

The British Sundial Society

BULLETIN

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Electronic Input of Fixed Dial Reports

1. Introduction

Members have traditionally sent dial reports to the Registrar in paper form – printed or hand-written Report forms, accompanied by printed photographs. With the increasing use of computers for the preparation and printing of the forms, and more particularly with the increasing use of high quality digital cameras for the photographs, I now welcome reports sent in digital form, with the following preferred naming conventions. (Traditional paper reports and photos are of course still very welcome! Please use whichever method is more convenient for you, but lean towards electronic if you have the facilities.)

2. Method

A typical ‘electronic’ report will consist of a skeleton covering email with attachments – one MS Word file of the present Report form, plus one or more jpegs of photos of the dial. **Examples below assume a membership number of 1130, and a personal Sequence Number of 073.**

- The Subject line of the email should start with your Membership Number and Sequence Number, and briefly identify the County and Location of the dial, and the SRN if known. For example **1130,073 Kent, Folkestone St Mary’s, 5182**. The content of the email is not important.
- Reports and photos are sent as attachments to the email – NOT on a CD.
- Only one dial report per email.
- Reports are attached as MS Word files. The first (and usually only) sheet is a Word document using the standard template BSSForm2005.doc from the web site. Additional information may be sent in further Word files, or exceptionally in Excel files where the information cannot conveniently be expressed in Word.
- **Reports** should be named Rmmmm,qqqa.doc, where ‘mmmm’ is the Membership Number, ‘qqq’ is the Member’s Sequence Number for this report, ‘a’ is a, b, c etc.

Example: **R1130,073a.doc** as the standard template report, plus if desired R1130,073b.doc containing a free-format table of additional data.

If an Excel sheet has to be used in addition, it would be R1130,073c.xls. Note that the suffix carries on from the .doc suffixes, it does not start again at ‘a’.

If additional graphical information needs to be sent (eg sketches, photocopies from books etc), it can be sent as supplementary jpegs as below.

- Photographs are attached as jpegs, preferably 0.5MB or less, certainly under 1MB.
- One photo per jpeg, not for example several on one A4 sheet (currently common practice for a few members).
- **Photos** should be named Pmmmm,qqqa.jpg, where ‘mmmm’ is the Membership Number, ‘qqq’ is the Member’s Sequence Number, ‘a’ is a, b, c etc for multiple photos submitted, example **P1130,073a.jpg** and P1130,073b.jpg.
- The sender should retain a copy of the email, including attachments, for at least one year.

*John Foad
BSS Registrar
25 June 2011*

Front cover: The 1680 Henry Wynne dial at Windsor Castle (SRN 6338). Now badly corroded, it features a fabulously pierced and engraved monogram gnomon with the cipher CR (for Charles II) visible from either side. It is one of a small number of dials from the late 17th century in which the dial plate comprises a thin plate carrying the actual engraving rivetted to a much thicker underlying plate. Another, also by Wynne and now at Clarence House, is thought to have been at Windsor originally. Photo by David Isaacs.

Back cover: The fine 1959 replica of the Thomas Tompion ‘Azimuth and EoT’ dial, at Kew Gardens (SRN 6740) with The Dutch House in the background. The original is one of a pair of dials made for William III at Hampton Court Palace, where there is now a more recent replica on display. Photo by David Isaacs.

BULLETIN

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EDITORIAL

This issue contains the report of our highly successful annual conference at Wyboston Lakes. That nearly 20% of the membership managed to attend must reflect highly on the keenness of our members – and the reputation of the event – especially when a significant number live overseas. The issue, together with the June one, presents written versions of some of the papers presented during the weekend. I know that members who are unable to get to the Conference sometimes find the brief reports of presentations tantalizing if the full version is not available in print. This also applies to Newbury talks. Attempts are made to persuade presenters to write up their talks but it is not a requirement and some are already too busy on their next project to do so. I will continue to seek articles, using the argument that preparing the talk represents three-quarters of the work and that having it in the *Bulletin* ensures their name and efforts are captured in the national lending libraries for all time.



An appropriate greetings card, published c.1950s with artwork from W Stocker Shaw. Image courtesy of our Polish member Dariusz Oczki: see his website <http://gnomonica.pl> for more examples.

A MEDIEVAL GUNTER'S QUADRANT?

JOHN DAVIS

Edmund Gunter (1581-1626) first described his eponymous quadrant as an appendix to his 1623 book *De Sectore et Radio*.¹ So a true medieval Gunter's quadrant is simply not possible. However, a fragment of an instrument excavated in Norfolk in 2009 suggests that the concept behind the instrument may possibly have been known around two centuries before Gunter developed his version.

Introduction

Many designs of quadrant have been used as forms of altitude sundials for at least a millennium. Exploring the development of the various types across the cultures of the world gives a valuable insight into the knowledge of mathematics and astronomy through history, and the types of timekeeping prevalent at any given period. In addition, the nature of the actual devices gives tangible evidence of the level of technology at the time.

The earliest quadrants tend to come from the Islamic world and were designed for unequal (temporal) hours, usually measured with 12 hours from sunrise to sunset and thus putting noon as 6 hours. At the low latitudes of the Islamic world they could be regarded as universal. This was not strictly true for Europe, where they often incorporated a moving calendar scale or cursor. These early quadrants are usually termed *quadrans vetus*.

Horary quadrants based on a similar layout but designed to show equal hours (usually counted from noon and mid-

night) became popular in Europe in the Middle Ages and these were sometimes combined with the older unequal hour scales on the same instrument. In addition, a very sophisticated design – the *quadrans novus* – based on the mathematical projections of an astrolabe was introduced in the late-13th century from Islamic Spain and although it never became commonplace it may have been influential amongst astronomers and advanced thinkers.

Sixteenth and seventeenth century Europe saw a profusion of new quadrant types being developed, either because they had some practical advantage (ease of use, accuracy, universality, ability to provide large amounts of information etc.), because they were easy or cheap to make, or simply because they were fashionable and well-marketed. Amongst these, the Gunter's quadrant was perhaps the most popular with a production life of over a century. Despite being a latitude-specific device, it was optimised for simplicity and accuracy in time-telling and could also give information such as the azimuth of the sun and its place in the ecliptic. It is a hybrid design, drawing on stereography but only for the basic grid on which the hourlines are plotted. Visually, the device is readily identifiable by the pairs of inward-facing arcs which fill a broad band around the limb and meet at cusps on a common circle.

The Norfolk Quadrant

The item shown in Fig. 1 was found in March 2009 by Graeme Simmonds, a Norwich metal detectorist, in an arable field in the Norfolk Broadlands. It was towards the bottom of the topsoil, about 300 mm deep, next to an ancient trackway which continues to a ruined medieval church. There were no associated finds in the immediate vicinity though other medieval artefacts and coins have been found in the same field. Many pieces of Roman pottery and tile have also been found but there were no finds from more recent eras. The field is quite elevated (for Norfolk!) and the trackway, running roughly N-S, is not part of any major route to Norwich so the manner in which the quadrant was lost remains a mystery.

After cleaning up, the find was shown to the local expert of the Portable Antiquities Scheme² (now administered by the British Museum) who declared that it was part of the plate of an astrolabe and dated from the period 1500 to 1700. It was



Fig. 1. Photograph of the excavated fragment.

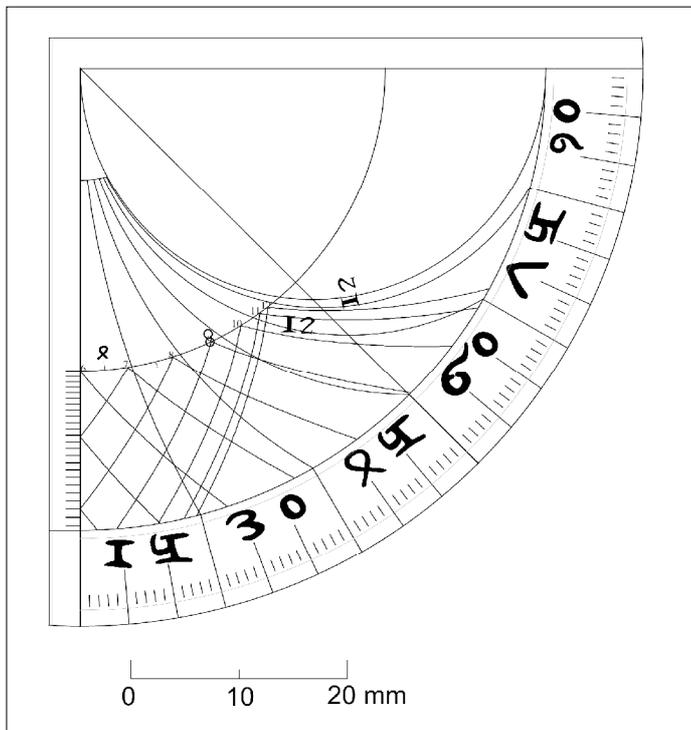


Fig. 2. Speculative drawing/reconstruction of the whole quadrant.

entered into the Scheme's database and a picture shown on their website, along with 650,000+ other items. The first person to spot the mis-identification was Glenn Grieco in the USA who correctly noticed that the numerals were medieval in style and that some of the engraved lines on the surface bore a strong resemblance to those on a Gunter's quadrant. These prompted this author to investigate further.

The find is in the form of just over half of a quadrant with an approximate radius of 52 mm (measured from the lost origin). It is clearly made of a copper-based alloy and it is about 1.0 mm thick. The left edge in Fig. 1, and the limb, are original and the right edge is where the instrument was broken, perhaps intentionally as the break is rather straighter than if, for example, it had been hit by a plough. The quadrant was rather bent and is split slightly but has now been gently flattened, though not perfectly.

The verso face is blank but the one shown has a number of engraved lines and numerals which may be divided up into three sets. The first set, around the limb, simply give a degree or protractor scale. Next inwards is a band of criss-crossing arcs which have strong similarities to Gunter's design. Finally, a small set of large-diameter arcs, passing through the origin or centre of the quadrant, represent the old *quadrans vetus* or unequal-hour quadrant. Fig. 2 gives an idealised view of what the whole instrument may have originally looked like, reconstructed mathematically from first principles.

The Degree Scale

The limb is divided into 15° segments, sub-divided to individual degrees. The segments are numbered anti-clockwise 15, 30, 4[5], 6[0], presumably continuing on the missing part to 75 and 90. The scale thus measures the altitude of the

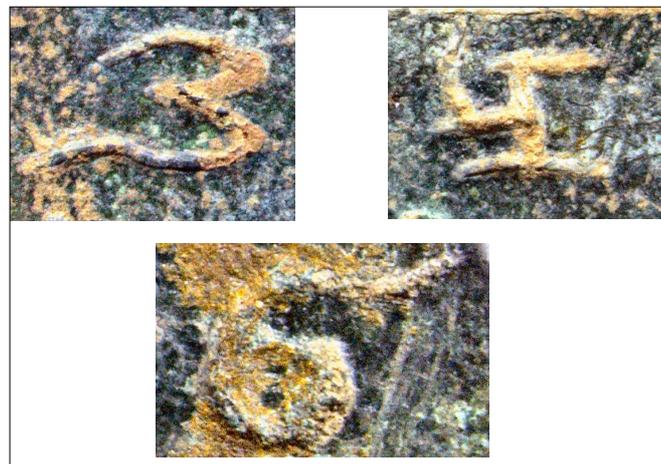


Fig. 3. Close-up of the numerals '3', '5' and '6' showing their medieval form. Photos: Dr P Northover.

sun by means of a plumb-bob hanging from the quadrant origin and a pair of sights along the top radius of the instrument (all now lacking). The division into segments of 15°, rather than 10°, is unusual but not unique. The 'physician's quadrant' at Merton College Oxford, dated to 1400-1450, uses the same scheme.³ The form of the numerals (Fig. 3), particularly the '5' and the '6' (and also the eroded '4' when viewed through a microscope), is clearly medieval, in a style that is not normally seen after the late 15th century.

Unequal Hour Lines

A set of large circular arcs, coincident at the (missing) origin of the quadrant and with their centres on the missing radius line, are the unequal hour lines found on the early form of the *quadrans vetus* (old quadrant) and also on the backs of many astrolabes. From a measurement of the sun's altitude, they give the time in the old 'seasonal' hours, dividing each day into 12, starting at sunrise. The radii and origins of the arcs can be calculated from:

$$r_n = R / 2 \cos(15n), \quad x = r_n \quad y = 0$$

where r_n is the radius of the n^{th} unequal hour before or after noon and R is the outer radius. It is also possible to find these arcs by trial-and-error with compasses, noting that the centre must lie on the meridian line (horizontal in Fig. 2) and the circumference passes through the origin and also through the point $(90 - 15n)$ on the altitude scale. This is probably the method a medieval maker would have used.

The arcs are independent of the design latitude meaning that the *quadrans vetus* is universal, although the underlying declination scale (rarely engraved on actual devices) is latitude dependent. The scale is calculated using the equation

$$r_\delta = R \sin(90 - \phi - \delta)$$

where ϕ is the latitude and δ is the sun's declination. A very short section of an arc, barely 2½ mm long, is visible on the left hand edge quite near the apex, terminating where it reaches the cluster of unequal hour lines, represents the declination of the winter solstice for the unequal hour lines. Several of the arcs terminate on this winter solstice declina-

tion arc rather than continuing to coincide at the origin. This means that the quadrant has been designed for a particular latitude, despite its inherent universality. This feature is often found on old quadrants with equal hour arcs e.g. the 1399 Richard II device,⁴ but rarely for unequal hours.

These unequal hour lines are entirely consistent with a standard medieval quadrant, the design of which can be traced back to ninth-century Baghdad.⁵ Strictly, though, they should not be exactly circular but the approximation is a good one at low latitudes – where the instrument was first developed in the Islamic world – and a passably good one for medieval Europe.⁶ However, the inner, semicircular, arc which represents noon appears to be labelled ‘12’ whereas for unequal hours counted from sunrise it would be expected to be ‘6’. None of the other lines are labelled.

Equal Hour Lines – Gunter’s Quadrant

The equal hour arcs which are the surprising aspect of this find are contained within a broad band between two arcs concentric with the limb. The similarity with an 18th-century Gunter’s quadrant can be seen by comparing with Fig. 4. The inner arc represents the celestial equator and the outer represents the tropics of both Capricorn (winter) and Cancer (summer). These curves result from drawing two stereographic projections of the celestial sphere onto the equatorial plane, one from the north celestial pole and the other from the south. The radial distance between the lines represents the sun’s declination (from 0 to $\pm 23.5^\circ$) in a non-linear manner, though the scale is not sub-divided on the Norfolk device.

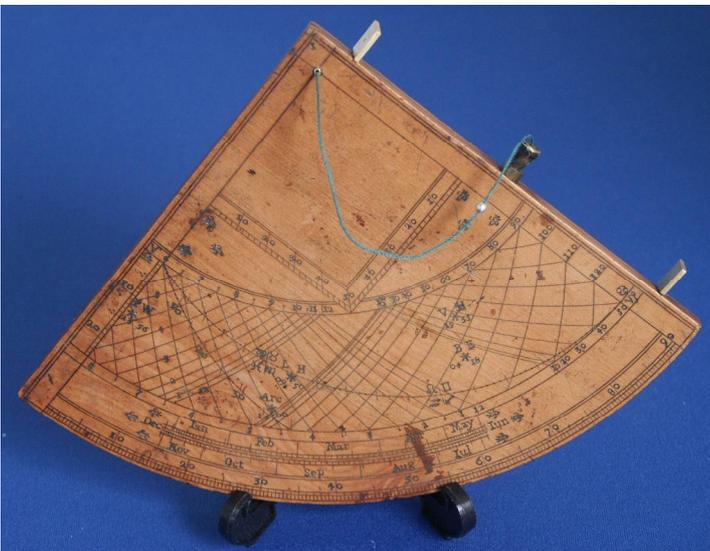


Fig. 4. A typical 18th-century Gunter’s quadrant in box-wood.

The equal hour lines occur as pairs of curves meeting on the equatorial circle and measure the time from noon (i.e. modern solar time). The curve sloping to the left from each pair is for use in the winter (i.e. from the autumnal to the vernal equinox) and that sloping to the right for the summer half of the year. The curves are not the result of a projection but come from solving the standard spherical trigonometrical

equation relating the sun’s altitude, a , with the latitude, ϕ , the declination for the date, δ , and the hour angle, h :

$$\sin a = \sin \phi \sin \delta + \cos \phi \cos \delta \cos h$$

The solutions of this equation, in polar co-ordinates (δ , a) and noting that the declination scale is non-linear (with a different form to that of the unequal hour quadrant) give the lines indicated. They are invariably drawn as circular arcs which is not quite exact: a complete numerical solution shows small deviations of less than the width of an engraved line. To draw the lines without resorting to extensive numerical calculations, a medieval maker would need to consult tables to find the sun’s altitude for the equinoxes and solstices and at two intermediate declinations (one in summer and one in winter) and then fit a circular arc through the points.

In addition to the hour lines, there are ticks on the equatorial arc denoting the equinoctial half-hours for 6:30 and 7:30.

The right-hand pair of hour lines represent noon and are again labelled “12” as would be expected for equal hours. The cusp where this pair of curves meet the equatorial arc ($\delta = 0$) gives the position where the sun’s altitude equals the co-latitude of the location for which the quadrant was designed. For the Norfolk quadrant, this has been measured to give a latitude of $\phi = 52.5^\circ \pm 0.2^\circ$. It is not insignificant that the latitude of Norwich is $52^\circ 38' N$ and so the quadrant appears to be locally made.

Problems

There are a number of areas of the Norfolk design which are deficient as representations of either an unequal or equal hour quadrant.

For the unequal hour portion, the labelling of the noon line is one such feature which suggests that the figure ‘12’ was a later addition made when this was the conventional time of noon – note that the use of equal and unequal hours overlapped by at least a century.⁷ Another instrument which has the noon unequal hour labelled ‘12’ is the navicula-like sundial in the Whipple Museum, Cambridge.⁸ This is dated to 1620.

Another problem is that some of the unequal hour lines appear to be absent. A more serious difficulty is that there is no indication of either a calendar or a declination scale. One or the other of these is needed for setting a bead on the plumb-line at a position which would allow it to indicate the time against the hour lines when the line is held taut along the current altitude line. It is, of course, possible that there was a declination or zodiac scale along the missing radius of the instrument (underneath the sights) as is seen in the drawing of Fig. 5, taken from Fale’s *Horologiographia* of 1593.⁹ The instrument could be used without a declination scale by using tables to find the sun’s noon altitude for a given declination ($a_{noon} = 90^\circ - \phi \pm \delta$) and setting the bead appropriately, though this is rather less than convenient.

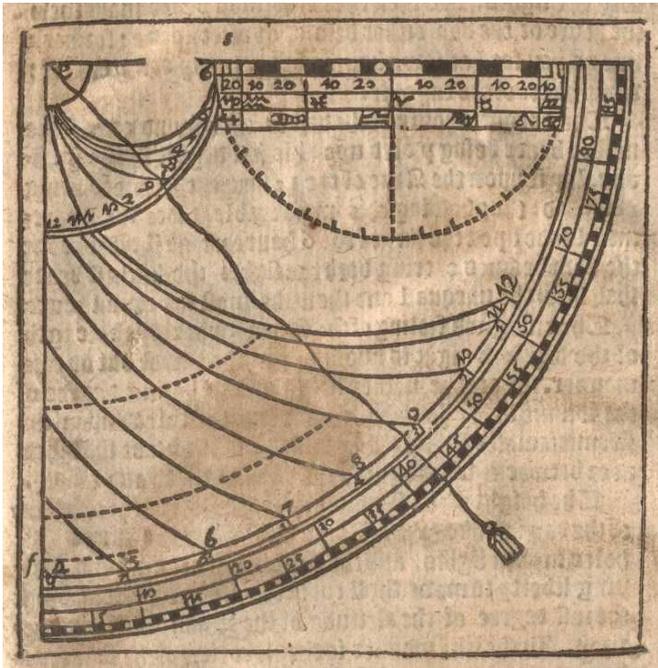


Fig. 5. A quadrant from Fale's *Horologiographia* showing the construction of a zodiac date scale underneath the sights.⁹

For the equal hour portion, the lack of declination or calendar scales is again crucial. Also missing from Gunter's full design, though optional for a basic time-telling instrument, are engraved arcs for the ecliptic (labelled by the zodiac signs), an arc representing the horizon, and a set of arcs giving the sun's azimuth. Another puzzle is the figure '8' which is engraved at the cusp of the lines representing 3 hours before and after noon. This looks to be a simple mistake but the absence of labelling of any of the other lines is difficult to understand.

The radii of the equator and tropics arcs of the Gunter projection are related by the same simple equation used for an astrolabe plate:

$$R_{Eq} = R_{Trop} \tan[(90 - \varepsilon) / 2]$$

where ε is the obliquity of the ecliptic. Note that the latitude does not appear. If an obliquity of 23.5° is assumed (although a value of 24° is not uncommon in manuscripts of this period) then the radius of the equatorial arc on the Norfolk quadrant is too large by about 2.2 mm.

Discussion

Whatever the problems and questions relating to the Norfolk quadrant, it is undoubtedly an intriguing find. It seems to represent a hybrid device and shows that the maker was interested in both equal and unequal hours and knew enough mathematical astronomy to produce an advanced instrument. It is possible that the device was only an experimental design, or that it was left unfinished for some reason.

With the potential importance of the quadrant and its relatively unknown provenance, the possibilities for its manufacture need to be considered carefully. The range of cases include:

- An outright modern 'fake'. Since the finder and the location are well attested, this option can be virtually ruled out. The lack of significant monetary value also makes it unlikely.
- A 17th- or 18th-century device for which its maker has adopted medieval numbering for some unknown reason. This seems unlikely.
- A medieval *quadrans vetus* which has later (in the 17th century or later) been brought up to date to indicate equal hours, using Gunter's scheme, by someone living in the Norfolk area. This cannot be ruled out. There is a precedent for a similar updating in the previously-mentioned 'physician's quadrant' at Merton College Oxford where the unequal hour lines have been partially erased and replaced by similar ones for equal hours.¹⁰ In that case, though, the new lines are of the type found on quadrants from the late-medieval period, such as that made for Richard II in 1399.¹¹ The fact that only medieval items or earlier were found in the locality where the quadrant was excavated points to it not being a later adaption.

A study of the engraving under an optical microscope shows that the lines of the degree scale and the equal hours have a similar appearance and hence may have been engraved at the same time. The unequal hour lines, by contrast, are engraved significantly less deeply and appear to underlie the equatorial arc. Whether it was engraved minutes, years or centuries earlier cannot be judged.

If the whole instrument was indeed engraved in the medieval period, it might be wondered why such a sophisticated device should be made for and found in rural East Anglia. In fact, the city of Norwich was second in importance only to London in medieval England and its cathedral was one of the very first to have a clock: it was already being repaired by 1291. Over the period 1322-5, a new astronomical clock of considerable complexity was built at great expense (£52 9s 6d), with the clockmaker Master Roger of Stoke (who also worked with Richard of Wallingford on the celebrated St Albans astronomical clock) being involved.^{12,13} Although the Norwich clock is now lost (probably by a 17th-century fire) its dial is likely to have included stereographic projections of the heavens such as those found on other astronomical clocks still extant (e.g. of the type still to be found in Prague, rather than the later and simpler type at Hampton Court Palace). Thus it is not inconceivable that the Norfolk quadrant had some connection with the Cathedral clock or its makers. Note that the projection point for the stereographic projection of an astronomical clock dial is normally the north celestial pole whereas that for an astrolabe is the south pole: both are combined in the Gunter quadrant.

If an accurate date for the instrument could be established it would be very useful in fitting it into the general time-line of quadrant development. Unfortunately, this has not so far proved possible. Initial metallographic analysis by Dr Brian Gilmour of the Materials Science-Based Archaeology Group at the University of Oxford show that it is composed

of a quaternary alloy (copper plus zinc, lead and tin). They suggest, mainly on the basis of the zinc concentration, that the device is probably from the 14th or 15th centuries, just possibly from the early 16th. The alloy is assessed as being “of reasonable quality, not the metal high in arsenic, antimony, and lead which was used for domestic wares of basic quality”.¹⁴

Optical microscopy also shows (Fig. 6) a network of very fine cracks on both sides of the device, some aligned along the engraved lines for short distances. These are stress/corrosion cracks, sometimes called ‘season cracking’¹⁵ resulting from attack by ammonia generated by decaying organic matter interacting with copper grain boundaries in the cold worked (i.e. hammered) brass plate.



Fig. 6. Optical micrograph showing a very fine stress corrosion crack which partially follows an engraved line.

Another early quadrant design which makes use of stereographic projections is the *quadrans novus* (new quadrant) usually attributed to Prophatius (1236-1304) and sometimes described as the astrolabic quadrant as it is effectively a simplified astrolabe folded twice. Many early texts describing the design are known but only eight actual medieval instruments are extant, one of which was excavated in Canterbury in 2005 and sold at auction for a considerable sum¹⁶⁻¹⁸ – it is now in the British Museum. Being based on an astrolabe but without moving parts (other than the plumb-bob), the *quadrans novus* was a very flexible and capable instrument though its many scales made it difficult to use. For basic time-telling, the Gunter’s quadrant was significantly simpler which accounted for its widespread and long-lasting use in the 17th and 18th centuries.

The Gunter quadrant was not the first design to use a scale with the outer radius representing the tropics of both Capricorn and Cancer. The *Horarium Bilimbatum* (double-scaled quadrant) used straight lines to indicate the equal hours. An example can just be seen in Hans Holbein’s famous painting *The Ambassadors*¹⁹ of 1533. This design may be attributed to the first edition (1512) of Stoeffler’s *Elucidatio*;²⁰

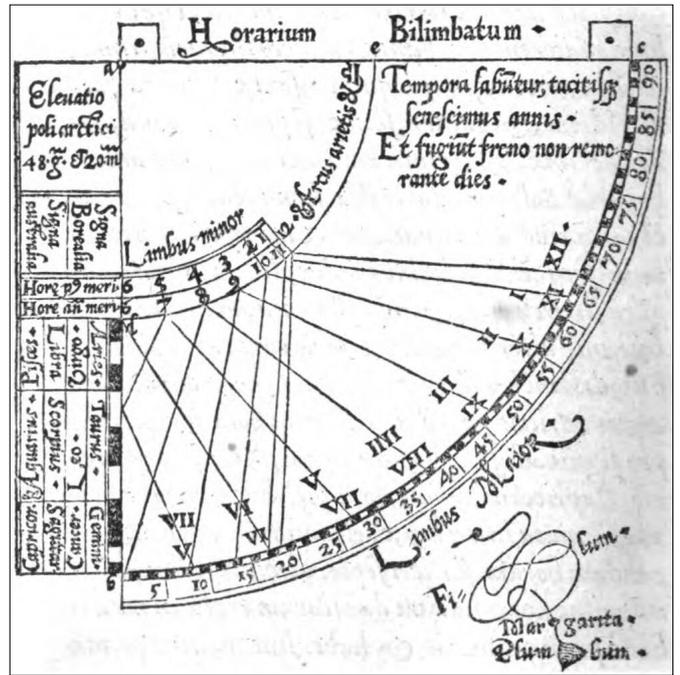


Fig. 7. The horarium bilimbatum, as shown by Stoeffler.²⁰

the version in Fig. 7 is reprinted from the 1564 edition. It is not immediately apparent that the straight lines can give an exact solution for the equal hours at all dates but the proof has been given by Alessandro Gunella.²¹ Note that the non-linearity of the date scale required for this design is not the same as that for Gunter’s quadrant.

It now seems clear that Gunter had a wealth of historical designs on which to draw when developing ‘his’ quadrant. He undoubtedly expanded the basic features of the underlying projections to produce a convenient and comprehensive instrument but he did not invent the basic form. Whether the ‘Norfolk quadrant’ was a one-off experiment or a rare survivor of a more common design which has not survived remains to be determined.

ACKNOWLEDGEMENTS

I am extremely grateful to Graeme Simmonds (Norwich Detectors Club) for allowing me to study the quadrant in detail. Peter Northover and Brian Gilmour (BegBroke Nano, Oxford Materials) kindly performed the microscopy and the metallurgical analysis and interpretation; Silke Ackermann (British Museum) offered much help and encouragement. I am also grateful for help and contributions from Glenn Grieco, Erica Darch (Portable Antiquities Scheme, Norfolk), Peter Baxandall, James E. Morrison and Mike Cowham.

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4. S. Ackermann & J. Cherry, ‘Richard II, John Holland and Three Medieval Quadrants’, *Annals of Science*, 56 (1999), pp. 3-23. The Richard II quadrant is also illustrated in F.A.B. Ward: *A catalogue of European Scientific Instruments in the Dept of Medieval and Later Antiquities of the British Museum*,

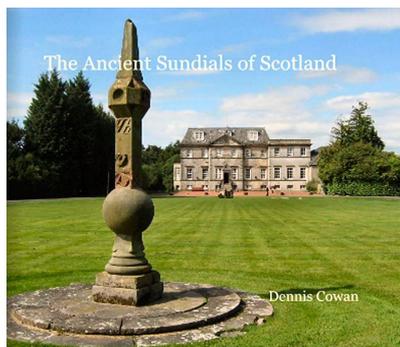
- British Museum Publications*, London, (1981), Plate XVIII, item 146.
5. D.A. King: 'A vetustissimus Arabic treatise on the Quadrans Vetus', *J. Hist. Astron.* **33**, 237-255 (2002).
 6. J.E. Morrison: *The Astrolabe*, Janus, Rehoboth Beach (2007). The formulae for the unequal hour quadrant are given on pp. 213-220 with the latitude-dependence of the deviations from true circularity being on p. 220.
 7. An illustrated manuscript c. 1450 (a French translation of Henry Suso's *Horologium Sapientiae*, now in the Bibliothèque Royale de Belgique, MS. Bruxelles, B.R.IV, f. 13v) shows a number of instruments including a one-handed clock with a 24-hour dial, a quadrant for unequal hours, a shepherd's dial (*chilindre*) calibrated in Italian and Babylonian hours, and portable sundials with polar-pointing gnomons.
 8. The Whipple 'navicula' is inv. No. 731 and is illustrated in C. Eagleton: *Monks, Manuscripts and Sundials: the Navicula in medieval England*, Brill Academic Publishers (2010), p. 134.
 9. Thomas Fale: *Horologiographia – the Art of Dialling*, London (1593).
 10. Gunter, *op. cit.*, (ref 3).
 11. Ackermann & Cherry, *op. cit.*, (ref 4).
 12. I. Atherton, E. Fernie, C. Harper-Bill & H. Smith: *Norwich Cathedral: Church, City and Diocese, 1096-1996*, Hambledon Continuum, see pp. 441-2 (1996).
 13. J. North: *God's Clockmaker – Richard of Wallingford and the invention of time*, Hambledon & London (2005).
 14. XRF (x-ray fluorescence) analysis of two uncleaned surface regions (back and front) were averaged to give a composition (in wt %) of: 71% Cu, 11% Zn, 8.5% Sn, 6% Pb, 1.85% Fe, 0.9% As, 0.3% Sb, 0.15% Ni, 0.1% Ag. Dr Northover comments "The effect of corrosion is rather difficult to estimate. Probably tin and lead are enhanced, arsenic and zinc are depleted, and it is a little difficult to guess for nickel and antimony. The alloy is a perfectly reasonable one for the period. I would be happy to see this alloy as being either 14th or 15th century; earlier the zinc would likely be lower and later the zinc would be higher and the tin probably lower."
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BOOK REVIEW

The Ancient Sundials of Scotland by Dennis Cowan

Self published (2011) 255 × 205 mm, pp. 120. Only available via <http://www.blurb.com/bookstore/detail/2082240> at £34 softcover, slightly more hardcover.

This is a beautiful picture book – with little text – illustrating Dennis's wanderings across Scotland in the footsteps of Thomas Ross who published in 1890 and Andrew Somerville who published in 1990. The result is a stunning set of photos covering some 56 dials, shown in both setting and detail, many in private hands or otherwise lost. Scotland's Enlightenment followed a different path to that of England. While intellectual thought, art and science in the latter looked largely south, Scotland looked to the Calvinist world and in particular to the Netherlands. This resulted in a Scottish flowering of 17th & 18th century dials celebrating technological craft and artistic understanding, that is in part unique and in part unfamiliar to the rest of Britain. The book is divided into sections covering Obelisk, Lectern, Multi-faceted, Mercat Cross and Globe Dials – together with the more familiar Church and House Dials. Anyone who has an interest in the history of dialling, or



For a larger version of the picture on the front cover, see the Photo Competition entry 'Lawn Ranger' on p. 9 of this issue. Above is the introductory page to the Multi-faceted dial section.

who has not had the luxury of seeing some of Scotland's finest, should seriously consider acquiring this book.

It is hoped that Dennis will continue his wanderings and prepare Volume II. I now hope for a BSS Sundial Safari north of the Border...

Kevin Karney

BSS PHOTOGRAPHIC COMPETITION 2010-11

Part 2 - The Conference Vote

IAN R BUTSON

As in the 2008-9 Photo Competition, delegates at the Wyboston Lakes Conference were once again given the opportunity to consider the photographs (before the official judging results were announced) and vote to indicate their favoured choices for first, second and third places in the competition. Three points were allocated for the first choice, two for the second and one point for the third choice votes. The entry receiving the most points would then be declared the winner of the Conference Vote. Ballot papers had previously been prepared, a ballot box provided and all those attending the conference were encouraged to make their choices and enter their votes.

27 voting forms were submitted with votes being cast for 21 of the 29 photos on display, with the following results:

First	(25 pts)	<i>'Sail into the sun'</i>	(Dennis Cowan)
Second	(24 pts)	<i>'It's not fair, he always gets more sun'</i>	(Dariusz Oczki)
Third	(17 pts)	<i>'Christmas Time'</i>	(Jackie Jones)

The scores given to the other 18 photos ranged from 10 points down to 1 point. The second and third placed photos appeared in the June *Bulletin*.

As in the main part of the competition, where a number of surprises occurred in the results; the Conference Vote also produced its own surprises, with the winner not having been placed in the main contest at all! Dennis Cowan's winning entry, "Sail into the sun" received 25 points, only just beating Dariusz Oczki's "It's not fair, he always gets more sun" (highly placed in the main competition) into second place, by 1 point.

Like the Conference Vote for 2008-9, quite a different set of results were produced from those as seen by the judges in the main section of the contest. But how interesting to see the difference in which the photographs were viewed by the delegates.

As Dennis Cowan was unable to attend the conference on Sunday morning when the results were announced, the winner's certificate was forwarded to him by post. Congratulations to all those who achieved winning results in this separate part of the photographic competition.



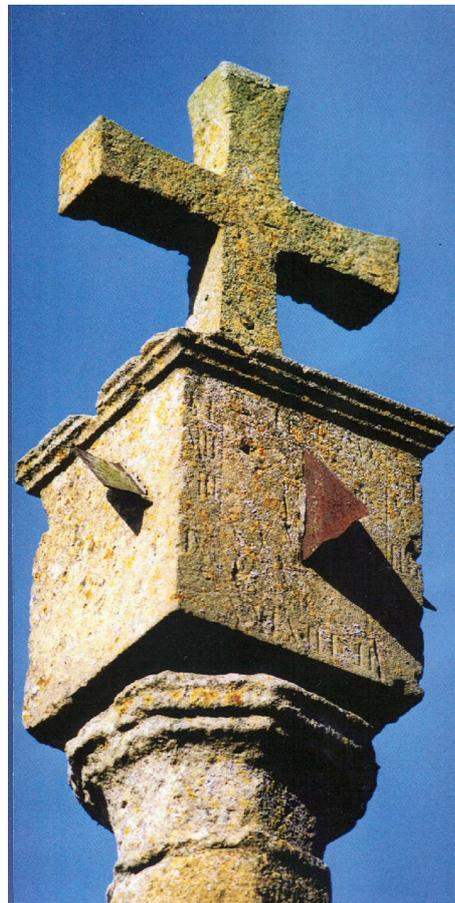
Conference Vote Winner

Sail Into the Sun

Dennis Cowan



Conference Vote—Fourth
Experimentum Crucis
 John Davis



Conference Vote—Fifth Equal
Blue Skies
 Tony Wood



Conference Vote—Fifth Equal
The Lawn Ranger
 Dennis Cowan



Editor's Choice
Autumn Time
 Irene Brightmer

Editor's Choice
Hebridean Time—
Always Slow!
 Andrew McVean



THE SUNDIAL GOES TO WAR

Part 2

MALCOLM BARNFIELD

Continued from *Bulletin* 23(ii), p. 20.

The Mearan-Kielhorn Director

The United States Navy, operating in the Pacific Ocean and other areas against the Japanese and Germans, used the Mearan-Kielhorn Director¹⁹ (Fig. 9), their lifeboats being equipped with them. The instrument is based on the Sapha universal astrolabe and is a horizontal stereographic projection for a given latitude, there being a set of plastic cards for many latitudes supplied in the instrument's bakelite case. In operation, the instrument worked very much like a sextant. It was suspended vertically and an altitude measurement of the sun or a star was taken through the sights. The sights had various filters to allow observation of the sun directly. Unlike the sextant, the image obtained was not lowered to the horizon, instead the instrument was then laid flat and the relevant information extracted. Results depended largely on the skill and training of the operator and LAT, true north, sun's declination and right ascension, sun's maximum altitude, time of sunrise and sunset and so on could all be found. The US Merchant Marine used this lifesaving device well into the 1970s. The Mearan-Kielhorn Director has been shown recently in the *NASS Compendium*.²⁰

The Howard Sun Compass

Yet another instrument is the hand-held Howard Solar Compass^{2,9} as used by British Forces until at least 1991 (Fig. 10). I have read a brief on-line article² about the How-



J. Davis

Fig. 10. The hand-held Howard Sun Compass: note the handle.

ard Compass, the instrument being stamped '91' which is presumably the date. Not much more could be discovered about it except that it had been in use by British forces well before WWII. It also used two styluses similar to the Cole Mk 2 & 3 and Bagnold compasses for night-time navigation by the stars.

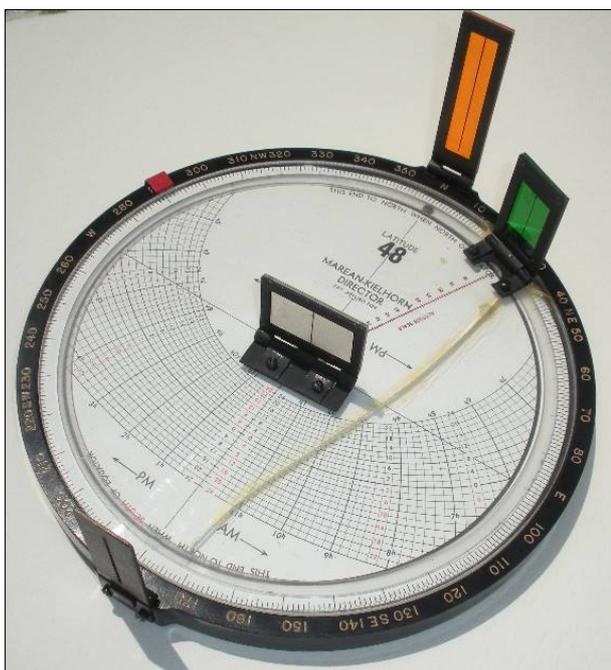


Fig. 9 (left and above). The Mearan Kielhorn Director. The picture on the right shows the handle on the back and the instructions Photos by Ed Popko.

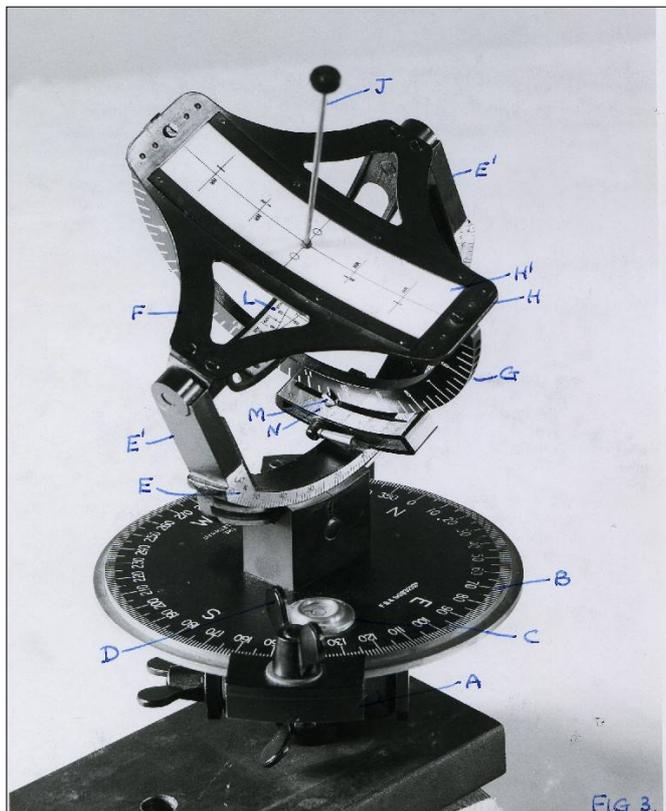


Fig. 11. The Micklethwait Sun Compass. Courtesy of the Tank Museum, Bovington, Dorset, England.

Other Solar Compasses

Two other solar compasses are mentioned by BSS Chairman, Christopher Daniel, in his 'Clocks Magazine' articles.^{21,22} These are the Evans-Lombe and Richards Sun Compasses. The Evans-Lombe Sun Compass was a rather flimsy device consisting of two printed plastic cards which rotated concentrically around each other. A set of 13 cards for different latitudes and dates was provided. It was used by the British Army. However, it seems that by 1940 it had been superseded by the metal Cole pattern sun compass.



Fig 12. The C Plath of Hamburg Sun Compass. Photo by Konrad Knirim.²⁹

Nothing further could be learned of the Richards Sun Compass except that it was presented at the Royal Geographical Society in 1941. The Richards instrument would seem to have been a completely independent development since he appeared to have been unaware of similar instruments already in use. So, perhaps it was only a discussion design. No surviving instrument could be found.

Even after extensive enquiries with the successors to the Admiralty Compass Observatory, the equally obscure Micklethwait instrument which Hickman⁵ mentions was not located. The instrument, pictured in Fig. 11, was complex to understand, use and set up but was equally usable in both hemispheres. Latitude, longitude and LAT all had to be known to use it and it was definitely not 'soldier proof'. In the only paper on it that I found,²³ Micklethwait himself seems more concerned with BST, GMT and LAT than with direction even though he states that the base of the compass is that of a standard Cole Sun Compass. From this it is easy to see why the instrument never gained vogue and soon slid into obscurity. It was made by the company F B & S Ltd. in 1932.

Navigation using compressed gnomonic projection maps and radio signalling to two fixed base stations at known locations and which possessed direction-finding antennae had been available before the 1920s but this method was unsuitable for the desert war.²⁴ Portable radio technology then was unreliable and of limited range at best, plus, with the ever-changing fortunes of war and locations in that battlefield, this meant that the possible availability of fixed base station signals within the range of radios were always changing. Security was another concern. The constant broadcasting from a 'callsign', looking for a confirmed global position, could easily have compromised the sender's position. It was not only the Allies who had 'ears'. Thus this method of navigation was never used by Allied forces in the North African WW II desert campaign.

German Sun Compasses

A German version of the solar compass is the device made by 'C. Plath of Hamburg' and shown in Fig. 12. This was used by Rommel's Afrika Korps in the Western Desert



Fig. 13. The Plath Compass in use calibrating compasses in a Heinkel 111 bomber plane. North Africa, early 1940s. After Konrad Knirim.

campaign from beginning to end. The instrument had its roots in polar exploration and had a clockwork-driven 24-hour clock that showed solar azimuth by the hour. The clock's movement was the 8-day Junghans cal J30D or E model. Otherwise it was a standard sun compass of the type with an adjustable bearing table that lay in the horizontal plane. The clock was set to LAT and true north was established along the vehicle's lubber line using the calculation of 4 minutes of time per degree of azimuth change or 15° per hour. Thus it could also be used at night since grid/magnetic variation could be established. The instrument was also used to calibrate the magnetic and gyrocompasses of planes during ground service periods. At high rates of acceleration and during violent turning both the magnetic and gyrocompass become unstable so the use of the sun compass allowed recalibration for both instruments. Fig 13 shows it in use on a Heinkel 111 bomber plane.²⁵ Later it was used to service the compasses of the Messerschmitt Me 262 aeroplane, the first operational twin jet fighter of WWII.

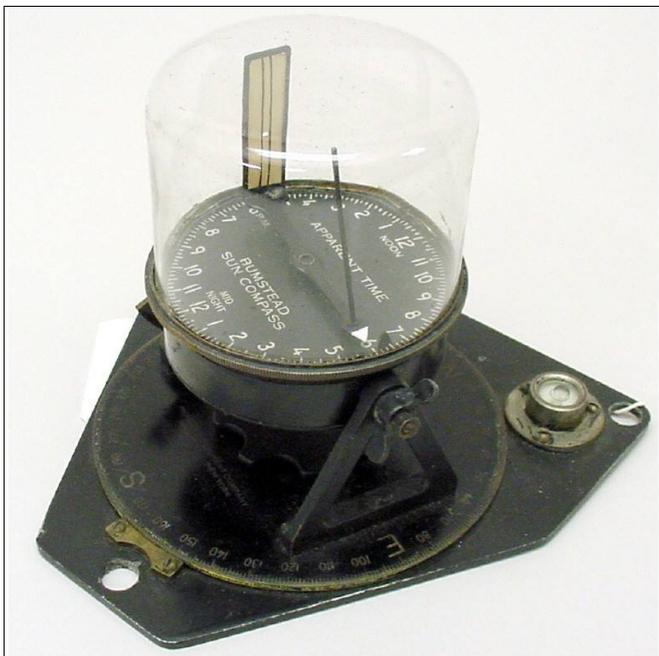


Fig. 14. The Bumstead Sun Compass. Photo courtesy of the Smithsonian Institute.

The original instrument of this type was developed by Albert Bumstead in the early 1920s. He was then Chief Cartographer at the National Geographic Society in the USA. It was designed specifically for use by Lt Commander (later Admiral) Byrd for his attempt to be the first man to fly across the North Pole. It was made by the Pioneer Instrument Company of New York, U.S.A., whilst the development and prototype came out of Bumstead's home workshop. Using the Bumstead compass, Byrd achieved his goal on May 9, 1926. See Fig. 14. This came at about the same time as the parallel and similar development of the Bumstead-type compass from the German company C.P. Goerz of Berlin. Again, great minds came up with the same solution at the same time. The Goerz Company were later part



Fig. 15. Capt J.M. Boykow and his Goerz Sun Compass. Photo from the private collection of Oliver Trulei.

of the Zeiss Ikon A-G optical conglomerate and had a branch in the USA. Surprisingly, their Austrian branch in Vienna supplied the RAF with gun sights even after the German Anschluss ('joining' in English) occupation of Austria in 1938,²⁶ more than 700 of the RAF's Hurricane fighter planes being equipped with them. The Goerz sun compass was made for Roald Amundsen's simultaneous dirigible attempt at Byrd's goal. Amundsen is better known for beating Capt. R.F. Scott to the South Pole in December 1911. Whether either of them used any solar compass during those expeditions is not known. Scott is known to have used the sextant and a theodolite and Amundsen the sextant.

The Goerz instrument was the brainchild of Capt J.M. Boykow (Fig. 15), a member of the Goerz technical design team.²⁷ For a constant course and through a periscope, it projected a reflected image of the sun onto a frosted glass screen with a target line. LAT being known and using the 4 minutes per degree calculation, true north was then established and the 24-hour clockwork mechanism started. That drove the mean sun's image across the screen from east to west at a constant speed equal to 15° of arc per hour. Adjustments for the ever-changing solar altitude were possible but unnecessary near the poles since solar altitude is virtually constant at such places. The chosen heading was then selected from a 360° calibrated and adjustable ring and followed. The pilot had only to keep the mean sun on the target line to maintain the required heading, adjusting his bearing as often as possible to minimize the slightly zigzag path that all navigation by sun compass can deliver. A deviation from that heading was just as easily accomplished as was returning to the original bearing simply by following the chosen bearing and keeping the sun's image focused on the screen's target line.

Byrd went on to be the first to fly across the South Pole in 1929, again using the Bumstead compass. He navigated the flight himself and would have had to contend with some unique polar navigational problems. For instance, you can



J. Davis

Fig. 16. The Astro Compass Mk. II.

only face north from the South Pole or south from the North Pole. There is no longitude at those places; the measurement is always zero because all meridian lines converge on one spot. Solar altitude is constant throughout all sunlit times and the maximum solar altitude at the relevant summer solstice is only 23.44° above the horizon and the sun is only visible above the horizon for six months of the year. Thus, whilst solar azimuth is constantly changing no indication of local solar noon can be obtained from observation instruments like the sextant, theodolite or astrolabe and till this day all Antarctic base stations use GMT as their time zone, there being no point in using any other. The brilliance of Bumstead in employing the 24-hour clock in his instrument overcame these problems so direction on a chosen bearing could be maintained. In peacetime and post-WWII, polar exploration resumed and once again various formats of the solar compass were pressed into service, the magnetic compass being of little use at such latitudes.

The Astrocompass

The astrocompass (Fig. 16)^{9,28} had been in British military use for many years before the war and by early 1940 RAF heavy bombers were equipped with British, American and Canadian versions of them. All seem to have come from a single British design by P.F. Everitt and all were called Mk II. The basic design came from his earlier Mk IX sextant and initial production was by Henry Hughes & Son of England. There were many other makers: Horstmann in the

UK; W.W. Boes Co. and Sperti, Inc. in the USA; and Dep & Co. in Canada. Later versions incorporated features from captured German instruments. This instrument is related to the solar altitude compass in many ways, delivering LAT, Local Sidereal Time at night, latitude, longitude, right ascensions and declinations of both sun and stars, true north and so on, in both hemispheres. It made extensive use of astronomical almanac tables to obtain the required direction after observation of the sun or a star through its sights. It had a weakness when using solar observation near the equator. Here, at certain times of day and year, solar azimuth is virtually impossible to measure since the sun is very high in the sky from early in the day until late afternoon. However it was generally employed in the higher latitudes with plane ferry flights to England from the USA, and in Europe, China and Japan plus the surrounding islands. Lloyd Owen¹⁴ mentions the same problem with the Bagnold compass. This latitude anomaly was the exact opposite of its Observatory Solar Compass 'cousin'. One huge advantage it held over the humble azimuth solar compass was that it could be used at night, far more accurately than by using Polaris, which is over 2° off true north anyway. Its use in the bombers, where there was a dedicated navigator, obviated the need for the Bumstead/Plath type compass and the single seater fighter planes that escorted the Allied bombers used the direction gyro and magnetic compass. The German Luftwaffe used a bubble octant in the bombers and the gyrocompass with the magnetic compass in the fighters.²⁹ After WWII it continued in use in the early trans-Atlantic flights made by USA-based commercial airlines and with many air forces worldwide.

Except in the cases of the Bumstead/Plath type compasses, it may be thought that every instrument mentioned above had a fatal flaw: the visibility of the sun or a known star. This was not a problem in the desert but even on the most clouded days at higher latitudes there is always a break in the cloud at some time, however momentary, and a skilled flying navigator could identify a star quickly using his star finder³⁰ and tables of right ascension and declination³⁰ or get a brief visual sighting directly on the sun. Fixed and known ground features were also used for orientation by both the ground navigator and flier, dead reckoning too, so he always knew his approximate position and heading and thus was able to know in advance what he should see when a cloud break appeared. It was his job to bring the ship, plane or battle group onto the target and then the final assault was visual anyway.

A seemingly glaring point missing from all the literature about solar compasses is that if true north had been established with the solar compass then the grid to magnetic variation at that place could easily have been established too, and so navigation by magnetic compass became possible. Many factors militated against this in the desert war. The steel bodies of the vehicles and its magneto or generator could well have caused magnetic compass inaccuracies as could ground minerals; the vehicles had no reliable

odometer for distance measurement and there were no maps to work from anyway. There were no known fixed points to work with and the method of sending out a lone vehicle on a given bearing and then taking another bearing on the forward vehicle from the command vehicle at the point of origin left that forward vehicle and crew vulnerable to ground ambush and air attack. More importantly, even a small error in compass reading at the outset would soon translate into a huge inaccuracy after a 100-mile drive. Plus, all of this was very time consuming. The problems went on and on so the method, whilst known, was seldom used and was not the first choice of the LRDG and most others.

No evidence of WWII Japanese or Russian military use of the solar compass could be found. This is surprising, especially in the case of Russia. Their army operated at very high latitudes against the Finns and magnetic compasses would have been unreliable there.³¹

German troops in North Africa were issued with a cardboard cutout horizontal sundial that was calibrated for the various latitudes in which they operated. Fig. 17 is the dial for the latitude of 31° north.²⁷ Most wristwatches then were not waterproofed and so the fine dust of the desert sands literally brought them to a grinding halt. The sundial remedied the problem to some extent since accuracy was only claimed to within 15 minutes.

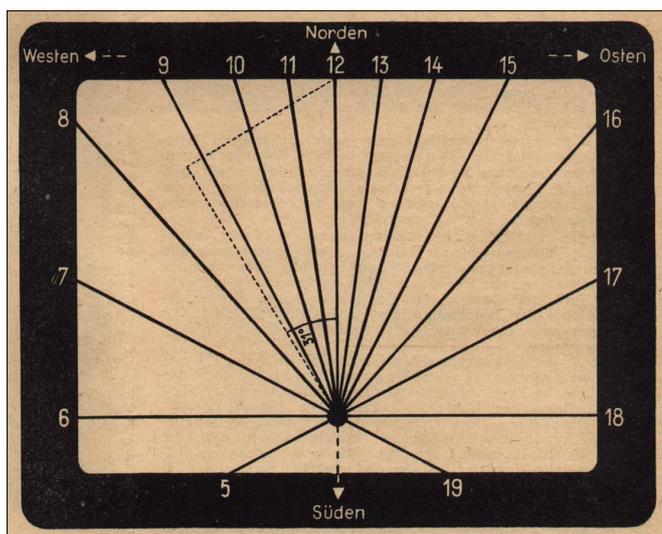


Fig 17. Cardboard cut-out horizontal sundial issued to German troops in North Africa during WWII. After Konrad Knirim.

The Italian Army's Auto-Saharan Company, a unit similar to the LRDG, had been operational deep in the Libyan Desert for many years before and during WWII but how they navigated remains unknown. It is known that they had their own spotter planes so perhaps the navigational information came from the air wing. The Italian military made unsuccessful attempts to adapt the Kaufman Solar Compass¹¹ for desert use during 1942.³² The failure of the project would appear to have been because the war theatre rapidly overtook the latitudes for which their version was designed (28° to 36° north). How they got the Kaufman design remains a mystery since the design was already being used by Abrams

for the US military and the USA and Italy were at war from 11 December, 1941. In any event, other partners in the Axis and Allied alliances had the solar compass technology had it been called for.

A final reference to the sundial at war again comes from Finsen's journal.¹⁵ Here he mentions the Observatory Sun Compass for use in artillery barrage gun laying. Whilst the method was investigated at the time, it seems unlikely that it was ever used in combat since as he says, the war ended.

Current Developments

Now, in the age of GPS, radar, laser and AWACS, the solar compass would seem to have run its course and become redundant but somehow I doubt that. Illustrating this is the fact that after WWII and when military surplus stores began operating, the astrocompass was snapped up by amateur stargazers, its capabilities making their learning of the night skies easy. The army prismatic marching compass became a favourite of campers and hikers. The Evans-Lombe compass was used for teaching purposes in the Boy Scout movement well into the 1970s. Furthermore, collectors and museums began assembling their treasures. Interest from sundialists continued and historians joined the quest as many published articles show. Today these instruments regularly appear for sale on and are prized items on auction web sites like eBay. The company of C Plath, now part of the Sperry Marine Northrop Grumman Group in the USA, still make a Pelorus, a basic sighted inshore navigation instrument used to maintain course on a chosen heading. The instrument easily and quickly converts to a sun compass with the installation of the central and vertical stylus provided. In addition, several clever adaptations of the sun compass principles given above are commercially available for the gardener, photographer, pilot, house buyer, tree surgeon, greenhouseman and hiker. Other sun compasses appear on the folding bezels of wristwatches and on Swiss army knives plus even cell phones. Thus the solar compass lives on and long may it continue so.

Apologies are given to every soldier for the phrase 'soldier proof' but as an ex-soldier I know how it goes in idle moments and battle has scant regard for equipment.

ACKNOWLEDGEMENTS

I sincerely thank all of those below whose keen, willing and expert input made this article possible. The list reads like a United Nations register and clearly illustrates the co-operative nature of diallists, scientists and historians worldwide.

Richard Hendrie, curator, South African National Military History Museum (South Africa); Prof Tony Voorvelt, Univ of the Witwatersrand (South Africa); François Blateyron, diallist (France); Denis Savoie, diallist (France); Dave Curry, military historian (Australia); Malcolm Kriel military historian (South Africa); Dr Ed Popko, solar instrument collector (USA); James E. Morrison, author of 'The Astrolabe' (USA); John Davis, BSS editor (England); Mike Cowham, diallist (England); Bill Gottesman, diallist (USA); Martin Garnett historian, Imperial War Museum (England); Klaus Eichholz, diallist (Germany); Walter Hofmann, diallist (Austria); Alaksandr Boldyrev, diallist (Russia); Fred Sawyer, diallist (USA); Michael Maltin, diallist (England); Oliver Trulei, historian (Austria); Johan Wikander, diallist (Norway);

Konrad Knirim, military historian (Germany); Giovanni Bellina, diallist (Sicily).

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Malcolm Barnfield lives in S. Africa and was originally a self-taught southern hemisphere hobby diallist, now professional for 16 years. He makes all formats of sundials, stereographic instruments and noon cannons in media ranging from brass to copper, mild and stainless steel, resins, perspex and stone. His dialling is influenced by James E. Morrison, author of *The Astrolabe*, and John Davis of the BSS. He can be contacted at sundials@sundials.co.za.

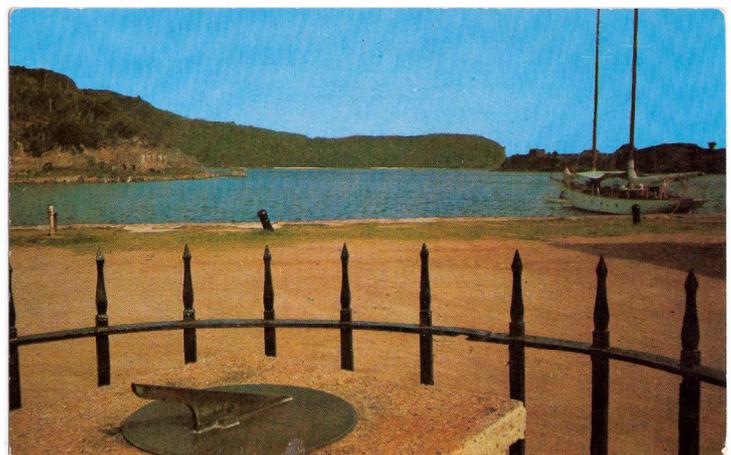


POSTCARD POTPOURRI 20 – English Harbour, Antigua Peter Ransom

The short article in the last *Bulletin* (23(ii), p.51, June 2011) by John Davis came as a surprise since I had just acquired a postcard of the said dial! A pity that one gets a better view of the railings than the dial, but it does afford another view of this low angle dial. The postcard is unused, so lacks any dating evidence and looks as if it was produced in the 1970s. It was published by Andrew Darby Ltd., St John's, Antigua.

For another low-latitude dial, see the article on p. 36.

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ANCIENT EGYPTIAN SUNDIALS

ALLAN MILLS

Ancient Egyptian dials were the subject of the Somerville Memorial Lecture given by Dr Sarah Symons in May 1998. This was subsequently published in the *Bulletin*.¹

Obelisks

Obelisks are widely thought of as likely gnomons for large horizontal sundials, but it was explained that this is mistaken. Not only is there a complete absence of any associated dials, but inscriptions on the obelisks themselves indicate a purely symbolic and commemorative function. Of course, this has not prevented later rulers from appropriating existing obelisks to form the gnomon of their own commemorative dials. Best-known is the 'Dial of Augustus', remnants of which remain buried in Rome.²

Staircase

Ludwig Borchardt, the doyen of scholars studying ancient Egyptian systems of timekeeping,³ mentioned an artefact in the Cairo Museum consisting of steps ascending to a central elevated platform.⁴ He thought it might have been used as a sundial, but most subsequent researchers appear to be agreed that it is more likely to be exactly what it resembles – an architect's model for a proposed temple.

Elimination of the above reduces ancient Egyptian dials to quite a small number of existing examples.

'Sloping' Sundials

Described by Symons and most writers on sundials is the 'sloping' or 'inclined plane' sundial. The type example is a stone object found in 1913/14 at Qantara, near the Suez

canal, and described by Clédat⁵. Further details were given by Sottas⁶ and Kuentz,⁷ and became the source of the drawings published by Borchardt³ (Fig.1). These have been widely copied because the artefact itself appears to have been lost, and no photographs are known. However, similar sloping dials (from which the shadow-casting blocks have been broken away) are in Paris and in the Flinders Collection at University College London⁸ (Fig.2).

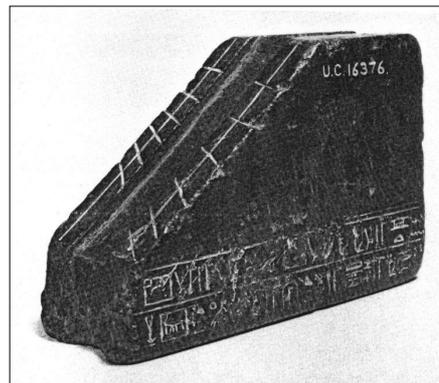


Fig. 2. Part of a 'sloping' sundial at University College London.

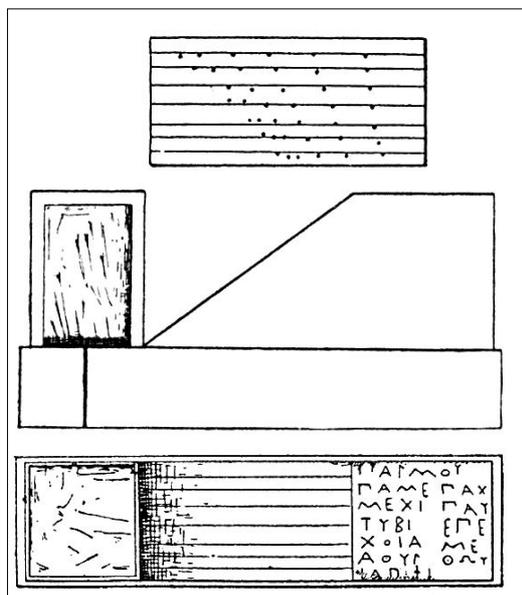


Fig. 1. The 'sloping' sundial found at Qantara. (Borchardt)

Figure 1 shows the drawings of the Qantara dial reproduced by Borchardt. Dated to Ptolemaic times (ca 380-310 BC) it was soon recognized to be a portable, seasonal-hour altitude dial, with the abbreviated Egyptian month names (showing which scale line must be read) written in Greek letters. Altitude dials need only to be pointed at the Sun,⁹ knowledge of the direction to north not being required. However, for reasonable accuracy they must be used around the latitude for which they were designed, and held level. Calibration may be in seasonal or equal hours.¹⁰ Construction of the Qantara dial (or at least its prototype) by direct observation would require some independent method of finding the seasonal hour, but at the late stage of Egyptian history with which it is associated Greek influence was strong, and a hemicyclium¹¹ or linear water clock¹² could have been employed.

Figure 3 shows a working model made to demonstrate the principle of this sundial. Some authors have suggested that the inclination of the dial plane to the horizontal was made equal to the latitude, and this was followed here by employing an angle of 30°. (Memphis is 30° N; Qantara about 31°.) However, there appears no great advantage in this; any shallow angle will serve to shorten the scale to manageable length. The dial pattern was calculated by standard methods¹⁰ for a latitude of 30° N, and a more detailed view is given in Fig. 4. A line weighted with a lead plummet is coincident with an inscribed mark when the instrument is held horizontally. (A plastic bead proved unsatisfactory,

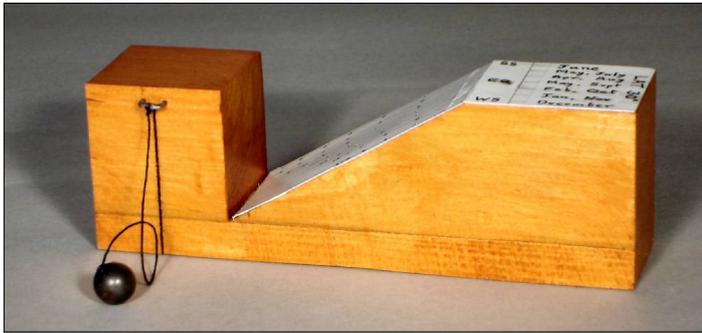
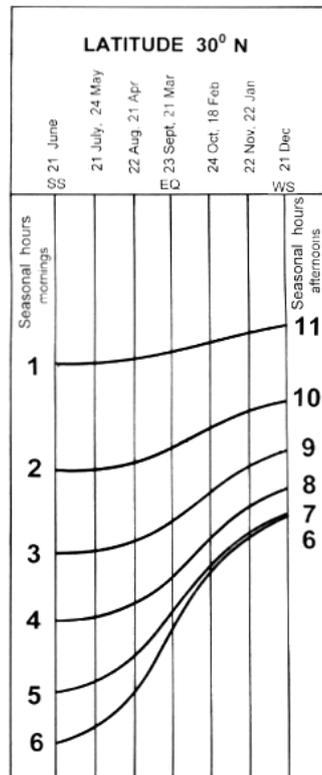


Fig. 3. Reconstruction of a 'sloping' sundial for 30° N.

Fig. 4. Pattern of a seasonal-hour dial at latitude 30° N inclined at 30°.



swinging in the slightest breeze or with the natural tremors of the hand.) The projecting plinth shown in some representations⁴ is confusing, for it prevents free motion of the plumb-line and infers the instrument is to be placed on a flat surface rather than held in the hand.

The method of use is shown in Fig. 5. The instrument is pointed at the Sun and adjusted so that the shadow thrown by the upper edge of the block exactly fills the width of the scale and is at right angles to it. The plumb bob must hang

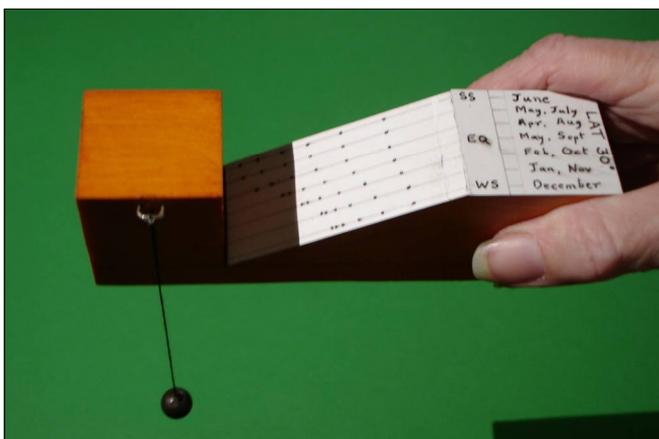


Fig. 5. Method of use of the portable 'sloping' sundial.

freely and vertically. The appropriate seasonal hour is then estimated from the appropriate date line. It is necessary to know the approximate date and whether it is morning or afternoon. It appears that during these periods it should be possible to determine the time of day to within a quarter of an hour or so.

The Shadow Stick

Over a thousand years older than the sloping dials are an enigmatic group of L-shaped devices from the New Kingdom. The oldest is illustrated in Fig. 6 and dates from the time of Tuthmosis III (1479-1425 BC). The damaged base is about 20 cm long and bears an inscription giving the King's name and epithets. On the upper surface are five marks increasing in spacing away from the block, the latter including a support for a plumb-line that suggests a hand-held application.

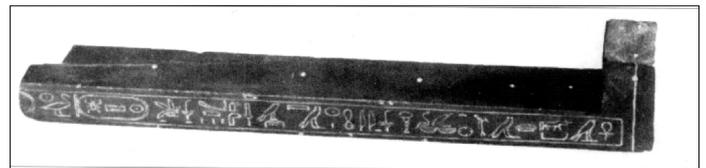


Fig. 6. Shadow stick of Tuthmosis III. (Berlin Aegyptisches Museum no. 19744.)

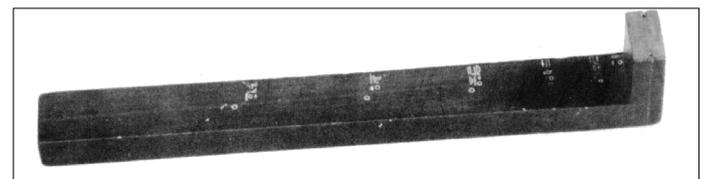


Fig. 7. A well-preserved ancient Egyptian shadow stick. (Berlin Aegyptisches Museum no. 19743)

Better preserved is the device shown in Fig. 7, which is about 500 years younger. It is made from two pieces of green slate held together with a mortise joint and presumably some adhesive such as resin. The base is about 30 cm long and again supports a terminal block with provision for a plumb-line. Circular marks occur at increasing distances from the block and it is tempting to infer that these shadow sticks were predecessors of the sloping seasonal-hour altitude dials discussed above. It would, of course, have been much easier to make 'ordinary' versions of these devices out of wood, but none have survived.

An L-shaped instrument is outlined in an inscription on stone slabs forming the ceiling of the Sarcophagus Chamber of the Osireion at Abydos, built by Seti I (1306-1290 BC). Reproduced here as Fig. 8, the characteristic outline bears five vertical marks along the base. The four spaces thereby delineated appear to be roughly equal, but ancient Egyptian draughtsmanship tended to ignore actual distances. Instead, we should look at the numerals indicated above the bar - namely 3,6,9 and 12 units with each measured from the *end* of the previous section. This is equivalent to 1,2,3 and 4 units, each of magnitude 3× of the first. Three problems remain:

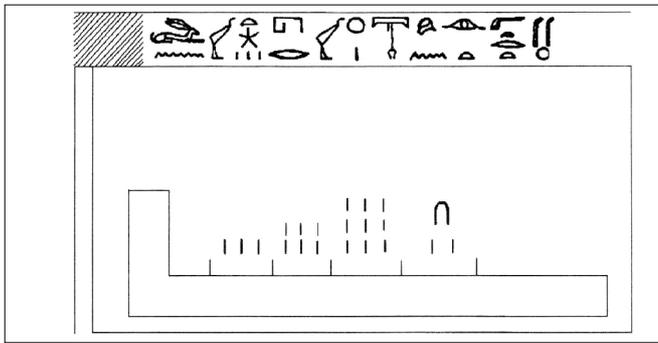


Fig. 8. Representation and explanation of the shadow stick on a ceiling at Abydos.

- Where is the beginning of the scale to be placed relative to the inner face of the block?
- What is the height of the upper (shadow-casting) edge of the block above the surface of the base?
- What unit of time is being measured, and where are the date lines?

The hieroglyphs above the outline are, we are told,¹ difficult to interpret, but do mention a recipe or *rule*, the integers 3, 6, 9 and 12, and the use of finger widths as units.

Borchardt was worried by the inaccuracies of the seasonal hours indicated by an L-shaped device when it was used as an altitude dial, and attempted to improve matters by postulating that:

- A long 'crossbar' was once attached to the top face of the block, perpendicular to the base.
- The complete device was to be placed on a level support, with the crossbar set north-south and the base east-west. (A clear illustration is given by Mayall and Mayall.⁴) The shadow of the crossbar would fall on the base, its position being controlled by both the altitude and azimuth of the Sun. This shadow would temporarily disappear at noon, which Borchardt believed was the signal for the complete instrument to be turned through 180°.

Timekeeping remained poor even with the variable height crossbar proposed by Bruins¹³, and most experts remained unhappy with the awkward scheme^{14,15}.

It seemed to me to be more reliable to go directly to the surviving artefacts.

Measurements on a particular photograph of the object shown in Fig. 6 gave a unit length of 8 mm, with the marks at 1,3,6,10 and 15 units from the inside face of the block. This results from a simple *rule*:

- Mark a line 1 unit from the base of the block
- Mark 2 units from this line, measured along the base
- Mark 3 units from this line, measured along the base
- Mark lines at 4 and 5 unit lengths, in the same way.

This easily remembered scheme facilitates use of the fingers as measuring units. The top, shadow-casting, edge of the block measures 2 units above the surface of the base. A reconstruction based on this scheme is shown in Fig. 9, and its method of use is proposed to be to point it at the Sun just like the altitude dial described above. See Fig. 10.



Fig. 9. Reconstruction of a shadow stick.



Fig. 10. Use of the reconstruction of a shadow stick.

However, there are still no date lines, and the marked intervals assumed to denote seasonal hours do not bear these exact ratios for any part of the day or year. The best fit for the 30° N seasonal-hour horizontal dial are the ratios 1 : 1.7 : 2.8 : 3.9 characterising the distances from the block for the 6th, 5/7th, 4/8th, and 3/9th hours of the days around the summer solstice.

Nowadays, we are conditioned to think in terms of constant intervals delineated by some form of carefully designed sundial or clock, but the many examples of scratch dials (or, better, *mass dials*) incised on south-facing walls of old churches in England and the Continent point to the success of a different method of denoting a 'happening'.¹⁶ They may therefore be termed *event markers*, and may be scratched by a parishioner on any convenient south-facing wall or fence to enable him to join spiritually with his local priest at one or more of the monastic hours of prayer; nominally sunrise, halfway through the morning (3rd hour), noon (6th hour), halfway through the afternoon (9th hour) and sunset (12th hour). To be readily constructed they must be available by following (even if not fully understanding) a set of simple *rules*:

- Hammer a nail perpendicularly into a vertical south-facing surface.
- Suspend another nail from it with a short string.
- Scratch the lower half of a circle below the first nail.
- Scratch a horizontal line through the centre of the circle.
- Scratch a vertical line through the centre of the circle. (The suspended nail acts as a plumb-line.)
- Divide each quarter circle into two equal arcs.
- Note when the shadow of a horizontal gnomon falls on a line.

A generalised result is sketched in Fig. 11; the forefinger or a thin stick would serve when the original gnomon was

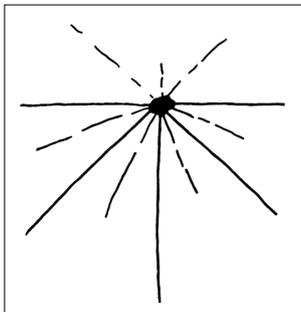


Fig. 11. Generalised sketch of a primitive form of mass dial.

Fig. 12. The well-preserved mass dial at Waltham, Kent. (BSS Mass Dial Group)



missing. Of course, the indicated times of prayer would not in general agree with clock time, and would vary through the year. But this did not matter – the main thing was that all participants in the area were united in spirit at the designated times of day. In due course the spread of the mechanical clock resulted in additional radii being scratched to (inadequately) indicate 12 hours, or even more in a full circle (Fig. 12).

Possible parallels with the ancient Egyptian shadow stick (this term would appear preferable to shadow clock) will be obvious, with the requirement of pointing the device at the Almighty Sun probably being theologically significant. Perhaps some Egyptologist will be able to identify points through the day when priests were expected to turn to give thanks to the Sun?

ACKNOWLEDGEMENTS

I wish to thank Sarah Symons for help and encouragement, and the Ägyptisches Museum und Papyrussammlung, Staatliche Museen zu Berlin, for permission to reproduce Figs. 6 & 7.

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ENGLISH MASS & SCRATCH DIALS c.1250 – c.1650:

Combining Statistical and Religious Evidence

CHRIS H.K. WILLIAMS

Statistical analysis and modelling has revealed the evolution of scratch dials.¹ Further elucidation, particularly their original—as opposed to surviving—appearance, calls for additional alternative lines of investigation. To progress further we must interpret statistical results within scratch dials' original contemporaneous religious and iconographic contexts. This article outlines powerful religious currents and change. Some readers may (initially) find this a little detached from direct, or immediate, dialling significance: but it is absolutely essential to any meaningful appreciation. The consideration of scratch dials has been artificially divorced from their religious roots for far too long. Subsequent articles will explore the iconographic contexts of differing dial types in more detail.

That mass dials and religion be associated can scarcely be considered a novel thought. Yet students have directed surprisingly little attention to the religious context of mass dials. Such consideration as there has been in the literature concentrates on the oldest mass dials – those of the 7th to 13th centuries. Its primary objective has been explaining hour lines in the context of monastic offices.² Important as this traditional focus might be, of England's 5,500 listed mass dials only a few hundred predate 1350.³ An extended and broader focus that includes religion in the 14th to 17th centuries is necessary to match the overwhelming bulk of surviving dials.

When juxtaposing the two streams of evidence, the statistical and the religious, one is immediately struck that each pivots around a common date (Fig. 1). A dramatic change in the appearance of mass dials, the ending of 360° dials, dated by statistical modelling to circa 1500, coincides with the onset of Reformation. The Reformation is one of his-

tory's great misnomers. It was not religious reform but revolution. That in turn begat total revolution – of politics, society, everything. Our closest historical analogue is 20th century Russia. As we shall see, there are seismic grounds for expecting the trauma of Reformation to have noticeably and visibly altered the appearance of dials.

But first, let us consider those aspects of medieval Catholicism that might have a bearing on the use and appearance of mass dials.⁴ Required church attendance embraced matins, mass and evensong on Sunday and feast days. Together these accounted for a quarter of the year. The remaining three quarters was not devotion free. Heaven's waiting room – Purgatory – where the souls of the deceased did time for their earthly sins, drove much devotional activity. Celebrating mass for the dead, and praying for them, was central to easing the pain and duration of purgatory. In a real sense there was a single community embracing both the living and the dead. The pantheon of saints played an intercessionary role, between God and supplicant, both in prayers for deceased souls and personal appeals for help or consolation. Veneration of saints afforded prayer a personal tailored expression of piety. Top of the list was Mary, but any one of hundreds might be appealed to. There were dedicated patron saints for anything and everything, from St Apollonia for toothache to St Zita for domestic servants.

Medieval clergy were a mixed bunch. The holder of a benefice often subcontracted his duties, but not his church income, to a lowly paid priest. Often these were from the labouring classes, with limited education, able to recite rather than *au fait* with Latin, and unburdened with sermons – a later invention. They could not afford to be full time, needing to work to support themselves. Masses for

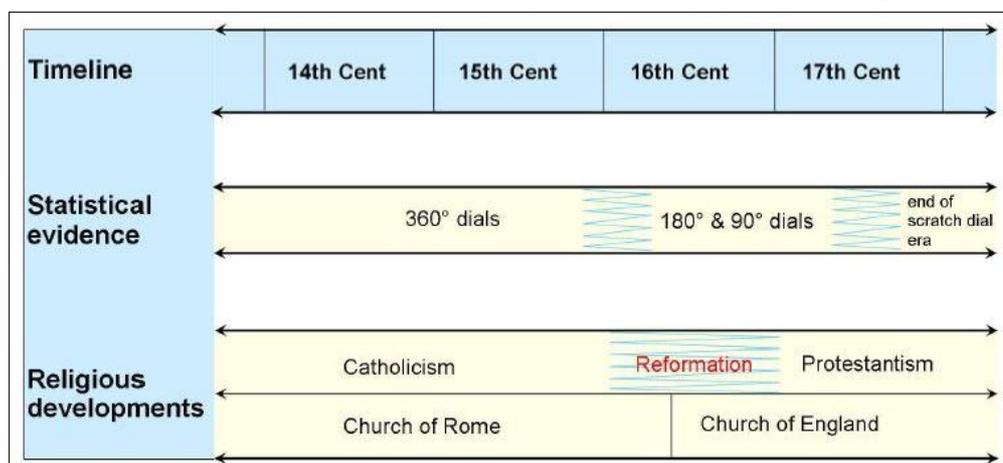


Fig. 1. The statistical and religious contexts of scratch dials. Note: The 360°, 180°, & 90° dial categorisation is illustrated and discussed in Chris H.K. Williams: 'The Evolution of English Mass & Scratch Dials c.1250 – c.1650: Part 1. Dial Categorisation', *Bull. BSS*, 22(iii), 24-26, (2010).



Fig. 2. 15th century Judgement scenes above the rood screen. (left) St. Peter's Church, Wenham, Suffolk. Photo: Anne Marshall; (right) Holy Trinity Church, Coventry, Warwickshire. Photo: Rob Orland.

(1) Note where the crucifixion statues once stood in front of the Wenham painting. The Coventry painting, in a larger church, was above the statues.

(2) These two examples are indicative of the colour and vibrancy that covered the entirety of all the walls in medieval churches.

the dead were funded by individual mortuary benefactions and guilds for their erstwhile members. Chantry and guild priests were non-beneficed, independently financed, and self-employed. They were a far more significant resource than suggested by surviving chantry chapels or altars, most being itinerant and peripatetic. A parish's ministrations was thus variable and multi sourced.

Guilds played a vital role in fostering devotional activities and, just as importantly, financing the necessary devotional infrastructure. Guilds were far more extensive than the familiar urban trade or craft variety. Every village had them; their number and scope dependent on population. There were general guilds; separate guilds for men, women, boys and girls; as well as guilds dedicated to individual saints. Guilds were the parish, and subsets thereof. As well as being in receipt of bequests and donations, guilds arranged the Parish Ales associated with feast days.

How did medieval Catholicism manifest itself in church furnishings and iconography? It did so in an explosion of colour and imagery! No surface – wood, stone, plaster or glass – was excluded. Most dramatic was the separation of nave and chancel: above the rood screen there were life sized coloured statues of the crucifixion flanked by Mary and St John. Above or behind these was an enormous painting of the Day of Judgement. (Fig. 2). The rood screen itself was carved and decorated, its niches containing statues and paintings. Whilst the rood, crucifixion and judgement ensemble constituted the most dramatic vista, no wall was left bare. Each was covered in a kaleidoscope of colour and paintings; its niches and brackets graced by statues – polychrome statues, often gilded. Lights—burning candles—were maintained before the principle statues.

We are describing a completely lost and unfamiliar world, difficult to imagine. But it is the world from which our oldest surviving scratch dials originate. If we are to meaningfully decipher and interpret them, we must, as diallists, be attuned to the wavelength of medieval Catholicism. This world was swept away by the Reformation.

The Reformation's intellectual roots lay in the Old Testament – “Thou shalt not make unto thee any graven image or likeness of anything that is in heaven above or that is in the earth beneath...”. Reformers saw reverence due to God dissipated on inanimate objects and images. Reformers saw holiness not confined to heaven but dissipated in imagery. Image fuelled devotion, ceremony and ritual was not the route to Salvation. Salvation lay wholly and solely in the bible, with the Word.

The image-infested Catholic Church had to go. It went in successive waves of legislation, regulation, and state sponsored iconoclasm – Henrican, Edwardian, Elizabethan, Cromwellian.⁵ The end result: Catholic colour, decoration, imagery and vibrancy all suppressed and supplanted by whitewashed Protestant minimalism. No rood, crucifixion and judgement ensemble; no altar, just a plain table; no statues and their lights; no colour and art, instead whitewashed walls, their only adornment, the Word; the single innovation, the pulpit, for sermons to preach the Word. Such purging and purification was unrivalled in Europe. It would be extraordinary for dials to have been immune to the Reformation's cataclysmic forces, and our statistical evidence (Fig. 1) shows they were not.

It can now be appreciated that the marked change in the appearance of dials in the 16th century was caused by compelling and profound religious change.⁶ This change is discernable in the surviving appearance of dials. However, it is high time diallists redirected attention away from surviving appearance to that when these dials were originally in use. We can do so by elaborating upon this article's foundations: subsequent articles will develop more detailed assessments of the contemporaneous religious iconographies relevant to medieval Catholic and Reformational/Protestant dials.

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For a photo and CV of the author, see *BSS Bulletin* 23(i).

THE CORONATION DIAL AT PAINSWICK

TONY WOOD

The village of Painswick, out in the Cotswolds, is home to quite a collection of sundials, all quite old, so it is perhaps no surprise to find that the Coronation in question is not that of our present Queen but that of her father, King George the Sixth. The Coronation was in May 1937 and the dial (Fig. 1) has apparently been in its present situation since then. It is a special souvenir Coronation dial and must be one of many¹ produced in 1937 to mark the event and as dials go it is essentially a mass produced popular garden dial of 8 inches diameter in bronze and seems to be marked out reasonably accurately together with a gnomon of 52°.

The inscription round the edge reads: GEORGIUS VI BRITT. OMN. REX. CORONATION 1937.

The delineation around noon gets a little hazy. The hours scale is divided into half-hours and eighth hours (7½ minutes). A long noon line implies a split noon but the intervals become very irregular. The royal coat of arms appears on the dial plate (Fig. 2) and raises the question of whether many (or indeed any) other dials are so marked. We had a royal monogram granted to us at Ruardean² for the Queen's 50th Jubilee but the Chamberlain's Office did not go so far as the coat of arms. Its survival for 74 years is perhaps surprising as it is located at a pub. The Royal Oak in Painswick has a courtyard and skittle alley out at the back and the dial is mounted on a rough-hewn block of stone with a mysterious row of holes and is barely large enough at the top to hold the dial plate securely.

On a personal note, I seem to have had particular difficulty in taking pictures of this dial (snow and camera problems) and it required at least three visits to the pub with the necessary courtesy of buying a drink (and a meal).

Apart from the challenge of royal coats of arms dials, I suspect we may now have on our lists a sufficient number of pub dials for an enthusiastic member to produce Monograph XXX 'Great Pub Dials of Britain'. In fact a few of us dipped a tentative toe in the water (or beer) with letters to the Editor a few years ago about pubs with dials.³ Any offers?

Fig. 1. The Painswick dial on its pedestal.

Fig. 2. The dial plate.



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DANIEL DELANDER DIAL RECOVERED

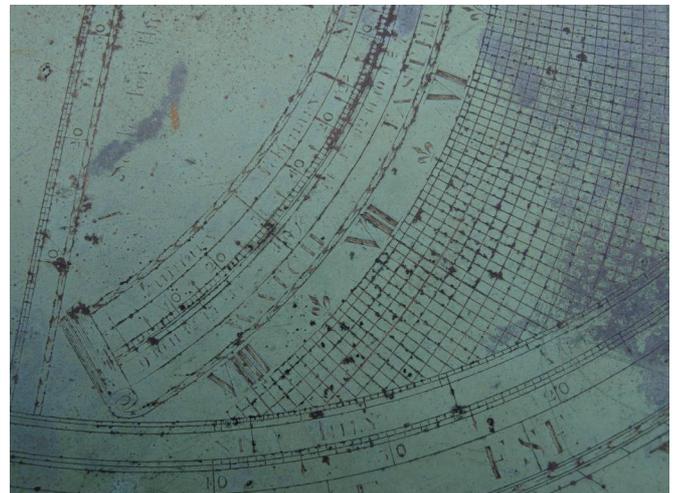
Great news! The large double horizontal dial by Daniel Delander which was stolen from Stanford Hall on 27 October 2008 has been recovered. The credit for locating the dial is all down to our Polish dialling friend Maciej Lose. He was perusing the internet looking at dials coming up for sale at a provincial English auction and amongst them he noticed the characteristic shape of a double horizontal gnomon with its vertical knife-edge. With the help of the BSS Stolen Dial Register and BSS Monograph No. 5 on *The Double Horizontal Dial*, he quickly identified the dial as 99% likely to be the Stanford Hall one, still attached to the stone capital from the pedestal.



Daniel Delander (c.1678-1733) was quite a prolific clockmaker but only two sundials by him are recorded in the BSS Register of Fixed Dials. The other dial, which is on a 'blackamoor' pedestal and currently privately owned in Wiltshire, is of the rare 'azimuth' type like the Rowley one illustrated in the June *Bulletin* (and see the back cover illustration). And since another very similar example is at Hampton Court Palace and signed by Thomas Tompion, and as Daniel Delander served his clockmaking apprenticeship under Thomas Tompion, some close working relationships are beginning to become evident!

The Metropolitan Police Art & Antiques Unit who dealt with the original theft were quickly informed and the dial was withdrawn from the sale. It was clear that the sellers did not really know what they had as the estimated price had been in the low hundreds of pounds range, not the several thousand that might be expected. With the help of high resolution BSS images of the dial, the Stanford managers were able to convince all concerned that they were the rightful owners and to recover it. Needless to say, it is now kept safely locked away. The seller claimed that he found it "in a skip" – suffice to say that the police are continuing with their enquiries!

The Delander double horizontal dial (catalogue no. DH-17, SRN 3607) is one of a small group of the very best quality dials with all the 'bells and whistles' in terms of Equation of Time scales and geographical place names in the main chapter ring. The basic dial is a not unimpressive 24" in diameter but it is made to look even bigger by the cast brass/bronze ring on which it sits. This ring is very similar indeed to those on the Rowley dials at Blenheim Palace (see p. 26 in the previous issue) and the Thomas Tompion dials at Hampton Court Palace. But in those cases, the ring is the other way up and so the dials look perhaps more elegant.



When the Delander dial was stolen, the column and base of the pedestal looked rather forlorn in the garden. Thus a replacement dial 20" in diameter in Welsh slate was made by the local firm of The Carving Studio (Stanford Bury, Shefford) with an appropriate coat of arms, to fill the gap in the garden. It is quite a decorative item but, it has to be said, it is a rather poor replacement for the magnificent Delander dial.



Acknowledgements

I am very grateful indeed to Maciek

Lose for enabling the recovery of the dial and to Sarah Maughan at Stanford Hall for keeping me informed of progress.

John Davis

THE GREAT AMWELL SCOTTISH RENAISSANCE OBELISK DIAL BOSS

Part 2. The Facet Record

MALCOLM BISHOP

In part 1¹ of this examination of the Scottish Renaissance Obelisk Dial Boss which was identified in 2010, and which had been unearthed some years previously in Great Amwell, the process of authentication was described. In this part, the archaeological record of the dial is set out. As in part 1, an exploded plan view of the boss was prepared, and was labelled for ease of reference. This version (Fig. 1) includes the burial tide-mark in red.

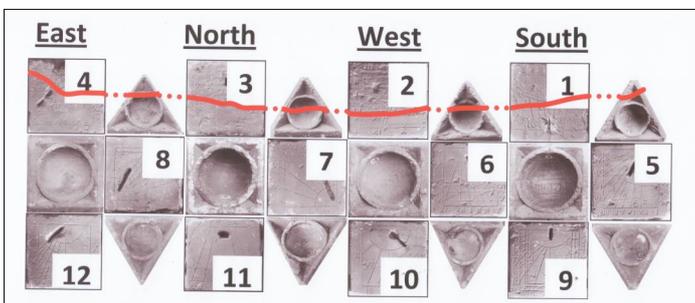


Fig. 1. Facet plan of the Great Amwell dial boss, showing the burial 'tide mark'.

Incised Marks

Ten groups or types of incised marks were identified on the dial. In addition there are defaced or otherwise unidentifiable marks which may or may not belong to further groups.

- Base lines
- Frames and decorative lines
- Hour, half-hour and quarter hour lines and marks
- Solstice and equinox lines
- Roman numerals
- Arabic numerals
- Signs of the zodiac
 - For the equinox and solstice lines
 - For the months
- Possible mason-marks
- Place names
- Compass bearings
- Other

The Planar Dial Facets

The 12 plane dial facets are paired, the pairing being accomplished with wit and sophistication by the designer of the dials.

Facets 1 & 3 (Fig. 2); the Upper South dial is the only dial on the boss mostly lettered 'sideways', with the individual feature of lines for the sun's azimuth labelled with the compass points SEbE, SE, SSE, SbE, S, SbW, SSW, SW, (SWbS defaced). The 'b' in each case where it occurs (for 'by') resembles a hockey stick.

On the Upper North dial the hour lines are very faint on what was once likely to have been a pleasantly decorative simple dial, the only plane dial with a circular layout.

Facets 2 & 4 (Fig. 3); on the Upper West dial the summer solstice line is doubled and is labelled by a juxtaposed ♈ Aries and ♊ Gemini. Both the West and East upper dials are inscribed with place-names, in this case LONDON.

On the Upper East dial the summer solstice line is quadrupled. Labelling at the upper end, if ever present, has been lost to erosion. This dial is of particular importance, being inscribed with several place names; ACRA, I(or L)ERU(S), O(or U)ML(E), ?PARIS, TANGIER, MADERA. These serve to give context and date references as described in part 1. This dial also differs in having month lines intersecting the hour lines. These are labelled anticlockwise from ♋ Cancer (bottom centre intersecting the frame line) ♌ Leo (above the frame line) ♍ Virgo (sideways, intersecting the frame line), ♎ Libra, ♏ Scorpio, and ♐ Sagittarius between XI & X. The shape of the Libra sign is most unusual on this and other facets in that instead of two separate lines the symbol is a closed shape, almost triangular.

Facets 5 & 6 (Fig. 4); the South East and South West Vertical dials. Unidentified marks on Face 5 include a set of short parallel lines, comparable to other Gemini marks, in the IX-X segment, and a small ellipse surmounted by a further short line in the XII-I segment, and a 'tadpole' shape like half of a Cancer to the right of the frame line above the lower Aries solstice. These three incidences of carefully incised marks may be the Arabic numerals, from right to left; 9, 10 & 11 in various orientations (but if so not corresponding to the hours beside whose lines they lie) or may be masons' marks.²

On both dials ♐ Capricorn and ♊ Gemini mark the higher solstice line. They are simple, well-preserved dials.

Facets 7 & 8 (Fig. 5); are simple dials which mirror each other.

Facets 9 & 11 (Fig. 6); the South Lower dial is far from simple and features two separate sets of hour lines/numerals. The outer triple frame delineates the normal equal hours, from 6 a.m. to 6 p.m., divided by quarters and labelled with Arabic numerals.

The inner lines, labelled with Roman numerals, initially looked to be projections of the domifying circles³ since they radiate from a point somewhat below the origin of the gnomon. However, their numbering does not fit this assumption.



Fig. 2. Left; facet 1, the Upper South dial. Right; facet 3, the Upper North dial.

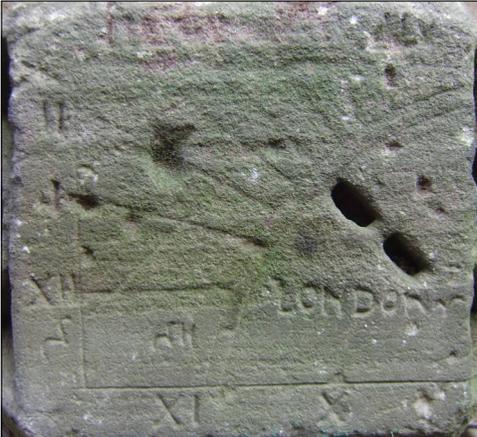


Fig. 3. Left; facet 2, the Upper West dial. Right; facet 4, the Upper East dial.



Fig. 4. Left; facet 5, the South East vertical dial. Right; facet 6, the South West vertical dial.



Fig. 5. Left; facet 7, the North West vertical dial. Right; facet 8, the North East vertical dial.

tion and on closer study it is believed they show the unequal (temporary) hours, counting from dawn and with VI at noon. It is likely that the gnomon had a horizontal lower edge projecting out of the bottom of the slot in the stone so that the dial would act somewhat like a scratch dial.

The North Lower dial is notable for its austerity, appropriate for its position. This is extremely simple, contrasting with the complexity of Face 9, but the shape of the gnomon socket indicates that this was of a different type from those of the other dials. There is no substyle line.



Fig. 6. Left; facet 9, the South Lower dial. Right; facet 11, the North Lower dial.



Fig. 7. Left; facet 10, the West Lower dial. Right; facet 12, the East Lower dial.



Fig. 8. Left; the Direct West scaphe dial. Right; the North West Corner scaphe dial.

Facets 10 and 12 (Fig. 7); A pleasing feature of the West Lower dial is the marking of the half-hours with dots. The East Lower dial resembles the West, and as with that dial and corresponding with most others, the upper solstice line is identified by ♄ Capricorn, the middle equinox line by ♈ Aries and ♎ Libra, and the short solstice lines in the bottom corners, ♋ Cancer.

The Scaphe Dials

The cardinal scaphe dials all have sockets for polar-pointing gnomons, hour lines with Arabic numerals, and where appropriate there are solstice and equinox lines. The corner scaphes are similar, with sockets for style gnomons, and hour lines with Arabic numerals.

Overall Measurement Results

The results of ‘reverse engineering’ the delineation of the clearest faces, described in Pt. 1, are shown in Table 1. The standard deviations of the ‘best fit’ lines are typically around half a degree which, although poor compared with a brass dial made by a mathematical instrument maker, is

Facet	Optimum latitude (°N)	Std Dev (°)
5	56.5	0.556
6	55.3	0.518
7	56.5	0.511
8	55.9	0.593
9	55.7	0.394
10	55.3	0.211
12	55.4	0.637
MEAN	55.80	

Table 1. Best fit latitudes for clearest facets.

perfectly acceptable for a stone dial. The smallest standard deviations indicate that the preferred latitude is perhaps 55.5°, slightly lower than the mean value.

Approximate latitudes were also measured from the gnomon angles of the scaphe dials. These were broadly in line with the above figures although the locations of the gnomon endpoints could not be located with sufficient clarity to add to the overall accuracy.

Summary

The high level of sophistication apparent in the dialling is accompanied by an equally impressive level of stonemasonry, both in the overall structure of the boss with its multiple scaphes, and in the execution of the dials.

REFERENCES & NOTES

1. M. Bishop: 'The Great Amwell Scottish Renaissance Obelisk Dial Boss – Pt. 1, Reading the Scottish Renaissance Sundial Boss', *BSS Bulletin*, 23(i), pp.52-6 (June 2011).
2. Some idea of the multiplicity of Stonemasons' marks may be

gained from the Proceedings of the Society of Antiquaries of Scotland; <http://tinyurl.com/5u8tmaq>. Vol IV plate XXI. Extensive work by Dr Moira Greig has largely failed to reveal ascribable marks, which might have been expected for such prominent masons as the Mylnes. Personal communication, Moira Greig Archaeologist Planning & Environmental Services Aberdeenshire Council.

3. A 'domifying circle' (*Domus Caelestius*) indicates the Houses of Heaven and indicates which section of the ecliptic is above the horizon at any time. The lines do not radiate from the origin of the gnomon like the hour lines but from slightly below, where the horizon line (if shown) would intersect the meridian. (There are a number of definitions of the lines but that most commonly used is due to Regiomontanus in the C15/C16). Dr John Davis, personal communication (December 2010).

Additional note to Pt. 1: the Mylne sandstone quarry at Abbeyhill near Edinburgh had been worked for some years before 1692. I.T. Bunyan et al. A.A. McMillan ed. *'Building Stones of Edinburgh'*. Edinburgh Geological Society. (1987) p.97.

For a picture and CV of the author, see Ref. 1

Umbra Docet - The Shadow Teaches

This is the title of an exhibition about time and sundials which will be presented in the museum of Moedling from September 24, 2011, until February 2, 2012. Moedling is a little town about 20 km south of Vienna, Austria. Centre of attention will be models of different sundials designed for the book *Gnomonica Universalis* by Johannes Gaupp, German Protestant pastor, mathematician, astronomer, 1665 - 1738. [Karl Hofbauer presented a lecture on this book and its dials at our Cambridge Conference in 2007. Ed] Ernst Steiner, born in 1935, will present symbolic pictures about his ideas of time. Also exhibited will be documentations of wall sundials in Moedling and tablets with information about sundials and time.

Moedling is a little picturesque town with a rich historical background and places reminding us of the composers Ludwig van Beethoven and Franz Schubert. Adjoining are lower mountains of the Vienna Woods area, with places of interest as e.g. the Romanesque abbey of Heiligenkreuz.

Visiting Moedling and the nearby situated spa of Baden with beautiful gardens would be an experience; further information can be found at www.museum.moedling.at, www.moedling.at and www.baden.at.

A Gaupp dial. © Karl G. Hofbauer, whose dedication to Gaupp's didactic ideas made their revival possible.



Walter Hofmann (wf.hofmann@aon.at)

Nature Club of Pakistan

Under the direction of the Principal, Muhammad Raza Khan, the Nature Club of Pakistan has been promoting a programme of gnomonical science studies with four schools in Lahore and Faisalabad. The programme was organised in three parts, in which students determined the meridian to find true north, studied the astronomical principles of the equatorial/equinoctial sundial, and acquired knowledge in the construction and use of horizontal sundials. The activities of the students included making com-

parative charts of apparent solar time and mean time. By all accounts, the course was most successful and is likely to be the first of several others in the future. The Principal acknowledged the help given by the BSS, notably by Tony Moss, and that of Muneza Akhtar, a local teacher, who coordinated the participation of the schools in this new venture.

Christopher Daniel

BSS ANNUAL CONFERENCE, Wyboston Lakes, 29 April—1 May 2011

FRANK EVANS

Our Society chairman, Chris Daniel, offered a warm welcome to the over eighty guests attending the meeting. He was pleased to note that the wedding which had taken place earlier in the day between Prince William and Kate Middleton was at a venue chosen because of its proximity to the Church of St. Margaret, Westminster, and its renowned dial.



The Friday evening talks were opened by Allan Mills, who considered the various materials which might be employed in showing the sun's position and hence the time. The most accurate of these, giving time within around a minute, was a solid object, a gnomon, throwing a shadow or sunspot. Slightly less so was a crystal, e.g. of calcite, whose polarised beam could give an accuracy of around four minutes. Even less accurate but, as he would hope to show, still useful, was a rainbow. Not any old rainbow but one produced by a garden hose in spray mode. Allan, true to form and ever ready to surprise us, had produced a Heath Robinson model to find the centre of the hose's (complete) artificial rainbow circle and hence the sun's position. Fred Sawyer said this had already all been done with a nomogram on a piece of card. Allan countered that this failed in its object as it did not wet the experimenter.

Next, Tony Moss began his address by describing his progress through the business of dial manufacture but it was principally taken up by his fascinating ac-

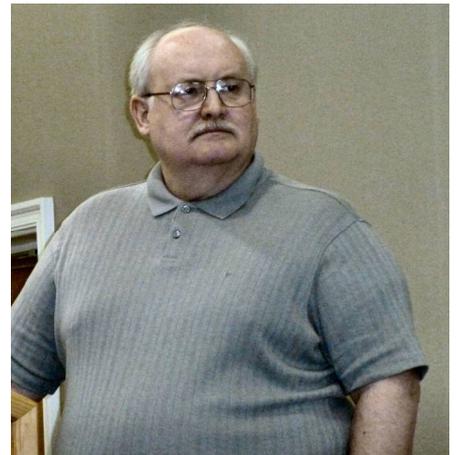


count of how, on finally bowing out of the practice, he found himself with a mass of scrap brass on his hands. With this he resolved to make identical sundials for each of his five grandchildren. Not knowing where the future would take them he made for them universal equinoctial dials. The production of the five dials was beautifully illustrated and gave an insight into Tony's great skill and elaborately equipped garage workshop.

The last paper of the evening was presented by Johan Wikander. Unsurprisingly he had news of yet another Norwegian dial, this one being a horizontal soapstone dial dated 1407 in Arabic numerals. It is owned by the University of Trondheim and probably comes from a monastery on the west coast of Norway. In Norway the practice of marking the day's beginning at the hour of sunrise was altered to a day starting at midnight in about 1450. This dial conformed to



the earlier practice as the date would suggest. But at this time the form of the digit 'four' was a vertical loop, quite unlike the modern form. The soapstone dial bore the modern form of 'four'. Johan Wikander then showed a series of examples where the old form had been used, right up to the end of the fifteenth century. He also demonstrated a similar disparity with 'seven'. Together, these improbable variants suggested that the date of 1407 was not the date of manufacture of the dial and his conclusion was that the dial was probably made about 1600 for a church built in 1407.



Saturday's procedures opened with an enquiry by Fred Sawyer on the seventeenth century astronomer Jean Picard's presentation of his new way of making large dials. It seems that any dial may be laid out by his method but it serves particularly well with large dials on walls. Fred Sawyer balanced it against the method of Picard's fellow astronomer, Philippe de la Hire, whose construction method depended on pure geometry while Picard's employed trigonometry, which can be more practicably employed in the layout of large dials. Picard is best known for calculating the length of a degree of latitude on a meridian through Paris, converting a value previously thought to be 60 miles to one of 69.1 miles, thus leading to a more accurate estimate of the size of the earth, with implications for clock pendulums.

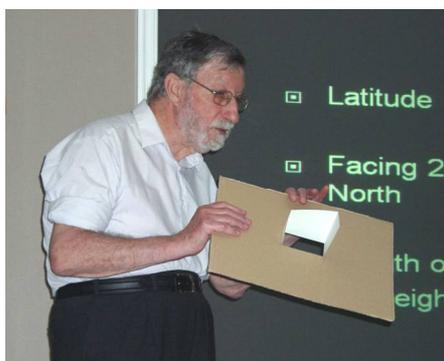


This, one of Fred Sawyer's less mathematically terrifying presentations, (positively no offence intended, Fred) was followed by a succession of pictures shown by Roger Bowling of large lead and stone figures, each bearing a sundial. He dwelt especially on the lead figure of a blue-eyed black man in Enfield Old Park, Manchester, whose published attributes he found to be wrong. A lady had complained that the newly-painted figure should not have blue eyes but it was found that the original eye colour was blue. What Roger Bowling's further investigations revealed was that such figures were not unique and surprisingly are still being made. However, his proudest revelation was that on being asked by his neighbour to check the accuracy of an equation of time curve the neighbour had drawn he was able to save a publishing blunder by indicating an error. Roger's neighbour is the retired Astronomer Royal.

Diallists are aware that the earliest known scientific dial, made by Ibn al Shatir and dated 1371, was to be found on the Umayyad Mosque in Damascus. John Davis's enquiry concerned the advance of this polar gnomon form into the wider world, particularly to England. He found early dials which could be accu-



rately dated, with examples from the early sixteenth century, back to dials whose dates could be approximated, such as the tile dial from St Augustine's Abbey, Canterbury, said possibly to be pre-1500. Even earlier are manuscript records describing scientific dials at e.g. Warrington Priory and St. Alban's Abbey, around 1450. He noted that what are thought of as scientific dials bear less furniture than Islamic dials with their guides to prayer times, etc. This sequence is clearly of historic importance and allows a diffusion rate from the Arab world to be estimated.



The audience next converted itself into a class of architecture students to follow John Lynes in his quest to keep the direct sun out of unwanted parts of buildings. He said that Vitruvius left us ten books of architecture, the ninth being on dials and water clocks. Modern architects pay little attention to dials and international architecture makes small acknowledgement of the sun's direction. Yet the sun's effect is important. In African schools, of necessity, no direct sunlight enters classrooms. In temperate latitudes sunlight needs management. He showed that a simple figure allowing no direct sunlight and the maximum of indirect light into a building would be a shadow ring tilted in the equatorial plane. The width of this solar bracelet would fit between the summer and winter solstices. It was,

however, an inconvenient shape for a window. To make the most of indirect sunlight, John Lynes developed a complex shape with a flat bottom and sloping upper edge. He called this a solar bucket and such a shape lends itself to forming a skylight. It can be modified to catch, as well as the indirect overhead light, the low light around the horizon.

Chris Daniel gave for his final paper as the Society's chairman an account of the early days of the Society and his own early career as a sundial designer. After thirteen years as a merchant seaman he took up, in 1967, the post of research assistant at the Old Royal Observatory in Greenwich where he was put in charge of, among other things, the sundials. A.P. Herbert's book, *Sundials Old and New* gave him a lead into the subject and by 1972 he produced his first written account of dials, *Sundials in NW Kent*, which was subsequently enlarged under the title *Sundials on Walls*. 1972 also saw the production of the symbol forming the logo of the Nautical Institute; this symbol was later incorporated into his fine dial adorning the headquarters of



the Marine Society in Lambeth. Around this time he was appointed Mate of the Tudor replica 'Golden Hinde' for her voyage to San Francisco and startled today's audience with a picture of himself on board, dressed in Elizabethan garb and wielding a cross-staff.

Perhaps his best-loved dial was the Dolphin dial he designed for the National Maritime Museum in 1978 for the Queen's silver jubilee. He became head of education services in the museum before, in 1986, taking early retirement and devoting his whole time to dial description and manufacture. Among his many later successes has been the little Shire book, *Sundials*, which has passed through numerous editions and has sold more than 26,000 copies to date. To the present audience the most important event in his dialling career was, of course, the foundation of the British Sundial Society in 1989. On Sunday he was to enlarge on this with a roll-call of the distinguished people who have brought the Society to its present elevation.

Come Saturday afternoon we explored dials around Hitchin, being driven there in a double-decker touring bus large enough to fit us all in. First call was to Chicksands Priory, located inside a military base. Chicksands was once a Gilbertine Friary but is currently an officers' mess. There in an upper room we found a stained glass dial, pretty but of unknown provenance. In Hitchin itself we first viewed a pair of 1660 dials on the

Ian Butson in earnest conversation with Val Cowham while Mike talks to Janet Jenkins.

Bottom right: Dennis Cowan receives the prize for the best Sundial Trail from SoTI's Piers Nicholson.

Graham Aldred, winner of the Sundial Design Competition, with the brass plaque which will accompany his replica dial at Lyme Park.



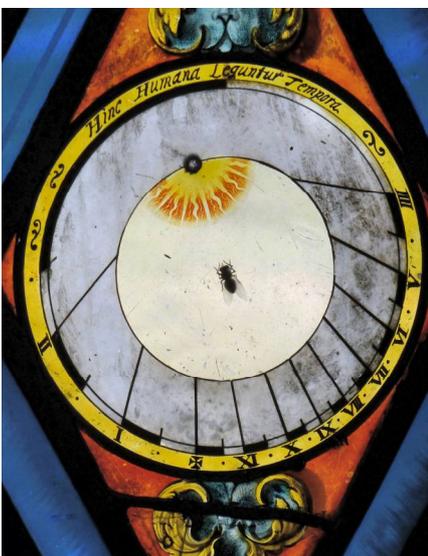
tower of St Mary's Church, then on to the William Ransom Physic Garden, a charming small garden featuring Joanna Migdal's 1990 dial in the appropriate form of a pestle and mortar. From there we nodded to a house dial on Hitchin Hill as the bus swept past, before pausing in Great Staughton for a cube dial on a pillar, dated 1637, worn but still working. Then home.

The Conference dinner followed. After the meal, a number of presentations were made, including the prizes for the Photographic and Sundial Design Competitions. Earlier in the day, we had had the presentation of the prize for the best new Sundial Trail, a joint BSS/SoTI competition, to our recent Scottish member Dennis Cowan. The final presentations were to our outgoing Chairman Chris Daniel, who was given a glass windowsill dial with a suitable inscription reflecting



Left: Leonard Honey inspects the Physic Garden pestle & mortar dial while Ian Maddocks photographs it.

Right: The BSS stops the traffic in Staunton Highway to photograph the cube dial.



Left: The stained glass dial at Chicksands Priory. The motto 'Hinc Humana Leguntur Tempora' was translated, after some discussion, rather literally as 'From here, human hours are read'.

Right: The pair of dials on St Mary's Church, Hitchin.

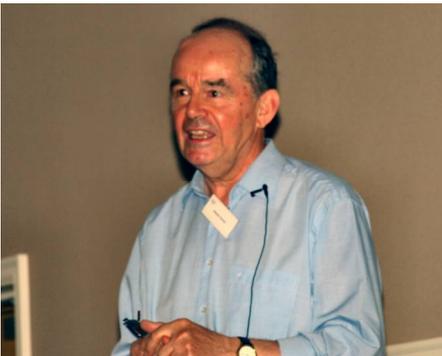




Our retiring Chairman Chris Daniel and partner Doreen Bowyer with the gifts presented to them by the Society.

21 years of service to the Society. It was made to align with the declination of Chris's study window by Jim Tallman, an American member. Chris's partner Doreen was given a silver and enamel brooch echoing the design of Chris's 'Nelson' sundial, made by Jackie Jones.

On Sunday we were addressed by Alistair Hunter whose Greenbank, Glasgow, dial in the National Trust for Scotland



grounds has now gained a 'highly commended' certificate in the recent design competition. His beautifully engineered dial crowned an interest which began with a 'length-o-meter' he once made to trace the seasons each noon. He progressed to a diamond-shaped dial plate of etched stainless steel which led him to discover that a highly polished surface does not take a shadow. His modern prototype in the Botanic Gardens in Edinburgh provoked much interest although he says sales have remained modest. Nevertheless, the Glasgow dial itself represents a fine addition to the garden.

It is said that scratch dials tell you absolutely nothing about themselves but Chris Williams's statistical procedures have made them yield up their secrets. Over many publications he has shown that dials were once present on every



church and a huge number have now disappeared. Further, scratch dials may fall generally into one of two groups, full circle and half circle. Full circle dials were once brightly painted while half circle dials were utilitarian and uncoloured. Chris Williams believes that this accorded with the general internal decoration of churches, being fully decorated in pre-reformation times, these times having many saints' days, numerous chantry priests, guilds in every village and a general demand for donations and bequests. In the later cataclysmic period when all these features had disappeared with the spread of Protestantism, churches were simply whitewashed. Photos of church interiors, painted and plain, illustrated this clearly. This remarkably simple classification was achieved with some very sophisticated mathematics.



Our late *Bulletin* editor, Margaret Stanier, a Fellow of Newnham College, Cambridge, has been commemorated with a dial designed by the modestly described Cambridge University Bellringer, Frank King. This dial pretends to follow the design of a medieval mass dial but is far more subtle and should properly be described as a scientific dial in a new form. Mass dials or seasonal dials show unequal hours through the year (as any fule kno), but it is less frequently recognised that on any day the individual hours may

be of varying length. Selecting the 6am, 6pm and noon lines as basically correct, Frank King showed that the 9am and 3pm lines did not fall 45 degrees from the vertical as tradition demands but when plotted through the year formed a substantial cone or triangular pattern some distance away. A piece of robust cheating resulted in the conventionally horizontal gnomon being tweaked into an 8.9 degree downward deflection. Bingo, the 9am and 3pm cones dwindled to straight lines but only to reappear as 6am and 6pm cones. Solution, delete these offending latter hour lines as redundant. Result, a splendid dial and a fine memorial to Margaret. The base of the gnomon, moreover, was in the form of a bell, a nice tribute to her bellringing activities.

Rebekah Higgitt of the National Maritime Museum, Greenwich, where she is the Curator of the History of Science, delivered the Andrew Somerville Lecture. She quoted the museum's motto, *Ne quid pereat*, or 'Let nothing be lost', which seems singularly appropriate for a museum. Her title was: "Researching and collecting sundials in the age of precision time-keeping".



Although the museum has collections extending far back in time, it itself is young, having been founded largely through the finances of Sir James Caird, a Glasgow shipowner, in 1934. His own substantial collections of mainly paintings and works of art were supplemented by the large scientific collections of George Gabb. At first no great attempt was made to collect sundials, which are basically not used at sea, but gradually, as instrument acquisitions increased, dials frequently appeared among the items secured. These mainly found their way to the Old Royal Obser-



BSS Group Photo – V



Mike Shaw shows his latest toy to Jackie Holland and Ben Jones.

Chris Lusby Taylor explaining a deep dialling concept to Kevin Karney.

More silver dials from Jackie Jones.



vatory. There and elsewhere the National Maritime Museum currently holds 361 dials from the fifteenth century onwards. Early collectors of these dials had regarded them as *objets d'art* but gradually their scientific interest became recognised. Rebekah Higgitt took us through some of the more recent literature on dials, showing how the flavour had changed in the last couple of hundred years. We enjoyed the list of citations, most of which the audience was familiar with. It began with Charles Lamb: "What a dead thing is a clock, with its ponderous embowelments of lead and brass, its pert or solemn dullness of communication, compared with the simple altar-like structure, and silent heart-

language of the old dial." The Pre-Raphaelites painted dials prominently in some of their pictures. Mrs. Gatty's *Book of Sun-Dials* (1872, 4th edition 1900) was mostly about mottoes, although later editions contained Wigham Richardson's directions on dial making. Alice Morse Earle's *Sundials and Roses of Yesterday* (1902) spoke of the charm and sentiment of dials. Henslow's *Ye Sundial Booke* (1914) displayed a love of antique dials, but included a history of pocket dials and listed some dial makers. Only fairly recently has dial technology returned as a subject in its own right, as it was at the time before the nineteenth century when dials were the only practical time-keeping method.

The presentations at this conference were among the best there have been, as was generally agreed, and the conference itself was a great success.

frankevans@zooplankton.co.uk

Pictures from J Davis, M Cowham & Tony Moss.



Photo by Chris Lusby Taylor

Vyboston Lakes 2011

Front row

- 1 Chris Lusby Taylor
- 2 Irina Tudorescu (non-BSS)
- 3 Geoff Parsons
- 4 Mrs K.B. Coe
- 5 Jackie Holland
- 6 Janet Jenkins
- 7 John Hayden
- 8 Piers Nicholson
- 9 Jackie Jones
- 10 Chris Daniel
- 11 Doreen Bowyer
- 12 Tony Moss
- 13 Rosie Evans
- 14 Kevin Karney
- 15 Elizabeth Karney
- 16 Jane Apfel
- 17 Jane Walker
- 18 Vera Naumann
- 19 Michael Maltin
- 19a Mary Isaacs

Second row

- 20 Ben Jones
- 21 Fred Sawyer
- 22 Graham Stapleton
- 23 Frank Coe
- 24 Val Cowham
- 25 Frank Evans
- 26 Rebekah Higgitt
- 27 John Foad
- 28 Ian Butson

- 29 Sandra Harrison
- 30 Owen Deignan
- 31 Maureen Harmer
- 32 Tony Wood
- 33 John Harmer
- 34 Andrea Richardson, née Daniel (non-BSS)
- 35 Shirena Counter, née Daniel (non-BSS)
- 36 Robert Fletcher
- 37 Graham Aldred
- 38 Jill Wilson
- 39 David Hindle
- 40 Roger Bowling
- 41 Pauline Mills
- 42 Allan Mills
- 43 June Mellor
- 44 Tony Belk
- 45 Mike Isaacs
- 46 John Lester
- 47 Pat Sedgwick

Back row

- 48
- 49 Jim Holland
- 50 Harriet James
- 51 John Davis
- 52 Martin Jenkins
- 53 Mike Shaw
- 54 Jim Marginson
- 55 Jenny Brown
- 56 Silviu Apostu (non-BSS)
- 57 David Brown
- 58 Elspeth Hill

- 59 Anton Schmitz
- 60 Veronica Schmitz-Haepf
- 61
- 62 Rob Stephenson
- 63 Johan Wikander
- 64 Liz Williams
- 65 Chris Williams
- 66 Andrew James
- 67 Mike Cowham
- 68 Dennis Cowan
- 69 Julian Lush
- 70 Jack Bromiley
- 71 Peter Walker
- 72 David Payne
- 73 Mike Faraday
- 74 Gerald Stancey
- 75 Ian Maddocks
- 76 Leonard Honey
- 77 Patrick Powers
- 78 John Lynes
- 79 Catherine Powers
- 80 Stuart Allen
- 81 Doug Bateman

Not present in photo
 Frank King
 Gillian Nicholson
 Irene Brightmer
 Alastair Hunter

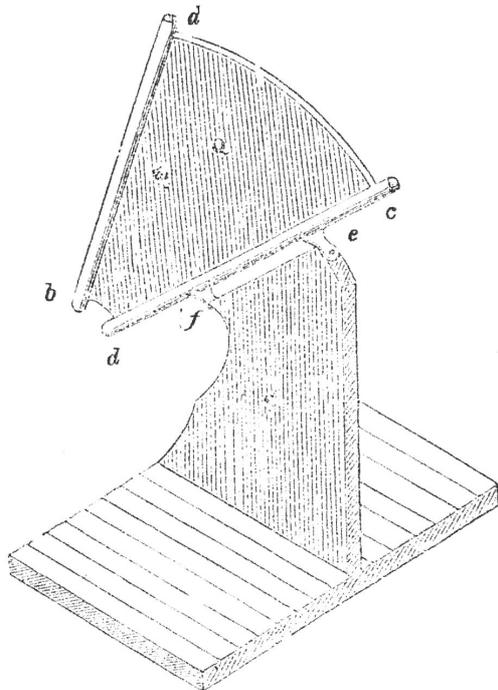
With apologies to anyone mis-identified!

SIMPLE INSTRUMENT FOR FINDING A MERIDIAN LINE

WILLIAM WATSON

[This article was first published as a reader's letter in **Mechanics Magazine**, February 1841, pp.103-5. The life and work of the author were described by Malcolm Young: 'William Watson of Seaton Ross (1784-1857) – East Riding farmer, land surveyor, map and sundial maker', BSS Bull. 21(iv), 6-9 (Dec 2009). I am grateful to Malcolm Young for providing a copy of the original Mechanics Magazine article. Ed.]

During a recent visit to London I have been contriving a new kind of instrument for finding a meridian line, for the making and fixing of sun-dials. But as I have neither time nor tools here for making a perfect instrument, I will describe it so that any other person may do so if they think it will be worth their while. The rough model sent herewith (represented in the accompanying engraving) may be suffi-



cient to give an idea how the instrument is to be made and used. Two tubes, *ab*, *cd*, are to be fixed fast on the moveable part Q, so that one of them shall point to the pole star, Alrucabbah, while the other points to the fixed star Capella. The line between the two joints or rings *ef*, on which the moveable part turns, is to make an angle with the horizontal board S, at the bottom, equal to the latitude of the place, and then (when the instrument is set right) this line will be parallel to the axis of the earth, and the pole star tube will be nearly parallel to it, being only about a degree and half (sic) from it. The other tube, pointing to Capella, makes an angle of about 45 degrees from that pointing to the pole star. Then, by setting the instrument on a level plane, and turning it about until the two stars can be seen through the

two tubes, the edges of the square horizontal board at the bottom will point exactly to the east, west, north, and south. No matter what o'clock it is when the observation is taken, nor what day of the month it is, nor what time of the year; *any time* will do when the two stars are visible. And when it stands upon the level plane the two stars cannot be seen through the two tubes, but only when it is set right in the meridian. The parallel lines in the bottom board being meridians, any of them can easily be marked on the level plane on which it stands. And this two-tubed instrument may be used with equal accuracy in a different way, for when the two tubes point to the two stars mentioned, the bottom board will be raised either on the north or south side, according to the difference of latitude. Any other two fixed stars would do for this purpose if they were at a considerable angle from each other, but many of them are not visible every night of the year. Perhaps the star Vega instead of Capella, would suit better for this purpose, as it is nearer to the equator, and nearer in the plane of the Pole Star and the Pole, and it is visible some part of every night in the year when the sky is clear. But Capella and the Pole Star never set in England, therefore they are visible all night, and every night in the year when the sky is clear.

I remain, Sir,
Your obedient servant,
W.W.

Michael Lowne comments:

For this device to operate correctly it should allow for the displacement of the Pole star (Polaris) from the true pole of the sky and its position angle on the small circle of the diurnal rotation about the pole, so that when sighting the star the rotation axis may be directed accurately towards the pole. Simultaneous sighting of another more distant star (Capella in this case) enables the displacement to be set at the correct hour angle of Polaris from the meridian at any particular time. It is therefore necessary for the Polaris sighting tube to be set at an angle to the axis equal to the polar distance of the star, 1.5° in 1841. The tube for Capella should be at an angle to the axis of 44.2° corresponding to its 1841 polar distance. The angle between the tubes measured at the axis should be 60.6° , equal to the stars' difference of right ascension in 1841. In this way sighting both stars through the tubes will align the rotation axis on to the pole.

It is not clear either from the diagram or the text that the device has been constructed in this way. The diagram appears to show the Polaris tube parallel to the axis, not displaced. Although the text mentions the necessary angle

between the Polaris tube and the axis, and refers to the angle between the tubes it does not mention the required angular separation in right ascension. In either case the result will be an incorrect setting for the meridian.

Gordon Taylor has shown¹ that, for latitude 52° at the present time, aligning on Polaris rather than the true pole can introduce a maximum error in the derived meridian of 1.2°, which in turn will give time errors with a maximum of over six minutes at noon on a horizontal dial. The polar distance is now 0.7° so that in 1841 the meridian and time errors would have been twice as large.

Even if the device was correctly made, using it would not have been easy. Attempting to sight both stars through the tubes while at the same time adjusting it in orientation and tilt would have been a frustrating exercise! Capella passes close to the zenith as seen from Britain, and for two hours or more either side of meridian passage it is south of the zenith, requiring the observer to lean backwards to observe it and Polaris simultaneously.

Reference

1. Gordon E. Taylor: 'The accuracy of using Polaris to align a gnomon', *BSS Bull.* 91.3, p.34 (October 1991).

NEW DIALS

Sokolniki, Moscow

The Rosarium of Moscow's oldest park 'Sokolniki' is located in the south part of the city. The head of the Rosarium, Marina, asked me to make a sundial for this enchanting garden. We walked around the garden discussing its construction and the place where it should be installed. An old piece of marble met our eyes and I asked Marina what it was. She told me that this piece of Italian marble had lain on the lawn at least from the end of the 19th century when there was a sculpture workshop not far away. At this point our discussion was over. We decided to use this marble architectural fragment inherited from our predecessors for our sundial. Thus, before our sundial was even delineated it had a century-old history.

The next step was to invent the most unusual construction. I decided to make an equatorial sundial with three gnomons casting shadows onto three scales. Roses grow in the Moscow climate from June to October. For the rest of the year, the Rosarium is closed for public. I liked the idea of making a sundial that, like roses, lives and works only between the spring and autumn equinoxes. To prevent vandalism I made short conical gnomons with 120 mm invisible parts cemented into the marble with two-part epoxy. The gnomons and dial plate are made of brass.



Marina, the head of Rosarium, and me.

The shadow of the central gnomon measures daylight saving time, its tip passing along the declination line calculated for the Rosarium's birthday – June 28, 1957. The west gnomon measures the true solar time on the local meridian. The east gnomon measures the azimuth of the sun.

The column supporting the piece of marble is made of limestone. On its west and east edges I carved the words of Ovidius "Everything is changed, nothing disappears" in Russian and Latin. On the northern edge of the column there are instructions of how to use the sundial. I have made it of 5 mm brass and covered it with 24 carat gold.

The dial disc was initially covered with 24 ct gold too. This is a result of my passion for the method of gilding that I have learned recently. My friends now tend to avoid me as I bothered them by asking to gild free their spectacles, cell telephones, watches and so on. But a bright polished gilded dial reflects sky, clouds, trees etc. but does not show even a trace of shadow. I had to remove the gold with very fine polishing paste. The gnomons remain gilded, though.

Aleksandr M Boldyrev

ANOTHER WEST INDIES DIAL?

PETER RANSOM

A few years ago I purchased a low-angle horizontal dial from that well-known on-line auction site. I always intended writing about it but, as time went by, I forgot until in the last edition of the *Bulletin* there was a short article by John Davis about the dial at English Harbour in Antigua.¹ When I received the dial its gnomon was not attached so I asked John to do a bit of restoration in providing the necessary screws and smoothing down the area near one of the screw holes.



Fig. 1. The restored dial.

The brass dial itself is 9 inches (228 mm) in diameter and 1/8 inch (3 mm) thick. The hours run from 6am to 6pm with the half and quarter hours marked on both rings around the numbers. The outside ring is further subdivided into 5 minute divisions. As this is a low-angle gnomon the subdivisions near noon are close together and quite far apart near 6am and 6 pm! There is a central eight-point compass rose and near the gnomon root the dial is signed Parnell, London. It is difficult to measure the exact angle of the gnomon but it appears to be about 16°. John calculated the hour-line angle for every 5 minute interval for an optimised latitude

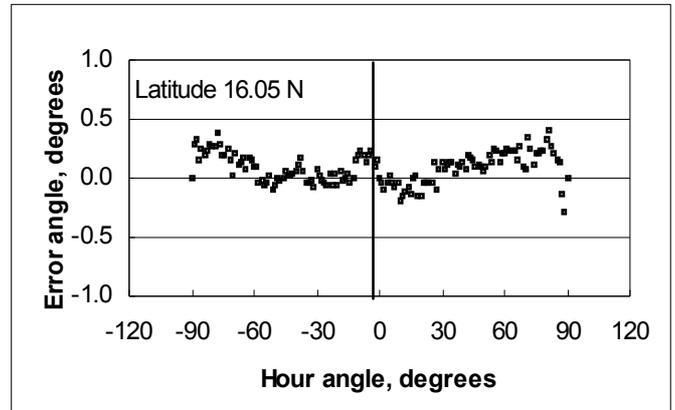


Fig. 2. The error analysis showing how far away from the calculated value the measured angle is.

of 16.05° then measured the angle on the dial. The resulting scatterplot is shown in Fig. 2.

There were two Parnells who made mathematical instruments and it is not clear who made this dial, though I suspect it was Thomas Parnell. E.G.R. Taylor² mentions only Thomas Parnell and has “fl. 1795-1846” meaning he was active in this period. She does not mention the ‘flourished’ dates for the supposed son, William Parnell, and I wonder whether the 1795-1846 covers them both. The Webster Signature Database Search Results³ yields the information in the table at the foot of the page.



Fig.3. The Parnell, London, signature.

The IM part of the abbreviation stands for Instrument Maker, with the initial M for Mathematical, N for Nautical, O for Optical and PH for Philosophical so MIM means Mathematical Instrument Maker. The ‘signature’ on the dial is shown above.

Unfortunately I do not know anything about the history of this dial. Guadeloupe lies on latitude 16.0° N, so it could

Name	Dates and speciality	Brief Biography	Known addresses
PARNELL, THOMAS	England, fl.1776-1811, MIM NIM OIM PHIM	He was apprenticed to John Blake in the Joiners' Company, Dec. 13, 1768; free of the Company, May 7, 1776; most of his instruments are signed "Parnell".	The Mariner and Quadrant, No. 94 (later No. 2) Hermitage Bridge, Lower East Smithfield, London.
PARNELL, WILLIAM	England, fl.1811-14, MIM	He took over Thomas Parnell's shop in 1814; might have been his son.	Hermitage (1811); No. 94 (later No. 2) Lower East Smithfield (1813-14); all in London.

have come from there at some point in the past, but there are many other places that lie on the same latitude!

I owe my thanks to John Davis for his work on this dial and the detailed angle analysis.

REFERENCES & NOTES

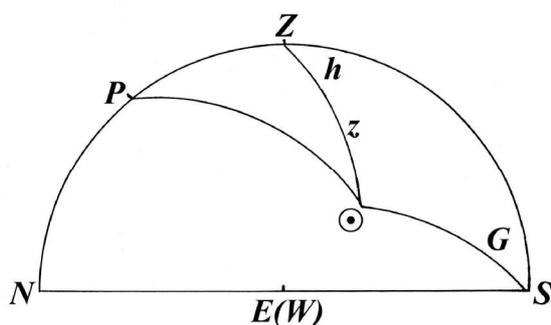
1. J. Davis: 'West Indies Dials', *BSS Bull.*, 23(ii), p.51 (Jun 2011).
2. E.G.R. Taylor: *The Mathematical Practitioners of Hanoverian England 1714-1840*, CUP, Cambridge (1966)
3. <http://historydb.adlerplanetarium.org/signatures/p.pl>

pransom@btinternet.com

READERS' LETTERS

Scratch Dial Shadows

In an addendum to his article concerning the time-keeping properties of scratch dials (June *Bulletin*, page 43) Peter Drinkwater asks for a method of deriving the length of the shadow of a vertical gnomon on a horizontal plane (in relation to the gnomon height) from the angle of the shadow of the horizontal gnomon on the dial face.



The diagram is a stereographic plot of the eastern half (or, as a mirror image, the western half) of the sky projected on to the plane of the meridian. Assuming that the dial is vertical and faces south with a horizontal gnomon pointing to S, NZS is the meridian with P the pole at latitude $\varphi = NP$, and Z the zenith. The dial plane is ZE(W). The sun \odot is at declination δ , positive north of the celestial equator. The shadow angle G on the dial from the noon line is identical to the angle between the sun and the meridian measured at the south point of the horizon, ZS \odot . The angle Z \odot is the zenith distance of the sun z whose tangent is the relative shadow length.

The problem is therefore to calculate z from a known value of G. The other known quantities are φ and δ . It does not appear possible to derive z directly and use must be made of auxiliary angles. B is the complement of the obtuse angle P \odot S to 180° and h is the hour angle ZP \odot .

$$B = \arcsin(\sin G \cdot \sin \varphi / \cos \delta)$$

$$h = \arctan(\cos \varphi \cdot \tan G) + \arctan(\sin \delta \cdot \tan B)$$

The zenith distance is found from:

$$z = \arccos(\sin \varphi \cdot \sin \delta + \cos \varphi \cdot \cos \delta \cdot \cos h)$$

and the relative shadow length L:

$$L = \tan z$$

Using the formulae and taking the input data from Drinkwater's diagram, $\varphi = 52^\circ$, $\delta = +23.5^\circ$ (not stated but measured from the diagram) and shadow angle 45° , the relative

shadow length is 1.056. From the diagram $VD/ED = 1.04$, a satisfactory correspondence in view of the complexity of the drawing and the small scale of the printed diagram.

Michael Lowne, East Sussex

The Ecclesiastical 'Scratch Dial' as a Serious Time-keeper

What a shame! What an enormous shame we had to wait some thirty years, a generation, for Peter Drinkwater's fascinating article (*BSS Bull.* 23(ii) 36-43).

Intellectually and artistically, scratch dials have neither traditionally nor naturally appealed to the majority of diallists. Yet the evidence is incontrovertible that they were used for over a millennium and are the earliest timekeeping artefacts to survive in abundance. Thus the scratch dial literature – both absolutely and relative to dialling generally – falls well short of the mark! As one labouring to level the scales it was a delight to read Peter's seminal contribution.

Peter's fundamental 'new' insight is to link scratch dials with Saxon and medieval calendrical/computus manuscripts; by showing shadow lengths therein relate to time as indicated by scratch dials – rather than the theoretically correct temporal hour. Clear corroboratory evidence, additional to their ubiquity, that scratch dials – whatever their apparent shortcomings to modern thinking – were used as serious timekeepers.

Several of Peter's (1980s) scratch dial suppositions were remarkably prescient. For example, their presumed extensive survival (now confirmed by the Mass Dial Register), their multiplicity per church, and continued use into the 17th century (both now confirmed statistically). He also argues persuasively that variability in the quality of clergy, and the not unrelated variability in their fastidiousness in discharging their ministration, accounts for the variability of both scratch dial delineation and quality.

Peter rightly enjoins us to interpret scratch dials within the broad sweep of timekeeping history. He sees their birth in the classical world; but their transmission to, or rediscovery in, western Europe remains to be explained. He links their demise to scientific dials and the mechanical clock: the details now increasingly being established by subsequent students. Missing is the water clock – a technology as ancient as sundials: also a technology as inherently 'equal hour' as the mechanical escapement, yet used in the temporal hour world, as indeed were the earliest mechanical

continues on p. 44

THE MARGARET STANIER MEMORIAL SUNDIAL: AN UNEQUAL-HOURS DIAL FOR NEWNHAM COLLEGE

Part 1. Some Design Considerations

FRANK H. KING

Unequal-hours sundials are rarely commissioned so there are very few modern dials whose sole gnomonic function is to indicate such hours. In this first part of a two-part article, it is shown that although one cannot indicate unequal hours precisely using a gnomon (as distinct from a nodus) one can indicate unequal hours to an acceptable approximation. In Part 2, the development of the design into a memorial to Margaret Stanier will be described.



Fig. 1. Margaret Stanier.

Genesis

Margaret Stanier, who is shown in Fig. 1 outside her home in Swaffham Prior, was the immediate past Editor of the *BSS Bulletin*. For many years she was a Fellow of Newnham College, Cambridge, and, following her death in 2007, the College invited me to design a sundial as a memorial.

Margaret had a particular interest in mass dials and I proposed a design that was loosely based on the only historic mass dial in Cambridge. This is on a south buttress of Little St Mary's Church and is shown in Fig. 2. The dial is featured in *Cambridge Sundials*,¹ the book which Margaret co-authored with Alexis Brooks. As usual, the gnomon is

missing but it is assumed that this would have been perpendicular to the plane of the dial.

Analysing the angles of the hour-lines on any particular mass dial tends to be unrewarding but the overall appearance of the Little St Mary's dial resembles that of the traditional design of unequal-hours dial illustrated schematically in Fig. 6 (below). This thinking led to the following outline specification for the proposed sundial:

- There would be a straight-rod gnomon.
- The hour-lines would radiate from close to the centre of the dial.
- The outer ends of the hour-lines would be bounded by a circle.
- The hour-lines would indicate unequal hours.

The intention is that the angle of the shadow of the gnomon should indicate unequal hours and this is asking for the impossible. The specification can be satisfied only at the equator.

There is no such problem if a nodus is used and one could, for example, use the tip of the gnomon as a surrogate nodus. This idea was rejected, in part because this is not how mass dials are generally understood to have functioned.



Fig. 2. Mass dial at Little St Mary's Church, Cambridge.



Fig. 3. The shadow of a nodus out of the field of play.

There is a more pragmatic reason for using a gnomon in preference to a nodus. When using a nodus there will always be times when the sun is shining on the dial but the shadow of the nodus is off the dial. In an early e-mail,² following the installation of the sundial at Selwyn College, the Master of the College noted that he had seen the shadow “about a foot to the left” of the dial itself. See Fig. 3. This is not a photograph that would fare well in a sundial photographic competition! The sun is shining brightly on the dial and is clearly casting shadows but the crucial shadow is out of the field of play. With a gnomon, provided only that the root of the gnomon is on the dial, this cannot happen.

Designing a gnomon-driven unequal-hours sundial is indeed impossible but the finished design is a close approximation to this unattainable goal. The reader may judge just how acceptable an approximation the result is.

The Celestial Sphere

The most direct way of visualising the daily passage of the sun across the sky is to draw sketches such as those in Figures 4 and 5. In both cases, the view may be imagined to be that captured by a camera with an extra-wide-angle lens. There is blue sky above verdant pasture with a clean horizon between.

The views extend from due east via due south to due west with a small black triangle on the horizon marking due south. The three circular arcs represent the path traced by the sun at the summer solstice (top arc), at the equinoxes (middle arc) and at the winter solstice (bottom arc). These arcs are appropriate for the latitude of Cambridge.

The rising sun is shown at the eastern ends of the equinoctial arc and the winter solstice arc. The setting sun is shown at the western ends. The sky represents part of the inside surface of the celestial sphere. No great claims are made for the projection used but it is quite helpful for sketching in different kinds of hour-lines.

In Fig. 4, hour-lines for common hours are shown from 6h to 18h and it is clear that, at the equinoxes, sunrise is at 06:00 and sunset is at 18:00. Likewise, at the winter solstice, sunrise is about 08:15 and sunset is about 15:45.

In Fig. 5, hour-lines for unequal hours are shown. These hour-lines divide the paths followed by the sun from sunrise to sunset into twelve equal parts. The one-twelfth divisions at the summer solstice are a little over twice as long, in time, as those at the winter solstice.

In Fig. 4, the equinoctial arc, the horizon and all the common hour-lines are great circles on the celestial sphere. With a gnomonic projection, great circles project into straight lines. Accordingly, the equinoctial line, the horizon line and the common hour-lines are all straight lines on an ordinary plane dial.

In Fig. 5, the equinoctial arc and the horizon are great circles but, of the hour-lines, only those for sunrise, midday and sunset are great circles. The sunrise and sunset hour-lines coincide with the horizon and the midday hour-line coincides with the common hour-line for noon. The other unequal hour-lines are not great circles or small circles. They are curious curves which, over the short lengths that run from the winter solstice arc to the summer solstice arc, are approximations to great circles.

In Fig. 4, the common hour-lines radiate from a point beneath the figure. This point is the south-celestial pole which is just over 52° below the horizon. This angle corresponds to the latitude of Cambridge. On a conventional sundial, this point projects into the root of the polar-oriented gnomon.

In Fig. 5, the unequal hour-lines, if extended, would converge on the triangular marker on the south horizon. This marker projects into the root of a horizontal gnomon.

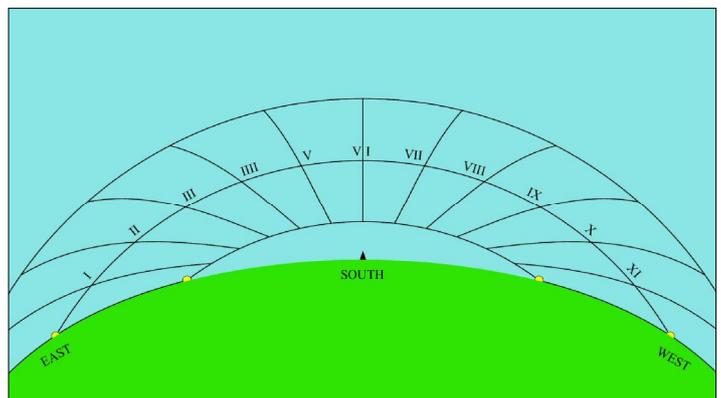
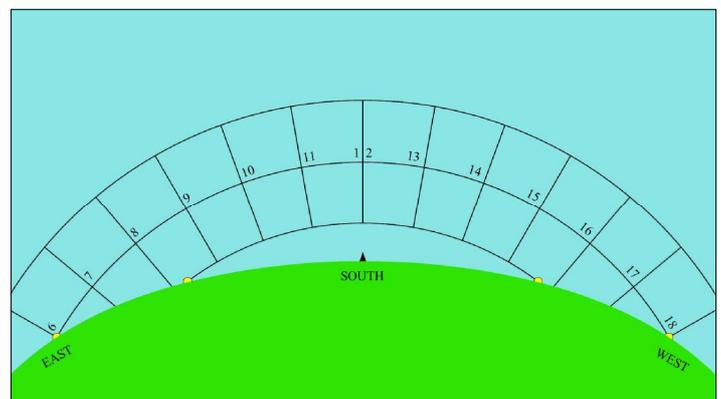


Fig. 4 (top). Equal hours on the celestial sphere.

Fig. 5 (bottom). Unequal hours on the celestial sphere.

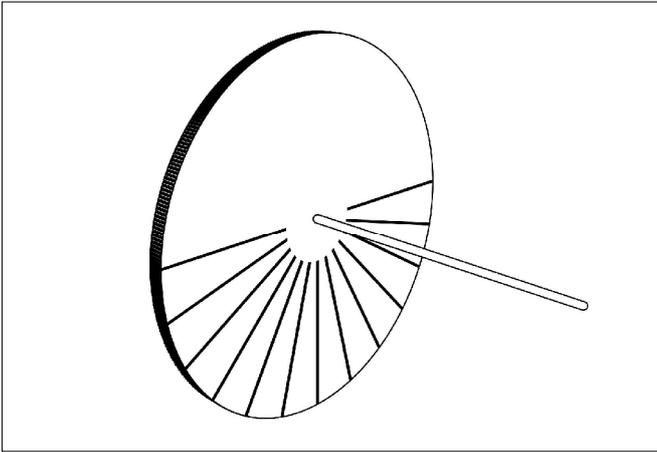


Fig. 6. Traditional design of an unequal-hours dial.

The Traditional Design of Unequal-Hours Dial

Fig. 6 shows the traditional design of unequal-hours dial implemented on a circular disc which is assumed to be vertical and direct south-facing. The 13 hour-lines run from sunrise (the horizontal line on the left) to sunset (the horizontal line on the right).

The gnomon is horizontal and aligned north–south. More pedantically, the gnomon lies at the intersection of a horizontal plane and the meridian plane. Accordingly, when the sun is on the horizon there is a horizontal shadow so the sunrise and sunset hour-lines are sound. When the sun crosses the meridian there is a vertical shadow so the mid-day hour-line is sound too.

The other hour-lines are naively placed at 15° intervals and unfortunately equal angular intervals don't translate into equal intervals of time. This design is therefore largely flawed but it is this design that I wanted to tweak so as to make it as gnomonically respectable as possible.

A Minimalist Unequal-Hours Dial

Fig. 7 shows the same dial with all the unsound hour-lines discarded but with an academic midnight hour-line added. Additionally, the gnomon is now shown extended through to the north side of the dial. This minimalist sundial divides the daylight period into two equal parts, morning and after-

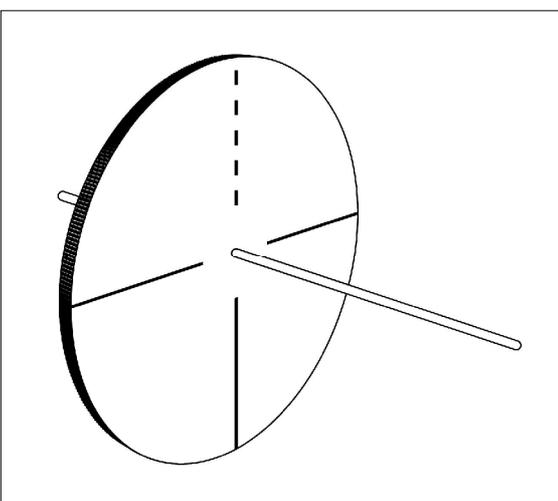


Fig. 7. Minimalist unequal-hours dial.

noon, and, in a theoretical way, divides the night into two equal parts too. This is close to being a universal design because it works at almost any latitude, at any time of year, and the dial can have almost any orientation. The only hard constraints are that the gnomon must be horizontal and aligned north–south.

There is one other detail that can be illustrated by considering what happens at sunrise. In winter, the sun rises to the south of due east so the shadow clearly falls on the sunrise hour-line. In summer, the sun rises to the north of due east and so shines on the north side of the dial. It is to attend to this difficulty that the gnomon is extended through to the north side. The shadow then still falls on the sunrise hour-line which is now imagined to run through the thickness of the dial. One may further imagine that the dial is made of some translucent material so that when the shadow falls on the north side it can be seen from the south side.

If one imagines the Earth itself to be translucent, then the midnight hour-line makes sense. In British latitudes the sun is always due north at midnight and below the horizon. The shadow of the north end of the gnomon will fall on the midnight hour-line.

In operation, the performance of this dial can readily be illustrated by imagining a time in high summer when, in the latitude of Cambridge, there are 16 common hours of day and 8 common hours of night.

At sunrise, the shadow falls on the sunrise hour-line. It then sweeps round the lower half of the dial at a very leisurely pace. It takes 16 hours to reach the sunset hour-line.

Then, continuing to imagine a translucent Earth, the shadow continues sweeping round the upper half of the dial but at a much faster pace, taking only 8 hours to get back to the sunrise hour-line.

The average speed of the sweeping shadow during the night is twice its average speed during the day. In the depths of winter it can be the other way round with the average speed during the night being half the average speed during the day. This changing of speed takes place continuously throughout the year quite automatically. No moving parts

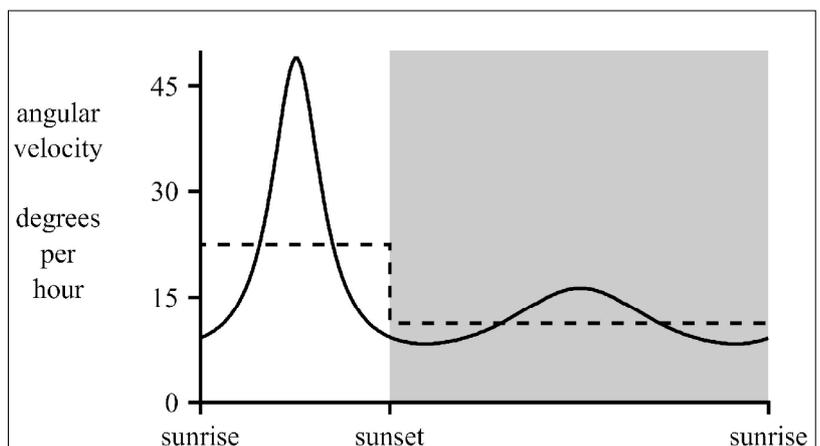


Fig. 8. Angular velocity versus time of day.

are required other than the Earth itself. To the uninitiated the simple geometry gives rise to an almost magical result.

Unfortunately, the speed of the sweeping shadow does not change instantaneously at sunrise and sunset. The speed changes throughout the day and night. Fig. 8 plots the angular velocity of the sweeping shadow (in degrees per hour) in the depths of winter. The plot starts at sunrise and, after sunset, the night time region is shown shaded.

If the sunrise and sunset labels are interchanged and the shaded region is shrunk and moved appropriately, the plot shows how the angular velocity changes in high summer.

The broken line in the plot shows the ideal profile. The angular velocity would be a constant $45/2$ degrees per hour during the day (eight common hours) and a constant $45/4$ degrees per hour during the night (sixteen common hours). There is evidence³ that some early verge and foliot clocks indicated unequal hours and followed this ideal profile. The clock-keeper had to move the weights on the foliot at sunrise and sunset each day.

It is the variability in the speed of the sweeping shadow that rules out having hour-lines at 15° intervals. Placing the intermediate hour-lines requires further analysis.

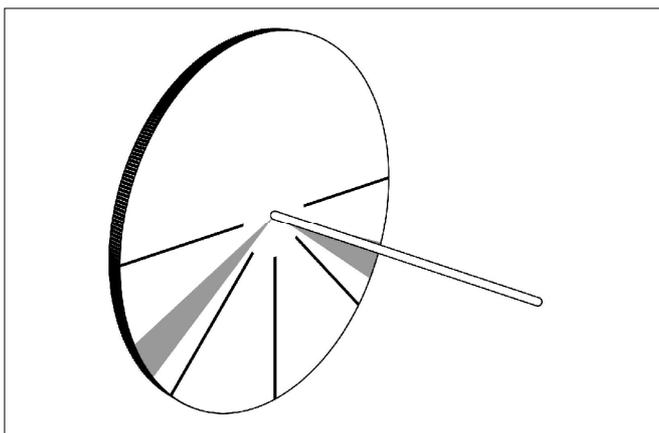


Fig. 9. Mid-morning and mid-afternoon errors.

Hour-lines for Mid-Morning and Mid-Afternoon

In the traditional design, the hour-lines for mid-morning and mid-afternoon are in the 45° positions, shown in Fig. 9 as the new heavy black lines.

The actual position of the shadow in mid-morning and mid-afternoon depends on the solar declination and the latitude and the orientation of the dial.

Assuming a vertical direct south-facing dial in the latitude of Cambridge, the ranges of directions in which the shadow can fall in mid-morning and mid-afternoon are shown in Fig. 9 as two grey regions each with an angular spread of about 12.6° . Interestingly, there is no time of year when the shadow in mid-morning or mid-afternoon falls on, or anywhere near, the 45° hour-lines.

The hour-lines can, of course, be shifted into the grey regions and placed, perhaps, at the mean angles of the shadows at the two times. They will be close to, but not coinci-

dent with, the centre-lines of the grey regions. Using the mean minimises the root-mean-square angular error.

Moving the hour-lines into the grey regions improves the accuracy but does nothing to improve the precision. That requires reducing the angular spread of the grey regions.

Improving the Precision

Short of moving nearer to the equator, there is no way of reducing the angular spread of the grey regions without incurring a cost: relaxing one of the hard constraints on the orientation of the gnomon.

Nothing is achieved by moving the gnomon out of the meridian plane but it is fruitful to consider the effect of dipping the gnomon slightly downwards towards the south.

Up to some critical angle of dip, this has the beneficial effect of reducing the angular spread of the grey regions but, beyond the critical angle, the spread increases again. Unfortunately, by moving the gnomon out of the horizontal plane, the directions of the shadows at sunrise and sunset will depend on the time of year.

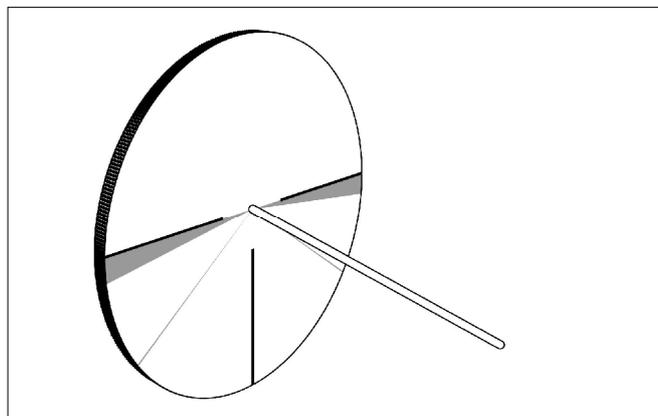


Fig. 10. Critical angle of dip.

The critical angle of dip depends on the latitude. It is 0° at the equator and increases to around 9.2° at 45° N after which it falls off again. In the latitude of Cambridge the angle is about 8.9° and Fig. 10 shows the consequences of dipping the gnomon by this critical angle. The angular spread of the mid-morning and mid-afternoon grey regions has been reduced to about 0.5° but new grey regions have been introduced at sunrise and at sunset. In calculating these regions, solar declinations for which the sun shines on the north side of the dial at sunrise and sunset have been ignored.

These new regions have an angular spread of about 7° and deciding whether or not it is worth incurring this cost is outside the realm of mathematics. To most people, sunrise and sunset are periods of time rather than instants and these new grey regions hint at this. On a more pragmatic note, in its intended site, the sundial does not get a clear view of the horizon in any direction so the gnomon will never cast a shadow at sunrise or sunset. Little is gained by worrying too much about these new grey regions.

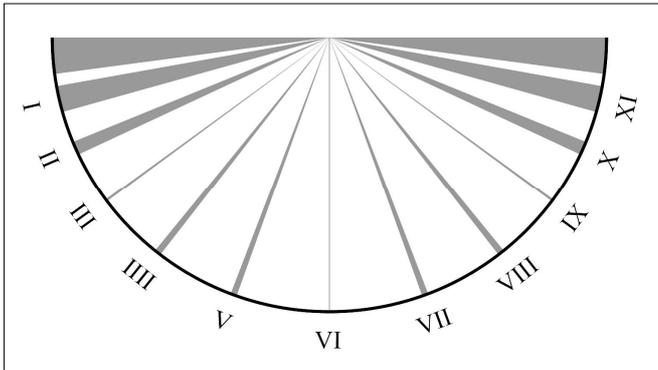
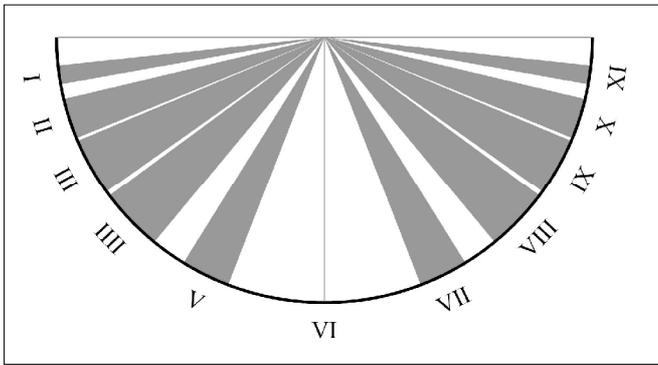


Fig. 11 (top). Errors with a horizontal gnomon.

Fig. 12 (bottom). Errors with a dipped gnomon.

The Other Intermediate Hour-Lines

Figs 11 and 12 show the grey regions associated with each of the 13 unequal-hours hour-lines in two different circumstances. In Fig. 11 the gnomon is horizontal and in Fig. 12 the gnomon is dipped at the critical angle.

The midday hour-line has zero angular spread in both cases because the gnomon is in the meridian plane. The sunrise and sunset hour-lines have zero angular spread provided that the gnomon is horizontal. This is true in Fig. 11 but not in Fig. 12. The differences between the two figures are stark. When the gnomon is horizontal, many grey regions are so wide that they are almost in contact with their neighbours. When the gnomon has the critical angle of dip, most of the grey regions are significantly narrower.

The grey regions for sunrise and sunset are unlabelled. The others are labelled I to XI. There is a case for labelling the 12 gaps instead. The gaps represent the hours whereas each hour-line represents the end of some hour. It was decided that labelling the gaps would have been a step too far for modern users!

The critical angle of dip minimises the angular spread of the grey regions associated with hour-lines III and IX. By inspection, it increases the angular spread at I and XI slightly, though much less than the increases at sunrise and sunset.

Some readers may consider backing off from the critical angle and deliberately degrading the improvement to hour-lines III and IX with a view to reducing the errors at I and IX. This thought was rejected on the grounds that hour-lines III and IX, as quarter-day markers, have particular importance.

On an historical note, hours III, VI and IX are nominally associated with the Christian offices of Terce, Sext and None which provides another reason for paying particular attention to the hour-lines which mark the ends of these hours.

The Celestial Sphere Revisited

The margins of the grey regions are all straight lines which radiate from a common centre. Viewed as a gnomonic projection, these straight lines are all mappings of great circles which radiate from a common point on the celestial sphere.

Fig. 13 is an augmented version of the celestial sphere as illustrated in Fig. 5. The black spot is the common point; it is 8.9° below the south horizon and maps onto the common centre in Fig. 12. The margins of the grey regions which envelop the (odd-numbered) hour-lines are great circles which radiate from the black spot. Subject to a caveat discussed in the next section, these margins map into the margins of the grey regions in Fig. 12.

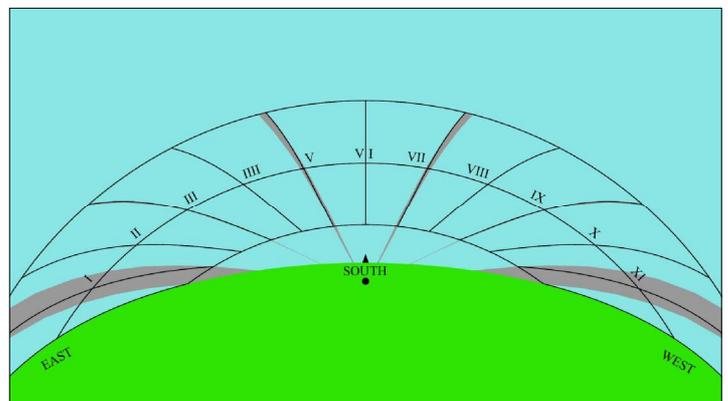


Fig. 13. Error regions mapped to the celestial sphere.

The hour-lines in Fig. 13 are shown as continuous curves but in any given (common) year the centre of the sun visits only 365 distinct points on each curve. There is a case for viewing each hour-line as 365 separate dots. The dots are much closer together near the ends of each hour-line than near the centre because the solar declination changes slowly at the solstices and rapidly at the equinoxes.

Using this view, each grey region is formed by drawing a great circle from the black spot through each of the 365 dots on the relevant hour-line on the celestial sphere. The

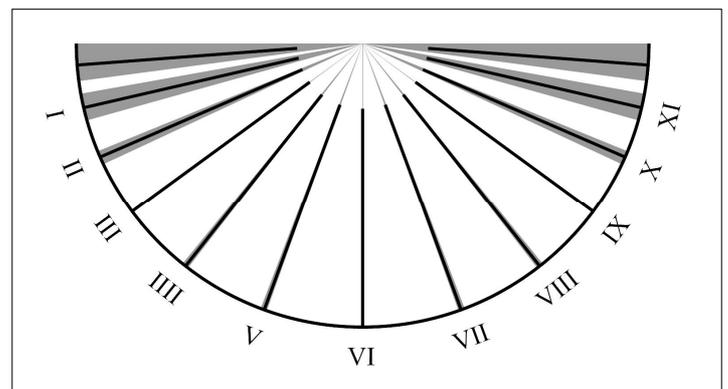


Fig. 14. Hour-lines and associated errors.

margins of each grey region are simply the two extreme cases.

The 365 great circles give rise to a mean great circle whose direction through the black spot is the mean of the 365 directions. This mean great circle maps onto the dial as a straight line and it is this which is used as the hour-line. The hour-lines which overlay the grey regions in Fig. 14 are the mappings of just such mean great circles.

Most of the extreme great circles run from the black spot to the dot at the winter solstice end of the relevant hour-line or from the black spot to the dot at the summer solstice end.

It is now clear that the position of the black spot is where the great circle that best approximates hour-line III intersects the meridian. By symmetry, the great circle that best approximates hour-line IX intersects the meridian at the same point.

It is also clear from Fig. 13 that the grey regions for hour-lines I and XI could be narrowed by raising the black spot and the grey regions for hour-lines V and VII could be narrowed by lowering the black spot. The chosen position is a compromise.

Raising the black spot to the horizon, to the triangular marker, corresponds to having a horizontal gnomon. The grey regions for sunrise, midday and sunset narrow to zero but the grey regions for most other hour-lines broaden.

Fig. 13 purports to represent the celestial sphere and is independent of the orientation of the plane of the dial. Different orientations of the dial alter the appearance of the gnomonic projection but, subject to the caveat below, make no difference to the errors. They can be changed only by altering the angle of dip.

Caveat

For certain hour-lines, some dots correspond to positions of the sun where it shines on the wrong side of the dial. It is unnecessary to draw great circles from the black spot through such otiose dots. Accordingly, a particular grey region may be formed from fewer than 365 great circles.

Although ignoring otiose dots reduces the angular spread of a grey region there can be circumstances where this may not be appropriate. The two dials of a dial-pair may have different orientations and, for a given hour-line, the otiose dots may be different for the different dials. This leads to different mean great circles being chosen for mapping into the hour-lines on the dials and the different dials may indicate slightly different times!

With a single dial, as in the present case, this problem does not arise. In Fig. 13 the lower margins of grey regions I and XI run to the summer solstice ends of hour-line I and XI. These ends are beyond due east and due west respectively and therefore behind a dial that is direct south-facing. By ignoring points beyond due east or due west, the lower margins of grey regions I and XI are raised a little and it is the revised margins that are used when mapping into Figures 12 and 14.

For a horizontal dial, Fig. 13 applies without any such modification. For a dial in any other orientation, it is expedient to augment the figure by adding the great circle that corresponds to the plane of the dial. Any dots on the hour-lines outside this plane are ignored.

Outline Design

Fig. 14 shows 13 hour-lines, each with an associated grey region. The margins of the grey regions show the maximum errors associated with each hour-line. The actual errors on a given day will usually be considerably smaller. If the margins had reflected the root-mean-square errors, the grey regions would be thinner.

As a design for an unequal-hours dial, this has high accuracy and acceptable precision, with particularly high precision at III, VI and IX.

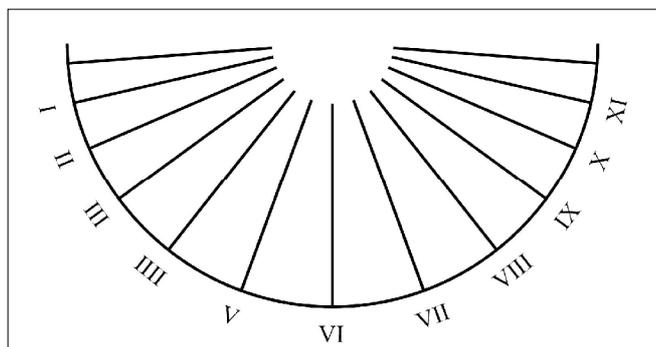


Fig. 15. Embryonic design.

Fig. 15 is identical to Fig. 14 but with the grey regions removed. This, at last, is an outline design for an unequal-hours sundial on a direct south-facing wall at the latitude of Cambridge. It is presented as a summary of the underlying mathematics and is decidedly lacking aesthetic merit – considerable further work is required to turn this design into a crowd-puller. That work was largely undertaken by Annika Larsson, who runs Inscriptorum,⁴ a noted Swedish design workshop. Her work will be the subject of Part 2.

ACKNOWLEDGEMENTS

The black spot in Fig. 13 is placed where the great circle that is the best approximation to hour-line III (or IX) on the celestial sphere intersects the meridian. The term ‘best approximation’ has not been specified.

A naive way to approximate each hour-line by a great circle is to choose the great circle that passes through the two end points (the summer solstice end and the winter solstice end). This great circle also passes through the equinoctial point and is a good candidate for the great circle of best fit.

In some early trials, this naive great circle for hour-line III was used to determine the position of the black spot. The results were reported on the Sundial Mailing List in a thread entitled *Another Dial and a Puzzle*.⁵ Geoff Thurston⁶ responded by suggesting that there might be a better approximation and he was right. Using the naive great circle

leads to an angle of dip of 8.6° and, on the dial, the angular spread of the grey regions for hour-lines III and IX is 0.60° . By dipping the gnomon to 8.9° the angular spread reduces to 0.49° . Thanks are therefore due to Geoff Thurston for prompting further exploration.

Thanks are also due to the noted Italian gnomonista, Gianni Ferrari, who commented⁷ that “these lines don’t have a great gnomonic meaning even if they have a mathematical one”. This comment prompted much careful checking.

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READERS’ LETTERS

continued from p.37

clocks. But these are quibbles taking us beyond the strict confines of dialling.

It can only be hoped that any other related or more detailed scholarship will be published sooner rather than later.

Chris Williams, Kent

Peter Drinkwater responds:

In his penultimate paragraph, Mr Williams raises the issue of the ‘transmission’ of scratch-dial technology from the classical world to Western Europe. Surely I have addressed this point already: the scratch dial was taken up by the church in classical times and, enforced by papal decree, became part of normal church practice, being taken by the church wherever it went. I wonder if it lasted long enough to be taken to the outposts of the burgeoning Spanish and Portuguese empires in the 16th century?

He also raises the position of the water clock. My understanding has always been that the water clock was primarily a timer, rather than a time-keeper, being of particular use in astronomical observations (its use for this purpose is on record) where Æquinoxial hours (the hours of right ascension) were the normal standard. They certainly appear on the astrolabe for this purpose, not for timekeeping. Some classical dials also contain an arrangement by which the varying length of the day could be measured in terms of Æquinoxial hours – but these hours do not appear as time-telling ones on any classical dial that I know of. See Sharon Gibbs for an extensive catalogue.

BSS Conference Venues

I wish to congratulate the Editor for including the list of Conferences and Somerville lecturers in the latest *Bulletin*; it brought back many pleasant memories of the time when I was General Secretary. However, historians like diallists tend to be picky about accuracy so I would appreciate the amendment of a minor error which has crept in to the

list. The 1992 Annual Somerville lecture was indeed given by Sir Francis Graham-Smith but at Bath not Cambridge. There was a very successful conference at Cambridge the previous year but this was a combined BSS and Zonnewijzerkring (Dutch Society) conference organised by Mr and Mrs Cowham. It was on this occasion that I organised and chaired the very first Scratch (Mass) Dial meeting, attended by some 13 members.

David Young, Essex

A Fathers Day Present

Peter Ransom

This year I was delighted to receive a copy of *The Book of Sun Dials* by Mrs Alfred Gatty from my younger daughter. She had acquired it for a single digit number of pounds off the internet. She knew I had a copy of the 4th edition (1900) by Eden & Lloyd, but was unaware that I also have a copy of the other three editions. This does not matter to me however since although the present was the first edition of 1872 it is very different from my other copy!

Top: The two copies of the 1872 edition side by side.

Bottom: The slight difference in the spines is the way the publishers are shown.



My copy has a green cover and this has a blue cover. Although the gold dial on the front is the same, the black tooling is quite different and the spines also vary.

I now wonder how many variations there are of the first edition – does it appear in red for example? Any information would be much appreciated.



A HORIZONTAL QUADRANT OF 1658 BY HENRY SUTTON

Part 2

MICHAEL LOWNE and JOHN DAVIS

Part 1 of this article was published in *BSS Bull.* 23(ii), 8-14 (June 2011).

The Matched Sine and Tangent Scales (Scale I)

Collins says he added this scale himself, presumably in addition to those on Gunter's sector. In spherical triangles of which one side is 90° (quadrantal triangles) the formula $-\cos C = \cot a \cdot \cot b$, where c is the 90° side and a, b the other sides, will find C , the angle opposite c . As engraved on the quadrant the scales are drawn for the complements of the sides and angle, becoming:

$$-\sin(C-90) = \tan(90-a) \cdot \tan(90-b).$$

This is convenient, as in many of the problems the sides represent values which are the complements of astronomical arcs, which can then be used directly. One side is taken to be the co-latitude $(90-\phi)$ and the other $(90-\theta)$ where θ is an arc to be read or derived from the quadrant. The tangent scale is calculated from $\tan\phi \tan\theta$, so that the scale value matching 1.0 on the sine scale is $(90-\phi)$. In fact the scales are not complete: the values run $38.5-0-76^\circ$ for the sine scale and $26.4-0-37.75^\circ$ for the tangents. To use the device, the value on the sine scale adjacent to that of θ on the tangent scale is the complement of the angle opposite to the 90° side.

A simplified drawing of part of the scale is given in Fig. 9, showing two examples of its use. The red arrow relates to finding the time of sunrise or sunset (the zenith distance of the sun is 90°). It is set to a declination of 21° on the tangent line which reads 29° on the sine scale. This is equivalent to $1^h 56^m$ in time and is called the 'ascensional difference', the time interval between sunrise or sunset and 6 am or 6 pm. Again, it is necessary for the user to supply the sign of the declination, and the actual times are 4:04 am and 7:56 pm for north declinations, and 7:56 am and 4:04 pm for southern. Another use is shown by the blue arrow, using the sun's altitude to find the azimuth from east or west when the sun is on the celestial equator at declination 0° , a north polar distance 90° . The arrow at 29° reads 44° on the sine scale: as the azimuth must be south of the east-west direction it is 46° east or west of south.

Collins makes use of these scales in conjunction with others to find angles relevant to a vertical declining sundial for the latitude of London: the substyle angle from noon, the style

height, the longitude difference and the angle of the 6 am or 6 pm hour line from noon. They will however not derive angles for intermediate hour lines. It is also possible from other scales to find the same quantities for direct east or west reclining dials.

Instructions are given for using these scales with others to solve different problems, in complicated ways involving the use of dividers to transfer values from one scale to another, sometimes doubling or halving them, or taking perpendicular distances to the cord from a scale. These instructions are mostly obscure: a typical sentence has about 200 words with no punctuation apart from five or six commas! It does not appear that any of these functions cannot be done (probably more simply) on the stereographic projection. Throughout the book examples of use are given with results that agree with the true values to a minute of arc. This is more accurate than could be obtained from most of the quadrant scales, leading to a strong suspicion that the answers were calculated.

The Star Positions

Twenty-two stars (lettered a-z omitting i, u, w and y) are listed in scale 18 on the reverse side, with the declination of each. By stretching the cord through a small symbol by each entry, the star's right ascension can be determined from the adjacent hour scale. This scale runs $0-12^h$ and those stars in the range $12-24^h$ are identified by a + sign, implying 12^h is to be added to the derived value. Two columns of hours and minutes are labelled *occasu stel* and *ortus stel*, with values entered as 0-0 for five circumpolar stars. Collins described these values as the "ascensional differences", defined as the interval between the times of rising or setting and an hour-angle of 6 hours east or west of the meridian, but the engraved times do not correspond to this. In terms of elapsed time *occasu stel* represents the time interval at setting since upper meridian transit and *ortus stel* the interval at rising since lower transit. Seven of those stars whose declinations fall within the tropics are plotted on the stereographic projection and identified by their letters, at the appropriate declination and on the time scale by an angle from the right edge which is given by the expression $\arcsin\{\sin(\text{meridian altitude}) \text{ minus } \sin(\text{altitude at } 6^h \text{ hour angle})\}$. For stars of southern declination which are below the horizon at 6^h hour-angle, the depression is accounted as a negative altitude. Collins implies that all stars falling within the tropics are plotted but this appears not to be the case. Five stars of

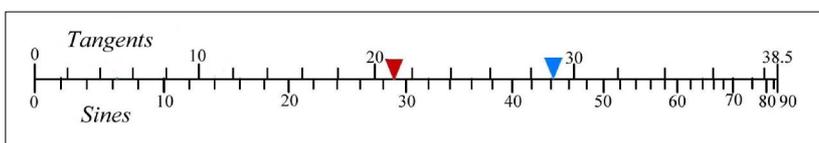


Fig. 9. Use of the matched sine-tangent scale.

northern declination are beyond the tropic of Cancer and cannot be plotted in this way: their angles derived from the expression are plotted between scales d and e. Two stars with southern declinations beyond the tropic of Capricorn and the circumpolar stars are not plotted at all. The book gives a list of 54 stars including all those on the quadrant, with their right ascensions, declinations and magnitudes.

The principal use of the star positions is for time-finding at night. For this, the star's altitude is measured, the bead set to this on scale g and moved round until it rests on the star's declination. The relationship is

$$\text{Local solar time} = (\text{RA}_{\text{star}}) \text{ minus } (\text{RA}_{\text{sun}} \pm 12^{\text{h}}) \text{ plus } (\text{hour-angle}_{\text{star}})$$

The full procedure has been given.⁴ The book refers to another work by Collins⁶ giving this method, but provides a complicated and probably error-prone alternative.

The Calendar Tables

The table on the reverse gives the week-day of March 1 for the years from 1657 to 1701 in the Julian calendar and indicates, by the appropriate week-day planetary symbols, on which day February 29 falls in leap years. The table on the fore-side provides for each month the dates which fall on the same week-day as March 1, enabling the full year's calendar to be deduced. The year is taken to start on March 1, so that January and February are part of the preceding year.

The table on the reverse also gives the epact for each year, a device for finding the age of the moon for any day. Collins' rule for this is to add the epact, the date and the number of months since March 1, March and the current month inclusive. If the sum exceeds 30, subtract multiples of 30 days. The moon's age so found should be correct to within a day or two, and a rule is given to find the approximate time at which the moon is due south. Multiply the age by four and divide by five: the quotient is hours and the remaining units each represent twelve minutes. The times so found are the same as those of the panel on the well-known Cambridge Queens' College sundial. The use made of this in the book is in a table to find the times of high water at various British and Continental ports, by adding the tabulated hours and minutes to the meridian transit time. For various reasons, such as errors in the derived moon's age and transit times, and the actual high water being the resultant of the tides raised by the moon and the sun, this can only be a very approximate guide.

The Shadows and Quadrats

These scales (d) represent the tangents of angles on the altitude scale (b). They can determine the vertical heights of buildings or other object from the elevation as measured with the sights and altitude scale, at a known distance from the building base. The shadow scale provides tangents of elevations greater than 45° and runs from 1 at 45° to a maximum value of 20 for about 87° elevation. Heights for elevations less than 45° use the quadrat scale but it is necessary to transfer the elevation reading to the other side of the altitude scale using the reversed calibration. The quadrat

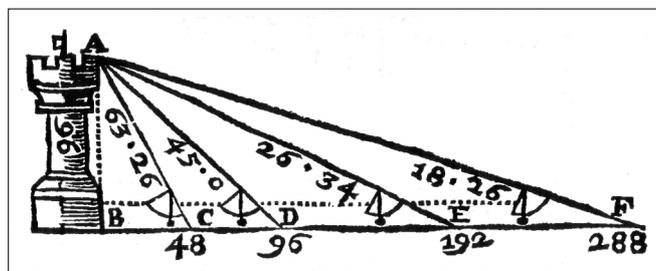


Fig. 10. The height of a tower by shadows and quadrats.

scale then shows tangents in the range 0-1 but is calibrated ten times greater to avoid the use of decimals. In either case the plumb-bob cord shows on the scale the tangent factor to multiply by the base distance to obtain the building height above eye level.

Collins gives only brief details of these in the book and refers to the instructions printed in the other work.⁶ One of the dimensioned diagrams from this is reproduced in Fig. 10. The tower height above eye level (the dotted line) is AB and four base distances are shown, C, D, E, and F with the elevations in degrees and minutes. These are carefully arranged to indicate tangents of 2, 1, 1/2 and 1/3, but to work in this way would require the fixed elevation to be measured first and then determine the base distance. Collins describes the dimensions as representing yards but there cannot be many towers 96 yards high!

It is also possible to find the height of an object whose base is inaccessible by measures at two points on the base line, as D and F. The height is given by the distance between the points divided by the difference between the cotangents of the elevations.

The Uses of Other Scales

A few of the other scales on the reverse side may be mentioned. Scale 15 ("the line of metals and equated bodies") carries the alchemical planetary symbols for the seven metals: tin (Jupiter), silver (Luna), quicksilver (Mercury), lead (Saturn), copper (Venus), iron (Mars) and gold (Sol). Perhaps unsurprisingly, this is one of the scales where Collins does not explain the use. For some others he gives only brief details, dismissing them as "meere toys".

Scale 17 ("the line of inscribed bodies") is intended to derive the lengths of the edges of the five Platonic solids (tetrahedron, cube, octahedron, dodecahedron and icosahedron), inscribed in a sphere of given radius. Unfortunately Collins appears to have made a mistake in the explanation of the use of this, missing out a step and making the results meaningless.

BIOGRAPHIES

The three men mentioned in this article, John Collins, Michael Dary and Henry Sutton, were part of a lively mathematical community in mid-17th-century London.

Michael Collins (1626-1683) can be described as the ring-master of this group, acting as a postmaster for the various members and distributing news and letters amongst them. Despite his lowly upbringing as the son of a nonconformist

minister, he eventually became an FRS, helping the secretary Henry Oldenburg on mathematical matters: he is listed in the New Oxford Dictionary of National Biography.⁷ He made his living in a number of administrative and accounting posts in London: an early role was as junior clerk to John Marr, clerk of the kitchen for the future Charles II and designer of sophisticated sundials. It is likely that this is where Collins initially learned his mathematics, complemented by learning navigation whilst on an English merchant ship during the period 1642-9. Afterwards, he earned his living as an accountant and teacher of mathematics until, after the Restoration, he gained a post in the Excise Office. His lack of capital prevented him realizing his intention to set up a stationer's shop and printing books, though his connections with printing allowed him to push several important works to publication, including works by Isaac Barrow and John Wallis and, posthumously, Jeremiah Horrocks.

Collins was able to act as an intermediary between the professional mathematicians of the age, such as Isaac Newton (whom he had a large correspondence, now mainly in the Cambridge University Library), Huygens, Leibnitz and Isaac Barrow, and the many mathematical practitioners and amateurs such as Michael Dary. In his own right, he was a capable geometrician able to describe techniques and instruments but not someone who was particularly creative. His most famous publication was *The Sector on a quadrant...*⁵ which was described in the record books of the Stationers' Company on 22 Sept 1657:

Entered under the hand of Master Lee warden a booke entituled: The sector on a quadrant, or a check to calculation, being a treatise containing the description & use of two quadrants, the one a quarter, of Stoffers projection, the other a quarter of the horizontall projection, both inverted, wth all ye sector lynes put on in circles & lines of versed sines, tangents, secants &c, so put on also with a curved lyne and fitted scales thereto for more ease in finding the houre & Azimuth in one latitude. And the serpentine lines in five turnes & two turnes with other mathematicall instruments. Written by John Collins, student in the mathematiques etc. Published by Henry Sutton.

It is possible that the warden 'Master Lee' who recorded this deposition was actually the Phillip Lea who advertised paper imprints of various instruments.⁹

Michael Dary (1613-79) is a rather obscure figure who described himself as a philomath and, despite being the older man, can be considered as one of Collins's protégés. One of his early works was *Dary's Diarie* (1649)⁸ which included the description of a quadrant. This contained a print of the instrument which could be cut out and pasted on a board or was sold separately by Phillip Lea.⁹ Only one copy of this book is known still to exist, in Christ Church Oxford, and its quadrant print is indeed replaced by a handwritten message:

"I have Taken away ye Quadrant or rather I should say ye whole Figure which heere was inserted ; and Pasted it on a Boarde. G.F."

In a 1919 catalogue describing this book, Florian Cajori has written underneath this quote "It was a Sutton's quadrant" but this is wrong: from the description in the text, it is clear that it was a form of Samuel Foster's quadrant – Sutton's had not been invented at that time.

Dary was initially a gauger in Bristol. Later, he was in London and a failed candidate for the mastership of the mathematical school at Christ's Hospital. Aubrey's *Brief Lives* has:

"Michael Dary, mathematician, and a gunner of the Tower (by profession, a tobacco-cutter), an admirable algebraician, was buried in the churchyard near Bethlem on May-day 1679. With writing in the frostie weather his fingers rotted and gangraened. He was an old man ; I guesse about 66+."

Dary's later books – never very well read – were typically on accountancy topics such as compound interest. He had a correspondence with John Pell and also, in 1674, with Isaac Newton writing, for example "Although I sent you three papers yesterday, I cannot refrain from sending you this. I have had fresh thoughts this morning." Not surprisingly, Newton was less than happy with the volume of correspondence.

Henry Sutton (c. 1624-1665) was an instrument maker by profession but his mathematical abilities were well above those of his fellow instrument makers. He was one of the most talented artisans of the 17th century. In 1758, long after his death, Edmund Stone paid him the following praise:

"Mr Sutton's Quadrants, made above one hundred Years ago, are the finest divided Instruments in the World; and the Regularity and Exactness of the vast Number of Circles drawn upon them is highly delightful to behold."

Details of his life are sparse but have been summarised as follows:¹⁰ He was apprenticed to Thomas Brown(e) in the Joiners' Company, being bound in 1638. He married twice and died of plague, a fact which "troubled" Robert Moray in a letter he wrote to the Secretary of the Royal Society, Henry Oldenburg. Many of his instruments carry the names of his collaborators and customers. For example, a dialling scale on a Sutton instrument features the name Euclid Speidell, a London-based mathematics teacher. Sutton was also associated with Sir Samuel Moreland for whom he made parts of his calculating machine and who invented a form of perpetual calendar which appeared on several of Sutton's instruments.

His place of work and the range of his stock can be determined from the following advertisement, which is written on this quadrant dated 1658:

"*This Instrument or any of the Mathematiques are made in Brass or Wood by Henry Sutton Instrument maker behind the royall exchange*".

The Royal Exchange, which is now a shopping complex, was a major landmark in mid 17th century London, having been built in the 1560s as a centre for merchants and tradesmen to do business. Sutton's shop on Threadneedle Street behind the Exchange would have been an important location for mathematical practitioners; not only did he make and sell instruments, he also collaborated on their design and sold mathematical books.

Sutton was a prolific instrument maker who is best known today for the eponymous Sutton's quadrant featuring a 'southern astrolabe projection', another variant of the stereographic projection. This was first described by Collins in *The Sector on a Quadrant*...⁶ a year after the horizontal quadrant of this paper. It was really invented by the mathematician Thomas Harvey, another of the group of London amateur mathematicians, but Sutton was sufficiently competent to work out its details himself from a basic description.

Sutton's position as a bookseller as well as a printing plate engraver and instrument maker led him to develop the technique of making counterproofs of his instruments; that is, accurate paper versions of engraved brass instruments. Although this technique of 'print-from-print' to reverse the mirror image of a first impression had been known before, it was Sutton who seems to have developed it into a commercial business in its own right.

Conclusion

It is perhaps surprising that the quadrant described in this article is the only known example of the instrument, as it is formed from paper prints mounted on wood and one might expect other copies to be in existence, even if unmounted. It could possibly be a counterproof from an engraved metal quadrant, now lost.

Never very popular, the use of horizontal quadrants as portable timekeepers was probably declining by the time this instrument was made. Pocket watches, although unreliable, were easier to carry, available at any time independently of sunshine and could be set to time from a sundial or good pendulum clock. Possibly if Dary's curve had been described earlier it might have been produced as an instrument in its own right, combined with a quadrant to measure the altitude and a table of solar declinations. Such a device might have been simpler to delineate than a stereographic projection and quite as convenient to use.

ACKNOWLEDGEMENTS

Sutton's quadrant is now in the Oxford Museum for the History of Science and we are grateful to the museum authorities for giving permission to examine and photograph the instrument. Janet McMullin of the Christ Church, Oxford, library kindly provided images of *Dary's Diarie*.

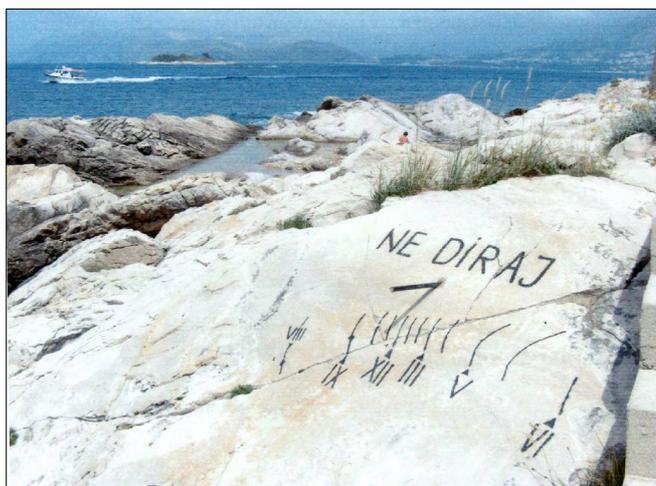
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For pictures and CVs of the authors, see Pt. 1.

Holiday Sightings



A holiday scene from a beach! This one is in Cavtat, Croatia, and the dial could technically be described as a declining, reclining one. Given that the shadow of the gnomon does not lie along the hour lines, it seems likely that the dial uses the tip of the gnomon as a nodus and the lines may have been drawn empirically. The motto translates literally as 'Do not touch'!

Photo from Mike North (brother of the late Prof John North) courtesy Tony Wood.

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