------------------------|-----------------|
| Dunswell, St Faith         | E. Yorks        |
| Nantmel, St Cynllo         | Powys, Wales    |
| West Halton, St Etheldreda | Lincs           |
| Birchencliffe, St Philip   | W. Yorks        |
| Orrell, St Luke            | Gtr. Manchester |
| Moston, St Luke            | Gtr. Manchester |
| Pyworthy, 'Parish Church'  | Devon           |

So there are still dials waiting to be recorded. Off you go folks!

Acknowledgements to Ian Butson and the Imperial War Museum.



# BEFORE THE BSS – A SUNDIAL CHRONICLE

CHRISTOPHER DANIEL

[This article is a version of the outgoing Chairman's talk at the 2011 BSS Conference.]

It has been a very great pleasure, privilege and honour to have been the Chairman of this Society – your Society – for the last twenty-one years, since the year 1990, when, following the sad death of Dr Andrew Somerville, our first Chairman, I was elected as his successor. It was Charles Aked, who turned to me after Andrew's memorial service and said something to the effect of "You'll have to be Chairman – there's no-one else. I'll propose you for election at the next AGM", which he duly did, thus causing me to be elected to this office.

As you all know, the British Sundial Society was founded in 1989 by four individuals, namely Andrew Somerville, David Young, Charles Aked and, via the telephone, myself. Since I could not be physically present at the inaugural meeting, which was held in David Young's house at Chingford, it happened that all the various tasks required, in setting up and running the organisation, were distributed to those three who were actually present. Thus, I was free from any of the administrative duties of the Society, although, at that time, I was the Senior Warden of my City Livery Company, the Honourable Company of Master Mariners, and in the following year, in 1990, I became the Deputy Master, in the second year of the titular Mastership of the Prince of Wales. This meant that I did all the work, attending lunches and dinners, making speeches and so on, whilst Charles had all the glory! Nevertheless, it was during this first year of the Society's existence that I contributed the design for the BSS symbol, which was later described by someone as being "a bold, strong and distinctive device." In his brief history of the Society, David Young recalls these early years;<sup>1</sup> but perhaps I might add a little pre-BSS history – at least so far as I remember it.

In 1964, following a thirteen-year career at sea, I was fortunate in receiving an appointment, as a Research Assistant

(Grade 1), in the Department of Navigation and Astronomy at the National Maritime Museum, Greenwich. At that time, the buildings on the hill, to the south of the Museum, were then known as 'The Old Royal Observatory' and had become an integral part of the National Maritime Museum, as they are to-day. Soon after joining the Museum, I was sent on a teacher-training course and on an astronomy course, with a view to my giving lectures in the planetarium, which was installed in the South Building of the ORO in November 1965. Thus I took up the study of astronomy and the history of astronomy, having been given an office in the west cupola of Flamsteed House, with a magnificent view, looking over Greenwich Royal Park towards the great City of London. However, it wasn't long before my superiors decided to give me some curatorial responsibility and, in 1967, I was put in charge of the sundial collection, which was on display in one of the galleries adjacent to my office.

My initial reaction to this new responsibility was probably not as enthusiastic as it might have been. After all, unless you know about these things, a sundial is principally an ornament that rests on a pedestal in a garden. However, I soon discovered that the science of astronomy and the science of *gnomonics*, called the *art of dialling* in England, were kindred subjects, as is the art of navigation. I bought a new book on sundials, by A.P. Herbert, which I discovered had a foreword by David Waters, the head of my department.<sup>2</sup> Also, I started in a small way to collect antiquarian books on sundials, since the National Maritime Museum library had almost nothing on the subject and, besides, it took some ten minutes to walk down the hill, to the main buildings, and fifteen or more minutes to walk back to my office in the ORO. This might have been good exercise; but it disrupted the day and so disrupted one's research. Nevertheless, I soon became absorbed in my sundial studies and began to believe that I knew something about the subject!

In the year 1968 I found myself involved in the setting up of the vertical *Meridies Media* mean time noon sundial, on the south wall of the Meridian Building in the Old Royal Observatory, designed in 1967 by Dr Tadeusz Przykowski.<sup>3</sup> In this same year, I also produced what can hardly be described as a 'design' – a very crude coloured drawing – for a vertical direct south sundial, at the request of a lady in Sturry, on the outskirts of Canterbury. (Thirty years later, she gave it back to me – she had never used it; but, on the other

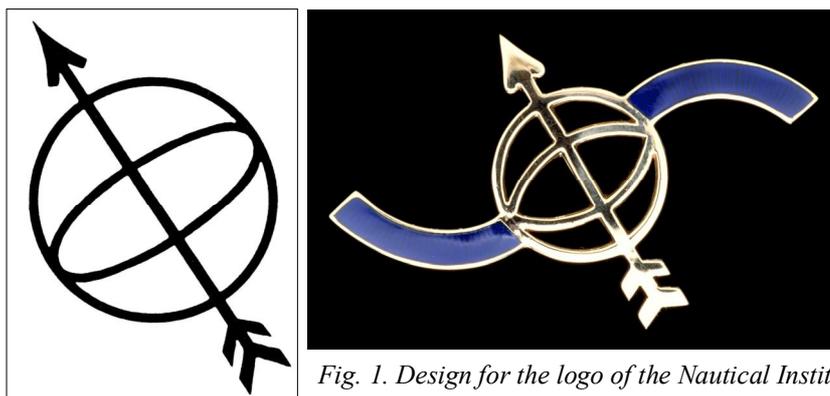
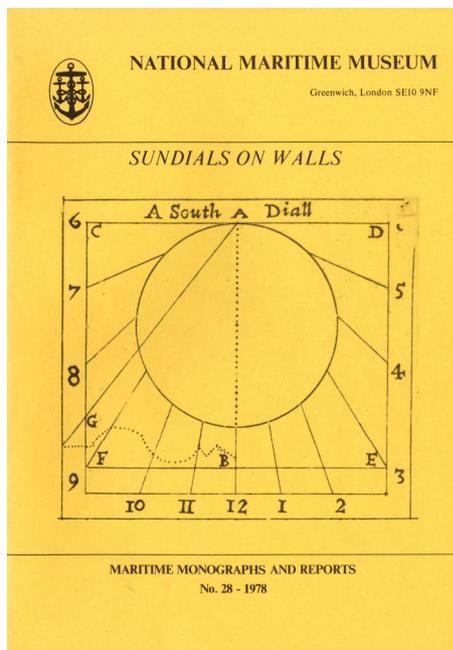


Fig. 1. Design for the logo of the Nautical Institute (1972) and (right) a unique brooch to the same design.

hand, she had kept it for all these years!) In the following year, in 1969, I contributed the equation of time delineation for the sliding cursor of an equinoctial mean time dial at East Leake. However, it was not until 1972 that I produced my first recognised sundial design, which was of an equinoctial dial. In fact, this was not actually a working sundial at all; but the armillary symbol for the newly formed Nautical Institute (Fig. 1). Much to my surprise and astonishment it was unanimously accepted from perhaps thirty entries, including those of professional designers. It is now a familiar emblem to possibly 6,000 or more persons around the world, who are members of or associates of the Nautical Institute! However, it was also in 1972 that I produced my first written work on sundials, developed from an article, which took the form of a small pamphlet entitled *Sundials – The Common Vertical in NW Kent*. This was later developed into what became a National Maritime Museum monograph,<sup>4</sup> (Fig. 2) under the title *Sundials on Walls* – now quite a rare publication!

Fig. 2. The front cover of the 1978 NMM monograph on wall sundials.



In 1973, the Museum gave me sabbatical leave to sail as second-in-command of the reproduction of Francis Drake's famous ship, the *Golden Hinde*. In fact, I joined her shortly after she was launched from Hink's shipbuilding yard, at Appledore, near Bideford, in North Devon. Here I spent much time working in the yard itself, as well as helping with the rigging of the vessel. This gave me valuable practical experience for the post which the ship's Master had bestowed on me; but this is another story! After sea trials of a sort and coastal sailing, visiting London and Plymouth, the *Golden Hinde* finally set sail out of Falmouth for San Francisco on the 1<sup>st</sup> October 1974. The voyage of 10,500 nautical miles took some five and a half months, across the Atlantic, via Lisbon, Barbados, Puerto Bello and Panama, to our destination. As a former navigator, the Museum had instructed me to make celestial observations using replicas of Tudor instruments. To this end, in particular, I carried a mariner's astrolabe and a cross-staff.<sup>5</sup>

In parallel with the Master and others, who used modern sextants to take 'sights,' I engaged in my practical work in Tudor navigation. I must say that, whilst copies of these two instruments have been used before, in comfortable conditions, aboard large seagoing ships, I know of no-one else who has had the unique experience of carrying out such observations at sea aboard a 'Tudor warship.' At first I used the cross-staff in the usual manner, as a fore-staff, observing the meridian altitude of the sun to determine the ship's latitude. Nevertheless, as we neared the equator and the sun's noon altitude increased, this became more difficult and, turning my back on the sun, I used the instrument as a back-staff. However, I also discovered that I could use the cross-staff at night, to make observations of Polaris, the pole star, when one could measure its altitude above the visible horizon.<sup>6</sup> In the case of the mariner's astrolabe, this proved to be something of a misnomer: it was exceedingly difficult to use it at night, especially on the windy, heaving deck of an English 'galleon'. Holding the astrolabe by its suspension-ring, or even using a cord to suspend the heavy device, it was almost impossible to align the sights with the pole-star. On the other hand, using the instrument to take the meridian altitude of the sun, using the projected rays of the sun to measure the angle at noon, was simplicity itself. Ultimately, I came to the conclusion that the mariner's astrolabe and the cross-staff were relatively accurate for their time, although Tudor navigation must still have been primarily a matter of 'by guess and by God'.<sup>7</sup>

I returned to my duties in the National Maritime Museum in the early summer of 1975, when I was promoted to the grade of Senior Research Assistant in the Education Department. Two years later, in 1977, I was promoted again to Assistant Keeper I and made Head of Education Services. Technically, I no longer had curatorial responsibility for the sundial collection; but, happily, the Museum continued to recognise me as their principal authority on the subject, whilst I continued to pursue my interest in the mathematical art of dialling. However, as it happened, during 1975, the Museum's Curator of Astronomy, Derek Howse, had been in correspondence, in which I was not involved, with Dr Robert d'E Atkinson, then Professor of Astronomy at Indiana University USA, formerly Chief Assistant at the Royal Observatory, Greenwich. Dr Atkinson had made informal proposals, based on his designs for a number of sundials, which it was thought might be suitable for display in the grounds of the Museum.<sup>8</sup> In fact, nothing happened until the beginning of 1977, when David W. Waters, then the Museum's Deputy Director, sent a minute to Derek Howse stating that the Director had given approval in principle "that the Museum should mark the occasion of the Silver Jubilee of Her Majesty The Queen by mounting a permanent sundial in the lawn south of Galleries 9 and 10 and south of the bronze bust of admiral Lord Nelson". The minute requested urgent consideration for such proposals, required by the Director on the 1st February 1977.<sup>9</sup>

As a result of this minute, which was circulated to Dr J. Bennett, the then Curator of Astronomy, and to myself, a variety of suggestions for a commemorative sundial were proposed. As it happened, in late January, I was in Orpington Hospital, apprehensively awaiting an operation, when I made the first crude drawings for the design of an equinoctial mean time dial, based on the ideas of Ferguson's portable 'universal' mean time dial and the Museum's coat-of-arms, that would ultimately result in the construction of the now well-known 'Dolphin' sundial.<sup>10</sup> The other proposals included Dr Atkinson's series of dials, giving world wide time; a giant common or garden floral sundial, using the lawn as the dial-plate, with narrow radiating flower beds for the hourlines;<sup>11</sup> and a replica of the Whitehall dial, which once stood in Charles II's privy garden.<sup>12</sup> The floral dial was suggested by Gordon Taylor, then of the Nautical Almanac Office at Herstmonceux Castle in Sussex. Gordon had designed the reclining equiangular sundial, set up in the rose garden at Herstmonceux Castle, marking the Tercentenary of the Royal Greenwich Observatory in 1975.

The first of these proposals was considered to be too expensive and not really striking enough; the second, it was thought, would almost certainly be very costly and it was doubted if it would be ready in time, although having great possibilities for the future; the third proposal was also thought likely to be very expensive and that it might easily be open to vandalism. Consequently, these three proposals were rejected; but the fourth proposal, for the flower dial, was strongly advocated by Derek Howse, in response to the Deputy Director's minute. He considered it to be the best, since the design could be flexible, it could be simple and it would be the cheapest.<sup>13</sup>

Perhaps my career in designing sundials might have ended here; but for the fact that the Museum was required to seek approval for such a proposal from the Royal Parks Authority and, more importantly, from the Directorate of Ancient Monuments and Historic Buildings (DAMHB) of the Department of the Environment (DOE). Mr J. Murray, Superintendent of Greenwich Royal Park, had no objections;<sup>14</sup> but Mr Harold Yexley, principal architect responsible for the National Maritime Museum buildings, gave what I considered to be a classic response to the formal proposal on the matter of the Silver Jubilee Sundial. In his letter he wrote "On the proposal to create a flower sun dial to mark the Queen's Jubilee, I suggest it will be difficult to avoid association with the 'floral clocks' at the popular seaside resorts, and in suburban parks." He concluded his letter saying "I confess I am less than enthusiastic about something I consider will rather detract from the dignity of the Museum buildings than enhance them".<sup>15</sup> On the 14<sup>th</sup> March, David Waters suggested to the Director that my proposed sundial "would be entirely appropriate" to mark the occasion and two days later the Director gave his approval. This time, there were no evident objections!<sup>16</sup>

As it so happened, in the summer of 1975, following my return from my voyage in the *Golden Hinde*, a certain Mr

Oliver Gero had called on me in the Museum, seeking my professional assistance. He was the Managing Director of Brookbrae Limited, a small close-knit family firm, specialising in the creation of sculptures, as well as high quality garden furniture and in garden design. His brother-in-law, Edwin Russell, was a brilliant leading British sculptor and also the artistic director of the firm. Brookbrae had recently decided to manufacture an instrument in brass, which they called the *Brookbrae Universal Sunclock*, which was virtually a replica of a portable equinoctial sundial in the Museum's extensive collection. Presumably, having gained some small recognition as an authority on sundials, I was invited to write the *Introduction* to the accompanying technical leaflet.<sup>17</sup> How many of these dials were produced, I do not know; but my acquaintance with Brookbrae, in the person of Oliver Gero, provided the immediate means of making progress with my design for the proposed Silver Jubilee Sundial.

On the 28<sup>th</sup> March, Brookbrae provided an estimate for the sundial and its plinth, for a price in the order of £3,000,<sup>18</sup> and on 20<sup>th</sup> April, Edwin Russell undertook to produce a model of the sundial, from my design, in the form of a beeswax maquette.<sup>19</sup> Quite when formal approval was given for the project to proceed I cannot recall; but it was probably in early May, since Edwin Russell was working on the sculpture itself in June and July, whilst I was working on the technical drawings of the dial. The plaster cast of the sundial was brought to the Museum on the 28<sup>th</sup> September for approval and placed in its ultimate position. Fortunately, the sun shone and the assembled Museum hierarchy were convinced that the sundial would not only work; but



Fig. 3. The well-known Dolphin dial at the NMM (1978).

that it would be a fitting work of scientific art to commemorate Her Majesty the Queen's Silver Jubilee. However, it was not until the 10<sup>th</sup> November that the 'pouring' was carried out in the foundry, when the bronze was poured into the mould of the sundial. At this stage, much work remained to be done to complete the task of making the sundial, and it was evident that the commission would be carried over into the following year.<sup>20</sup> Indeed, the plinth arrived on the morning of Friday 10<sup>th</sup> February in the New Year, when the grounds were being prepared. In the early Summer, the surrounding gardens were planted out and the dial itself was duly delivered and set up in position. At last, at 1300 (1200 GMT) on Monday the 5<sup>th</sup> June 1978, the 'dolphin' sundial was officially unveiled by the Baroness Birk, Parliamentary Under Secretary of State for the Environment. The sun shone brightly that day in more ways than one; but, at the time, it never occurred to me that this sundial would be the beginning of what would ultimately become a career in designing sundials. I can only say that I am immensely indebted to all those who helped in its creation, especially Edwin Russell who brought this work (Fig. 3) to life!

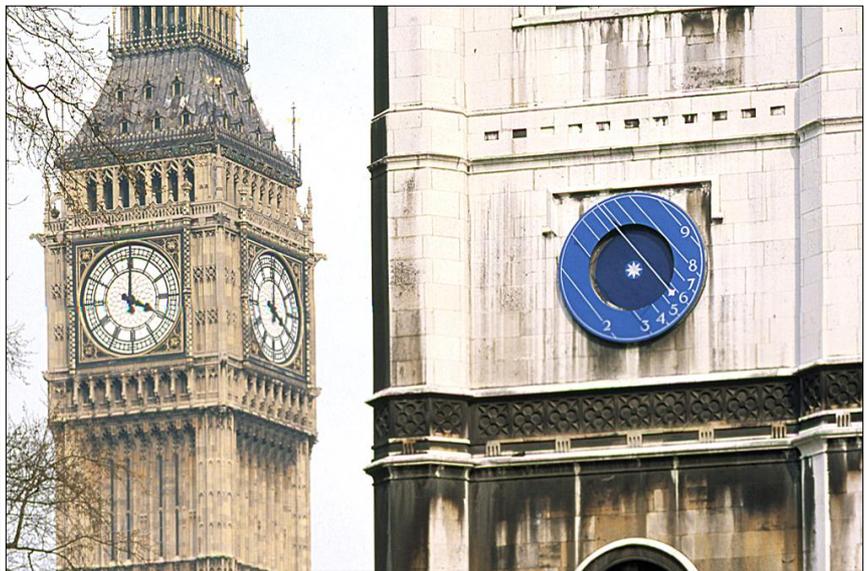


Fig. 5. One of the four dials on St Margaret's, Westminster (1982).

Fig. 4. The Marine Society and Nautical Institute sculptured sundial (1979).

There followed, almost immediately, another commission for a sundial for the new headquarters of the Marine Society and Nautical Institute, (Fig. 4) when again I invited Brookbrae to undertake the construction. This was for a vertical sculptured dial, incorporating the symbols of the two institutions, which was set up in 1979 and unveiled by Her Majesty the Queen. In 1980, a few months later, I found myself making the calculations and delineating the Victoria Cross & George Cross Association horizontal sundial, presented to HM Queen Elizabeth the Queen Mother, and set up in the garden of the Royal Lodge in Windsor, when Her Majesty was actually present. The following

year, in 1981, I provided the calculations for the direction (and distance) of Mecca from the Central London Mosque, and in 1982 there followed another major commission, when I again involved Brookbrae, for the construction of the four vertical sundials for St Margaret's Church, Westminster (Fig. 5). In 1983 I became interested in reconstruction design work, when I produced drawings for an historic horizontal sundial in Northumberland. In 1984, I designed and delineated the 'human' *analemmatic* sundial for the Wimpy garden at the Liverpool International Garden Festival, for which Wimpy was awarded a gold medal!

After my return from my epic voyage in the *Golden Hinde*, the National Maritime Museum had encouraged me to give public lectures on this venture and endorsed my empanelment on to the Foyle's list of speakers. Likewise, they gave tacit approval to my sundial design work and when, early in 1979, I was promoted yet again, this time into the 'Keeper Class', to the upper museum grade of Deputy Keeper, as Head of the Department of Museum Services – the largest department in the Museum, with a total staff of thirty-one – I was permitted to use the resources then at my disposal.

The department comprised the Design Services Section, the Education Services Section, the Photographic Section and the Publications Section, which included conferences. Although this was not a curatorial department, I had a marvellous team, with considerable expertise, which enabled me to carry out my official duties and still engage in my sundial interests. In sundial design, one particular advantage was my knowledge of astronomy and earlier experience in the planetarium. Nevertheless, I came to realise that designing a sundial was akin to composing a piece of music for an orchestra: it involved many others to accomplish the finished work of scientific art. Of course, I couldn't advertise; but I didn't need to – my commissions came by recommendation and, in the circumstances, this was all I needed. Thus, I pursued my unofficial sundial design career, design-



Fig. 6.  
The Tower of  
London dial  
(1988).

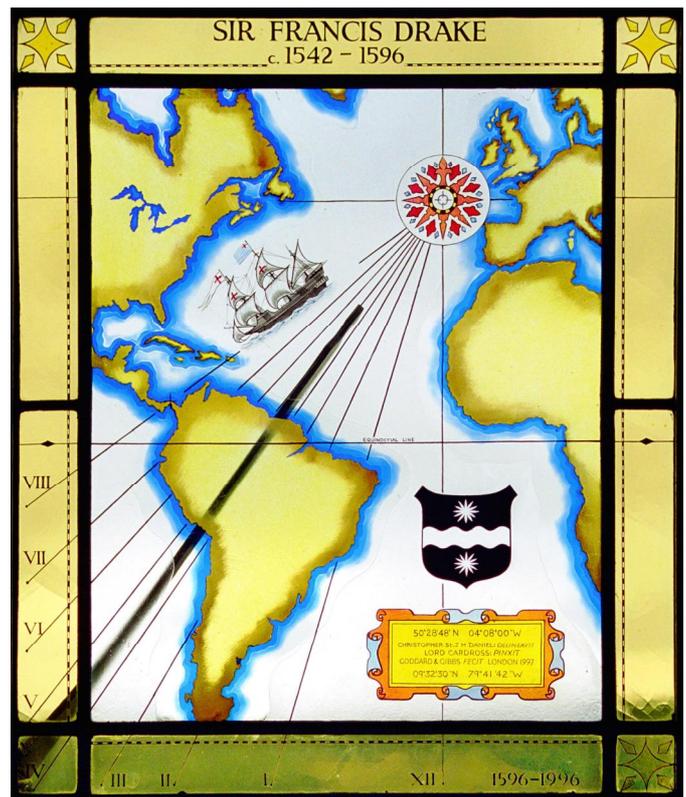


Fig. 7. The  
armillary  
sundial at The  
Savoy, London  
(1989).



Fig. 8. The Hydrographic Office dial (1995).

Fig. 9. The stained glass dial at Buckland Abbey (1996).



ing one or two dials a year, until 1986, when I took early retirement from the Museum. In this same year my *Sundials* Shire album was first published, being reprinted in 1990, 1993, 1997 and 2000. It was revised, augmented and illustrated in colour, as a second edition, in 2004. To the best of my belief, it has sold well over 24,000 copies (it might be 26,000 or more) and has been reprinted this year.

As it happened, 1986 was also the year in which I first learned of a certain Dr Andrew Somerville, who had been enquiring about a facet-headed multiple dial. It was also later the same year that I heard of a gentleman in Essex, who gave talks to local societies on the subject of sundials, who turned out to be David Young. I should perhaps add that those who reviewed the first edition of my Shire album included Charles Aked and Andrew Somerville, who were Founding Members of the Society, and Gordon Taylor, who

became the first official Registrar and with whom, many years earlier, I had corresponded on the idea of a *Register* of British sundials. In his 'A Brief History of the British Sundial Society,' David Young takes up the story.

With perhaps one or two exceptions, I have never really written up my sundial designs for the BSS *Bulletin* and neither have I ever entered an Awards Scheme – despite suggestions that I should do so – believing that the Awards were for the encouragement of others. Nevertheless, over the years, I continued my design work, with some forty

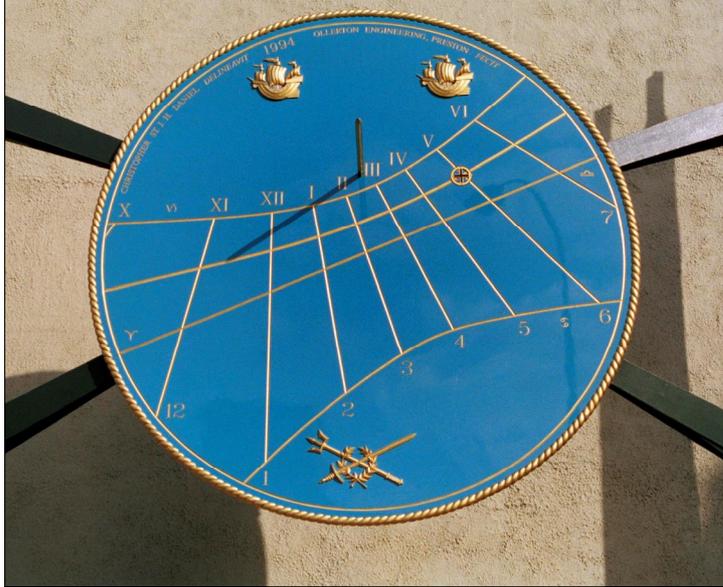


Fig. 10 (above left). The 'Nelson' dial at Chatham (1994).

Fig. 11 (above). The Argos dial at Wimbledon (1996).

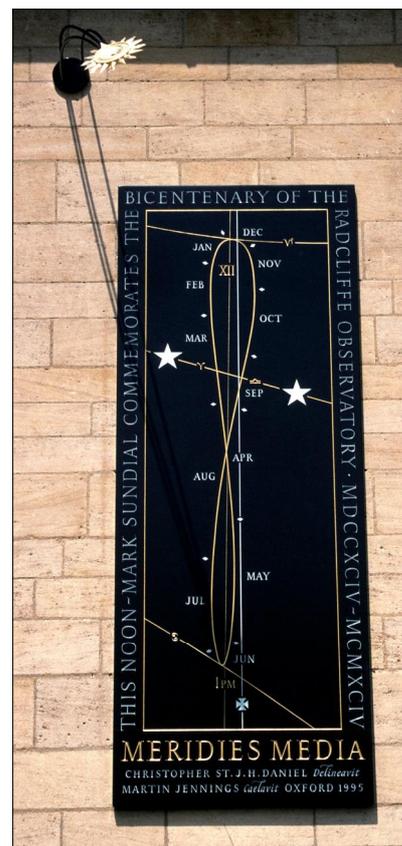


Fig. 12. The noon mark at Green College, Oxford (1995).

major works, seventeen reconstruction works and a multitude of lesser projects, such as the use of shadows to prove that Metropolitan Police surveillance photographs were not all taken at the same time, as claimed! During this time, I have had the privilege of working with the best artists and craftsmen, sculptors and letter-carvers, skilled metalworkers and others, who have produced sundials for me, of which I feel justly proud and for which I thank all those concerned. These sundials include, of course, the 'dolphin' sundial at Greenwich; the vertical dials on St Margaret's, Westminster (Fig. 5); the reconstructed 17<sup>th</sup> century vertical dial on the Martin Tower, in HM Tower of London (Fig. 6); the vertical declining commemorative 'Nelson' sundial at Chatham (Fig. 10); the noon dial at Green College, Oxford (Fig. 12); the stained-glass sundials in Buckland Abbey (Fig. 9) and in the Chapel of the Merchant Adventurer's Hall in York; the large *analemmatic* commemorative sundial in the National Memorial Arboretum; and last, but by no means least, the simple logo of this Society.

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# THE SUNDIAL GOES TO WAR

## Part 1

MALCOLM BARNFIELD

Technological innovations developed during World War II, such as radar, jet engines and electronic aviation navigation, defined the last half of the 20<sup>th</sup> century and were instrumental in the successful execution of the war. At first glance, it seems unlikely that medieval technology would be useful in 20<sup>th</sup>-century warfare, but once one realizes that much of the war was waged in areas where more modern technology was either not available or useless, it becomes obvious that the old ways may well be the best ways.

Such an environment was the Sahara Desert where mapping was nonexistent or impractical. Desert navigation has been a problem for travellers, and warriors, since the dawn of time and the methods used by caravans and nomads to find the way are as useful now as they were 2,000 or more years ago.

This article deals mainly with the military use of the solar compass during World War II (1939-1945) and after. Obviously some of the instruments had been developed prior to WWII and used knowledge from pre-WWII: many sun compasses were pressed into service during that conflict and new developments did also appear.

The purpose of any compass, solar or magnetic, is to locate, as accurately as possible, the direction of true north. Once north is found, the current or desired bearing can be determined. Positions are determined with dead reckoning or by

reference to a chart or map. Knowledge of the bearing is critical for ocean or desert travellers as it avoids the distinct possibility of going in circles

Most solar compasses are actually an adaptation of the analemmatic sundial which is rather old and came from French mathematician Antoine Parent in 1701.<sup>1</sup> The standard horizontal format sundial is oriented to true north and works by using a calibrated hour curve (part of a conic section) indicating local apparent solar time (LAT) for a given latitude and date. The time is indicated on the plane by using a suitable vertical stylus/gnomon to create a shadow. The sun's declination on this dial is set by using a calendar scale along which the sliding stylus can be moved throughout the year. So, when orientated to true north, the current LAT is revealed for that day and in that place.

The solar compass works in the reverse order of this: when LAT, date and latitude are known, and when the dial is set to these parameters, true north is indicated by the compass as the midday position, its dial plate having been calibrated for many latitudes.

Archeological records show that Viking mariners used a form of solar compass in the early 11<sup>th</sup> century AD and probably before.<sup>2</sup> The discovery and calculation of conic curves for sundials is attributed to Apollonius of Perga in ancient Greece, as is the naming of the resulting parabola and hyperbola. The theory was further developed by the Persian scholar and poet Omar Khayyám, but he was only born in the mid-11<sup>th</sup> century AD and no record of Viking/Greek communication exists. A completely plausible explanation of how the Vikings may have achieved their solar compass is given by Folkard & Ward<sup>3</sup> and by Cowham<sup>4</sup> who produced a replica compass to test his theory.

Many fine examples of analemmatic sundials have been made over time and their construction continues as several recent BSS *Bulletins* show.<sup>5</sup>

### Early American Examples

Centuries later, when North America began to develop, the solar compass came back into use and William Austin Burt<sup>6</sup> obtained an American patent<sup>7</sup> for his solar compass in 1836. The device (Fig. 1) was used to survey and map mining areas where the iron content in the ground precluded the use of the magnetic compass. Burt explains its use in the following way:

“To run a north and south line with the solar compass.  
Set off the declination of the sun on the declination arc.  
Set off the latitude of the place (which may be deter-

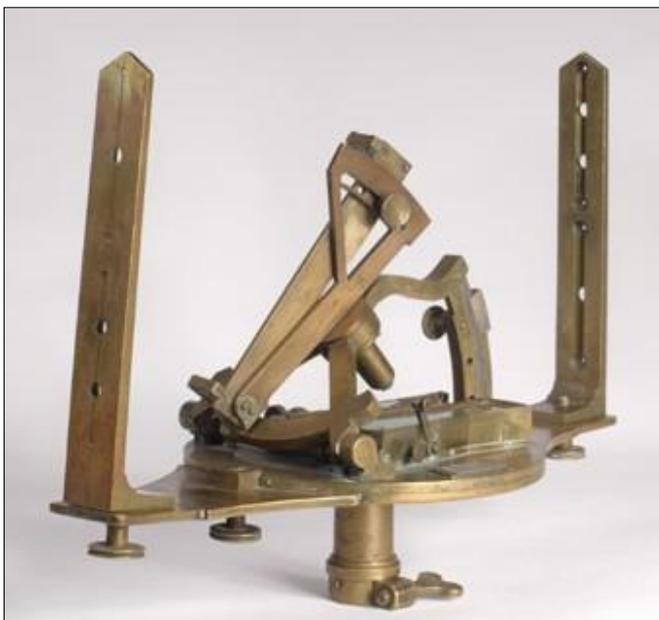


Fig. 1. The Burt Solar Compass. Picture courtesy of the Wisconsin Historical Society catalogue #1962.60.2.a.

mined by this instrument) on the latitude arc. Set the instrument over the station, level, and turn the sights in a north south direction, approximately by the needle. Turn the solar lens toward the sun, and bring the sun's image between the equatorial lines on the silvered plate. Allowance being made for refraction, the sights will then indicate a true north south line."

Burt's book 'A Key to the Solar Compass & Surveyor's Companion' is still available.

Later, the Wright brothers flew the first aeroplane and this fascinated a young Talbot 'Ted' Abrams who by 1916 was working for the Curtiss Aeroplane Company, building early aeroplanes. He learned to fly at the Curtiss Aviation School and his Fédération Aéronautique Internationale pilot's licence, number 282, was signed by Orville Wright himself.<sup>8</sup> Abrams then went into aerial photography but found the cameras and compasses then available quite inadequate for accurate mapping. So he founded the Abrams Instrument Company and developed his own instruments. One of those instruments was the Abrams Solar Compass which is discussed below.<sup>9</sup> Unfortunately, no picture of the original instrument could be found. The company still exists and now specializes in electronic instrumentation.

Thus, there were commercial sun compasses available before WW II.

### World War II Experiences

After the 'Phony War' phase of World War II in 1939 and the 1940 disastrous British 'victory' at Dunkirk,<sup>10</sup> the real action was about to begin in the North African deserts, first against the Italians and then against the German Afrika Korps led by Field Marshal Erwin Rommel.

The first part of this conflict with 'Wavell's 30,000' against the Italian 150,000 mostly ran along the wooded and hilly coast of Egypt, Libya and Tunisia and resulted in some stunning tactical victories for the British but later, after the Italian defeat, when the Germans joined in, heavy fighting took place up to 950 miles into the Western Desert of Egypt and Libya. These territories were largely unmapped so grid/magnetic compass variation was very difficult to establish. Since the sand dunes were constantly moving with the wind, no fixed point of reference existed, so even if maps had been available they would have been of little use.

### Abrams Solar Compass

The all-steel Abrams Solar Compass (Fig. 2) was actually a licensed version of the Kaufman Solar Compass to which American patent 2441636 later applied.<sup>11</sup> It was calibrated for both hemispheres and from the Equator to 45° north and south of it, in 3° divisions. Several different length styluses were provided, the tallest of which would have been used within the tropics and the shortest in conjunction with the others for night navigation by orientation to Polaris, the north polar star. The tips of the styluses contained a tiny glass capsule apparently filled with a luminous substance and were presumably used at night but their exact function

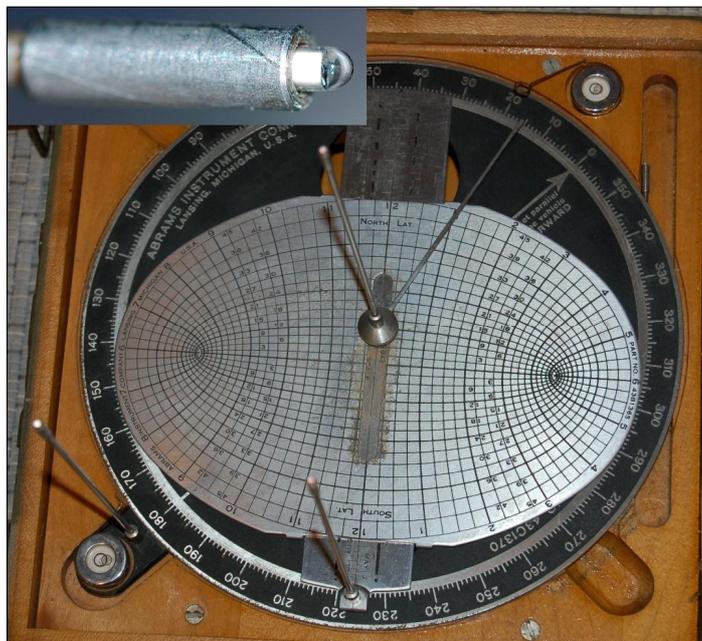


Fig. 2. The Abrams Sun Compass. Inset: the glass-tipped gnomon. Photos by Bill Gottesman.

and method have yet to be discovered. The date plate was calibrated for both northern and southern latitudes. Thus the instrument was immediately usable in either hemisphere and so was consistently universal within its calibrated latitudes, unlike most others.

American-made B-24 Liberator bombers, operated by the RAF and US Army Air Corps (later USAAF) in the North African campaign and also the American forces who invaded Morocco and Algeria during Operation Torch late in 1942, were all equipped with the Abrams instrument. It allowed aircrew to find their orientation in the unmapped desert if the plane crashed. Very little of its use or popularity could be learned from research although it was also used by US Forces in the Philippines. Several good examples survive in various museums and private collections and many web articles and pictures exist.

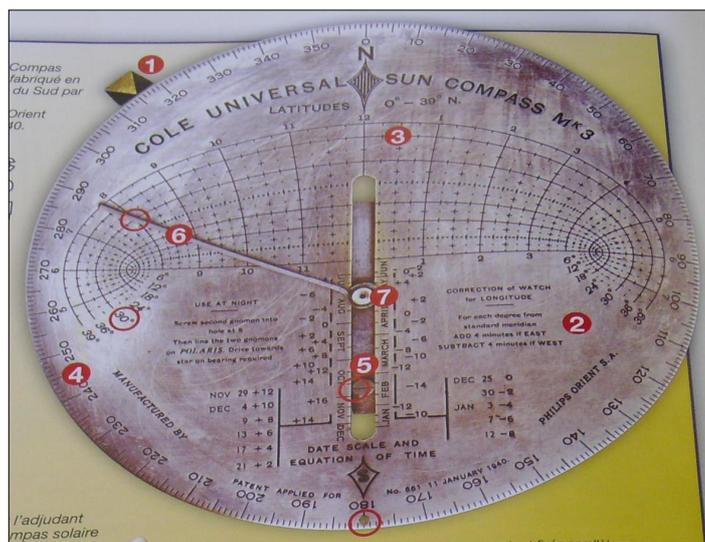


Fig. 3. The Cole Universal Sun Compass Mk. 3. After Thierry & Mary Monét.<sup>12</sup>



Fig. 4. The Cole Mk. 3 compass in French Army use on a South African made Marmon Herrington armoured car. North Africa, early 1943. After Thierry & Mary Monét.<sup>12</sup>

### The Cole Universal Sun Compass

Another sun compass used in the North African desert campaign was the Cole Universal Sun Compass Mk 3, shown in Figs. 3 & 4.<sup>2,9,12</sup> This instrument was calibrated in 6° divisions from the Equator to 36° N and by a further 3° division to 39° N, so it could hardly be called ‘universal’. Its design and operation were very similar to that of the Abrams Solar Compass but, whereas in the Abrams design the whole dial plate moved up or down the date scale with the stylus fixed in the centre, the Universal Sun Compass had the opposite arrangement.<sup>12</sup> The instrument in Fig. 3 was made by the Philips Orient Company in South Africa. The Philips Company still exists and is known in the UK as a map supplier to schools. It is now in the Octopus Publishing stable and an enquiry there revealed nothing about who Cole was, when the compass was developed, how many instruments were made or why the company left South Africa. However, as Fig. 4 shows, at least 661 instruments were made by 11 January 1940. A web auction site recently had a Cole instrument for sale which was claimed to be “c. 1920”.

The Cole Sun Compass was particularly popular among the French forces in North Africa.<sup>12</sup> It continued in use until at least 1967. This information is from an old Rhodesian SAS army friend and former Sergeant Major in the French Foreign Legion, who actually used one in 1967. Amusingly, he stated that the “hard bitten Thomases” still slyly checked their results with a magnetic compass, a pointless exercise in unmapped desert conditions. Using a second gnomon also allowed the compass to work by night which close examination of Fig. 3 explains. The South African instrument was definitely made for the North African conflict only. Proof of this comes from the limited northern latitude calibration (e.g. Benghazi 32° N, Siwah Oasis 29° N), the



J. Davis

Fig. 5. The English-made Cole Sun Compass Mk. 2.

clockwise hour calibration, and the use of Polaris at night. Polaris is never visible from anywhere inside South Africa. The same applied to the Mk. 2 version.

Fig. 5 is an English made version of the Cole Solar Compass, the Mk 2, also limited to northern hemisphere use. It is perhaps not as ‘soldier proof’ as the Philips Orient version but it is equally as effective. It was calibrated to a slightly higher latitude (40° N) than the Philips version as the picture shows. The Mk 4 version of this sun compass was still in British military use in the Iraq ‘Desert Storm’ conflict of 1991.

### The Bagnold Sun Compass

The famous British Army’s Long Range Desert Group (LRDG) was founded by Major Ralph Bagnold in 1940 mostly, it would seem, by chance.<sup>6</sup> Bagnold, a veteran of WWI trench warfare and later an old hand in the desert, was on his way to East Africa when the troop ship he was on was accidentally rammed and disabled near Alexandria in 1940. Whilst cooling his heels in Cairo he conceived the idea of the LRDG and approached General Wavell with it. The concept was eagerly approved and a unit of 87 New Zealander officers and men, all volunteers, along with Bagnold and two British officers, was formed.

Navigation was always going to be a problem for this unit and operating far behind enemy lines, up to 950 miles from the coast, was a challenge. Bagnold was a qualified engineer and tackled the problem by using BBC short wave radio broadcasts to obtain GMT and sextants for basic navigation. Initially they used the Cole Solar Compass for following a chosen heading and they even tried the Abrams Solar Compass but both were found to be woefully lacking for delivering the reliable and quick navigation results required. In fairness though, neither was designed for the needs of Bagnold’s group.

In his book ‘The Long Range Desert Group 1940-1945’, Major General David Lloyd Owen laments this fact and goes on to say:<sup>14</sup>

“The compass we used was invented by Bagnold, and the advantage that it gave us over the sun-compasses used by the rest of the Army lay in the fact that it showed the true bearing of the course followed at any moment, whereas the other types only made certain that if the sun’s shadow fell on the correct time-graduation the truck was following a set course. This meant that if one had to change course for any reason (and this happened all the time in rough country or sand dunes), the truck had to be halted and the compass set again. This was all very time consuming, and I have never understood why the Army did not adopt the Bagnold sun-compass, which was far simpler to operate, absolutely ‘soldier-proof’ and, I would have thought, cheaper to produce.”

*Fig. 6. The Bagnold Sun Compass. Courtesy of the Imperial War Museum, London.*



The Bagnold compass is shown in Fig. 6. Later, Owen describes using the compass:<sup>14</sup>

“The principle can be briefly described as keeping the shadow from the sun of a vertical needle (which projected from the centre of a small table graduated into 360 degrees) on to the appropriate reading in order to maintain the direction required. If one was forced off this bearing it was still possible to read the direction in which the truck was then traveling. There were problems connected with the sun’s azimuth at various times of day and seasons of the year, but those too were overcome by the inventive genius of Bagnold.”

Navigation by the LRDG was precise as is shown by their extraction of the men from the very first of then Lt. David Sterling’s SAS raids in the desert during 1941. Their accurate traverse of the ‘sea of sand’ (dubbed ‘on the blue’ by British soldiers) was easily comparable to that of any Navy Captain’s efforts on the oceans. They also travelled using the moon for direction but whether this was by using the sundial with a moon correction chart or a sextant is not made clear in the literature I have seen. The Bagnold instrument had a set of removable card dial plates for different dates and latitudes, calibrated in 3° divisions from 0° to 46° N. Presumably the 46° card only showed 1° of latitude. For southern latitudes another set of cards would have been needed but the LRDG never operated south of the equator. However, they certainly found themselves well south of the Tropic of Cancer at times. Waterproofing of the cards was unnecessary – it does not rain in the desert.

Using the Bagnold compass was relatively easy, mostly for the driver. Global position and LAT were established by the navigator, around midday, using the sextant, theodolite and GMT radio signals. Armed with this knowledge the driver set the Bagnold compass to the given parameters and established true north. The compass was mounted in the centre of the dashboard, usually to the right of the driver since these were often North American-made lefthand-drive vehicles. The orientation came from a central line from front to back of the truck, the lubber line, north to the front. He then rotated the bearing ring of the compass to alignment with the lubber line of the vehicle and onto required bearing and then drove along with the shadow from the stylus on that bearing. If a deviation for a large obstacle was required the driver made the adjustment to the bearing ring with the adjusting wheel, one full turn of the wheel equating to exactly 2° of bearing alteration. When the obstacle had been passed the driver/navigator simply reset the bearing ring to the original course and continued on his way without stopping the patrol convoy. Even if he did not adjust the bearing, the original bearing could easily be re-established after bypassing a small obstacle by simply bringing the shadow from the stylus back onto the original bearing. When travelling in a southerly direction the back-bearing (bearing – 180°) would have been used. Adjusting the bearing to the ever-changing solar azimuth was also performed using the adjusting wheel at regular intervals.

Bagnold ended WWII as a brigadier and with an OBE, a fitting recognition to a great mind and a great man, a soldier’s man who ensured his men were well equipped and well looked after thus ensuring willing and effective service to the greater cause. In my opinion Bagnold should be ‘right up there’ with Brahe, Kepler, Hartman, Oughtred and other luminaries of our sundial passion.

### **The Observatory Universal Sun Compass**

Britain’s allies included many Commonwealth countries, most of which had troops particularly suited to the local conditions. One requirement led to the hasty formation of the South African Armoured Car Regiment (SAACR). A tool which this regiment lacked was a reliable navigational capacity in uncharted territory.

In 1940 the Union Observatory (Union of South Africa) at Observatory, Johannesburg, was directed by Prof W.H. van den Bos and he was ably assisted by W.S. Finsen (MSc, later DSc and observatory director). Finsen relates in his journal<sup>15</sup> that one afternoon in early 1940, a major and a lieutenant from the SAACR approached him with a wooden model of a solar compass they had unsuccessfully been attempting to develop for desert navigation. They asked for his help. He immediately warmed to the idea and between himself and van den Bos they designed and developed the Observatory Solar Compass very quickly, producing the instrument shown in Fig. 7.

The instrument worked on different principles to the compasses described above. It had a sliding lens that moved

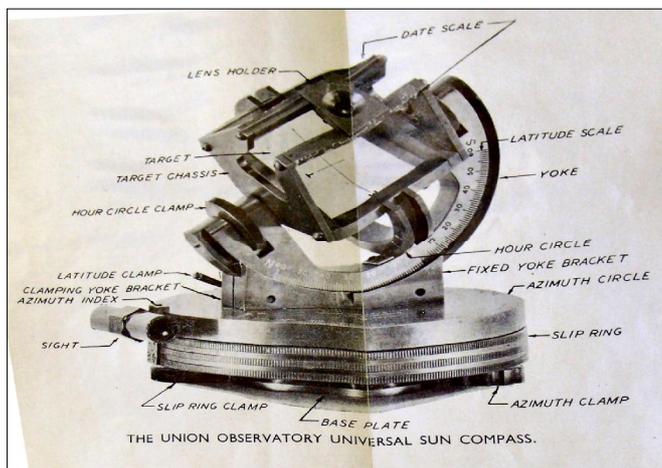


Fig. 7. The Union Observatory Universal Sun Compass. Courtesy of the SANMHM.

along a date scale which allowed the focused beam of sunlight to be projected onto a frosted cellulose target screen that swivelled to the hour calibration after being adjusted to the latitude. Thus it did not employ a gnomon since it worked on solar altitude and not solar azimuth. This compass had several advantages over other designs. It was not necessary to know LAT or longitude to set it. Also, adjusting it to another bearing whilst on the move was possible. It was equally as easy to reset to the original bearing after a deviation for obstacles on the route, like a sand dune or ravine, also whilst on the move. Lastly it was 'soldier proof' and compact being constructed sturdily from solid brass and its moving parts were all closely engineered to prevent the ingestion of sand and dust. Like its 'cousin' the astrocompass, it was usable in both hemispheres without any hardware reversal. Its latitude calibration markings, also like the astrocompass, were filled white and red for the northern and southern hemispheres respectively and were marked from the equator to 60° N and S. However, because it worked on solar altitude, it became increasingly useless above latitudes of 60° because solar altitude at the high latitudes is steadily more constant throughout any sunlit day as the pole is approached.

A then 'Top Secret' but now derestricted letter to the War Office in London in 1940 is on file and offers the instrument to the British. Their response is not recorded but since only 128 of the instruments were made, it was definitely



Fig. 8. WWII prismatic marching compass issued to BSAP Sgt Grover in 1939.

not accepted. Price is nowhere mentioned. Every squadron of the SAACR was equipped with one though. The instruction booklet that accompanies the compass<sup>16</sup> explains three methods for setting-up, one for use within the tropics, another for use outside them and the third a combination of both. The SAACR only ever operated north of the tropic of Cancer during WWII but the instructions are valid for use in South Africa, parts of which are within the tropic of Capricorn. Strangely, the instruction booklet also gives every trigonometric formula used in the design, hardly appropriate for a combat soldier's use.

The SAACR used the Observatory compass to great effect and had a proud record in the desert campaign. Towards the end of the African phase of WWII, the fighting was confined to the narrow coastal plain of Tunisia and its adjacent highlands. Here the solar compass had very little use because the coastline was easily visible and good survey maps existed so the trusty prismatic compass (Fig. 8) was employed instead. After the surrender of African Axis forces in May 1943 the SAACR was sent home and demobilized. A few months later the regiment was resurrected as the South African Tank Regiment and equipped with modern tanks complete with their Observatory Universal Sun Compasses. The unit was eventually deployed around the Mediterranean, Middle East and North Africa. Italy was well mapped so the solar compass found no place there.

#### The Armstead Sun Compass

A further instrument was developed during this period, the Armstead Sun Compass. Sadly no pictures of the two prototype versions made of this instrument can be found. The compass came from the British Indian Army's need for a solar compass to be used in desert warfare. This compass has been described in the *Bulletin* previously,<sup>17,18</sup> and Michael Lee has made a fine and accurate instrument<sup>18</sup> based on Armstead's original design. Judging from Armstead's logic and mathematics alone, he must have been a huge asset to his military logistical office. However, as an ex-military man, my opinion of the instrument is that that whilst it demonstrated Armstead's complete understanding of gnomonics, trigonometry and solar geometry and was a very clever concept, it contained too many flimsy parts and screws that would vibrate lose and be lost so it could never have been 'soldier proof'. It was also complex to use, set up and understand and could not be used on the move, so was never destined for production and use in a mechanised and mobile theatre of war. The basic principles of the Observatory Compass and the Armstead Compass are the same and it is amazing how great minds came up with the same navigation solution simultaneously, albeit continents apart and without joint knowledge of each other's work.

So, was the end in Africa the end for the solar compass? Emphatically, No!

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8. From the Abrams Planetarium web site [www.pa.msu.edu/abrams/](http://www.pa.msu.edu/abrams/) follow the link 'Our History' then 'Talbot (Ted) Abrams'.
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16. [www.samilitaryhistory.org/vol024mn/html](http://www.samilitaryhistory.org/vol024mn/html) gives more detail on the Observatory Sun Compass.
17. N. Darwood: 'A Moondial', *BSS Bull.*, 18(i), pp.14-15 (June 1992).
18. M. Lee: 'A Universal Heliochronometer', *BSS Bull.*, 21(iv), pp.28-33 (Dec 2009).

*To be continued*

## READERS' LETTERS

### Scottish Polyhedral Dials

I notice in the March edition of the *Bulletin* two line drawings of Scottish dials and can add some further information.

**Queen Mary's Dial at Holyrood Palace:** Although this sundial is popularly associated with Mary, Queen of Scots and indeed is known as Queen Mary's Dial, it was constructed in 1633 for the coronation of her grandson Charles I, long after Mary lost her head in 1587 at the hands of Queen Elizabeth I of England. The dial includes the crowned initials of Charles I, his queen Henrietta Maria, and other royal heraldic devices and badges. Like his grandmother, Charles was also executed, in 1649. As with the fabulous obelisk dial at Drummond Castle Gardens featured on the back cover of the March *Bulletin*, it is credited to John Mylne, the King's master mason. I have included this dial in my entry for the 2010 Sundial Trail Competition (The Royal Mile Sundial Trail).

**Mount Melville Multiple Dial:** As stated in the caption, Mount Melville became Craigtoun House and was also Craigtoun Maternity Hospital latterly until it closed in 1992. It lay derelict until it was bought by Golf Resorts International who had plans to turn it into a golf resort and spa. It is adjacent to the Duke's Course just outside St Andrews which is also owned by Golf Resorts International. They were subsequently bought by Kohler Co, an American plumbing business who have entered into the luxury hotels market specialising in golf resorts. Unfortunately, the company carrying out the refurbishment works went into administration and work was stopped. There have been ongoing problems with the planning permission which may also have affected progress on the works. The building is now boarded up and empty once again.

Photographic evidence (above) shows that the sundial was in position at the front of the house on 12 May 2006, but was missing by 2 February 2008. However, I did eventually manage to contact a representative of the owners, who said



Ian Hayton

that it had been removed for safe keeping. They plan to re-instate it at the front of the house once restoration of the house is complete, which is currently planned to recommence next year or the beginning of 2013.

I look forward to visiting Craigtoun again in a few years time, hopefully to photograph this lovely sundial in much grander surroundings.

*Dennis Cowan,  
Rosyth, Fife*

*Continued on page 43*

# A DIAL TO TRAVEL WITH

JACKIE JONES

I recently received my new passport and was amazed to find it includes a picture of a sundial. It is a beautiful image; about 4 cm high, of a detailed gnomon on what I would imagine is a stone plinth. I then wondered if it was a real dial, or an artist's interpretation of one. I scanned into the computer the page of the passport and by playing around with intensifying the colours, I was able to get a good enough image to send to other members of the BSS Council in the hopes that it might be identified. The original is quite pale greens and blues, designed to be over-stamped with visas etc.

John Davis recognised it as being the 'missing' John Rowley one at Blenheim Palace which was only found again recently and which was re-installed in 2008. The clues are:

- The deep double-ogee rim which was mainly used by Thomas Tompion and John Rowley (and later by Daniel Delander etc.),
- The vertical back edge to the gnomon which marks it as an azimuth dial, as made by Tompion and Rowley (and Thos Wright etc.),
- The centre of the gnomon with its solid crown but open-work centre to the circle – the Blenheim azimuth dial is the only Tompion/Rowley known to be like that.

Jeri Bapasola, an historian at Blenheim, was able to confirm this, saying: "The garden scene is taken from the upper water terraces at Blenheim. The sundial is not an exact depiction. Apparently, we were only informed that BP was chosen as one of the sites to be included; there was no involvement on our part, and nothing given by us. The passport office design team visited without

announcement and we are told that the drawing they produced has certain encrypted features (for the detection of forged passports), so it was all quite hush-hush." The identification was then also confirmed by the Passport Service.

The rest of the pages are equally interesting. All the pages are of picture postcard Britain and include the White Cliffs of Dover, Gower Peninsula, Ben Nevis and many other scenes such as village



greens, fishing villages, canals, dry stone walls and lakes. There are also many Met Office weather symbols: isobars, fronts, clouds and suns. Each page also has a Fahrenheit /Centigrade conversion chart – useful for those travels to other countries.

Jackie@waitrose.com

## The John Rowley Dial

When delegates to the BSS Oxford Conference visited Blenheim Palace in 2004, two of the set of four sundials which John Rowley made for the 1<sup>st</sup> Duke of Marlborough in 1710 were on display. To our delight, a third dial, a double horizontal which had long been thought lost, was unveiled from a packing crate. The final dial from the set, an 'azimuth and equation of time dial' was still missing but it was 'found' in 2008. It had apparently been given by the 4<sup>th</sup> Duke to his third son, Lord Francis Almeric Spencer, created Baron Churchill of Whichwood in the 18<sup>th</sup> century. He had taken it to his estate Cornbury Park near Charlbury, not very far from Blenheim.

The dial was given back to the current Duke of Marlborough and I was able to photograph it in time for my talk on John Rowley at the 2008 BSS Conference. In September that year, I also had the honour of reinstalling the dial on a refurbished contemporary

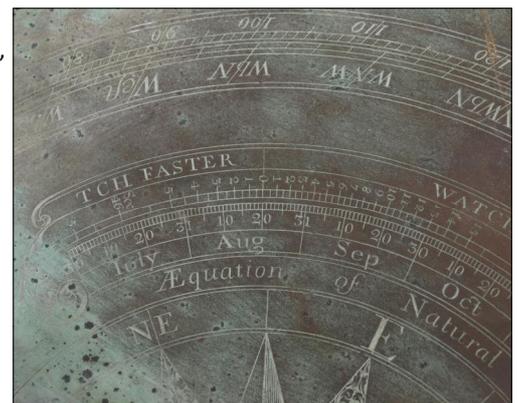


pedestal where it was drawn for the passport.

The deep cast rim of the dial had been filled with a mortar/cement mix, making the dial rather heavy and with a flush base. This was attached to the pedestal with a set of stainless steel studs set in polyester resin. Since these studs were blind, a temporary template was needed to locate the holes in the pedestal.

The dial, which cost £60-0-0 in 1710, is in good condition. The engraving includes an azimuth scale centred on the vertical northern edge of the gnomon. Inside that is an Equation of Time scale reading to half-minutes. If any reader visits and checks the alignment, bear in mind that this scale was calculated for the Julian calendar and that the actual values have changed slightly in the three centuries since it was made. The coat of arms on the gnomon features the Churchill lion couchant holding a flag.

John Davis



# MINUTES OF THE 22<sup>ND</sup> ANNUAL GENERAL MEETING

## Wyboston, 1 May 2011

1. About 70 voting members were present for the meeting, which was opened by the Chairman, Christopher St J H Daniel, at 12:30 pm. He commenced with some personal remarks on his twenty-one years in office, and expressed his thanks to the very many members who had helped him and the Society over this time.

### 2. Apologies for Absence.

No apologies for absence had been received.

### 3. Minutes of Previous AGM.

The minutes of the 21<sup>st</sup> Annual General Meeting, held at Exeter University on 11<sup>th</sup> April 2010, had been published in the *Bulletin* of June 2010, were taken as read, and were approved by a show of hands. There were no matters arising and the minutes were adopted.

### 4. Council member's reports.

The reports of the Honorary Secretary and other members of Council had been circulated with the Conference papers, and are shown below.

#### SECRETARY: 2010-2011 Review – *Graham Aldred*

Further progress has been made in improving the administration of the Society and effort has been applied to several specific issues. We have investigated in depth the proposal to change the Society's domain name and found that it cannot be justified. The reasons for this were published in the June Newsletter. The new Charity Commission Act places more stringent requirements on any Society which wishes to claim charitable status and recover the tax paid on membership fees in the Gift Aid scheme. In particular, we are required to define the 'Public Benefit' that is available to the public at large beyond the membership. It has not been easy to get unambiguous advice from the Charity Commission because they need to interpret the new Act in detail, so it has been necessary to seek professional advice. The Council have also reviewed the AGM procedures and voting arrangements. We have examined the Society's income streams in the light of the decline of membership and very low bank interest and this shows a shortfall against our running expenses. Unless we can recruit 70+ new members and nobody else leaves, we will need to raise the membership rates in 2012. The Treasurer's report provides more detail and the rationale for this.

We have been able to make a significant saving by consolidating our requirement for commercial storage in a single store at Maidstone. The number of surplus copies of old *Bulletins*, hitherto demanding considerable storage space, can now safely be reduced because they have all been scanned and are available on a single DVD largely due the efforts of Kevin Karney and John Davis.

The Society's achievements and Public Benefit are largely expressed in its publications. The all-colour *BSS Bulletin* has continued to attract compliments and praise for its quality both in content and presentation. The growing series of monographs

have proved very popular and profitable. The fifth edition of the *Sundial Register* has been published this year in various forms. This national survey is a tremendous achievement of careful data collection and management although, sadly, it is rather unrecognised outside the Society in the heritage world. The new website, completely rebuilt, is now operating after great efforts by our Webmaster. It is now fully compliant with web standards and provides considerable dialling information to the public. All these publications form a significant part of the BSS legacy.

I shall be retiring as Secretary after two years in office, as planned, but have offered my extended support to my successor.

#### Restoration Enquiries and Grants

The Society is pleased to support the restoration of the *Meridies Media* noon-mark mean-time sundial at the Royal Observatory at Greenwich by providing a grant from the Restoration Fund and supplementing it (by agreement) with the dormant St Catherine Cree Fund, which the BSS has held for many years. It is expected that the preliminary work will start soon. Members are reminded that the Grants can be made to any restoration or educational project which meets the given criteria.

#### BULLETIN EDITOR – *John Davis*

As usual, four issues of the *Bulletin* have been produced during the year. There were some distribution problems with the December 2010 issue and some minor printing problems with the March 2011 one but these have, I think, now been overcome: our Membership Secretary was kept busy sending out replacement copies. We have had an increasing number of overseas authors which is very much welcomed. As always, I am very grateful to all the authors and the proofreaders for all their efforts. Although there is rarely a problem filling the *Bulletin*, new stories on all aspects of dialling are continually sought.

Two new monographs were published over the year (No. 7, *Sundials in Museums of the British Isles* by Ian Butson, Jill Wilson & Tony Wood; and No. 8, *Timekeeping in the Medieval World - a study of Anglo-Saxon and early Norman sundials* by David Scott & Mike Cowham). Reference copies of these, and earlier titles, are deposited with the British Library and other copyright libraries so they are listed and available worldwide. Sales of the earlier titles have been good and three have recently been reprinted, a benefit of the 'print-on-demand' system. Further titles in the series are in the pipeline.

The full archive of the *Bulletin*, from the start of the Society in 1989 up to September 2010 (a total of 75 issues), have now been transferred onto DVD-R which can be purchased by members and (at a premium price) non-members. Not only does this ensure that the archive is widespread, it means that our extensive holdings of back-issues can be disposed of, re-

*continued on p. 30*

**BRITISH SUNDIAL SOCIETY  
STATEMENT OF FINANCIAL ACTIVITIES  
FOR THE YEAR ENDED 31ST DECEMBER 2010**

|  | Notes     | Unrestricted<br>Funds<br>£ | Restricted<br>Funds<br>£ | TOTAL<br>2010<br>£ | TOTAL<br>2009<br>£ |
|--|-----------|----------------------------|--------------------------|--------------------|--------------------|
| <b>INCOMING RESOURCES</b>                        |           |                            |                          |                    |                    |
| Voluntary Income                                 | <b>2a</b> | 900                        | 875                      | 1,775              | 2,382              |
| Investment Income                                | <b>2b</b> | 312                        | 0                        | 312                | 719                |
| Incoming Resources from<br>Charitable Activities | <b>2c</b> | 30,586                     | 0                        | 30,586             | 49,002             |
| <b>TOTAL INCOMING RESOURCES</b>                  |           | <b>31,798</b>              | <b>875</b>               | <b>32,673</b>      | <b>52,103</b>      |
| <b>RESOURCES EXPENDED</b>                        |           |                            |                          |                    |                    |
| Charitable Activities                            | <b>3a</b> | 30,762                     | 0                        | 30,762             | 41,770             |
| Administration Costs                             | <b>3b</b> | 8,311                      | 0                        | 8,311              | 5,808              |
| Governance Costs                                 | <b>3c</b> | 540                        | 0                        | 540                | 0                  |
| <b>TOTAL RESOURCES EXPENDED</b>                  |           | <b>39,613</b>              | <b>0</b>                 | <b>39,613</b>      | <b>47,578</b>      |
| <b>NET INCOMING/ (OUTGOING) RESOURCES</b>        |           | <b>-7,815</b>              | <b>875</b>               | <b>-6,940</b>      | <b>4,525</b>       |
| Total Funds Brought Forward                      |           | 77,618                     | 8,703                    | 86,321             | 82,179             |
| Prior year Adjustment                            |           | 0                          | 0                        | 0                  | -383               |
| <b>TOTAL FUNDS CARRIED FORWARD</b>               |           | <b>69,803</b>              | <b>9,578</b>             | <b>79,381</b>      | <b>86,321</b>      |

Movements on all reserves and all recognised gains and losses are shown above. All of the organisation's operations are classed as continuing.

The notes on pages 7 to 10 form part of these financial statements.

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#### **Treasurer's Comment**

As required by charity law, the Society has submitted its accounts for Independent Examination by qualified accountants. The resulting report, which finds that the accounts are in proper order, runs to ten pages. These two pages summarise the whole. Should it be required, the full version is available as a PDF file from the Treasurer.

**BALANCE SHEET  
AS AT 31ST DECEMBER 2010**

|   | Notes | Unrestricted Funds<br>£ | Restricted Funds<br>£ | 31-Dec-10<br>Total<br>£ | 31-Dec-09<br>Total<br>£ |
|---|-------|-------------------------|-----------------------|-------------------------|-------------------------|
| <b>Fixed Assets</b>                                   |       |                         |                       |                         |                         |
| Tangible assets                                       |       | 16,635                  | 0                     | 16,635                  | 16,635                  |
| <b>Current Assets</b>                                 |       |                         |                       |                         |                         |
| Debtors   | 7     | 0                       | 0                     | 0                       | 0                       |
| Cash at bank and in hand                              | 6     | 53,708                  | 9,578                 | 63,286                  | 69,686                  |
| <b>Total Current Assets</b>                           |       | <b>53,708</b>           | <b>9,578</b>          | <b>63,286</b>           | <b>69,686</b>           |
| <b>Creditors:</b> amounts falling due within one year | 8     | 540                     | 0                     | 540                     | 0                       |
| <b>NET CURRENT ASSETS</b>                             |       | 53,168                  | 9,578                 | 62,746                  | 69,686                  |
| <b>NET ASSETS</b>                                     |       | <b>69,803</b>           | <b>9,578</b>          | <b>79,381</b>           | <b>86,321</b>           |
| <b>Funds of the Charity</b>                           |       |                         |                       |                         |                         |
| General Funds   |       | 69,803                  | 0                     | 69,803                  | 77,618                  |
| Designated Funds                                      |       | 0                       | 0                     | 0                       | 0                       |
| Restricted Funds                                      | 4     | 0                       | 9,578                 | 9,578                   | 8,703                   |
| <b>Total Funds</b>                                    |       | <b>69,803</b>           | <b>9,578</b>          | <b>79,381</b>           | <b>86,321</b>           |

**Trustees Responsibilities**

The Charities Act 1993 require the trustees to prepare financial statements for each financial year which give a true and fair view of the state of affairs of the trust and of the surplus of the trust for that period. In preparing those financial statements the trustees are required to:

- Select suitable accounting policies and apply them consistently
- Make judgements and estimates that are reasonable and prudent
- Prepare financial statements on the going concern basis unless it is inappropriate to presume that the trust will continue in existence.

The trustees are responsible for keeping proper accounting records, which disclose with reasonable accuracy at any time the financial position of the trust. They are also responsible for safeguarding the assets of the trust and hence for taking reasonable steps for the prevention and detection of fraud and other irregularities.

These accounts were approved by the Trustees and signed on their behalf on the 18th March 2011

Signed  ..... G Stapleton. Treasurer

Signed  ..... C. St JH Daniel, Chairman      Date: 1 May 2011.

ducing our storage costs. Additionally, it means that individual articles can readily be reproduced if required. The work of scanning all the early, non-electronic copies, and then forming the resulting files, was ably performed by Kevin Karney, assisted by Elaine Hyde and Ian Butson.

#### **REGISTER – John Foad**

My thanks to members who have continued to find and report new dials, and to extend our photographic coverage. The *Register of Fixed Dials of the British Isles* now records 6670 dials, with photographs for 74% of them. While the number of previously unrecorded dials has grown by a modest 3% this year, the number that now have a photograph or photographs has risen by 10%! The fifth edition of the *Register*, including all this new material, was published in 2010 in paper and DVD form.

The main part of the Society's archives, which had been held in stores in Macclesfield and Luton, has been moved to Maidstone. This has saved rental costs and made the contents more readily available to me, as the most frequent user. The largest part of the material consists of the original reports, photographs and slides sent in by members from 1989 to the present day.

#### **MASS DIAL GROUP – Tony Wood**

New reports continue to trickle in, with new reporters contributing; all very welcome. Enquiries from various sources (including Isle of Wight Libraries) were answered. The main work has been the continued entry of reports into the *Mass Dial Register*: Essex, Staffordshire, Leicestershire, Derbyshire, Isle of Man, Hertfordshire, Isle of Wight and Devon are now all entered and the reports archived in York. The completed Yorkshire is in the queue to be the Appendix to Monograph 3 for Yorkshire dials. We are setting up a 'parallel entry' facility to speed up the *Register* entry and a computer has been purchased. Ian Butson has offered to help here and we hope to have the system in operation during the year. Ian has also helped with the necessary sorting of Edward Martin's papers and photographs, now all assigned to their sites, with a wealth of 'new' pictures and reports to add to our files. The restoration of the Celtic dial to its church at Tywyn in Wales was helped by our little network of enthusiasts, Mike Cowham and Bill Linnard carrying out a successful rescue operation. Particular thanks to Ian Butson, Irene Brightmer, John Lester, Mike Cowham and a little band of non-members who seem happy to send in details for us. Also to Johan Wikander and Philip de Jersey of the Guernsey Museum for contributions to the 'Celtic Quartet' investigation.

#### **Museums Survey**

The results are now published as Monograph No. 7 *Sundials in Museums of the British Museums* by Ian Butson, Jill Wilson & Tony Wood – now available from our Sales Department!

#### **ADVERTISING – Mike Cowham**

Advertising in the *Bulletin* is still running at a low level with just Green Witch making regular insertions. They seem happy to continue for the moment.

I have not done any advertising for the BSS in this last year but will consider what we can do now that the Summer is approaching. The most efficient way is to do reciprocal advertising with similar societies, such as SIS, AHS and BAS.

#### **SUNDIAL SAFARIS**

**Le Mans September 2011.** Things seem to be coming together quite well for the Safari. I have enlisted the help of Michel Lalos who lives nearby. We have 34 people booked, so far, but could definitely take a few more, *subject to there being space in the hotel*. (There is another hotel adjacent so we have the possibility of more rooms if necessary.)

There are some great dials to be seen there, especially in Chartres and in Le Mans itself.

Deposits have been paid to the hotel for those already booked.

Any suggestions for extra delegates will be welcomed. It would be nice to get one or two people who are not 'sundiallers'. There will be plenty of interesting things to see apart from the dial or two.

**Proposed Safari to Catalonia, September 2012.** I have been in contact with the Catalonian Sundial Group and we are working towards a Safari there next year. We have been to the area and checked it out and feel that this region will make an interesting visit. I will have some details at the Conference. Basically we will probably be based in Girona, north of Barcelona, and hope to see some good dials in this region. It seems to have perhaps the highest density of dials in Europe, some good and quite a few in quite poor condition. Naturally, we will concentrate on the better ones.

#### **TREASURER – Graham Stapleton**

In the language of Mr Micawber, our situation is rather 'twenty pounds ought and six'. Our finances actually remain in a very healthy state: yet although our overall spending has been reduced, our income has fallen faster and we are starting to run down our reserves. Conventional thinking of the moment may find this laudable, but it is no way to ensure the long-term survival of the Society.

That our situation is not weaker is in no small measure due to the great popularity of the Monographs and the *Register*; sales of which have been unprecedented. However, the underlying troubles come from continued low interest rates, a falling membership and consequent smaller Gift Aid income.

A word of clarification is called for concerning the apparent £6000 deficit appearing in the Accounts. As the timing of the Conference relates to Easter, receipts and subsequent expenditure always fall to a greater or lesser degree into the previous year. Once these effects are removed, the underlying decline in funds is marginally over £2000. However, as we are legally obliged to ensure that our events do not run at a loss, any margin that might be made on the current year's Conference will offset this.

The Council are clear that there are few measures open to us and that none are easy. In the shorter term, the subscription rate has not changed for the greater part of two decades; as of spring 2012, the rates will have to rise. I sincerely hope that members will still feel that it represents excellent value. The increase has still to be fixed, but it will be lower than if we had adopted the commercial practice of an annual increase by inflation. The other measure is only to a limited extent in the Council's hands: to increase the membership. We can work on initiatives that broadly address the likely audiences, but there really is no substitute for the personal encouragement of the individual member to recruit others. Please continue and if

possible, extend your support: the future of the sundial is not yet guaranteed.

#### **MEMBERSHIP – Jackie Jones**

There are at present 434 members of the Society of which 411 are paying and 23 receive complimentary copies of the *Bulletin*. These are mainly other societies with which we have an exchange of journal agreement. Of these members, 302 are in the UK and 64 in Europe. There are 68 in the rest of the world; 39 in the USA, 4 in Canada, 8 in Australia and the rest spread far to include Japan, Mexico, Russia, Brazil, South Africa and New Zealand.

Since the last conference we have welcomed 12 new members. This is a decrease as the previous two years have each seen 20 people join us. 32 have left in the past year; 4 died, 8 said they were too old and frail and the rest, if they gave a reason, left for financial reasons. We have an ageing membership and live in bad financial times.

Members have often asked if there are any other sundial enthusiasts in their area, so I would like to propose the idea of local groups. If you would like to form one, I can supply you with a list of members in your area (except those who have requested confidentiality). How you manage the group is totally up to you, but we would like some feedback on your activities and we may be able to give advice on talks etc. Do contact me if you are interested.

#### **THE BSS-SOTI SUNDIAL TRAIL COMPETITION – Patrick Powers**

This joint Sundial Trail Competition was run again in 2010 and five judges were appointed to comment on them. Three trails were submitted by the deadline of 31 January.

They may be accessed on the SOTI website at: [www.sundials.co.uk/competition2010.htm](http://www.sundials.co.uk/competition2010.htm)  
St Andrews - Edinburgh's Royal Mile - Wellington NZ

The judges have completed their assessment and the two winning entries will be announced at the 2011 conference.

#### **CONFERENCE ORGANISATION – Patrick Powers**

The Exeter Conference was considered a great success. At the 2010 conference, we asked delegates to complete a questionnaire and 100% of the replies received indicated that delegates had found it enjoyable, 75% felt that the University accommodation was satisfactory or good and 79% felt that the conference was good or very good value for money. Just over half said that they would definitely pay a little more to have a hotel/conference centre base and with those who said they *might* consider it, this made 86% in favour of giving such an approach a try. This year at Wyboston Lakes is the outcome of that.

By our practice of moving to different venues each year there is always an element of having to organise these meetings from scratch each time. However, this year we have continued last year's innovation and placed particular emphasis on giving more information about the arrangements by running a special conference web page and upon trying to improve the organisation of presentations by having them submitted to the organiser in advance of the meeting.

The organiser would like to receive input from this year's delegates about their perception of this latest conference.

#### **SUNDIAL DESIGN COMPETITION 2010 – Tony Belk**

This was the fourth competition in a series which started in 1995 under the title 'Open Awards Scheme', and is aimed at encouraging the production of high quality dials. There were 14 entries covering a wide range of types and purposes from England, Scotland and Wales. This was only half the number received in 2005. In addition to horizontal, vertical, equinoctial, polar and spherical dials we also had a moon dial, a hemicyclic dial and one which sounded an alarm at a time set. Apart from celebrating individual lives one dial celebrated a garden and another an author. On our judging visits we met a number of interesting people, with a wide variety of different views on the value and significance of sundials.

3 Restoration, 7 Professional and 4 Amateur entries seemed a reasonable spread but unfortunately there were no Junior entries. We need as a society to continue to try to find some means of encouraging and assisting schools to take part in such activities.

The overall requirement of the competition was that the dials should encourage the design and manufacture of good new dials. This involved accuracy of delineation, suitability for its environment, quality of workmanship, aesthetic quality, creativity and a clear written explanation for public dials. We also looked to see whether there was any simple modification that would have improved the dial's performance.

The standard of design and workmanship was good, and almost all entrants had received good advice from a sundial expert. We hope that in five years time the economic clouds will have lifted and more entries will be forthcoming.

I would like to thank my fellow judges Jackie Jones, Douglas Bateman, Frank Evans and Geoff Parsons, for their enthusiastic participation in the judging and for so readily making themselves available for our visits and meetings. I found it an interesting and enjoyable activity which gave me some new understandings of the design, use and value of sundials. I am even inspired to try to make an entry myself in the next competition. I must also thank the entrants for producing such interesting dials, for submitting all the required information and for hosting the judges on our various visits.

The following prizes were recommended in the three categories:

##### Restoration:

|                  |            |               |      |
|------------------|------------|---------------|------|
| Overall winner   | Lyme Park  | Graham Aldred | £500 |
| Highly commended | Leamington | Harriet James | £100 |

##### Professional:

|                  |          |                 |      |
|------------------|----------|-----------------|------|
| Highly commended | Bicester | Harriet James   | £100 |
| Highly commended | Glasgow  | Alastair Hunter | £100 |

##### Amateur:

|                  |             |                 |      |
|------------------|-------------|-----------------|------|
| Best amateur     | Winchester  | Chris Pile      | £200 |
| Highly commended | Petersfield | Heiner Thiessen | £100 |
| Highly commended | Burnham     | Andrew James    | £100 |

#### **SUNDIAL PHOTOGRAPHIC COMPETITION 2011 – Ian Butson**

With two weeks only remaining before the final entry closing date to the competition of 28 Feb 2011, a disappointing total of only 15 entries had been received. A reminder was posted onto the sundial website and also past entrants to the competition were approached to encourage them for their support once

again. By the entry closing date, a total of 29 photographs had been received, providing a good varied choice of subjects and a sufficient number to make for a worthwhile competition. The entries are currently in the process of being marked by the panel of six judges prior to the the results being announced at the Conference in April. As in the previous competition held two years ago in Cumbria, a 'Conference Vote' will again be held this year, with delegates being asked to give their choices for the top three photographs.

### 5. Treasurer's Report

The Treasurer's report, which had been circulated previously (see above), was accepted. Gerald Stancey asked why it had been necessary to employ external accountants on this occasion Graham Stapleton explained that it was a requirement of the Charity Commission, with the Society's turnover exceeding the level of £10,000 pa, and would therefore be necessary from now on.

### 6. Election of Officers

On the retirement of both the Chairman, Christopher Daniel, and the Honorary Secretary, Graham Aldred, Dr Frank King and Christopher Williams were appointed in their places respectively. Graham Stapleton was re-elected to the post of Treasurer.

### 7. Election of Further Trustees

Four other Trustees were also re-elected, John Davis, John Foad, Jackie Jones and Patrick Powers.

### 8. Appointment of Scrutineer for the 2011 Accounts

The appointment of Independent Examiners Ltd, who examined the 2010 accounts, was approved by a show of hands.

### 9. Close of AGM

The Chairman presented the gavel to Frank King, as the incoming Chairman, and closed the meeting at 12:45pm.

### 10. Post-AGM Matters

Immediately following the meeting, in his new rôle as Chairman, Frank King announced that Sir Francis Graham-Smith had retired from his position of President of the Society, and that by decision of the Trustees, Christopher Daniel was appointed in his place. This was widely welcomed by all present.

The floor was then opened for any general discussion. Kevin Karney suggested that Trustees might be appointed for a limited maximum period, possibly three or four years. This could encourage other members to become involved in the operation of the Society, who might otherwise be put off by feeling that they would be expected to serve for an extended period. The view was opposed by others who made the point that there had never been sufficient volunteers for Council service for that to work. They felt that the present requirement for annual re-election of every Trustee adequately provided for new Trustees to come forward.

A further suggestion was made that we consider enrolling assistants to the functional Council posts, to facilitate hand-over as and when required. No strong feelings were expressed either way and it was left as an option that should always be kept in mind and implemented whenever appropriate and possible.

Patrick Powers then asked for views on a cost-saving and rather more democratic measure whereby in future we would

publish the Society's full accounts on the website rather than specifically printing what is now a 12-page booklet, solely for the AGM attendees. Of course and as required by the Constitution, a copy of these full accounts will always be available to view at the conference prior to the AGM and additionally those unable to access the web site will always be able to receive a text copy of them on request. The short version of the Accounts will in any case continue to be published in the Bulletin each year. No dissenting views were expressed.

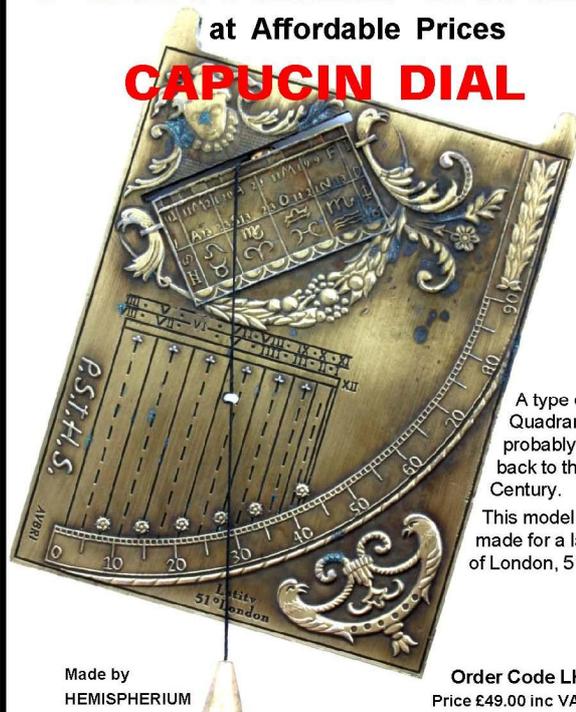
The opportunity for discussion was re-opened after lunch, but no members attended and the Chairman (Frank King) closed the meeting at 2:15pm.

## Holiday Sightings



This dial was spotted by member David Payne in Odouheiv Secviesc, Transylvania (lat. 46° 18' N), Romania.

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# PHOTOGRAPHIC COMPETITION 2010-2011

IAN R BUTSON

Following a two year break, the Society again ran its Photographic Competition in 2010 with a closing date at the end of February 2011 for submissions from its members.

With only two weeks remaining before the deadline for entries, a relatively small number of entries had been received and so a further reminder was sent out over the Society web site, in the hope that more entries might be attracted. Past entrants to the competitions of previous years were also contacted to enlist their support by submitting entries if possible. In the event an additional number of photographs were received to produce a pleasing total of twenty nine entries from twelve members, to give the second highest number of entries in the history of the competition. The judging panel comprised six people, five being from those who judged the competition of 2008-9.

Once again, each entry was marked with a differing number of points being awarded to a series of categories, as follows:

- Choice of Dial – 12 Points
- Artistic Merit – 12 Points
- Focus – 8 Points
- Exposure – 8 Points
- Illumination – 8 Points
- Title – 8 Points
- Print Quality – 12 Points
- Presentation – 12 Points
- Overall Impression – 20 Points

A number of the qualities upon which each of the photographs are marked are of course subjective, as well as some judges tending to mark somewhat higher than others. To ensure that this can have no resulting effect upon the order of the winning entry, all the results are normalised to allocate a notional thousand marking points to each judge, these then being distributed amongst all entries in proportion to each judge's original markings.

As in previous years, judges were allowed to submit their own entries, but not of course allowed to mark their own photographs. Instead, marks were awarded to them based on an average of the other judges' marks given for their entry and with the normalisation check applied, this further ensured that there would not be any bias from the marking method used.

This year a completely unprecedented result occurred with the overall winner Mike Cowham, repeating his winning success from 2008, also gaining the second and third places as well with his entries, *Winter sunshine*, *Fascinating brickwork* and *What do you make of this then Pepe?* Mike's winning entry, *Wake up Luigi, it's nearly time for lunch* was only marginally higher placed than his other two

entries. To further add to this unusual occurrence, the next three places were similarly won by one person, Dariusz Oczki, a new entrant to the competition from Poland. With only a very small number of marks separating the first six places, the final results could so easily have been different. The next four photographs, making up the Top Ten, scored highly with just a few marks separating them all.

Although not obliged to, the judges are encouraged to give their comments about the entries. Their views are never constrained, both praise and constructive criticism being freely given. Their comments about Mike's winning entry were: *The 'natives' justify the title. Suggest half an inch off the bottom of the picture would help. Beautiful picture. Remarkable. Feels cold! I don't know why! A well-composed record of an unusual dial in a historic location; the title lifts it as one perched bird addresses another. Would a coloured mount have helped? The white mount detracts from the off-white/cream pedestal and grey dial; the blue lettering picks up the sky colour well. Contrived conversation for a title. Ugh!*

Many congratulations to Mike Cowham, a well deserved winner, who received the winning trophy, a replica cube dial from Green Witch, together with a certificate from our Chairman, Chris Daniel. He was also awarded certificates for his second and third placed winning entries.

The next seven photographs that, together with the three winning ones, made up the Top Ten entrants were also identified in the order as selected by the judges as:

- |  |              |
|--|--------------|
| 4. It's not fair, he always gets more sunshine | D Oczki      |
| 5. Time gate                                   | D Oczki      |
| 6. Give me a second and I'll put it upend      | D Oczki      |
| 7. Christmas Time                              | J Jones      |
| 8. Yet a little while is the light with you    | M Ribchester |
| 9. The Lawn Ranger                             | D Cowan      |
| 10. 'Time' at the Queen Vic                    | D Cowan      |

Following the precedent of the 2008-9 competition, it was decided that certificates would also be awarded to the three next highest placed entrants who had not previously been a winner in any of the earlier photographic competitions. The certificates were duly awarded to Dariusz Oczki, Jackie Jones and Margaret Ribchester, by our Chairman. Congratulations and thanks go also to all the other entrants in the competition for their contributions that made for an interesting, varied and challenging competition, especially for those judging the entries.

The Council has agreed that the competition will be run on a two year basis in order to encourage rather more members to enter than previously. The next BSS Photographic Competition will therefore be held at the end of 2012, with

the winners being announced at the 2013 Conference. Entry forms will be included with the September and December 2012 issues of the *Bulletin*.

If after reading this and seeing some of the entries here or at the conference you feel that you could match or improve the standards set, then be sure to have your camera with you over the next two years, to seize that winning shot. Perhaps someone will arise to challenge our worthy winner Mike, dislodge him from his 'winning perch' and prevent him from making it three-in-a-row.

---

We are very grateful to Ian for organising this competition.

The winning pictures are shown here. See also the back cover. More examples, and the result of the Conference vote, in the next issue (space permitting). Ed.

Left:  
**Overall Winner - Mike Cowham**  
*Wake up Luigi, it's nearly time for lunch*



Below:  
**Second Place - Mike Cowham**  
*Winter sunshine, Fascinating brickwork*





**Third Place - Mike Cowham**  
*What do you make of this then Pepe?*

*What do you make of this then Pepe? Sant Feliu de Guixols, Catalonia*



**Fourth Place - Dariusz Oczki**  
*It's not fair, he always gets more sunshine*



**Fifth Place - Dariusz Oczki**  
*Time Gate*



**Top Ten - Margaret Ribchester**  
*Yet a little while is the light with you*

# THE ECCLESIASTICAL ‘SCRATCH DIAL’ AS A SERIOUS TIMEKEEPER

PETER I. DRINKWATER

[This article was originally written in the 1980s but it has not been published previously. Although sundial research has moved on in some areas since then, there are sufficient ideas here to warrant its consideration. It is presented retaining the author’s own distinctive style. Ed.]

## SUMMARY

The ‘typical’ Scratch Dial is described. Contemporary Mediæval and Anglo-Saxon descriptions of its use are considered, as are the Temporal Hours, the Classical origin of the Scratch Dial, the Hours of the Church, the modern parallel of Islam, and the Ecclesiastical Hours in Mediæval usage. Other methods of finding these Hours are described. Further topics are: the Shadow scale, a particular Shadow scale apparently calibrated by the use of a scratch Dial, some particular Scratch Dials, other evidence for the Scratch Dials’ timings being respected, and the effects of the introduction of Clock time on the old Temporal Hours system.

The basic form of the so called Scratch Dial is familiar to most people, as at least one example is to be found on nearly all of our Mediæval English parish churches.<sup>1</sup> Essentially, the Scratch dial is an incised circle, usually (but not always) made with the aid of compasses, the lower half of which is divided into approximately 15° intervals by radii (often cut freehand) running from the circumference to the centre, where a large deep hole is bored into the wall: the wall being (if the Dial is in its original situation<sup>2</sup>) one which faces more or less due South. There are many variations on this basic form.<sup>3</sup> The earliest specimens, dating from Anglo-Saxon times, often have their lower halves divided into approximately 22½° or 45° intervals, and are occasionally found with *raised*, rather than incised, markings.<sup>4</sup> Later Mediæval examples are found in which the *upper* half of the circle is also divided,<sup>5</sup> while on others it (and sometimes the whole circle) is omitted altogether.

The view that these markings are in fact intended as Sundials has prevailed over more exotic theories,<sup>6</sup> the understanding being that the central hole originally held a horizontal gnomon to cast the Shadow. It seems that those Dials with very large central holes were anciently furnished with wooden pegs,<sup>7</sup> while those with smaller holes had rods of latten or iron.<sup>8</sup> A messily elaborate specimen, on the little chantry attached to the parish church of Long Compton, still has an iron stump in its style hole.

On some Scratch Dials there is no style hole, but merely a shallow rounded depression in the centre. Such Dials are always at chest height; and it has been assumed, in my view correctly, that in these instances the user’s own forefinger took the place of a gnomon.

That these gnomons really were horizontal is evident from the chance comment of John Hovedon (obit. 1275) that the gnomon to be used (on a vertical surface) to investigate the properties of the *umbra versa* should be conceived as: “stilum ortogonaliter prominentem, sicut sunt stili qui prominent in parietibus ecclesiarum ad horas sumendas” (‘a style jutting out at a right angle, like the styles which jut out from the walls of churches for taking the hours’).<sup>9</sup> The time-telling properties of these Dials is further testified by an inscription on one of them, a quite famous one at Kirkdale, Yorkshire (datable by its other *flanking* inscriptions to c.1060,<sup>10</sup> reading: “+ ÞIS IS DÆGES SOLMERCA + ÆT ILCVM TIDE”: (‘This is a day’s sunmark / at every tide’, rather ‘This is the daily march of the sun / at each Hour’).

Nevertheless, it is on this crucial point that the scholarly nerve fails, the apparent consensus being that it is impossible to take seriously the pretensions of so simple an instrument when set up at latitudes as high as our own, where it can only have been conceived in a purely symbolic role.<sup>11</sup> The purpose of this article is to suggest, respectfully, that this view is an erroneous one.

The Classical world, in which Christianity (as a system) had its origins, had developed a scheme of time-telling (along with the rest of the Ancient world in general) entirely different from our own. The Day, by which is meant the period of daylight (some-times counted from dawn to dusk,<sup>12</sup> but more frequently from sunrise to sunset) was divided into twelve parts or (Temporal) Hours; theoretically equal in any one Day, but varying in absolute length with the seasons: sunrise being the start of the first Hour, midday the end of the sixth and the start of the seventh, and sunset the end of the twelfth. This may seem a strange method of timekeeping; but is not our own, which takes no account of the obvious *times* of sunrise and sunset, not an even odder system in practice? Is it not perverse to sleep when it is daylight, and to make whoopee half-way through the hours of darkness? It is certainly more *expensive* than a strict observance of the Natural Day.

Sundials designed to record these hours were initially constructed for a particular latitude, the commonest type<sup>13</sup> being a segment of a hollow sphere (or a part of the surface of a concave cone approximating to it) with a horizontal gnomon projecting from its northern edge, the shadow of whose *tip* traced out the parallel circular ‘Day curves’ of the summer, winter and Æquinoctial seasons; these Day Curves being each divided into twelve equal parts, and connecting lines (the *Hour* lines) drawn between the corresponding points on the three Curves to give the Hours on the intervening days.<sup>14</sup> These Day Curves were of course the Æquator and the Tropics of Cancer and Capricorn. Lines for the Temporal Hours drawn by this method do not (if treated as great circles, which they are not) converge upon a single point, much less upon a point coincident with the root of the gnomon. This was obviously felt to be an æsthetic drawback, since many Classical Dials are found with a *single* Day curve (often the Tropic of Cancer) from which, it being equally divided, the Hour lines (suitably distorted) *are* drawn to the root of the gnomon, so that its whole Shadow, not merely the shadow of its tip, is the time teller.<sup>15</sup> Such a Dial is still constructed for a *particular* latitude, however, for the Day Curve generating the Hour lines lies parallel to the Æquator. But there are several Late Classical Dials which take the form of a full quarter of a hollow sphere, and completely lack any true generating Day Curves, the Hour lines being instead produced by an equal division of a parallel, or parallels, to the prime vertical circle: exactly according to the principle of our Mediæval Scratch Dials.<sup>16</sup> Also on record are a number of *true* Scratch Dials found on sites of Late Classical date in the Mediterranean area, but indistinguishable from our mediæval Scratch Dials; save only that some of the former have their Hours marked by a numerical sequence of Greek letters.<sup>17</sup> Such a Dial, although undoubtedly arrived at through a process of debasement by unsophisticated diallists, is essentially different in concept from a true Dial for the Temporal Hours: instead of an equal division of the visible *daily track* of the sun into *twelve parts*, we have here a division of the *whole visible hemisphere* into *twelve fixed segmental zones*, from ‘poles’ at the due north and due south points of the *horizon*, through which segments the sun passes *unequally*; within a Day, as well as from season to season. The implied system is the same, in principle, as that of the cycle of ‘Great Sky Houses’ used by astrologers in setting up Horoscopes. If these Houses are drawn according to the method of Giovanni Campanus<sup>18</sup> (obit. 1300), the earliest now used, then each of them answers *exactly* to two hours as shown on a Scratch Dial. How far this is coincidental is a moot point.

We must now consider what Hours were in fact observed by the early Church, and by its mediæval successor in Western Europe.

The full system probably took some time to develop. Tertullian (c.160-230) says that the third, sixth and ninth of the ‘Common Hours’ are observed in Scripture to be “more

solemn than the rest”,<sup>19</sup> and none of the other Early Fathers dissents seriously from this concept. The *totality* of horary observance is most clearly given in the Rule of St Benedict (obit. c.547)<sup>20</sup> beginning with the named Hours:

**VESPERS** (preces vespertinæ) after Hesperus, the Evening Star; observed at, or around, sunset.

**COMPLINE** ‘a completing’; observed before retirement, when the night is dark.

**MATINS** (preces matutinæ) ‘Morning Prayers’; observed at, or following, midnight.

**LAUDS** (laudes) ‘praises’; from the ‘Laudate’ psalms recited at this office, with reference to the ‘dawn chorus’ of birdsong; observed at daybreak.

Then the numbered Hours:

**PRIME** ‘the first (Hour)’ observed at, or following, sunrise.

**TERCE** (tierce) ‘the third (Hour)’; observed at the third Hour of the Day.

**SEXT** ‘the sixth (Hour)’; observed at midday.

**NONES** ‘the ninth (Hour)’; observed at the ninth Hour of the Day.

There is nothing very remarkable, nor particularly ‘Christian’, about these Hours. They are merely an expansion of ancient Jewish practices. The named ones (except for Matins) are pretty well defined and might well be considered as the quarters of Night. The numbered Day Hours are certainly the quarters of the Day; and are so specifically emphasized on several recorded Late Classical Dials, including some which follow the Scratch Dial division according to the prime vertical.<sup>21</sup>

It seems that it was not crucial that these Hours be taken as more than indicators of quite broad periods of time. Benedict himself says that Matins should be observed in winter at the eighth, rather than at the correct sixth, *Hour of the Night*; (the Night Hours being in inverse proportion to the Day Hours); that the brethren “may rise with digestion completed”,<sup>22</sup> while Vespers should always be held sufficiently early for the following meal to be completed by daylight. The Day Hours also were movable up to an hour either way to accommodate work or study according to the season of the year.<sup>23</sup> It is of course these Day Hours which particularly interest us.

It appears that the use of a Dial was envisaged from the start, it being often stated<sup>24</sup> that Pope Gregory the Great, or (according to some) his successor Pope Sabinianus, ordained in 606 that “clocks [bells] and dials... be set up in churches to distinguish the hours of the day”.<sup>25</sup>

William Durandus (13<sup>th</sup> Century) specifically states (The Rational Book 1, Chaper 1, section 35) that “The Horologium [i.e. Sundial, *not* clock, as the word now implies] by means of which the Hours are read, teacheth that diligence that should be in Priests to observe at the proper times the Canonical Hours: as he [i.e. David in Psalm 119, v.164] saith, Seven times a day do I praise thee”.

Be that as it may, it is clear, in the light of surviving specimens throughout Europe,<sup>26</sup> that no other type of Dial was apparently set up in or on a church (until the introduction of clockwork in the 13<sup>th</sup> Century, and scientific Sundials in the 15<sup>th</sup>) than the simple Scratch Dial type which we are now considering. We may take the testimony of John Hovendon<sup>27</sup> as a proof text for this usage in our own country, although more sophisticated methods for measuring the Temporal Hours were by then available: specifically the method inherent in such instruments as the horoptrium, quadrant etc.,<sup>28</sup> relying on the (false) assumption that the sun reaches the same *altitude* at the end of each Temporal Hour as it does on the day of the *Æ*quinox at a place whose co-latitude is equal to the sun's midday altitude on the day, and at the place in question, i.e. it is assumed that the sun's visible daily track is a half circle, even when it is not. But is it possible to determine these times, even approximately, without the aid of these gimcrack instruments, or even the use of a Scratch Dial?

The Islamic faith, no longer particularly exotic in this country, observes certain Hours of Prayer which differ from those of Christianity only in the detail that they must always *follow*, never anticipate, the 'event' by which they are timed.<sup>29</sup> They are these, and thus (in theory) determined:

**MAGHRIB**; observed distinctly after sunset.

**'ISHĀ'**; observed when the twilight has ended.

**TAHAJJUD**; enjoined to be observed *after* midnight, especially during Ramadan, but not compulsory.

**FAJR**; called before daybreak and observed between daybreak and sunrise.

**'ISHRĀQ**; a voluntary observance *after* sunrise.

**DUḤĀ**; a voluntary midmorning observance; not strictly time.

**ZUHR**; called at midday, but observed distinctly *after* midday; specifically when the shadow of an upright staff has *grown* from its length, even to the extent of a quarter of the staff.

**'AṢR**; observed at mid-afternoon, *after* the ninth hour's ending; specifically when the staff's shadow has grown by the whole staff's length from its midday extent, or even by *two* staff lengths.

Analysis by trigonometry shows that, for the latitude of Mecca (21½° N) and thereabouts, the rule for adding the whole staff's length to the midday shadow to determine the

time for 'Aṣr is surprisingly accurate; the time determined, at all seasons, is always a little later than the end of the ninth Temporal Hour, as required by the rules. The two-staff-length rule was introduced by the Hanafite school of Islam, based in more northern latitudes, to ensure that the correct time for 'Aṣr is not at any season anticipated (as it would be if the one-staff rule were applied in more northern latitudes in the winter season).<sup>30</sup>

The Islamic Observances are, unlike the Christian, applicable to all professed Moslems. There are no monks (nor any other full-time clergy) in Islam.

For the Moslems at Coventry, tables of the correct times for prayer are published for each day of the year and in standard hours and minutes.<sup>31</sup> Trigonometrical analysis shows how the old rules have been interpreted and applied.

Maghrib may begin two or three minutes after true sunset.

'Ishā' may begin two or three minutes after the sun has sunk 12° below the horizon (rather than the 18° of the Classical rule<sup>32</sup>).

Fajr may begin when the sun has come up to 12° below the horizon.<sup>33</sup>

Zuhr may begin ten minutes after true midday.

'Aṣr is calculated by the Hanafite two-staff rule.

We must now consider how differently and similarly the Hours were conceived and timed by the early ecclesiastics in our own country.

Little attention was in fact paid to any Hours *apart from those of the Church*. 'Prime' gave its name to the whole first quarter of the Day, the 'Morning'. 'Terce' was called 'Underne', which became the name of the second quarter of the Day in Anglo-Saxon times.<sup>34</sup> Later the *name* Underne transferred itself to midday,<sup>34</sup> and later still to the Hour of Nones! 'Nones' gave its name to the third quarter of the Day; and eventually became the modern noon.<sup>34</sup> The last quarter of the Day was always called 'Evening', and 'Vespers', in consequence, 'Evensong'.<sup>34</sup>

The Venerable Bede confuses the issue by quoting<sup>35</sup> a table which can only have been devised for Mediterranean latitudes, whereby a person's *own* shadow, measured in terms of his own feet 'heel to toe' is supposed to indicate the end of each of the Classical Temporal Hours: it being assumed (generally correctly) that each person's height always equals six of his own foot lengths. Only odd numbers are used, and only one set of figures for each paired set of months. The midday shadow in June and July has to be one foot. At the fifth and seventh Hours it is three feet; at the fourth and eighth, five feet; at the third and ninth seven feet, and at the second and tenth nine feet, with a jump to nineteen feet for the first and eleventh Hours. Each pair of months increases these figures by two feet, always with the final jump of ten feet for the last pair of Hours (see Table 1).

| Hour | Jan        | Feb        | Mar        | Apr        | May        | Jun        | Hour |
|------|------------|------------|------------|------------|------------|------------|------|
| 1    | 29'        | 27'        | 25'        | 23'        | 21'        | 19'        | 11   |
| 2    | 19'        | 17'        | 15'        | 13'        | 11'        | 9'         | 10   |
| 3    | 17'        | 15'        | 13'        | 11'        | 9'         | 7'         | 9    |
| 4    | 15'        | 13'        | 11'        | 9'         | 7'         | 5'         | 8    |
| 5    | 13'        | 11'        | 9'         | 7'         | 5'         | 3'         | 7    |
| 6    | 11'        | 9'         | 7'         | 5'         | 3'         | 1'         | 6    |
|      | <b>Dec</b> | <b>Nov</b> | <b>Oct</b> | <b>Sep</b> | <b>Aug</b> | <b>Jul</b> |      |

Table 1. Bede's Shadow Scale (for Latitude 35°?).

Table 2. An Anglo-Saxon shadow-length calendar, exhaustively analysed. Columns A, B, E & F are transcribed from Brit. Lib. MS Cott. Tiberius, A. iii f.176.<sup>37</sup>

See text below for column titles.

| A         | B                          | C                            | D         | E      | F      | G        | H      | I      | K      | L       | M     | N         | O     | P |
|-----------|----------------------------|------------------------------|-----------|--------|--------|----------|--------|--------|--------|---------|-------|-----------|-------|---|
| 8Kal Jan  | Christmas Day              | 25 Dec <sup>r</sup> 3 3/4    | 24 26 1/2 | 23 1/2 | 25 3/4 | 23 1/2   | 25 3/4 | 6 3/4  | 23 1/2 | 25 1/4  | 32    | 0 1/2     | 6 1/4 |   |
| 8Ides Jan | Twelfth Day                | 6 Jan <sup>r</sup> 15°       | 22 25     | 21 1/4 | 24 1/4 | 18°      | 21 1/2 | 23 1/2 | 30     | 1/4 3/4 | 5 3/4 | 1/4 3/4   | 5 3/4 |   |
| 12Kal Feb |                            | 21 Jan <sup>r</sup> 0°       | 18 1/2    | 21     | 17 1/2 | 20 1/4   | 0°     | 18 1/4 | 20     | 25 1/2  | 4     | 1/2 1/4   | 5 1/4 |   |
| 2Non Feb  |                            | 4 Feb <sup>r</sup> 15°       | 15 17 1/2 | 14 1/4 | 16 3/4 | 18°      | 14 3/4 | 16 1/2 | 20 3/4 | 17      | 4     | 1/4 3/4   | 4     |   |
| 12Kal Mar |                            | 18 Feb <sup>r</sup> 0°       | 12 15     | 11 1/4 | 14 1/4 | 0°       | 11 1/2 | 13 1/2 | 17     | 14 1/4  | 2 3/4 | 1/4 3/4   | 2 3/4 |   |
| 2Non Mar  |                            | 6 Mar <sup>r</sup> 15°       | 9 12 1/2  | 8 3/4  | 12 1/4 | 18°      | 9 1/4  | 11 1/4 | 14 1/4 | 12      | 2     | 1/2 1     | 2     |   |
| 12Kal Apr | Æquinox                    | 21 Mar <sup>r</sup> 0°       | 8 11      | 7 3/4  | 10 1/4 | 0°       | 7 1/4  | 9 1/2  | 12     | 10 1/2  | 1 1/4 | 1/2 3/4   | 1 1/4 |   |
| Non Apr   |                            | 5 April 15°                  | 6 8 1/2   | 6      | 8 3/4  | 18°      | 6      | 8 1/4  | 10 1/2 | 9 1/2   | 1 3/4 | 0 1/2     | 1 3/4 |   |
| 12Kal May |                            | 20 Apr <sup>r</sup> 0°       | 5 7 1/2   | 5      | 7 1/2  | 8 3/4    | 5      | 7 1/2  | 9 1/2  | 9       | 2     | 0 0       | 2     |   |
| 2Non May  |                            | 6 May 15°                    | 4 7 3/4   | 3 3/4  | 7      | 18°      | 4 1/4  | 6 3/4  | 9      | 8 1/2   | 2     | 1/2 1/4   | 2     |   |
| 12Kal Jun |                            | 21 May 0°                    | 4 7       | 3 1/2  | 6 1/4  | 0°       | 3 1/2  | 6 1/2  | 8 1/2  | 8 1/2   | 2 1/4 | 1/4 1/4   | 2 1/4 |   |
| Kal Jun   |                            | 1 June 11 1/4°               | 4 7 1/4   | 3 1/4  | 6 1/2  | 14 1/4   | 3 1/4  | 6 1/2  | 8 1/2  | 8 1/2   | 2     | 0 0       | 2     |   |
| Ides Jun  |                            | 13 June 22 1/2°              | 4 7 1/2   | 3 1/4  | 6 3/4  | 25 1/2   | 3 1/4  | 6 1/4  | 8 1/2  | 8 1/2   | 1 3/4 | 0 1/2     | 1 3/4 |   |
| 8Kal Jul  | St. John Bapt <sup>t</sup> | 24 Jun <sup>r</sup> 0°       | 4 7 3/4   | 3 1/4  | 7      | 69 6 3/4 | 3 1/2  | 6 1/4  | 8 1/2  | 8 1/2   | 1 1/2 | 1/4 3/4   | 1 1/2 |   |
| 2Non Jul  |                            | 6 July 15°                   | 4 8       | 3 1/2  | 7 1/4  | 18°      | 3 1/2  | 6 1/2  | 8 1/2  | 8 1/2   | 1 1/4 | 0 3/4     | 1 1/4 |   |
| 12Kal Aug |                            | 21 July 0°                   | 4 8 1/4   | 3 3/4  | 7 1/2  | 0°       | 3 3/4  | 6 3/4  | 8 3/4  | 9 1/4   | 1 1/4 | 0 3/4     | 1 1/4 |   |
| 8Ides Aug |                            | 6 Aug <sup>r</sup> 15°       | 5 8 1/2   | 4 1/2  | 7 3/4  | 18°      | 4 1/2  | 7      | 9 1/4  | 10      | 1 1/2 | 0 3/4     | 1 1/2 |   |
| 12Kal Sep |                            | 21 Aug <sup>r</sup> 0°       | 6 9       | 5 1/4  | 8 1/4  | 0°       | 5 1/4  | 7 3/4  | 10     | 11      | 1 3/4 | 0 1/2     | 1 3/4 |   |
| Non Sep   |                            | 5 Sept 15°                   | 7 10 1/2  | 6 1/4  | 9 3/4  | 18°      | 6 1/2  | 8 3/4  | 11     | 12 3/4  | 1 1/4 | 1/4 1     | 1 1/4 |   |
| 12Kal Oct | Æquinox                    | 20 Sep <sup>r</sup> 0°       | 9 12      | 8 1/4  | 11 1/4 | 0°       | 8      | 10     | 12 3/4 | 14      | 1 1/2 | 1/4 1/4   | 1 1/2 |   |
| 2Non Oct  |                            | 6 Oct <sup>r</sup> 15°       | 11 14     | 10 1/4 | 13 1/4 | 18°      | 10     | 12     | 14     | 18 1/2  | 3/4   | 1/4 1/4   | 3/4   |   |
| 12Kal Nov |                            | 21 Oct <sup>r</sup> 0°       | 13 16 1/4 | 12 1/4 | 15 1/2 | 0°       | 12 3/4 | 14 1/2 | 18 1/2 | 22 1/2  | 3     | 1/2 1/2   | 3     |   |
| Non Nov   |                            | 5 Nov <sup>r</sup> 15°       | 17 19 1/4 | 16 1/4 | 18 1/2 | 18°      | 16     | 17 3/4 | 22 1/2 | 27 1/4  | 4     | 1/2 3/4   | 4     |   |
| 12Kal Dec |                            | 20 Nov <sup>r</sup> 0°       | 21 23 3/4 | 20 1/4 | 23     | 0°       | 19 1/2 | 21 1/2 | 27 1/4 | 30 1/2  | 4 1/4 | 3/4 2 1/2 | 4 1/4 |   |
| 4Non Dec  |                            | 2 Dec <sup>r</sup> 11 1/4°   | 23 26     | 22 1/4 | 25 1/4 | 14 1/4   | 22     | 24     | 30 1/2 | 34 3/4  | 5 1/4 | 1/4 1/4   | 5 1/4 |   |
| 19Kal Jan |                            | 14 Dec <sup>r</sup> 2 2 1/2° | 24 27     | 24     | 26 1/4 | 25 1/2   | 23 1/2 | 25 1/2 | 32 1/4 | 36 3/4  | 6     | 3/4 3/4   | 6     |   |

The absurdity of the system is obvious. The most that can be said for it is that at about Latitude 35° N it would give a quite reasonable location of Terce and Nones, and this is perhaps its true purpose. Bede's authority led to its being used as a computus in at least two early English Church Kalendars,<sup>36</sup> but *only* for the hours of Underne, Sext and Nones; and in both cases with an alteration to the June/July midday figure: in one instance to one and a half feet, and in the other to two.

But there is another scale of this type,<sup>37</sup> of Anglo-Saxon date, which is entirely distinct from the mere numerical progression of the former, and deals only with Underne, Sext and Nones. The figures are indeed so irregular as to strongly suggest actual observation and measurement. Refer to Table 2. Columns A and B reproduce the dates, according to the Roman Kalendar, with the three named festivals and æquinoctial days, as given in the original. Column C gives the same dates according to our modern reckoning. It is clear that the Tabulator intends these dates to mark the sun's entry into each of the twelve Signs of the Zodiac, with its midpoint in each of them. He is obliged to make March 21<sup>st</sup> the Spring Æquinox, in accordance with the rules of the Church for calculating Easter, rather than March 25<sup>th</sup> (as indicated by Cæsar) or March 18<sup>th</sup> (or thereabouts) to which it had certainly slipped back by his own period.<sup>38</sup> He still wishes, however, to mark the original dates of the solstices, since they coincide with the important festivals of Christmas and St John the Baptist's Day. This is accomplished by dividing the periods from 0° *Gemini* to 15° *Cancer*, and 0° *Sagittarius* to 15° *Capricorn* into four parts. The Tabulator's supposed intentions are given in Column D. What I think is a more realistic assessment appears in Column I.<sup>39</sup>

Column E (copied from the original) purports to give the length of one's shadow at midday: the Hour of Sext. Column F purports to give the length of one's shadow at the Hours of Underne (Terce) and Nones,<sup>40</sup> in each case on the dates of the given Kalendar. These figures are easily reduced to altitudes.<sup>41</sup> 90° – (midday altitude ± appropriate solar declination<sup>42</sup>) should yield the latitude of the place where the observations were taken. Application of this formula yields latitudes as high as 57° for the mid-summer figures down to latitudes as low as 52 1/2° for the midwinter figures. A little thought gives us the reason: the Tabulator is counting in the foot upon which he is standing when he starts to pace out the shadow, and is assuming that the crown of his head stands perpendicular to his heels. Now the crown of my *own* head stands over my toes! But I am very round-shouldered. A military man might hold the crown of his head over the *middle* of his foot. Let us be charitable, therefore, and suppose that a monk or cleric might hold the crown of his head three-quarters of a 'foot' in from his heels. If we omit three-quarters of a 'foot' from each of our figures, then we will have those given in Column G (for Sext) and Column H (for Underne and Nones); and the midday figures will yield an average latitude (with very little variation) of 52°.

Theoretical midday shadow lengths are easily calculated.<sup>43</sup> I tabulate them in Column K. They bear good comparison with the modified figures of our original table, the slight differences being given in Column N.

Column M gives the shadow lengths which *would* apply, at the Hours of Underne and Nones,<sup>44</sup> if true Temporal Hours were being used; Column P gives the very great differences between these and the modified figures of our original ta-

ble. Column L gives the shadow lengths which *would* apply if the shadow for Underne and Nones had been paced out when the shadow of the gnomon of a well-made Scratch Dial fell at 45°.45 The difference between these figures and the modified figures of our original Table are given in Column O. The correspondence will be seen to be dramatically close; the widest differences appearing in the autumn, probably because I have accepted the original Tabulator's equal divisions of the year, and have not adjusted for the inequality in the lengths of the seasons. I have no means of knowing what these differences were at the period in question, there being no reason for supposing that they were the same as those which now apply.

The indications are clear; the Scratch Dial is here taken, *at our latitudes*, as a serious timekeeper, and as the monitor for another method of 'telling the time'.

What other evidence is there for this reliance on the Scratch Dial?

In 1938 a small portable Sundial was found under the Cloister Qarth at Canterbury Cathedral. It dates from the Anglo-Saxon period, and purports to give the Hours of Sext, Underne and Nones by the shadow of the tip of a removable horizontal gnomon on each of six vertical columns, which serve for the twelve months: paired in exactly the same sequence as they are in Bede's Shadow Scale. I am hampered by working only from a poor set of photographs of a mere replica,<sup>46</sup> but the marks are certainly not compatible with the altitudes suggested by Bede, nor are they entirely compatible with the marks which should apply (especially at high summer) had the true Temporal Hours been intended: but they are certainly within the range which we would expect had they been timed by one of our Scratch Dials.

Let us now look closely at some early Scratch Dials, shown in Fig. 1. Dial A is on the church at Saintbury (Gloucs); it has a symbolic Midnight Line, with plain horizontal lines for sunrise and sunset. The Midday Line, and the lines marking the quarters of the Day in the Prime Circle, are carved with crosses for the 'Solemn Hours' of Underne,

Sext and Nones: there are lighter halfway lines between these Hours. Dial B, on the church at Daglingworth (Gloucs), has similar markings, but no Midnight Line, and only one halfway line: between sunrise and Underne. This extra line must have had some significance, because Dial C, the famous one at Kirkdale (I omit the surround) which has all of the halfway lines, has this one specially lengthened and emphasized with an asterisk; probably it marks the time of the daily Mass, outside of the usual cycle of the Hours. Dial D, on the church at Bishopstone (Sussex) extends over a little more than 180° (again I omit the surround) and has all of the Ecclesiastical Hours emphasized with crosses: but between them are marks for the usual Temporal Hours, as on the Classical Scratch Dials.

It has been noted<sup>47</sup> that Scratch Dials of a rather later date than these are more carelessly constructed, containing only one or two irregularly spaced lines. This is not strictly true: both careless, and more careful, Scratch Dials are found throughout the early Middle Ages.

The doorway of the church at Sutton-under-Brailes, which is markedly later than the Anglo-Saxon or Anglo-Norman periods, has a very small Scratch Dial engraved into one of its jambs, and under several layers of whitewash. It is a full circle divided neatly into eight equal parts; this giving, symbolically, the quarters of the Day and of the Night. This Dial must be near contemporary with the doorway, as it is completely obscured from the sunlight by the Tower-cum-Porch, which is only a little later in time. There are many other such examples.

Those Scratch Dials which *are* incomplete and carelessly made merely reflect the sloppy character of the priests who made them; can we really imagine that a hired curate, who could not give an account of his own ordination, who could not read even such a basic modicum as the Canon of the Mass, nor even recite it 'parrot fashion'<sup>48</sup> would have the ability to make a decent complete Scratch Dial? Yet this was the type of person whom we must imagine as making them, since they do not in any way compare with the work of a mediæval *craftsman*. The fact is that the position of many village priests *was* largely symbolic; providing 'the Priest' appeared to perform the actions of a priest it little mattered what he actually said, or when he said it; people attended at Mass or (less frequently) at the Offices, for the good of their souls, not to follow the service, much less to take part. Even a well-lettered conscientious priest had the easy option of saying his Offices by anticipation, a group of them all together at one time. Chantry priests, whose sole duty was to say Masses for the dead, did not even have the responsibility of a congregation to contend with. This business of anticipation led to some strange results: one reads of Evensong being said in the morning, while Matins was said so frequently in the afternoon (on the preceding day) as to give rise to the word *Matinée*: a performance taking place in the afternoon. A practical priest would naturally mark only those times which *he himself* observed; which explains not only the great variety of markings found, but also the

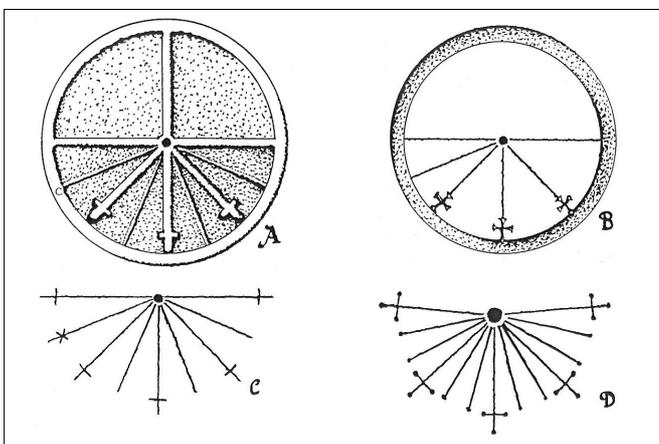


Fig. 1. Four Scratch Dials. Dial A is at Saintbury, Gloucs; Dial B is at Daglingworth, Gloucs; Dial C is at Kirkdale, Yorks; Dial D is at Bishopstone, Sussex.

| Hour           | Jan        | Feb             | Mar        | Apr            | May             | Jun            | Hour           | Middle English alternative names |
|----------------|------------|-----------------|------------|----------------|-----------------|----------------|----------------|----------------------------------|
| 1 <sup>a</sup> | 29'        | 27'             | 25'        | 23'            | 22'             | 11'            | 11             | a = Half Prime                   |
| 2 <sup>b</sup> | 19'        | 17 <sup>h</sup> | 15'        | 14'            | 13 <sup>j</sup> | 12'            | 10             | b = Prime or Hool Prime          |
| 3 <sup>c</sup> | 15'        | 13'             | 11'        | 10'            | 9'              | 8'             | 9              | c = Half Undron or Half Undern   |
| 4 <sup>d</sup> | 12'        | 10'             | 8'         | 7'             | 6'              | 5'             | 8              | d = High Undorn or Hool Undern   |
| 5 <sup>e</sup> | 10'        | 8' <sup>k</sup> | 6'         | 5'             | 4'              | 3 <sup>l</sup> | 7 <sup>f</sup> | e = Midday time                  |
| 6 <sup>g</sup> | 9'         | 7'              | 5'         | 4 <sup>m</sup> | 3'              | 2'             | 6 <sup>g</sup> | f = Overnoon (Nov/Dec)           |
|                | <b>Dec</b> | <b>Nov</b>      | <b>Oct</b> | <b>Sep</b>     | <b>Aug</b>      | <b>Jul</b>     |                | g = Noon                         |

Table 3. Palladius's Shadow Scale (for Latitude 37½°?).  
 h = 16' Nov.  
 j = 14' May (13' in Latin).  
 k = 9' Feb.  
 l = 4' Jun.  
 m = 3' in all versions.

presence of a number of Dials on one wall, since each priest would presumably make his own.

That there were some who still regarded the traditional Hours, and the traditional method of marking them, even in the later Middle Ages, is evident from the Middle English (c.1420) translation of the *De re rustica* of Palladius (4<sup>th</sup> Century).<sup>49</sup> Now Palladius gives a Shadow Scale for the Temporal Hours which is quite a bit more sophisticated than that given by Bede; although, like his, based on a mere numerical progression: it would do quite well for its intended Sicilian latitude (see Table 3).

What interests us is the way in which the English translator renders the names (rather numbers) of the Hours. After following the Latin faithfully for the months of January, February, March, April and May, he suddenly changes to a version of the Ecclesiastical Reckoning for the High Summer months of June and July. The first Hour becomes 'half prime', the second 'prime' or 'hool prime', the third 'half undron' or 'half undern', the fourth 'high undron' or 'hool undern', the fifth 'midday time', the sixth 'noon'. For the months of November and December (alone) we find the styles 'midday' and 'overnoon' given to the fifth and seventh Hours respectively. This curious system of nomenclature leaves the next five Hours untitled. So far as it goes it distinctly suggests the clear intention of moving the Offices nearer to midday than would be the case if the true Temporal Reckoning was strictly adhered to. In the case of Underne, this is an effect distinctly *achieved* if a Scratch Dial be taken as monitor; the observance really will be at the end of the true 'Fourth Hour'. It is also the case that if, in mid-

summer, the observance of Prime be deferred until a Scratch Dial (being on a south facing wall, and therefore not illuminated until well after sunrise in summer) actually *receives* the beams of the sun, then this really will be around the end of the second true Temporal Hour. The translator apparently *realises* this fact, and prefers the Scratch Dial reckoning for the long days of High Summer. We may assume that, the Offices of Sext (midday) and Nones (noon) having been cleared at 'midday time' and 'noon', the next observance would be 'Evensong' at the end of the eighth true Temporal Hour, or rather the next quarter mark of the Scratch Dial; with Compline to follow, as suggested by the rules formulated at the foundation of a hospital at Ewelme (Oxon) in c.1438.<sup>50</sup>

By this period, however, the advent of clocks and clockwork had initiated a popular abandonment of any pretence at observing the old Temporal Hours, one supposes with much confusion. It is amusing to note the chaos caused by the choice of different standard setting times for these machines in different parts of the civilised world.<sup>51</sup> Italian clocks were set to strike 24 at sunset, and went through a full sequence of 24 equal hours from this time. German clocks were also set to run from sunset, but set again to run from sunrise, in two unequal sequences of an uneven number of equal hours. The 'Babylonians', whoever they might be, had a full 24 hour sequence starting from sunrise. Islamic states in general used a 'Double Twelve' cycle counted from sunset; while England, France and most of Western Europe used a 'Double Twelve' cycle commencing at midnight or midday. We are not surprised to find a

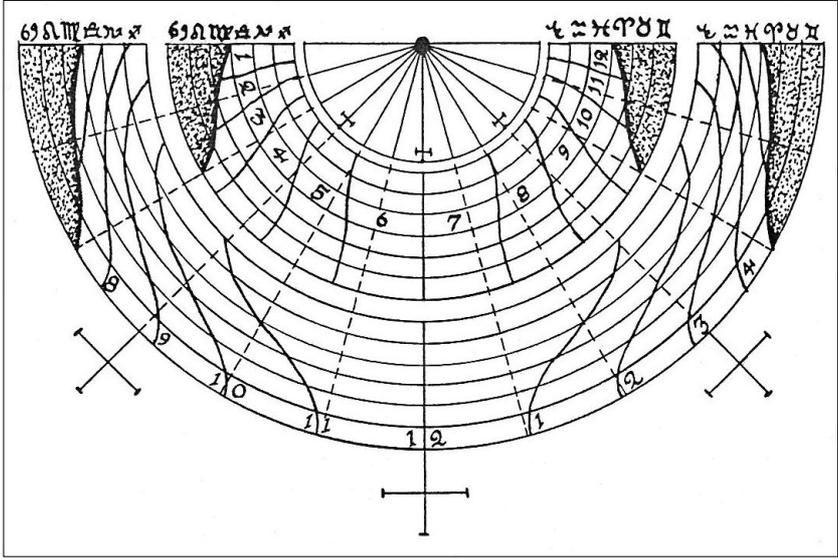


Fig. 2. A diagram giving, at Lat 52° N, the Angles of the shadow cast by the gnomon of a Scratch Dial throughout the year. The innermost semicircle is a Scratch Dial. The medial series of arcs compares its reading with the True Temporal Hours, using the Signs of the Zodiac as references. The outermost series of arcs compares the reading of the Scratch Dial with modern clock time, again using the Signs of the Zodiac as references. The shaded areas represent those periods in the early morning and in the evening in summer when the sun is shining on the north wall of the church and the Dial is in shadow. It will be seen how closely the Scratch Dial approximates, around latitude 52° N and at midsummer, to modern clock times. A Scratch Dial at Todenham, Gloucs, for example, is actually marked with these clock times.

good number of late Scratch Dials (some as late as the 17<sup>th</sup> century in my opinion) which are marked with hour numbers *as if they told clock time*. An example at Todenham (Gloucs) has Arabic numbers from six to nine, and Roman numbers thereafter; a coach bolt pushed into the style hole now forms the gnomon, and local people will tell you that its timekeeping is “not far wrong”! And around midsummer *it is not*. Fig. 2 shows this in detail. Only in Japan did they manage to make clocks tell Temporal Hours!

True Sundials for telling the ‘Æquinoctial’ or ‘Clock’ Hours began to be made in Germany in the early 15<sup>th</sup> century,<sup>52</sup> but it was not until the beginning of the 16<sup>th</sup> that the art began to penetrate this country,<sup>53</sup> and not until the last quarter of the 16<sup>th</sup> that a practical handbook in English was published.<sup>54</sup> A glance at the earliest work on the subject to be published anywhere<sup>55</sup> shows us that the form of the Scratch Dial was long retained: for we see continually the circle or the semi-circle, but no longer equally divided, with the round rod emerging from the centre, no longer horizontal but in line with the Axis of the Earth.

## REFERENCES and NOTES

1. T.W. Cole: *Origin and use of Church Scratch-Dials*, (1935), lists 1,300 churches which have them. He produced a supplementary typed list in 1945 which, for the area which I know, is still incomplete.
2. Cole notes many Scratch Dials on stones that have been later reused; as does Dom Ethelbert Horne: *Scratch Dials, their Description and History* (1929).
3. Horne (ref. 2) lists twelve basic types.
4. As at Saintbury (Gloucs) Horne P1.1a.
5. That is Horne P1.VII (East Pennard, Somerset). Scratch Dials at Long Compton (Warwickshire) and Lower Lemington (Gloucs) are of this type.
6. Horne pp. 9-19.
7. Horne pp. 31-37.
8. *Ibid*.
9. John Hovendon (Ed) & Edmund Brock (Trans): *Essays on Chaucer*, Part II; III ‘Practica Chilindri’ section, section 6, ‘De Umbra Versa’ (1868).
10. Photographs in: J.B. Priestly: *Man and Time* (1964) p.25; E. Bruton: *The History of Clocks and Watches* (1979) p.17; L. Coleman: *A Book of Time* (1971) p.49.
11. See T.W. Cole: ‘Church Sundials in Medieval England’, *J. Brit. Arch. Assoc.*, third series, Vol. X, pp. 78-79 (1945-7).
12. O. Neugebauer: *The Exact Sciences in Antiquity*, p.86 (1957).
13. See S.L. Gibbs: *Greek and Roman Sundials*, passim, Yale University Press (1976).
14. Gibbs (ref. 13) pp. 66-78.
15. Gibbs (ref. 13): examples 3033G, 3017G, 3018G, 3066G, 3088, 3091, 3099 & 3103. Also 1011, 1042, 1067G.
16. Gibbs (ref. 13): pp. 18-19; examples 1013, 1048G, 1049, 1050G, 1053G & 1054G.
17. Gibbs (ref. 13): pp. 45-46; examples 5003G, 5004G, 5009, 5012, 5017, 5018G & 5019G.
18. See Louis MacNeice: *Astrology*, pp. 50-51.
19. De Orat., c.25.
20. Abbot Justin McCann (Trans.): *The Rule of St Benedict*, passim (1976).
21. Gibbs (ref. 13): examples 1016G, 1022G, 1054G, 1056G, 2023G, 3022, 3017G, 3076, 3080G and especially 5017 on St Agapito’s Cathedral at Palestrina, Italy.
22. Benedict (ref. 20): C. 8.
23. Benedict (ref. 20): Passim.
24. In ‘coffee table’ books, which are without references.
25. Coleman (ref. 10), p.48, quoting “John Stow”.
26. Cole (ref. 1) gives examples in France and Germany. I have seen a ‘coffee table’ book photograph of a Romanesque specimen in Italy, with a horizontal gnomon *in situ*.
27. See ref. 9.
28. See R.T. Gunther: *Early Science in Oxford*, Oxford University Press, Vol. II (Astronomy), passim (1922).
29. My Moslem friends are particularly emphatic on this point.
30. These ‘Staff rules’ are summarised in *The Dā’ire-yi Mu’addel of Seydī ‘All Re’is*, p.8 (July 1976).
31. Tables published by The Islamic Brotherhood, The Mosque, Eagle Street, Coventry.
32. i.e. the ‘Civil’ rather than the ‘Astronomical’ twilight. See the work mentioned in ref. 30.
33. See ref. 32.
34. See the quotations for these words in the Oxford Dictionary. See also R.T. Hampson: *Medii Ævi Kalendarium*, Vol. II, p.201 (19<sup>th</sup> C).
35. Quoted by Hampson (ref. 34): Vol. II pp.200-201. Also given by A.E. Waugh: *Sundials – their theory and construction*, p.2. Dover Publications, New York, (1973).
36. MSS Kal, Cott. Vitell. E, XVIII; and Kal. Titus, D., XXVII, f.12v, as given by Hampson (ref. 34): Vol. I. pp.422-433 and Vol. II p.313.
37. MS Cott. Tiberius, A. iii., f. 176; given in Vol. III pp. 218-223 of the ‘Saxon Leechdoms’ Vols. of ‘The Rolls Series’ (1866).
38. This ‘slip-back’ was caused by the inherent inaccuracies of the Julian Calendar.
39. I have simply adjusted for March 18<sup>th</sup> being the Spring Equinox, making no allowance for the varying lengths of the seasons, by adding 3° to each putative figure.
40. I have interpreted “lytle lengre ponne” (etc.) as a quarter, and “forneah” (etc.) as less a quarter.
41.  $6 \div$  the figure = the tangent of the altitude.
42. Sin of Degrees from the Æquinox (plus for north, minus for south)  $\times$  Sin of Obliquity of Ecliptic (about 23.666° at the period in question) = Sin of Declination.
43.  $\tan \{ \text{Latitude} \pm \text{Declination (minus for north, plus for south)} \} \times 6 = \text{Theoretical Shadow Length}$ .
44.  $\tan \text{Declination} + \tan \text{Co-latitude} = \text{Sin difference}$ .  $90 \pm \text{difference} = \frac{1}{2} \text{Arc of the Day}$ .  $\frac{1}{2} \text{Arc of the Day} \div 2 = \text{Hour Angle for Underne and Nones}$ .  $(\cos \text{Hour Angle} \times \cos \text{Latitude} \times \cos \text{Declination} (\pm) + (\sin \text{Latitude} \times \sin \text{Declination} (\pm)) = \cos \text{Co-altitude}$ .  $\tan \text{Co-altitude} \times 6 = \text{Correct Shadow Length}$ .
45. This can only be done by stereographic or (with difficulty) by orthographic construction, checked by the following formula, which gives the Angle of the Shadow on the Wall from a known Hour Angle,  $h$ , and other co-ordinates:
$$\tan(\text{shadow angle}) = \frac{\sin h}{\cos \phi \cos \delta - \sin \phi \tan \delta}$$

N.B. minus for north declinations,  $\delta$ ; plus for south declinations. See Addendum (opposite) for more details.
46. Waugh (ref. 35) p.166.
47. Cole: *Church Sundials in Medieval England*, p.1.
48. See G.G. Coulton: *Life in the Middle Ages* Vol. II, pp.39-41 (1967 Edn.).
49. Edition edited by Mark Liddell (1896).
50. Quoted by Hampson (ref. 34) p.201, who shows a certain lack of historical perspective in his mixture of quotations.
51. Cf. the works of Samuel Foster (17<sup>th</sup> C.) and William Emerson (18<sup>th</sup> C.).
52. George of Peurbach is believed to be the initiator.
53. Nicholas Kratzer, Diallist to King Henry VIII, is the earliest known practitioner in our country. His Notebook (Bodleian MS CCC 152) is largely copied from earlier German MS material.
54. Thomas Fale’s *Horologiographia* of 1593.
55. Sebastian Munster’s *Compositio Horologiorum* of 1531.



# A STAINED GLASS SUNDIAL WITH A MAGNETIC GNOMON

JOHN CARMICHAEL

My dialling friends know that I've had an ongoing love affair with stained glass sundials (SGS) for many years now. It began during a BSS conference tour when I saw Chris Daniel's wonderful SGS at The Merchant Adventurers' Hall in York. Since then, I jump at the rare opportunity to design or make one, and I've made several. Because few people realize they even exist, commissions don't come along often. In December of 2010, I received an order to make a rather large (2 ft × 3 ft) vertical declining stained glass sundial for a private home in Boulder City, Nevada, USA. The client wanted to install it permanently in his bedroom's south-facing window and wanted it to tell the time and date from inside his house. It would show Solar Standard Time with built-in longitude correction. He also wanted it to be embellished with lots of colourful artwork. He likes frogs. So he wanted frogs incorporated into the design somehow (Fig. 1).

My first thought was to make the gnomon in the shape of a frog. That idea came from my research on painted wall sundials which turned up many wall dials that have unusual gnomons resembling common objects. Most of these unusual gnomons are on Italian wall dials. I love this idea! Diallists should use them more often. There are unusual gnomons that look like boats, swords, rockets, hands, suns, anchors, birds, arrows and all sorts of unusual objects. There's no gnomonic rule that says a gnomon or parts of a gnomon can't be these things. You can be very creative in designing a gnomon especially if your sundial design requires a nodus-based or point-in-space type gnomon. All you need is something with a point, a ball, or even a hole on

it. The frog idea worked out fine because the frog's nose is pointed and acts like a nodus. I just cut a frog shape out of brass sheet and soldered it to a brass rod.

Since the 16<sup>th</sup> century, stained glass sundial makers have struggled with the problem of how to attach gnomons to these fragile and breakable glass sundials. Typically, they would drill a hole in the glass and bolt the gnomon directly onto the glass. As you might suspect, this practice resulted in many of these wonderful dials being cracked and damaged over the years. A careless window-cleaner, a house-painter, a bird or even a hailstone could accidentally hit the gnomon, moving it and causing it to crack the glass. Some SGS designers avoided this problem by attaching the gnomon to the lead 'came' or to the window frame. But often the lead came or window frame are not in the right gnomonic place, especially for nodus-based dials. Also, when attaching a long polar axis rod gnomon to the window frame, ugly support struts are sometimes needed. Support struts can create confusing shadows for the users. Naturally, I really wanted to avoid all these things with this dial.

My first thought was to bolt the perpendicular rod and frog gnomon to a brass disk that would be incorporated into the leaded window. I made one of these gnomons for a SGS at Oxford University several years ago. Since the brass disk is firmly attached to the surrounding glass by lots of soldered lead came, it is harder to break the glass if the gnomon is impacted by something. This idea worked well for that dial, and has since been used by other SGS makers: see Fig. 2.

But in the back of my mind was a different idea that has been simmering for years. I thought that gnomons might be



Fig. 1. Interior view of the new SGS with its frog gnomon.



Fig. 2. Oxford SGS with a gnomon bolted to brass disk.

safely attached to stained glass sundials with magnets and conjectured that a magnetically attached gnomon would protect the glass from damage from impacts by simply falling off the sundial when hit. Also, gnomon installation would be a breeze without any bolting, soldering or gluing. To my knowledge, there were no known examples of magnetically attached gnomons on stained glass sundials or on any type of sundial for that matter. Finally, I had a chance to try it. But it's not so simple as I soon found out. As always, I had to test my idea first with experiments. Theory is nice and can provide guidance, but theory sometimes fails in practice. An experiment removes all doubt and proves that a new idea will actually work or fail.

I began these experiments without much knowledge of magnets. All I knew was that opposite poles attract and similar poles repel, and that big magnets are stronger than small ones. Using two common ceramic disk refrigerator door magnets, I saw that they stuck together only if the opposite poles were pointed to each other. (Think of a disk magnet as if it were a coin—heads attract tails, but heads repel heads, and tails repel tails.) My first thought was to attach a disk magnet to the bottom of the gnomon rod and place it on the outside of the glass, and then place another disk magnet on the inside of the glass. The gnomon's magnet would stick to the window by attracting the opposite pole of the other magnet on the inside of the glass. This test highlighted four problems:

1. The disks must have the same diameter or they don't stick to each other when stacked.
2. Glass is slippery, and the weak ceramic magnets tended to slide down the glass especially if the gnomon was heavy.
3. Magnets rust so I was worried about the external magnet rusting over time.
4. The attractive force was decreased when glass was placed in between the two magnets.

The magnets needed something to keep them from moving and rusting, and needed to be stronger. I could prevent rusting if the outer magnet were coated with something, and movement could be prevented if the magnets were surrounded by lead came. I almost used this configuration, but then I came up with an even better idea. Read on...

NASS member Art Krenzel told me about a company, K & J Magnetics,<sup>1</sup> that makes all sorts of very strong rare earth neodymium 'mounting magnets'. These new revolutionary magnets are ten times stronger than common ceramic or iron magnets. This means you can use smaller magnets. They are mounted in protective stainless steel casings that come with threaded holes that can be used to screw in a gnomon rod. How convenient! The magnets are even triple-plated with nickel and copper that prevents rusting. They come in many sizes and attractive strengths and weren't too expensive, so I ordered about twenty different ones for testing. I also tested neodymium disk magnets without the steel mounting casings. My tests told me the size and strength of

the mounting magnet I needed for the size and weight of the gnomon. The tests also showed that I did not need two magnets. A magnet attracts a steel disk almost as well as another magnet, and by using a steel disk, you don't need two matching diameter disk magnets. Tests also revealed something important. Window glass is 1/8" thick. A magnet's attractive force diminishes quickly with distance. A piece of glass sandwiched between two magnets or between a magnet and a steel disk greatly decreases the attractive force. Therefore, you must use a stronger magnet in a sandwich configuration.

The configuration I finally settled on is probably the safest and easiest way to attach a gnomon to the face of a stained glass sundial. The mounting magnet on the gnomon rod attaches directly to a steel disk which is incorporated into the design of the glass sundial face with soldered lead came. This direct high-strength contact between the magnet and the steel disk allowed me to use the smallest possible magnet and a small steel disk. You really need to feel it to see how well it works. Since the gnomon rod acts like a lever when moved, when I violently hit the gnomon with my hand to test what would happen, the gnomon rod 'pried' off the mounting magnet and it simply fell to the ground. The glass was saved and even the gnomon was undamaged and unbent! I just stuck it back on the sundial and everything was as good as new! See Fig. 3.

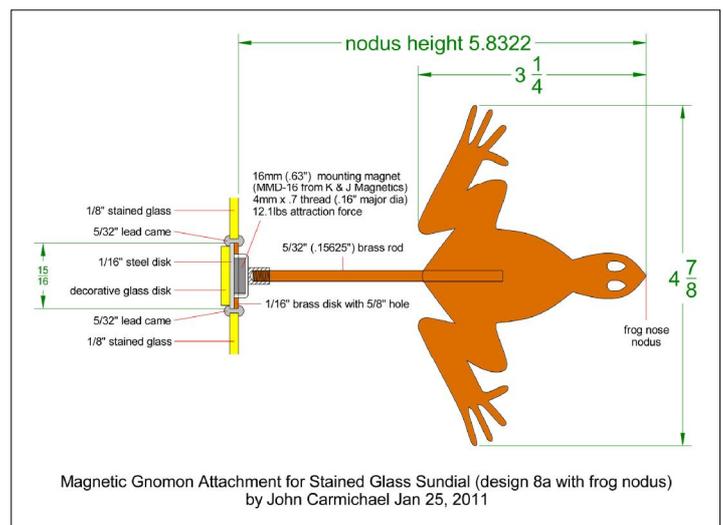


Fig. 3 Magnetic gnomon design drawing.

I obtained the round 7/8" diameter, 1/16" thick zinc-plated steel disk from an electrical junction box hole cutout. The zinc plating prevents it from rusting. Then I placed a flat brass ring of the same diameter on top of the steel disk. The 1/16" thick brass ring has a 3/8" hole in it and looks like a brass washer. Together, the steel disk and brass ring have a thickness of 1/8" which is the same as glass, so the two stacked together fit nicely into the slot of lead came. I surrounded the disks with lead came (Fig. 4). The 16mm mounting magnet on the gnomon sits nicely in the hole of the brass disk so the magnet is in direct contact with the steel disk. The hole in the brass disk keeps the mounting magnet from sliding around. The gnomon has a 5/32"



Fig. 4. Steel disk with brass ring surrounded by lead came.



Fig. 5. The mounting magnet fits nicely inside a brass ring and sits on the steel disk.

threaded brass rod that is screwed into the mounting magnet (Fig 5). I cut the brass frog from a 1/16" thick sheet of brass and soldered it to the brass rod. Installation was simple, and no nuts and bolts were required! Although the frog nose nodus works well at any time of the day, its shadow changes shape depending on the time and season. The owner can twist the frog gnomon into any rotational orientation that produces the most pleasing shadow for the time of day when he most uses his sundial. The magnetic frog gnomon only cost me ten dollars to make (disregarding the cost of the experiments of course). Just to make sure that the magnet and steel are well-protected from rust, I painted them with a couple of coats of clear enamel.

Magnetic gnomons could also be used for other types of sundials. I envision them being used for table-top analematics that have moveable gnomons (like magnetic pieces on a chessboard). Come to think of it, a magnetic bishop from a chess set would make a pretty nice gnomon! I also see them being used on traditional wall sundials or cast iron or steel horizontal dials.

There are 218 pieces of stained glass in the sundial window. I delineated the sundial using a combination of Shadows Pro and ZW 2000 dialling software. Then I exported those drawings into DeltaCAD where I added the artwork, and the sundial face numerals. I designed the artwork myself and borrowed some designs from my stone sundials. DeltaCAD is fantastic for designing stained glass window pat-

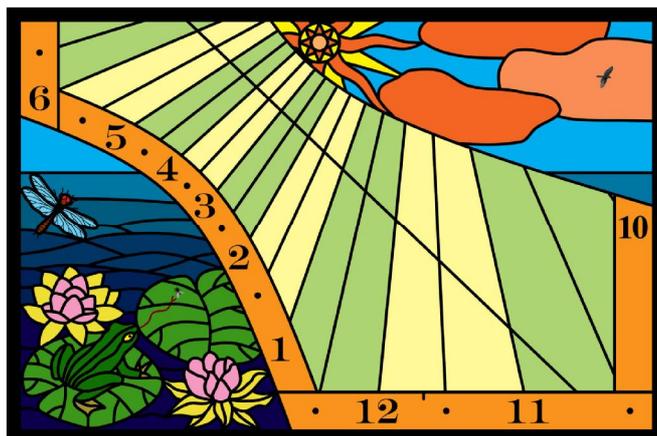


Fig. 7. SGS Photoshop coloured glass pattern.

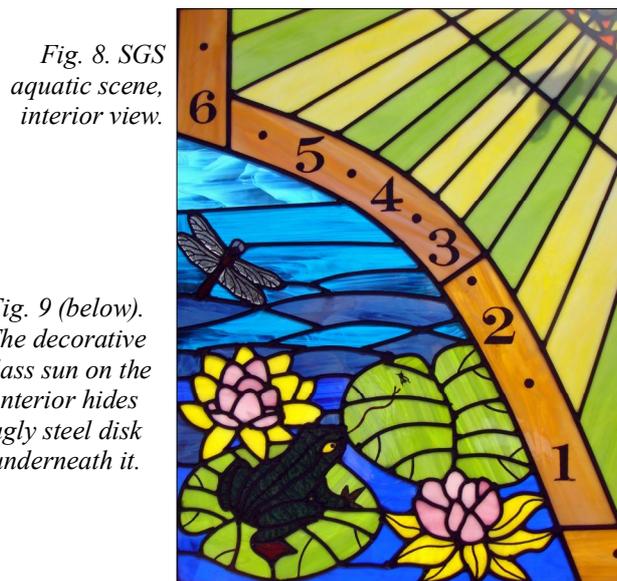


Fig. 8. SGS aquatic scene, interior view.

Fig. 9 (below). The decorative glass sun on the interior hides ugly steel disk underneath it.

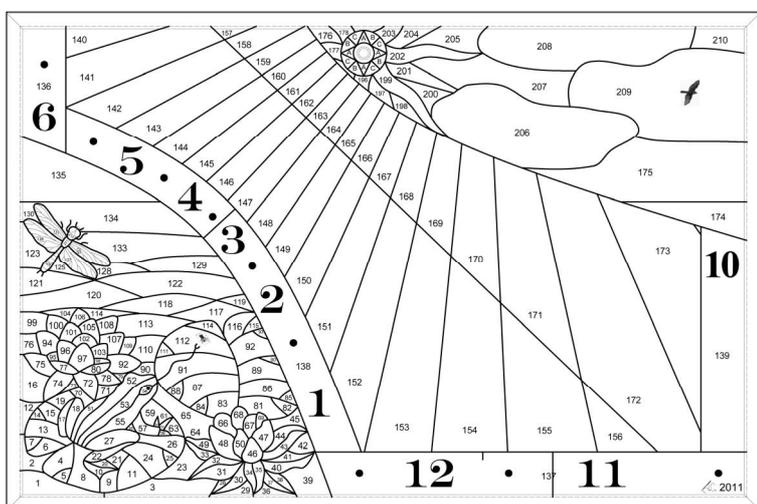


Fig. 6. SGS DeltaCAD glass pattern.

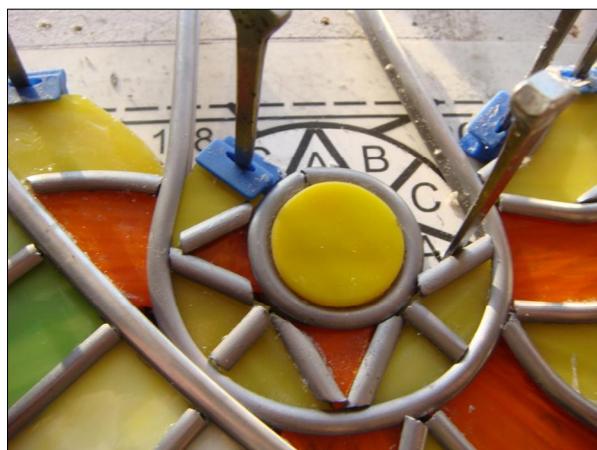




Fig. 10. Shadow test of the frog gnomon's shadow on glass.



Fig. 11 Exterior view of the frog gnomon's shadow.



Fig. 13. Extra rod & ball magnetic gnomon.

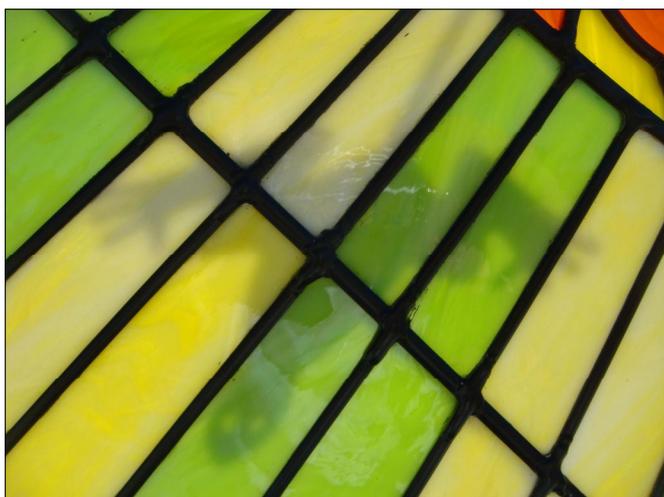


Fig. 12. Interior view of the frog gnomon's shadow.



Fig. 14. Exterior view of the sundial under reflected light. Compare the colours to those in transmitted light in Fig. 1.

terns. The spline tool lets you draw nice curved lines, and the program lets you control the critical line thickness needed for stained glass patterns. The local blueprint shop plotted out the full-sized glass pattern on water-proof Mylar plastic paper that I used on my workbench to guide me during assembly (Fig. 6). Finally, I made a PDF copy of the finished DeltaCAD drawing and played with it in Photoshop Elements to pick the best glass colours for the project (Fig. 7). In keeping with the frog theme, I decorated the non-dial parts of the window with an aquatic scene featuring blooming water lilies, a dragonfly and a frog catching a fly. It had to have the traditional SGS fly! And a frog eats flies (Fig. 8). Perfect! At the top is a sky scene with clouds,

a hawk, and a sun with many sun rays. The sunrays have lots of soldered lead came which adds beauty and strength to the steel disk that is hidden behind the  $\frac{7}{8}$ " diameter yellow glass sun that is glued to the disk with silicone (Fig. 9).

Before selecting and using the pastel green and yellow streaky opalescent glass of the hour segments, I tested the glass to make sure that the gnomon would cast a highly visible shadow through the glass (Figs. 10, 11, 12). The hour numerals and much of the detailed artwork are made from oven-baked enamel that is painted onto abraded portions of the glass. Abrading the glass before painting allows the paint to adhere firmly to the roughed up glass behind it. I abraded the glass using the same high speed diamond burrs that I use to engrave my stone sundials. I used both lead and zinc came to give the panel extra strength. Then for even more strength and to waterproof the panel, I spread silicone in the lead grooves and to the edges of the glass pieces during assembly. After the panel was assembled and soldered, I painted the interior lead and zinc with two coats of satin black Rustoleum enamel to give the metal came a clean black look. I also supplied the client with an extra magnetic traditional rod and ball gnomon just in case he loses or breaks the frog gnomon (Fig. 13). Viewed from exterior of the building, the glass looks different with reflected light. Note that the painted engravings are almost invisible from the outside (Fig. 14).

#### REFERENCES and NOTES

1. See: <http://www.kjmagnetics.com>
2. Visit the Flickr website to see more photos of this new sundial: <http://www.flickr.com/photos/jlcarmichael/>
3. You can see a large inventory of stained glass sundials from around the world at this educational website: <http://www.stainedglasssundials.com>



**John Carmichael** (b. 1954) lives in Tucson, Arizona, and is a member of the British and North American Sundial Societies. He has been designing and making sundials professionally since 1994. Mostly, he makes exquisite hand-carved stone sundials with lots of individualized artwork, but also designs large public monumental sundials built by others. Occasionally, he makes stained glass, porcelain, ceramic and painted wall sundials. His sundial business is Sundial Sculptures at [www.sundialsculptures.com](http://www.sundialsculptures.com).

# RESTORING THE SUNDIAL AT ST NICHOLAS' CHURCH, LEICESTER

ROBERT OVENS

[In 2009, the BSS made a contribution from the Andrew Somerville Memorial Fund towards the cost of the restoration of the vertical declining slate sundial at St Nicholas' Church, Leicester (Sundial Register No 5101). Here Robert Ovens describes how he carried out the work.]

The Anglican parish church of St Nicholas (Fig. 1) is the oldest place of worship in Leicester. It is in St Nicholas Circle, to the west of the modern city centre and adjacent to Vaughan Way, a very busy inner ring road. It lies between the surviving Jewry Wall, part of the Roman baths, and the site of a Roman Forum, near to the centre of the Roman Town of *Ratae Coritanorium*. Excavations in 1971 confirmed that foundations of the Roman baths actually run under the present church floor.

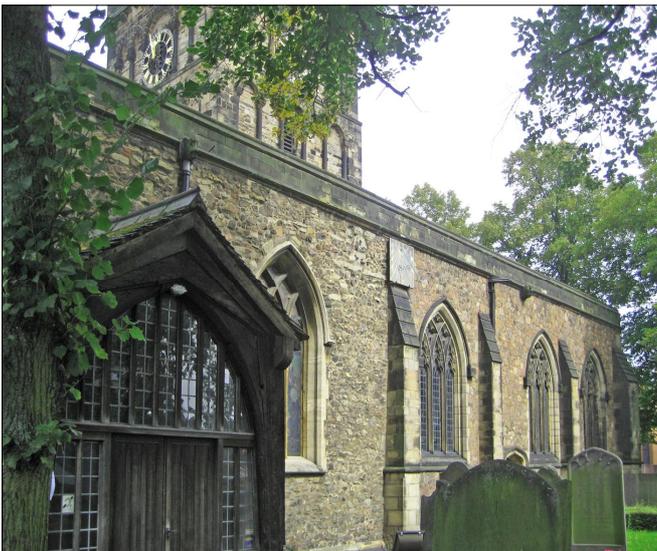


Fig. 1. The location of the sundial on the south wall of the south aisle.

Inner-city redevelopment has meant that the church has lost much of its local congregation, but it survives as an active and well-cared-for place of worship. However, this has not always been the case. At the beginning of the 19<sup>th</sup> century it was in a very dilapidated condition having lost its north aisle in 1699 and its spire sometime later. By 1825 it was in such a poor condition that plans were made for its demolition. Fortunately, it survived until 1875 when extensive renovation work commenced, including the building of a new north aisle. Committed fundraisers and generous donations mean that in recent years the church has benefited from a continuous programme of repair, maintenance and appropriate enhancement.

This programme recently included work on the church clock. As a clockmaker, and Clocks Advisor to the Diocese

of Leicester, I was invited in 2009 to advise on and assist with this work, which included the repair and restoration of the clock movement and its conversion to automatic winding. The final task was to clean, paint and gild the two clock dials. Whilst carrying out this work I was asked to inspect the sundial, with a view to carrying out a full restoration.

St Nicholas' vertical declining sundial is located above a buttress and under the eaves of the wall of the south aisle, west of the Priest's door. The dial plate is a slab of Swithland slate, approximately 600mm square and 60mm thick. It came from the village of Swithland which is in Charnwood Forest, about 8 miles north of Leicester. Slate quarrying in the area dates back to Roman times and it was a particularly important activity in the village for 600 years until the middle of the 19<sup>th</sup> century. Throughout this period Swithland slate was much in demand for roofing and gravestones. Since then the site has reverted to nature, with the slate pits now flooded.

The sundial is dated 1738 but there is no maker's or engraver's signature or mark. A visit to the Record Office for Leicestershire, Leicester and Rutland (ROLLR) at Wigston to search through the parish records did not provide any further information as the Churchwardens' Accounts and Vestry Minutes covering 1738 have not survived. These might have recorded the purchase or donation of the sundial. It is possible that the engraving was carried out by a monumental mason as there are many Swithland slate gravestones in Leicestershire and the surrounding counties. However, although the sundial is beautifully engraved, it is not to the same high standard seen on most of these gravestones. The Roman numerals are deeply incised into the smooth face of the dial plate, but the time lines, border lines and dial furniture (date and sun face), are all quite shallow. In fact, the hour and border lines are more like scratch lines than traditional engraving.

The bronze gnomon is an obvious replacement, at least in part. The shadow bar carries (Fig. 2) the stamped inscription "ELGOOD BROS 1896" on its west face, suggesting a restoration of that date. Kelly's *Directory* of 1895 for



Fig. 2. 'Elgood Bros' stamped on to the west face of the gnomon.

Leicestershire & Rutland records, under *Leicester* (page 221):

**Elgood Brothers, art metal workers, lock manufacturers, engravers &c.; office, 12 Pocklington's walk; works, Peacock lane**

Further research at ROLLR failed to provide any further information regarding this possible restoration.

Initially, the plan was to remove the sundial from the wall so that it could be restored inside the church. However, because of the weight of the dial plate (approximately 60 kg), the cost of its removal and replacement proved to be prohibitive. At this stage, a major concern was the state of the iron cleats which supported the sundial (Fig. 3). As a result of weathering, these were all dangerously thin where they entered the wall. New stainless-steel cleats were later installed to solve this problem.



Fig. 3. One of the original iron cleats supporting the sundial.

The alternative of an *in-situ* restoration using scaffolding was also considered to be problematic owing to the location of the church near the city centre and consequent fears of vandalism. However, this was the solution adopted and security was improved by enclosing the base of the scaffolding and by adjusting the floodlighting so that the church was illuminated from dusk until dawn.

Gilding of external features can only be carried out in temperate, calm and dry weather conditions. Fortunately these conditions prevailed during the first week of October 2009 when the restoration work took place.

A detailed inspection prior to restoration revealed that the dial surface was in good condition, without any significant surface deposits that needed removal. It was also clear that



Fig. 7. Masking by covering and cutting.



Fig. 8. Detail showing gilded sun face and date.

all numerals, lines and furniture were originally gilded. Often these are encrusted with thick layers of gold size. This has to be removed by very careful scraping if a crisp and attractive result is to be achieved. The facets of deeply incised Roman numerals need particular attention in this respect. Fortunately, there was very little old gold size left on the St Nicholas sundial.

The next step was to mask round the engraved areas which were to be gilded. Good-quality 18 mm and 25 mm masking tape was used for this purpose. Such tape seals well to the surface and pulls off without leaving a sticky deposit when its job is done. This stage could possibly have been avoided by using a good quality artist's brush to apply thinned-



Figs. 4, 5 & 6. VIII after masking, immediately after applying gold size and after gilding.



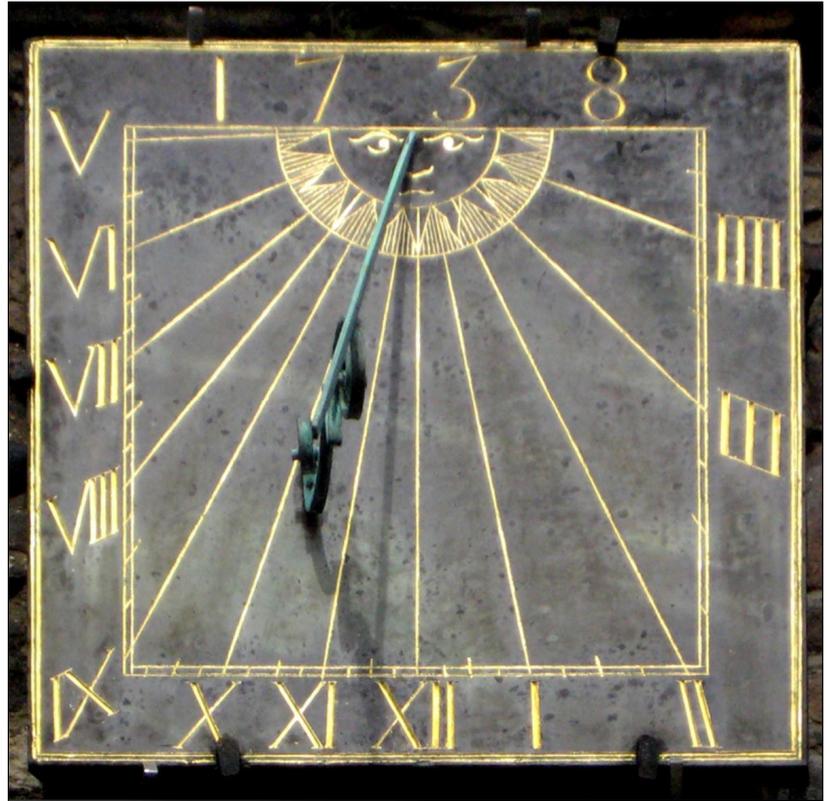
*Fig. 9. The restored clock dial and sundial showing scaffolding access.*

down gold size, but it is very difficult to create straight lines without spreading outside the edges of the engraved areas, particularly on a vertical surface whilst standing at the top of a somewhat wobbly scaffolding tower. Masking results in a much neater outcome, but takes considerably longer. Also, with masking tape, it is best to use full-bodied size otherwise there is a tendency for it to creep under the edges of the tape.

Various techniques were used in applying the masking tape. For straight lines it was carefully placed either side, making sure that the straight edge of the tape was exactly on the edge of the engraving. For more complicated detail, the engraving was covered with masking tape and the area to be gilded carefully cut out with a surgical knife. Short lengths of masking tape will stretch round gentle curves and this method was used for the lines round the upper end of the gnomon. In all cases, the back of a hard plastic spoon was used like a burnisher to gently press the critical edge of the masking tape into good contact with the slate surface.

Having applied masking tape to a number of areas to be gilded, it was time to apply the gold size. The size has to be virtually dry before gold leaf can be applied, so it was a careful balancing act between applying size to sufficient areas for continuous working, and not applying too much to the extent that the size was too dry before I could gild it.

To some, the subject of gold size is surrounded by mystique and confusion. From my point of view it has to have good self-levelling properties so as to give an even coverage without leaving brush marks. It also has to have good covering properties because I am usually gilding over dark



*Fig. 10. The restored sundial.*

backgrounds. It must also be suitable for outdoor use and have an 'open time' of one to two hours. The 'open time' is the period from when the size is not too wet to apply the gold leaf to when it is just too dry. There are many grades of gold size available with 'open times' ranging from a few hours to several days. What to use and when and how is shrouded in mystery, particularly as all sizes are affected by temperature, humidity and the absorbency of the surface being gilded. In the past, many substances, including blood, egg white, honey and ordinary paint have been used, as well as proprietary gold size. After years of trying virtually everything (but not blood!), I now always use chrome yellow Blackfriar QD90 metal paint, which my supplier refers to as 'tractor paint'. It performs well in all circumstances and satisfies all the requirements outlined above. Gold leaf is slightly transparent and the yellow size permanently enhances the appearance of the finished project. Note that this technique is known as 'oil gilding' and is the only durable gilding solution for outdoor surfaces. 'Water gilding' is a very different system. It is only used for indoor decoration such as furniture and picture frames, particularly where highlights are to be burnished to a high shine.

I applied the gold size using a good quality 12mm artist's acrylic paint brush, making sure that there was an even coverage with no runs or build up in tight corners. Because masking tape was employed, size could be applied very quickly as there was no need to be careful to keep within the engraved areas. I used a second 'dry' brush to remove any excess size in corners and I cleaned both brushes thoroughly immediately after each application. Whilst waiting for the gold size to dry to its 'open time' I set about mask-

ing a different area of the dial. As mentioned before, there was a delicate balance between masking, sizing and gilding to achieve a continuous work programme.

Gold leaf is gold that has been hammered into extremely fine sheets. These are much thinner than paper with about the strength of a cobweb. It comes in a variety of different grades (carats), shades, thicknesses, and either as loose or transfer leaf. For outdoor projects I always use double thick 23½ carat medium deep transfer leaf. It is virtually pure gold. Anything less than 23 carat will not retain its characteristic glittering gold appearance for very long. 24 carat is pure gold but it is very difficult to use because of its softness. Lower carat grades consist of increasing quantities of other alloyed metals, particularly copper, to give different shades. Gold leaf is usually supplied in books of 25 leaves, each leaf being 80 mm square. Consequently, it was easy to work out the quantity to order for the St Nicholas sundial, working on the basis of the area to be gilded plus 50%. Loose leaf can only be used indoors because the merest breath of wind will see it fly away. Transfer gold leaf comes on loose backing sheets of thin tissue paper which allow it to be cut into smaller pieces and handled like paper. The downside is that it is more difficult to push into recessed areas, but it is the only solution for outside gilding.

I removed the masking tape immediately after application of the size. If it is left in place until the size 'open time' there is a high risk that it will not pull off cleanly. I started to apply the gold leaf when the size was just very slightly tacky – the start of its 'open time'. Identifying this state is very much down to experience. As a guide, an applied finger will pull away with a slight click without any paint

transfer. In applying gold leaf, my technique is to remove a sheet of transfer leaf from the book, holding it only by the tissue edges, and to press it into the sized area, being as economical as possible by working from one edge to the opposite edge across the sheet of gold leaf. Ideally, the leaf will stick to sized areas only, but a little excess will often pull off the paper backing sheet. A second or third application is sometimes needed to get to the bottom of deeply recessed areas. I used a fairly stiff artist's oil paint brush to push the transfer paper and leaf into such areas on the St Nicholas sundial. For small areas, I cut the transfer leaf into halves or quarters with sharp scissors.

Using the materials and techniques described here the sundial at St Nicholas was completed in about four days. The only remaining task was to remove any small areas of excess leaf not attached by size, best achieved when gilding slate by flicking with dry fingers! This was not too critical as it would soon be washed off by the next rain shower.



**Robert Ovens** was born in Rutland and has recently returned to live there. His background is in electrical engineering and his passion for antique clocks also resulted in him becoming a qualified member of the British Horological Institute. His main horological interests are in English domestic clocks, church clocks and sundials. He is also involved in local history research and is co-author of *Time in Rutland – A History and Gazetteer of the Bells, Scratch Dials, Sundials and Clocks of Rutland* and *The Heritage of Rutland Water*, both published by Rutland History Society ([www.rutlandhistory.org](http://www.rutlandhistory.org)). His email address is [rfovens@yahoo.co.uk](mailto:rfovens@yahoo.co.uk).

## WEST INDIES DIALS

In an article last year,<sup>1</sup> Tony Wood and Jill Wilson reported on two horizontal dials made for the West Indies but now in Gloucestershire. Now our former member John Hayes has gone one better and found an example still in the West Indies. It is located



at Nelson's Dockyard, English Bay, Antigua (left). At a latitude of just 17° N, the dial (top right) has a very low-angled gnomon and a time range of 6am to 6pm.

The 18<sup>th</sup>-century dial is nicely protected by railings and signed "Gregory & Wright, London". Henry Gregory was also the maker of one of the Gloucs dials so it seems he had good connections with the area. Until now, though, we had no knowledge of him working with [Thomas] Wright so the dial provides another nugget of information on

the interconnections between the London mathematical instrument makers. The dial certainly follows the style of Thomas Wright.<sup>2</sup>

John Hayes was also able to view another London-made West Indies dial when he visited Barbados. This one (bottom right) is by Henry Pyefinch and is already recorded as an overseas dial in the BSS Register (SRN 3799). It has been described previously,<sup>3</sup> is at an even lower latitude of 13° 15' N, and is complete with an Equation of Time ring.

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JD (photos by John Hayes)

# THE GREAT AMWELL SCOTTISH RENAISSANCE OBELISK DIAL BOSS

## Part 1. Reading a Scottish Renaissance Sundial Boss

MALCOLM BISHOP

Scottish renaissance obelisk sundials are sufficiently uncommon for the finding of a boss, or capital, from one on the terrace of a private house in Hertfordshire (Fig. 1) to be worthy of note. Ross,<sup>1</sup> Somerville,<sup>2</sup> and Cowan<sup>3</sup> between them record some 26 in Scotland. This paper attempts to give an answer to the question of how this rare and important artefact came to be where it was found last summer.

This first report is divided into the sections under which the examination of the dial took place – General description, Recent history, Provenance and the Mylne family, Geometrical analysis for latitude, Social analysis of inscriptions, and ‘Dating’ the dial. A second paper describes the boss in detail for the archive.

### The ‘Pickwick’ Caveat

In 1836-7, Charles Dickens poured gentle scorn on the amateur antiquarians of his day in *The Posthumous Papers of the Pickwick Club*, a warning to anyone who wishes to read into a stone which, like Mr Pickwick, they have ‘discovered’ and unearthed, significance that is not, in fact, justified. The Amwell dial has inscriptions which need to be demonstrably not the equivalent of the

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of Mr Pickwick’s great find.<sup>4</sup> Establishment of authenticity is undertaken in this first part of the study of the dial to establish that it is not, for example, a Victorian replica, and that it complies in all details with what is known of Scottish renaissance obelisk dials.

### 1. General Description

The boss is a rhombicuboctahedron, an Archimedean solid with fourteen square facets and eight equilateral triangular facets. The material appears to be sandstone, which is

readily available in a broad oblique band across Scotland in the Edinburgh region.<sup>5</sup> Each edge is 7 inches (178 mm), so the boss is approximately 14 inches (356 mm) high and wide. This form and dimension is consistent with that of other known dial bosses.

The cardinal facets are presented as scaphe dials. The bosses or capitals of fifteen of the known obelisk dials are of the same general pattern as the newly discovered boss; however, the boss described here appears to be unique in also having scaphe dials at each of the inclining and declining corners, rather than the cut away corners of the others.<sup>6</sup> The base has a square socket about 4 inches in width to locate a shaft, and a circular recess about one inch in diameter in the top shows the location of the peg

(probably of iron) which helped secure the tapered obelisk finial section.

Each plane facet carries a different dial, and the gnomon sockets are symmetrically arranged around the North/South axis. None of the gnomons is present, although there was part of one gnomon to be seen on the South upper inclining facet when the boss was unearthed, and its bedding of lead can still be seen. Most of the gnomon sockets have survived with little spalling or other damage to the stone, so the shape of the base of the gnomon can be seen. It may

be conjectured that the gnomons had been lost before burial, and early enough for rusting and expansion of the iron not to have occurred, or that they were not of iron.

The buried surfaces have been remarkably well preserved from weathering, in contrast to the exposed section, which has been weathered and broken away, and which carried a rich growth of moss and lichen. It is only to be regretted that chance has favoured the simpler dial facets for better preservation.



Fig. 1. The Amwell obelisk dial boss. (Inverted, south scaphe and inclining dials shown with foot rule above).

## 2. Recent History

The boss was found in 1974 by the current owner two thirds buried in a bank in the garden at Walton Lodge, Great Amwell, near Ware in Hertfordshire, and not the least pleasing part of the recent history of the dial is that for the last thirty-seven years it should have been in the custody of a person whose own grandfather, James Hiddleston, was a Scottish Master Mason.

At present no other parts of the dial have been located, and it is possible that they remain buried. As noted above, its identity as a sundial was not recognised until summer 2010, by which time it had accompanied the owner in at least two moves away from Great Amwell. At one time an attempt was made to grow strawberry plants in the larger scaphe dials, without any great success.

It is pretty certain that the boss was not part of an erected sundial in 1951 when, shortly after the Act,<sup>7</sup> the survey for the Listing of British Buildings listed Amwell Grove (built by Robert Mylne FRS (1733-1811) in 1795-7),<sup>8</sup> and various items of stonework on the extensive Mylne lands at Great Amwell. Similarly, the boss was not mentioned at Walton Lodge in 1983 when the Observatory in the garden was listed.

## 3. Agent, Means and Motivation; The Mylne Family

For the boss to have reached the garden in Great Amwell, there needed to be an agent with both the means, the specialist knowledge, the skill, and the motivation to have transported the stone from Scotland, and the Mylne family of Master Masons, civil engineers, and architects had all three.

Somerville comments on the vulnerability of obelisk dials. The boss is very heavy and is perched on a slender column, so any failure will send the structure toppling with lethal effect. They were knocked over by horses and cows, and as the present owner described, and which must have been apparent to others over the years, a damaged obelisk is extremely dangerous. The requirement for all styles to be parallel means that there is no surface that does not carry an ingeniously shaped but sharp gnomon. The boss was at the same time both dangerous and delicate to handle.

The two Mylnes most concerned with Walton Lodge were Robert William Mylne FRS FRSE FSA (1817-1890) who built the house as Home Lodge, which was then divided in the 20<sup>th</sup> century to make the two dwellings now known as Walton Lodge and Home Lodge, and his son the Revd Robert Scott Mylne, FSA, FRSE (1854-1920).<sup>9-11</sup> Whilst Rector of Great Amwell, Home Lodge served as his Rectory, and his daughter, Miss Jean Mary Home Mylne (1896-1978), the last of the Mylnes of Great Amwell, lived on there until her death.<sup>12</sup>

The history of the Mylne family, and their known behaviour towards artefacts they had themselves been responsible for creating, provides a satisfactory answer to all three questions of Agency, Means, and Motivation. That history, and the lineage of the Mylnes, is recorded in

*The Master Masons to the Crown of Scotland and their Works* (1893).<sup>13</sup> This handsomely bound and printed work is not only a comprehensive presentation of the subject but an act of filial piety by Robert Scott Mylne.

In 1912 R.S. Mylne described the recovery and repatriation from Great Amwell to Edinburgh of renaissance stonework from the Netherbow Port, including the spike on which the heads of Covenanters and others were once displayed.<sup>14</sup> His ancestor John Mylne (c.1585-1657) was recruited from Perth to work on the Port in 1616/7.<sup>15</sup>

A further major piece of stonework from the Netherbow Port (Fig. 2) was recognised in 1950 built in to the gable of Mylne Field,<sup>16</sup> built by Robert Mylne as a farmhouse in the early 19<sup>th</sup> century.<sup>17</sup> The present central crown is presumed to have been inserted on the Restoration to replace work defaced during the Commonwealth. This additional work may also have been done by the Mylnes, and the stone was presumably acquired by them in 1764 when the Port was demolished.

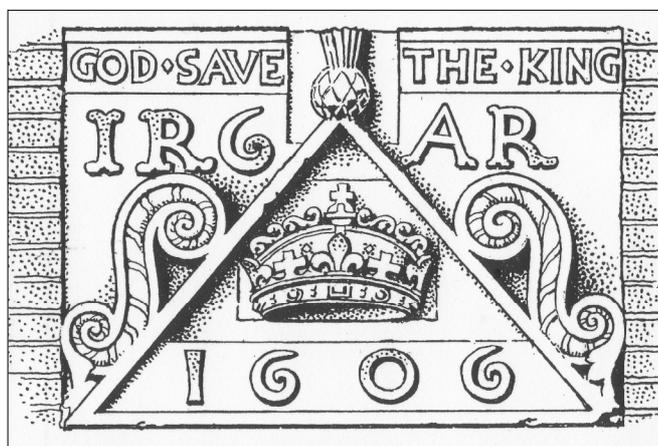


Fig. 2. Stone from the Netherbow Port, size 3' × 4' × 6". By permission of the East Herts Archaeological Society. Drawing Gordon Moody. 1974.

That R.S. Mylne did not mention the boss in his writings makes it almost certain that it was in his time already lost – a view supported by the degree of weathering to the exposed surfaces compared with the buried surfaces.

As to who was initially responsible for bringing the boss to Great Amwell, that was most probably “*A rare gentleman, “Hot as pepper and as proud as Lucifer”*”,<sup>18</sup> R.S. Mylne’s great-grandfather Robert, architect and engineer, who moved to London in 1759 after studying in Italy with Piranesi. The family’s long association with Great Amwell is accounted for by his and his successors’ duties to the New River Company.<sup>19</sup> (Robert may well have given his son William the middle name Chadwell after the spring at Ware supplying the New River. Amwell itself is Emma’s Well, another of the original springs.)

## 4. Analysis for Latitude

With a reasonable provenance established, the next step was to decide where the dial was designed to be placed when it was made. Each facet was photographed under prevailing (and very variable) natural lighting conditions.



Fig. 3. Photograph of the East reclining facet.

This could not be done under studio conditions, but the results are reasonably representative. The photographs were converted to greyscale and cropped in order to assemble a facet map for reference (Fig. 4).

Working rubbings were taken of each plane facet to allow for accurate measurement of the dials to be undertaken. Each was numbered according to the exploded plan (Fig. 5). When transferred by photocopier<sup>20</sup> to photographic paper for working, the dimensions could be checked for accuracy thanks to the translucency of the paper.

A regression analysis was made from the rubbings by John Davis. Seven faces had hour lines sufficiently well preserved to allow the hour line angles to be measured, to a precision of perhaps half a degree. These angles were

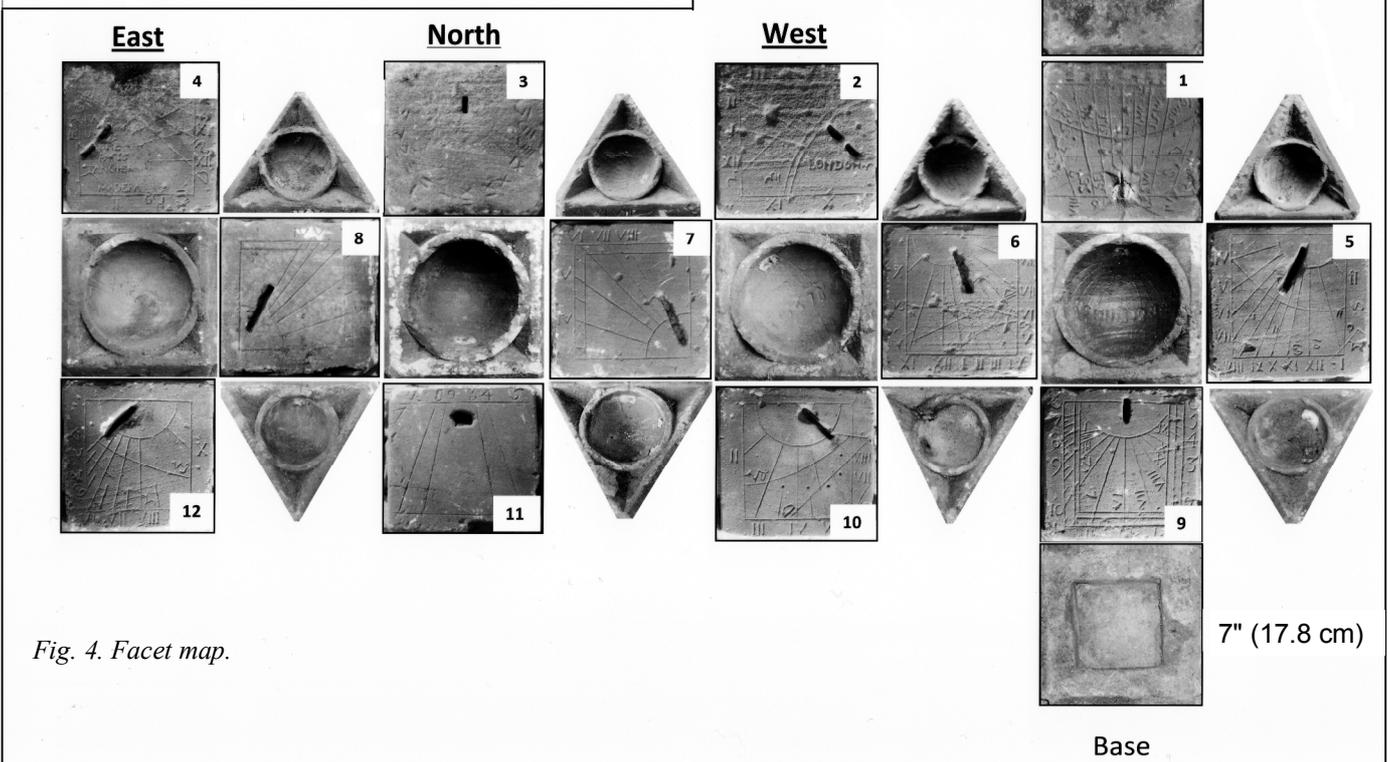


Fig. 4. Facet map.

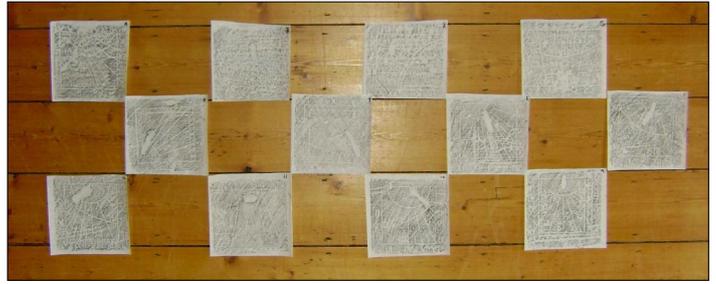


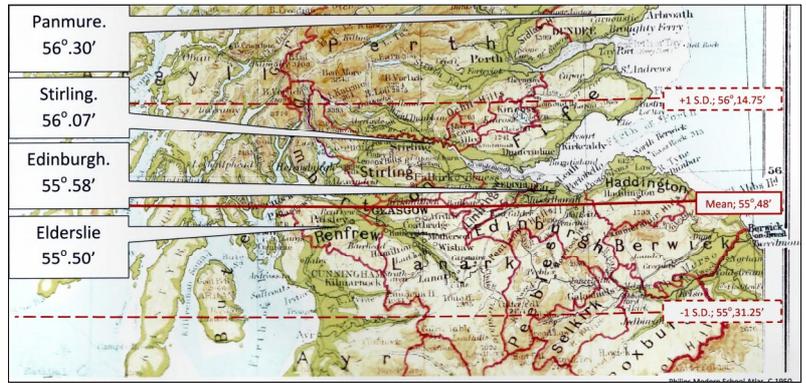
Fig. 5. Working rubbings. (Board width 6 3/4").

mathematically compared to the theoretical values for a perfect dial at a presumed latitude, this value being optimised to obtain the best least-squares fit. Individual best-fit latitudes were thus obtained for each of the seven faces, varying between 55.3° and 56.5°. The mean value was 55.8° ±0.5°, although the faces giving values at the lower end of the range were judged to be most reliable. The results allowed for the preparation of a map (Fig. 6) showing the mean and one standard deviation for the resulting latitudes. There is thus confidence in a North British location for the original siting of the dial.

### 5. Social Analysis of Inscriptions; Authentication and Dating the Boss

Once it was known where the dial could have originated, an analysis of the inscriptions was made to see if they furnished clues as to the date of the boss. This could be very important, as Somerville records the long gap between the 1630 Mylne dial at Drummond House, and the first dated dial (1695) of the standard boss type at Asknish.

Fig. 6. Latitude map derived from analysis of the rubbings. Red solid line = mean. Red dashed lines =  $\pm 1$  S.D.



Both the fact that this new boss differs from the standard boss, with its corner scaphes, and in particular the datable inscriptions, make this boss of considerable significance as a potential 'missing link' for the obelisk dial type in the sixty years between 1630 and 1695.

The inscriptions which are clear refer to LONDON on the West reclining dial, and to ACRA, PARIS, TANGIER, and MADERA (*sic*) on the East reclining dial. Damaged and incomplete inscriptions on the East reclining dial read IERU (S) and O(or U)M(E or L).

ACRA and TANGIER are the most significant for dating purposes. ACRA was named as a port of particular interest in the 1672 Charter of The Royal African Company, which succeeded the previous (English) Company of Royal Adventurers Trading to Africa, set up after the Restoration. The wording shows that Acra was already well established before 1672; "more Leewardly, the Company hath another factory at Acra, for gold, to be sent thence to Cabo-corso."<sup>21,22</sup>

Scottish Lords who might have commissioned such a high status object as this obelisk dial were concerned with the West African (Guinea) coast before the Civil War. Patrick Maule, first Earl Panmure, and Henry, the son of William Alexander, first Earl Stirling, were two of the four courtiers of Charles I who formed the Scottish Guinea Company (1634-1639).<sup>23</sup> If either of these Scottish Noblemen commissioned the dial, a date after 1634 is indicated.

TANGIER came to the British Crown as part of the dowry of Catherine of Braganza (1638-1705) when she married Charles II in 1661, and was razed before being abandoned to the Moors in 1684. The brief inglorious history of the English ownership of Tangier is given its most interesting historical record in the Diaries (1660-1669) and later Tangier Journal, (1683) of Samuel Pepys FRS (1633-1703).

The spelling of MADERA is correct for the proposed date in the seventeenth century, persisting at least to the mid-eighteenth century in English usage. The account of earlier, 16<sup>th</sup>-century voyages to the Guinea coast (probably those of Hawkins)<sup>24</sup> notes Madera (and Tangier) as staging posts when both were in Portuguese hands (it also names 'Arra', a possible variation of Acra).

Unless the obelisk was commissioned to record events in the owner's past life, secure and documented dating for Acra and Tangier therefore indicate a date for the construction of the dial before 1684.

## 6. Evidence in Scotland of Mylne Dials and of Incomplete Obelisk Dials

With provenance and dating for the dial reasonably established, and for want at present of documentary evidence, attribution of the sculpting of the boss to the

Mylnes depends on circumstantial evidence and subjective opinion. Two Scottish renaissance sundials are definitely attributable to the Mylne family. John Mylne of Perth (c.1585-1657) Master Mason to the Crown from 1631, together with his own sons John and Alexander, erected the sundial at Holyrood House for Charles I. (See *Bulletin* 23(i) p.14.) He resigned his crown appointment in 1636 in favour of his son John (1611-1667). This John Mylne (known as Junior or the Younger) was responsible for the obelisk sundial erected in 1630 at Drummond Castle (see back cover of *Bulletin* 23(i), March 2011).

As said earlier, the rest of the dial may still lie buried at Great Amwell (a large water cistern for the estate laundry was filled with rubble at the site). However, the Mylnes may have acquired the boss alone, so it is worth looking at the shafts known to be still in Scotland.

Of these three partial or broken obelisk shafts, the dial facets of the pillar now at Brechin, originally at Panmure, do not match the Great Amwell boss, being cut by the mason in the same clearly demarcated high relief form as those on the shaft of the obelisk at Drummond House. On stylistic grounds, these remains may be considered to be the shaft of another Mylne obelisk dial. (This detailing is



Fig. 7. Left; the Panmure (Brechin), and right, the Stirling partial shafts. Copyright. © RCAHMS (Dr Andrew R Somerville Collection). Licensor www.rcahms.gov.uk.

coherent for the full height of the Drummond House dial, running upwards through the boss to give a pleasing unity to the whole.) In 1666 John Mylne designed and was engaged to build Panmure House, for the 2<sup>nd</sup> Earl of Panmure.

The provision of sundials for Drummond House and Holyrood House gives the impression that a Mylne sundial was almost a signature of their work, so it would not be surprising to find one at Panmure, but as said, the remains of the shaft do not match the Amwell boss.

The shaft at Stirling Castle is stylistically much more comparable with the rediscovered boss. The dial facets are separated by a simple incised line, and the vertical edges of the shaft are not detailed in the way that the Drummond House and Panmure shafts are. The connection between the Mylne and Stirling Castle is not direct, though John Mylne did work in Stirling and Cowane's Hospital was built to his design in the mid-17<sup>th</sup> century. If the Amwell boss is pictured surmounting a column of the Stirling type, the visual unity of the vertical aspect is preserved.

As yet, the shaft in the keeping of the Society of William Wallace, which was discovered during the excavation of the cellars at Wallace House, Elderslie, in the early 20<sup>th</sup> century, has not been accessible for comparison.

### Summary

An artefact with such historic significance as this recently rediscovered Scottish renaissance dial boss may be read in three different but complementary ways.

First, there is the ongoing narrative of its recent provenance and history, for which the next step is its appearance for sale by auction at Christie's on 6 April 2011.<sup>25</sup> Second, the evidence contained in the dial of the social environment in Scotland at the time of its creation is important to the understanding of those tumultuous times, and this narrative can change substantially if documentary evidence for the dial turns up, as it yet may. Third, the dial has its own integrity and can be read objectively as an advanced scientific instrument.

The very high quality of the boss cannot be questioned. Sundials, like music and games of chance, provide mathematicians with challenges and diversions. The Scottish renaissance sundials in their varied forms, and perhaps most particularly the obelisks, seem to be an expression of a particular *jeu d'esprit* in stone amongst their designers, those who commissioned them, and the Master Masons in whose workshops they were made.

### ACKNOWLEDGEMENTS

I am most grateful to the owner of the dial for kindly permitting free access for photography and examination. John Davis is thanked for analysis of the dial. Mr Piers Nicholson and the Librarians of the Athenaeum are also thanked.

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**Malcolm Bishop** lives in Hertfordshire. As a retired dental surgeon/part time lecturer in dental radiology, his interest in this particular sundial, seen in a corner during a summer lunchtime on the owner's terrace, came from the challenge of finding out what it was. Much enjoyable research followed, in a new and fascinating discipline, initially guided by Piers Nicholson, but following many of the principles employed to arrive at a professional diagnosis.



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The Society's website is at [www.sundialsoc.org.uk](http://www.sundialsoc.org.uk)  
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