BSS Bulletin 19(i)

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March 2007

GUIDELINES FOR CONTRIBUTORS

1. The editor welcomes contributions to the *Bulletin* on the subject of sundials and gnomonics; and, by extension, of sun calendars, sun compasses and sun cannons. Contributions may be articles, photographs, drawings, designs, poems, stories, comments, notes, reports, reviews. Material which has already been published elsewhere in the English language, or which has been submitted for publication, will not normally be accepted. Articles may vary in length, but text should not usually exceed 4500 words.
2. Format: The preferred format for text is MS Word or text files sent by email to *john.davis@btinternet.com*. Material can also be sent on CD or as a single-sided typescript, single- or double-spaced, A4 paper.
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4. Mathematics: symbols used for the common dialling parameters should follow the conventions given in the appendix section of the *BSS Glossary* (available online on the Society's website). Consult the editor if in doubt or for help in laying out equations.
5. The *Bulletin* does not use footnotes. Where additional information is required, notes should be numbered as a Reference with a superscript number. For very long notes, use an appendix.
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   Examples:

   A.E. Waugh: *Sundials, their theory and construction.* Dover, New York, (1973).
   D. Colchester: 'A Polarized Light Sundial', *Bull BSS,* **96.2**, 13-15 (1996)
   A.A. Mills: 'Seasonal Hour Sundials', *Antiquarian Horol.* **19**, 142-170 (1990)
   W.S. Maddux: 'The Meridian on the Shortest Day', *NASS Compendium,* <u>4</u>, 23-27 (1997).

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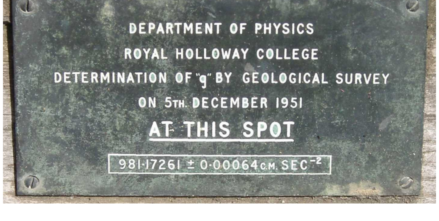
Front cover: *The polar dial at Royal Holloway College, Egham as seen during our 2005 Conference. The dial is dedicated to Victor Little, Reader in Physics at RHC, 1965 - 1976. Below it is a plaque (shown right) to commemorate the determination of the acceleration due to gravity, g, there in 1951. Photo: Mike Cowham.*



Back cover: *A semi-circular mass dial with radial lines at St Martin, Barcheston, Warwickshire, photographed in morning sun. It is one of four mass dials here and probably the most recent. As it declines roughly 15° east, any noon line will appear in the right side quadrant. It seems that a principal mass line is also (unusually) in the right quadrant. The initials are thought to be unrelated to the dial. Photo: John Lester.*

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BULLETIN
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EDITORIAL

New Author Award 2006

I'm delighted to announce that the first BSS New Author Award has been won by Geoffrey Lane for his paper 'Glass Sundials of 17th Century London', (18(i) pp. 40-47, March 2006). The paper was chosen unanimously by the three judges who noted that it had wide appeal and significant new information, was easy to read and had excellent illustrations. Geoffrey is not only a new (to the Bulletin) author but also a recent recruit to the Society so his paper should provide encouragement to all. His prize is a replica portable dial and a certificate.

The winner Geoffrey Lane inspecting the 1649 stained glass dial in Bucklebury church near Newbury, Berks.

Three papers shared the runner-up spot, being put in different orders by the judges. They were from Aleksanda Boldyrev, Ian Butson and Kevin Karney. There were 12 eligible papers from 11 authors (one author produced two papers within the year). This represents a good selection in a single year. For next year, of course, these authors will no longer be eligible so the rest of the members (and outsiders) have a chance—get writing!

Readers will notice that there are no colour pages in this issue. This is due to unforseen circumstances but fear not, a double dose is planned for the next issue in compensation.

DERBYSHIRE SUN DIALS

MAXWELL CRAVEN

[The author of this article, Maxwell Craven MBE, FSA, AMA, former Keeper of Antiquities at Derby Museum, is not a BSS member but is an horological expert and historian, having published books on Derbyshire clockmakers. He writes regularly for the Bygones supplement of his local newspaper: this article has been adapted from one of his contributions there. Many, though by no means all, of the dials mentioned are in the BSS Register 2005*. Serial numbers (SRN) or NIR (not in Register) have been shown where appropriate. Ed.]*

I suppose that the best known sundial in Derbyshire is that erected over the porch at Eyam parish church, a highly sophisticated piece of eighteenth century refinement of a very ancient method of reckoning the time. Whilst use of shadows to tell the time goes back into the mists of antiquity, the earliest sundial in this country is thought to be one in the museum at Chesters on Hadrian's wall, a stone with scratched gradations on it intended to be read by inserting a staff or similar – called a style – into a hole placed where the angled divisions seem to converge. This artefact was recovered a very long time ago from the Roman site at Housesteads, also on the Wall. Because of this, its precise find-spot and stratification are obscure, but it is assumed to be of Roman origin.

Fig. 1. The dial on St Wilfrid's church, West Hallam.

The habit of scratching a crude dial on a vertical surface seems to have continued, although it is on the exterior walls of medieval churches that the earliest specimens are found in this county. They are so simple that they are impossible to date stylistically, although the one at Upper Langwith church is inside the (south) porch, and thus clearly predates the erection of that structure in the earlier 14th century.[1]

There are a good few of these scratch dials in Derbyshire, all on parish churches:[2] Alsop-en-le-Dale (2), Bradbourne (on the exterior of a porch of later 15th century date), Brailsford[3], Clowne, Croxall (now in Staffs; 2), Horsley (2), Keldeston, Upper Langwith, Mackworth (4, one, quite late, with a cheerful inscription beneath it: "UT HORA SIC FUGIT VITA HOMINIS 162[ ]", roughly *Thus fly the hours like the life of man*), Marston Montgomery, North Wingfield, Pentrich, Repton, Spondon (3), Stanton-by-Dale, Steetley chapel (2), Taddington and Whitwell. When churches were lime-washed over in white or light shades in medieval times, there is also evidence to suggest that painted scales were used, most traces of which eventually vanished along with the covering, hence not every church has a visible scratch dial.

Fig. 2. The vertical dial, possibly a modern replacement, at Chapel-en-le-Frith.

The dial on the parish church was probably the only indication people had in those days of time bar their own observations of the position of the sun, and this situation persisted for ordinary folk right into the 18th century, long after the local lord had acquired a table clock or similar mechanical method of telling the time.

Yet the lord, as patron, more often than not, of the church, frequently took steps to replace the old scratch dial with a wall sundial with a permanent register and gnomon. These may be seen at St Wilfrid, West Hallam (SRN2833, Fig. 1), a fine but extremely simple one at Chapel-en-le-Frith (SRN3485, Fig. 2) and quite a late one with a round dial at Edlaston (SRN5237, Fig. 3) – nor are these the only ones in the county.

The finest anonymous example is on the church at Kedleston (SRN0624, Fig. 4), set in a baroque aedicule at eaves level, with "WEE SHALL" over the dial (We shall die all). It is also unusual in that it is set on the east wall of the church and thus reads, not radially, but in graduated parallel lines, the shadow being cast by a gnomon or style itself

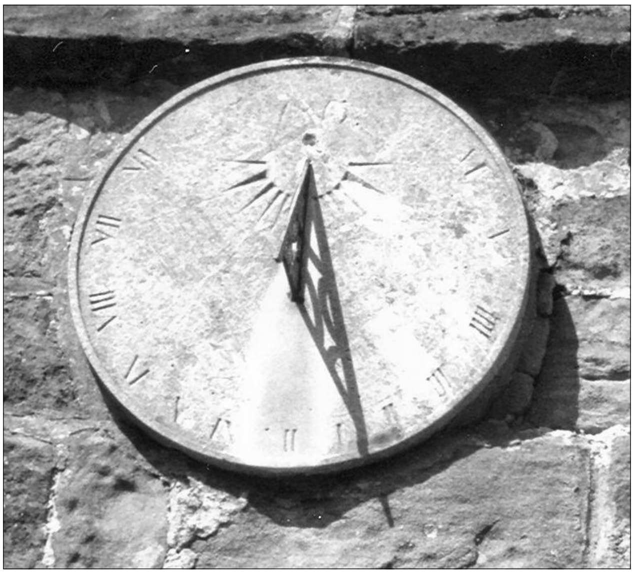


Fig. 3. (Top left). The vertical church dial at Edlaston

Fig. 4 (Bottom left). The fine direct east dial at Kedleston. Photo: BSS Register.

Fig. 5. (Left). Cube dial and sphere on the roof of a house in Codnor

almost parallel to the dial and raised on a pair of dainty metal brackets. Because of this, only the hours six to ten are shown. The traditional explanation of its position is that it was put up for the benefit of the hall staff, whose quarters in the previous house looked out onto the church at this point. This previous house was built from 1700 to the designs of Francis Smith of Warwick, who may also have been responsible for the delightful aedicule in which it is set.[4]

Dials were also erected on buildings and in public places. Whilst several country houses had dials set on them, there are some on humbler abodes. There is, for instance, a farm near Brailsford – appropriately named Sundial Farm – which boasts another one of baroque type, set angled to the sun on a SW facing end wall of a barn below the dovecote (NIR). Its curly pediment suggests that it may well have started off somewhere else rather grander.

Another example (SRN5838, Fig. 5) graced the roof of the Stonehouse, 37, Nottingham Road, Codnor, using two sides of a coal measures sandstone stone cube topped by a ball finial, but latterly the styles had long since rotted away. The house is dated 1649, but the dial's surviving Arabic numerals look late 17th century at the earliest. My late friend and former colleague Roy Hughes, FSA, suggested that it might be the work of James Woolley of Codnor (1695-1786) a notably fine clockmaker of the period, making it not earlier than c. 1716. Unfortunately when recorded by Roy it was very decayed – coal measures sandstone does not weather particularly well at the best of times – and was later replaced by a poor copy, the process of replication having also no doubt been hampered by the poor preservation of the original.

A similar cuboid one topped by a ball (NIR) once stood atop a Baroque column in the village of Allestree (now a northern suburb of Derby), presumably provided by one of the Mundy family in whose estate the village once lay. It survived long enough to have been drawn by a local anti-

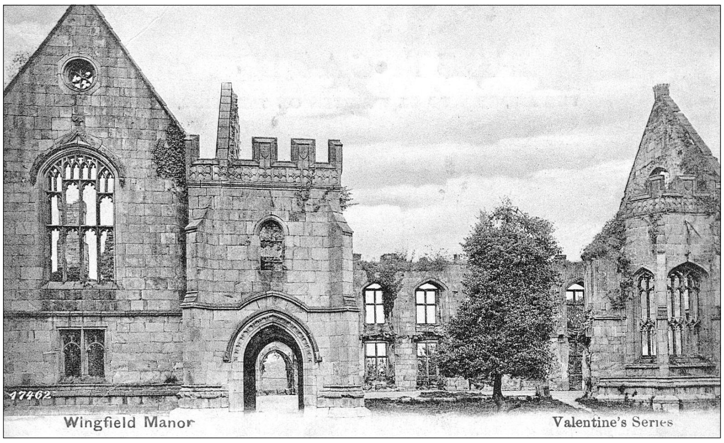


Fig. 6. Wingfield Manor, from a postcard c. 1902. Dials can be seen over the doorway left of centre and over the window far right.

quary, George Bailey in the 1880s.[5] When it was removed I am not sure. Doubtless there were others, like this, modelled on the famous Seven Dials in London.

The grandest house to have a wall sundial was Wingfield Manor (Figs. 6 & 7, NIR). Indeed, if you go to visit the ruins of this stupendous 15th century mansion, you will notice at least three scattered around and 150 years ago, when recorded by pioneer photographer Richard Keene of Derby, there were more.[6]

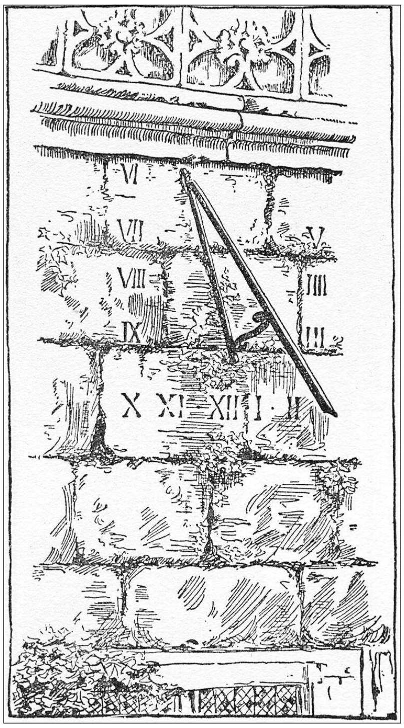


Fig. 7. One of the dials on Wingfield Manor, as shown in Henslow's 'Ye Sundial Booke'.

After this enormous 15th century mansion house had been severely pasted by Cromwell's artillery in the Civil War, it was granted to his agent, Immanuel Halton (1628-1699), a Cumbrian gentleman, by its then owner, the Earl of Arundel and *de jure* Duke of Norfolk. Here Halton dabbled in mathematical and astronomical experiments – he was a pioneer of algebra and a notable astronomer – including the venting of his penchant for improving sundials. He re-roofed the enormous great hall of the mansion and adapted it as a sizeable Caroline country house and it remained in his family for two centuries, although a descendant un-roofed it again in the mid-18th century and removed a great deal of stone to build the present Wingfield Hall, on the other side of the valley.

Halton embellished his new home and the romantic ruins around it with several sundials, hence those remaining today. Shortly after settling at Wingfield, he took the young John Flamsteed – the future first Astronomer Royal – under his wing and "taught him all he knew". Flamsteed, whilst still living with his family in Derby, later made useful modifications to Halton's "improved sundial", although it has long since vanished. The remnants of the Flamsteed family home survive in Derby, however, currently derelict and embedded in 27, Queen Street.[7]

Incidentally, Sir Isaac Newton's enthusiasm for sundials – from childhood – is well known and rather parallels Halton's. An early example by Newton mounted much later in Colsterworth Church, Lincolnshire, the great luminary's boyhood parish is set in a plaque of Derbyshire alabaster by a Squire whose ancestry stretches back to nearby Bonsall. In the end Newton and Flamsteed ended up hating each other having fallen out over the former's piratical and premature attempt to publish the latter's seminal *Atlas Coelestis*. Newton was a genius, ever in a hurry; Flamsteed on the other hand was a perfectionist.

Flamsteed, we know, greatly influenced the mechanical engineer George Sorocold of Derby, the builder of the first dock at Liverpool in 1708, the installer of the first carillon in the tower of All Saints', Derby (now the Cathedral) and the man who perfected a method of providing more than 17 towns with a viable water supply. His legacy seems to have been passed on to the young John Whitehurst, either directly or possibly through a protégé like James Woolley of Codnor, who seems to have tipped Whitehurst off about the most effective method of getting registered as a Freeman, despite not being qualified under the terms of the town's charter.[8] Either way, Whitehurst was very soon providing sundials for his clients and indeed, that at Allestree has been attributed to him.

JOHN WHITEHURST

John Whitehurst was born in 1713, the son of a Congleton clockmaker who was probably trained in Liverpool and the grandson of a minor landowner with an estate, from which the family took its name, at Dilhorne in Staffordshire. After some interesting vicissitudes, he came to Derby in 1736 and gained his freedom to trade in September 1737. In the years following he became friendly with Erasmus Darwin at Lichfield and Matthew Boulton in Birmingham and through them with the American patriot Benjamin Franklin.[9]

Together they formed the nucleus of the Lunar Society, one of the prime intellectual driving forces behind the industrial

Fig. 8. The vertical south dial at St Modwen, Burton-upon-Trent, canted slightly to the east.

revolution. Their friend, the Scots astronomer and mathematician James Ferguson, FRS, toured Britain, lecturing on all manner of aspects of science including dialling. He visited Derby in 1762, Whitehurst acting as agent for the tickets for the 20 week series. His lectures inspired the local artist Joseph Wright ARA to paint *A Philosopher Lecturing upon an Orrery* (1765) commissioned two years earlier by another amateur astronomer, 5th Earl Ferrers, whose grandfather had commissioned a superb double horizontal dial from Henry Wynne c.1685 for Staunton Harold, his seat in Leicestershire but only ten miles south of Derby.[10] Ferguson used an engraving of a complex Wynne dial in his *Lectures on Select Subjects* (London, 1773).

Whitehurst, elected FRS in 1776, wrote a seminal work in the development of modern geological studies, *An Inquiry into the Original State and Formation of the Earth* in 1778, having been previously appointed Inspector of the Money Weights at the Royal Mint in 1774. Eventually, in 1780, he moved to London permanently. At the time of his death he was working on a uniform system of measurement based on a pendulum standard, which was uncannily close to the unit eventually chosen in France and imposed on much of Europe by Napoleon as the metre.

On his death in 1788, he was succeeded by his nephew, John II, who died in 1834 to be succeeded by his son, John III on whose death in 1855, the firm was taken over by Roskell of Liverpool and virtually asset-stripped, closing finally in 1862. Throughout its 119-year existence, the firm Whitehurst established made sundials and surviving examples are extremely widely scattered in the region. The tradition of placing such instruments on the south wall of churches survived, as exemplified by that on William Smith's fine parish church of St. Modwen, Burton-upon-Trent (Fig 8, NIR), a particularly delightful example by John Whitehurst II in Ashford Black Marble in a classical stone aedicule and dating from 1785.

The first John Whitehurst, despite making a living at clock manufacture, was an important scientific figure, as well as a man with detailed interests in geology, meteorology and astronomy, all encouraged by his friends such as Darwin. Consequently, a really sophisticated dial, like that over the porch at Eyam parish church would seem to owe much to him.

Eyam Church Dial

This famous dial (SRN0486) is shown in Figs. 9 & 10. Datable to 1775, the impressive gritstone 5 ft square dial is set at latitude 53° 17' North and longitude 1° 4' West. Furthermore, it declines 18° to the west of south and includes the parallel of the sun's declination for every month in the year, the scale of the sun's meridian altitude, the scale of the azimuth, the points of the compass and a number of other meridians. The principal one consists of a total of eighteen delineation arcs divided by the equatorial line and bounded by others representing the tropics, all to mark the passage of the sun. Where the eighteen lines cross the hour lines, a grid is formed from which the time and position of the sun in the heavens may be calculated either by date or zodiacal sign. The hours themselves are indicated in Roman numerals with half and quarter hour divisions and even five minute ones.

At the point where the gnomon – believed to be a 19th century replacement of the original, for the dial has been twice moved, in 1868 and 1882 – springs from the top of the dial, emanating points indicate the time of noon at various places like London, Jerusalem, Mecca and so on – all unexpect-

Fig. 10. (right). The famous Eyam dial, with a design attributed to John Whitehurst.

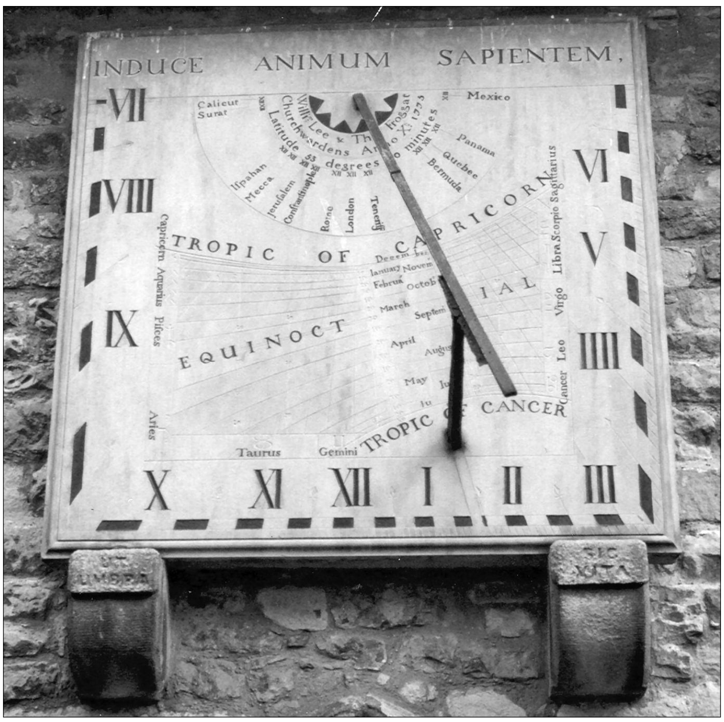
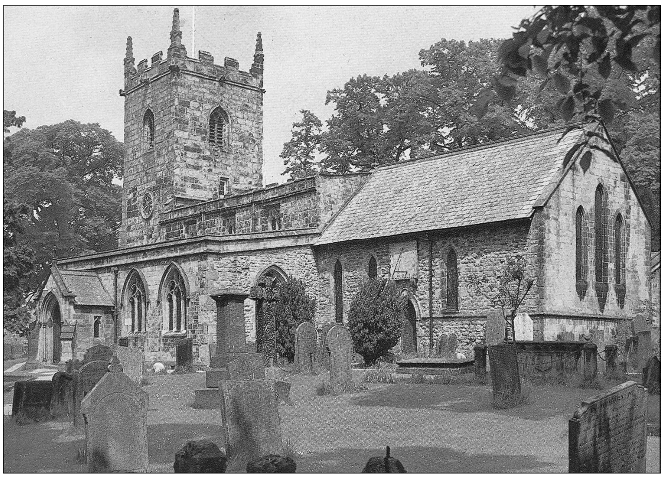


Fig. 9. (below). St Lawrence's church at Eyam from the south



edly ecumenical for the period. The dial is ensigned with the Latin *induce animum sapientum* ('foster an enquiring mind') and the corbels on which it all rests are further inscribed *ut umbra/sic vita* ('as shadows [pass] so [does] life') – all wonderfully appropriate.

It was commissioned by the incumbent, Revd Canon Thomas Seward and the dial was apparently delineated by one Duffin, clerk to Revd John Simpson of Stoke Hall, Grindleford, the carver being William Shore, a local mason. Without doubt, the delineation was done from a template supplied by John Whitehurst.

Canon Seward had been appointed rector of Eyam in 1739 at the age of 31 by the patron, the 4th Duke of Devonshire, and held the living until his death in 1790. Seward, a canon of Lichfield, was a friend and neighbour of Darwin's and well known to Whitehurst too, whilst the Duke himself had by this date already commissioned clocks from the Derby man. Furthermore, the new Rectory at Eyam of c. 1765 in a muscular Palladian style - most regrettably demolished some forty years ago - was almost certainly the work of Derby architect Joseph Pickford (1734-1782), who was also extensively patronised by the Duke as well as by several members of Whitehurst's Lunar coterie. John Simpson was a client of Whitehurst's as was his brother-in-law Richard Bagshawe of Wormhill Hall and Oakes Park, Norton. This concatenation of patronage, style and identifiable works points unerringly to Whitehurst as the designer of this important dial.[11]

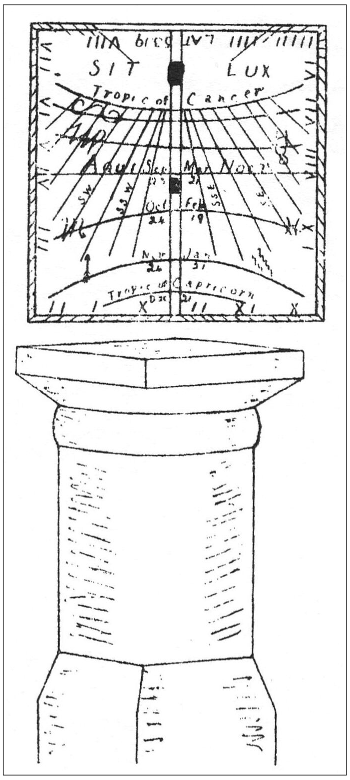


Fig. 11. A drawing, c. 1932, of the dial once at Bank House, Stoney Middleton.

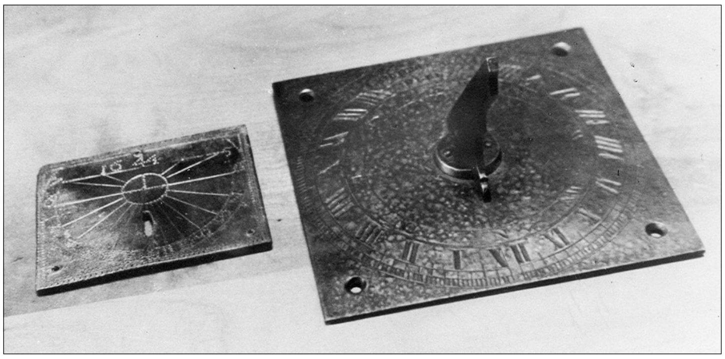


Fig. 12. A simple Whitehurst dial (right) and an earlier dial, both for regulating a longcase clock. (Derby Museum).

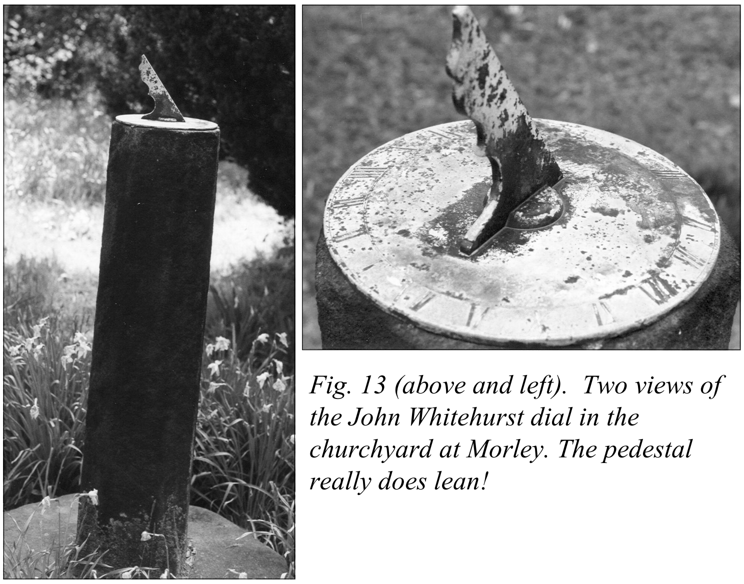


Fig. 13 (above and left). Two views of the John Whitehurst dial in the churchyard at Morley. The pedestal really does lean!

Other Whitehurst Dials

A possible spin-off from the Eyam dial was one which once stood in the grounds of Bank House, in the adjacent village of Stoney Middleton, being engraved in a bowdlerised version of the complexities of that at St. Lawrence, Eyam (Fig. 11, NIR). The owners of the house were the Furness family, close kin to the Furnesses of Eyam where they were substantial yeomen. It shows little sign of the hand of anyone of Whitehurst's stature, however, from the drawing provided in T. E. Cowen's *In Derbyshire Dales* of 1932, nor it is known if it is still *in situ*.

Whitehurst also made a good number of what we might call domestic dials – simple engraved bronze dials intended to be set on a plinth or similar in the garden. This was part of the stock-in-trade of most competent clockmakers in those days, but the earlier examples tend to be anonymous, like one dated 1644 from a local source and once in Derby Museum's collections (Fig 12).

Oddly, there are very few recorded by Derbyshire makers except Whitehurst, his circle and family – or if there are more, they have not surfaced. Whitehurst himself made a wide variety of types, from simple dials, which just told the time, to amazingly sophisticated ones packed, to the initiated, with potential information, astronomical, seasonal and topographical and it may well be no co-incidence that the best bear a close resemblance to that illustrated in his friend Ferguson's book. His later ones and those by his successors have particularly plain gnomons set onto an inserted disc, so that even when the maker's name has weathered off, the essential clue is often there. Earlier ones bore more decorative gnomons fixed in the usual way.

There are one or two public ones, like those in the churchyards at Morley (Fig. 13, SRN0480?) and Thorpe (SRN0481), the latter set for latitude 53° exactly, dated 1767 and set on a plinth so high as to be usable only by

Fig. 14 (far left). The John Whitehurst dial, c. 1738, at the Tissington Hall.

Fig. 16 (left). The John Whitehurst horizontal dial now at High Ercall, Shropshire.

someone on horseback. It was also at some time moved from elsewhere – perhaps the stable yard of a great house – for its present position is actually at 53° 3' and Whitehurst was nothing if not a stickler for precision.[12] The former was set up by the Revd Dr Richard Wilmot, the incumbent, in 1762. The Moravian settlement at Ockbrook also has one (NIR) in front of its pretty chapel of 1750s date.[13]

Numerous country houses had them, too: Tissington Hall (Fig. 14, SRN4097) – very early and associated with the installation of the turret clock in the stables in 1738[14] - Calke Abbey, Park Hall, Barlborough,[15] Flintham Hall, Notts. (an odd specimen with 45° gnomon) and others. Some vanished houses are known to have had them, for in 1775 Whitehurst wrote to Revd Dr Thomas Gresley concerning his sundial for Netherseal Hall, "soon to be ready"; one wonders where it went when the house was dropped in the 1930s.[16]

That surviving at Clumber Park (NT), Nottinghamshire (Fig. 15, SRN0612), was part of works for the 2^{nd} Duke of Newcastle which included a sophisticated turret clock and a complete system of plumbing, flushing loos and back-boiler heated water. The unlikely friendship which developed between aristocrat and engineer, led to Whitehurst's preferment to the Mint and his move to London.

There are others in local collections, not to mention further afield, like the one in the churchyard at High Ercall, Shropshire (Fig. 16, NIR?), and another at Llanigon church, near Abersoch, Carms., the latter dated 1760 and neither in their original position.

This tradition continued under Whitehurst's short-lived and self-appointed successor, James Wright, his wife's nephew, one example signed by him having recently come to light, sold at Bonhams in September 2003. A wall-mounted dial by John II and dated 1800 was observed in 1938 on the wall of Victorian "Seathorn", Shardeloes Road, Skegness, a house built by the Eastwood family, Derby iron founders, but whence it came remains obscure.

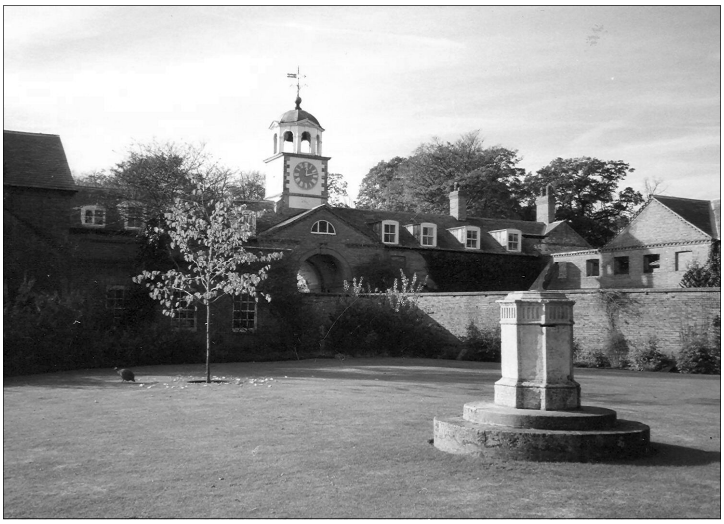


Fig. 15. Clumber Park (NT), Nottinghamshire, with the sundial and turret clock by John Whitehurst.

Fig. 17. One of the more complicated John Whitehurst dials, including an EoT scale, in Derby Museum.

Fig. 18. A dial and pedestal sold at auction in 2005, possibly from Elvaston Castle. Photo courtesy Bamfords.

A very fine 'domestic' example dated 1812 in Derby Museum (Fig 17) from the Summerfield collection has a complex and beautifully engraved dial, mirrored by one formerly on display at Locko Park. The musuem also has an example dated 1834; all three are signed "Whitehurst & Son/ Derby". From 1809 to 1834 all instruments were signed thus instead of just "Whitehurst/Derby", this being the period between the end of the apprenticeship of John III and the death of his father, when they were in partnership. One or two other local country houses have similar examples, one dated as early as 1792 and probably supplied to Erasmus Darwin, no less.

A fairly simple example was sold recently at Bamford's auctioneers of Derby set on an octagonal stone plinth (Fig. 18). The provenance was unclear, but a few clues suggest that it might have originally have been made for the Earl of Harrington's new gardens at Elvaston Castle in the 1830s or when the house was re-modelled in Gothick style to the designs of James Wyatt in 1813.[17]

After the end of the Whitehurst firm, I know of no signed Derbyshire dials and the trend thenceforth was to produce imitations of 17th century types to varying standards. One quite respectable one, however, was done in approximate Whitehurst style and unveiled by HRH the Prince Edward, Earl of Wessex, when he opened Pickford's House Museum in Friar Gate, Derby in 1990, although it had to be replaced after being stolen soon afterwards!

In this case, the house, in the garden of which it stood, was built for himself by Whitehurst's friend Joseph Pickford and the association was entirely appropriate. Unfortunately, what subsequently befell it says everything about why there is no serious market for traditionally made hand engraved sundials today: they will inevitably be stolen.

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6. M.A.J.B. Craven & M.F. Stanley:*The Derbyshire Country House* 3rd edn., 2 vols, Ashbourne, II. pp. 243-244, (2001).
7. Ref 5 pp. 13-14 & pl. I/2.
8. He himself installed a turret clock in the pediment of the new Exchange in Nottingham's Market Place for which he was made a burgess in July 1728. Whitehurst did the same in Derby in 1737; the co-incidence is instructive (Ref 5 p. 27).
9. On Whitehurst see Craven, *op. cit.* and in more condensed and purely horological form M.Craven & R.G. Hughes *The Clockmakers and Watchmakers of Derbyshire,* Mayfield, pp. 27-46 & 194-209 (1998).
10. J. Davis & C.M. Lowne: 'Henry Wynne's Double Horizontal Dial at Staunton Harold', *BSS Bulletin*, 15(ii) pp 46-58 (2003).
11. Ref 5 pp. 33-34 & pl. II/21; J.C. Cox: *Notes on the Churches of Derbyshire* 4 vols, (Derby 1874-1879) II. p.195; W. Wood:*History & Antiquities of Eyam,* 3rd Edn., (London & Derby 1859) p.133, which description is modernised and amplified by a pamphlet published anonymously as *Eyam Church Sundial* by the church in 1975, its bicentenary.
12. Ref 5 pp. 33 & pl. II/20. It probably came from Wilmot's family's seat, Chaddesden Hall (demolished 1926), not so very far away.
13. It is now too worn to read. The chapel was built in 1755-56 and it is assumed the dial is contemporary.
14. Ref 9 pp. 32 & pls. II/17-18.
15. Both now rather worn and difficult to read; Ref 6 I. pp. 61-64 & II. pp. 174-175.
16. Ref 6 I. pp. 156-157; Letter, Derbyshire Record Office, D803/M/F16.
17. Bamford's sale 13-14/9/2005, Lot. 1913.

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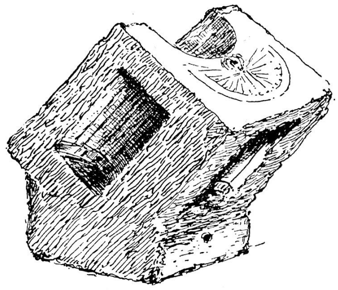

A dial from Wigborough House, Somerset, now in Taunton Museum. After *Gatty*.

READERS' LETTERS

Hooke's Joint

Allan Mills[1] shows how a Hooke's joint can be driven by a 24 hour clock to move a pointer that lies in the plane of the shadow of its input shaft. The pointer thus correctly points to the time on a horizontal or direct south-facing dial.

But Hooke's joint is more flexible than that. As long as the output shaft is perpendicular to the dial, a single joint is all that is needed to make a pointer show the correct time even on a declining and/or reclining dial. Just keep the input shaft polar, keep the phase so that 12 o'clock is in the meridian plane, and make the output shaft perpendicular to the dial. The pointer, being constrained by the input arms, must remain in the shadow plane.

Prof. Mills relates the pointer (or output shaft) movement to the input shaft by the familiar-looking equation:

$$\tan(\textit{pointer angle}) = \tan(\textit{input angle}) \times \sin(90° - \textit{articulation-angle})$$

The equation for hour lines on a horizontal, vertical, declining or reclining dial is:

$$\tan(\textit{hour line angle}) = \tan(\textit{sun's hour angle}) \times \sin(\textit{style-height})$$

where the hour line angle is measured from the substyle and the sun's hour angle is measured relative to the time shown at the substyle. The equation commonly used is more complicated because it measures angles and time relative to vertical and noon.

The only practical limitation is that the angle between the input and output shafts can't, in practice, exceed about 70° so it won't work for some walls, such as direct east or west facing.

I am sure that Hooke was aware of this capability as he wrote of the uses of his joint for moving a hand: "In the Azimuth of any Celestial Body, that is, in the shadow of an upright, or any other way inclined Style, upon any plain."[2]

Less importantly, in the same article it is claimed that my mechanism, shown there as Fig. 1 and consisting of just the input stirrup and spider of a single Hooke's joint, cannot be mechanised as the pointer must scrape the dial. My mechanism was created to show that the Hooke's joint can be placed at the centre of the dial, and could be used to delineate a new dial without needing a hole through it. I believe that putting the joint at the centre of the dial, with the input shaft polar, makes clear that it operates by constraining the pointer to be in the shadow plane. If a hole were made through the dial, the output shaft could easily be added and used to support the pointer just clear of the dial. This would show that the mechanism is indeed a Hooke's joint and would allow mechanization. It would be very similar to Hooke's own drawing – Fig. 2 in reference 1.

REFERENCES

1. *BSS Bulletin*, 18(iv), pp.167-170 (Dec 2006).
2. Quoted in *NASS Compendium*, 10.3, p. 20 (Sep 2003).

Chris Lusby Taylor
Newbury, Berks.

Allan Mills replies:

Peter Somerville has drawn my attention to an error in my paper in the *Bulletin* for December 2006. In the first paragraph on p.168 I should have written ' . . . . a nodding motion of the cross gives rise to a variable output speed decelerating from 0 to 90°, and then accelerating from 90 to 180°'. This describes the behaviour of a single Hooke's joint, but is also applicable to the shadow of a gnomon moving over a horizontal or vertical sundial and leads to information rarely discussed in standard dialling literature. There is too much to present here, so I am preparing a further paper for submission to our Editor.

Chris Lusby-Taylor's comment that a single Hooke's joint is sufficient to drive or delineate a *declining* vertical dial both contradicts Hooke and puzzles me. The horizontal N-S output shaft of a single joint may certainly be repositioned through an angle towards the east or west to penetrate a declining wall, and (provided the articulation angle is less than about 60°) will happily rotate when the input shaft is turned. The trouble is that its motion does not correctly delineate a declining vertical sundial, for slightly altering the viewpoint will show that input and output shafts continue to fall in the same plane. All we have done is to slightly alter the latitude and phase of the original direct vertical dial. Conventional graphical techniques for designing a declining vertical dial take the direct south vertical dial for a given latitude, and then *project* it upon the declining plane to give an asymmetric pattern. A second Hooke's joint attached to the horizontal output shaft of the first joint (this shaft may be held in bearings) accomplishes an identical projection if the phasing is set correctly. An experimental test of a double Hooke's joint (my Fig. 7) in a test rig modified from my Fig. 4 gave an output matching a dial previously drawn graphically for a vertical dial at 52° N declining 20° E.

The Egyptian Face

On page 176 of the December 2006 Bulletin, Tony Wood shows the four faces of the sundial pillar at the Isle of Wight home of Alfred, Lord Tennyson.

Three of the faces are quite straight forward depictions relevant to the first three lines of the second motto quoted and inscribed under the figured carvings: *For every grain of sand that runs*, the hourglass; *every span of shade that steals*, the sundial; *every kiss of toothed wheels*, the clock face. What about the fourth line, and the design above it, with the rather vague description 'something Egyptian'? Tony's article has the suggestion that this may just be a scribe compiling a calendar. After the definite connections on the other three sides, surely we must be able to improve on this somewhat prosaic description.

As this is deemed to be the 'earliest' of the four designs (Tony's first paragraph *working backwards in time*) then a reference back to ancient Egypt has logic to it. We can note that this is the only one of the designs which has more than the figure and an artefact. It includes the sun and moon and also a series of arcs of different sizes within the arch. Although the reproduction is not too clear, close inspection of the top of the object the figure holds in his left hand seems to show a reed boat of the Sun-God Ra. According to ancient Egyptian mythology, this boat carried the sun across the sky during the day and through the underworld at night to reappear at dawn the next day. Some curved triangles to the left of the moon could, perhaps, represent stars or constellations.

I suggest that the iconography of this design indicates that the subject of this face is Ptolemy, he of the *Almagest* and other books. Ptolemy, of course devised his system of epicycles, eccentric circles, deferents and equants to enable the future courses and positions of the planets – which in his day included the sun and moon – to be calculated. The parameters needed for the calculations were different for each of the seven bodies in his earth-centred system, hence a multiplicity of arcs. By Tennyson's time, Ptolemy's works were available in English, well known and studied.

This suggested attribution is consistent with Tennyson's fourth line *and all the courses of the suns* (note the plural). In the 19th century, following Napoleon's campaigns in Egypt, there was a great interest in the artistic world of Pharaonic Egypt. Hence the inclusion of the symbolic imagery of Ra's reed boat.

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1. G.E.R. Lloyd: *Greek Science After Aristotle.* Norton & Company Ltd, London, (1973).
2. Sally Ashmore. Personal communication.

Tony Ashmore,
Didcot

EARTH'S ROTATION

JOHN WALL

In the December 2005 issue of the *Bulletin* the Editor kindly published my letter under this heading, in which I asked readers to list what they imagined the consequences would be if the earth rotated on its axis in the opposite direction to the norm. To date we have received only two replies. I hope therefore that readers will forgive me if, in the light of the small number of responses so far, I contribute my own rather more mundane additions to the list – all open to correction!

1. The first and most obvious consequence is that, instead of the sun rising in the east and setting in the west, it would rise in the west and set in the east. This would have profound consequences for gnomonics since *inter alia* all sundial hour-line numerals would have to reversed.

2. Were the earth to rotate in the opposite direction at the same rate the biggest effect, after producing sunrise in the west and sunset in the east, would be a little under 367.2422 noon-to-noon periods from vernal equinox to vernal equinox, making a calendar year of 367 days. Leap years would still work reasonably well with the present rules.

In the present situation the sun (apparently) moves around the ecliptic in the same direction as the earth's rotation. Therefore, starting with the sun on the meridian of some locality, after one earth rotation relative to the stars (a sidereal day) the sun will have advanced by about 1/366 of its rotation (just under one degree). The earth must rotate that much further to bring the sun back to the meridian and the solar day is about 4 minutes longer than the sidereal day. With the opposite sense of the earth's rotation, the sun would arrive at the meridian before the earth had completed one sidereal rotation and the solar day would be shorter than the sidereal. Hence the hours, 1/24 of a mean solar day, would be shorter, the second would be fewer vibrations of the krypton-86 atom and all scientific constants and units involving time would be different. This would include length, which is now defined in terms of the distance travelled by light in a vacuum in 1/299792458 of a second.

A sundial, which determines time by the hour-angle of the sun with respect to the meridian, would still operate satisfactorily with an altered length of the day, as long as the order of the numerals was reversed! A new 'hours' motion would still occupy an hour interval on the dial.

(I am indebted to a private letter from a member, Peter

Somerville, for much of the material in this section).

3. In the northern hemisphere the firmament of stars at night would appear to progress around the celestial North Pole (close to the North Star) in an anti-clockwise direction instead of a clockwise direction. Conversely in the southern hemisphere the firmament would appear to progress round the celestial South Pole (just below the Southern Cross) in a clockwise instead of an anti-clockwise direction.

4. When travelling across the International Date Line (IDL) from *east to west*, against the rotation of the earth, it is currently necessary to subtract a day from one's calendar in order to arrive back at the starting point in agreement with the calendar still functioning there. Given a reversal of the rotation of the earth the same adjustment would need to be made when travelling from *west to east* to achieve the same result.

5 A related consequence of a reversal in the direction of the earth's rotation would be a reversal of time-zones expressed + or – Greenwich Mean Time (G.M.T.), that is Standard or Universal Time. For a variety of reasons many states have adopted boundaries to their time-zones that do not coincide with single lines of longitude. However, since they would be obliged to alter their times from + to – or from – to + G.M.T. as the case may be, some jurisdictions might find it prudent to adjust the boundaries of their time-zones to take account of developments since they were first introduced.

6. On a more personal note, shortly after the publication of my article on 'The Sunset Line (BSS *Bull* 11(iii), pp.118-119, 1999), in order to deal with the many questions that remained unanswered, I subsequently purchased a remarkable if expensive globe of American manufacture. It is inscribed 'The Sunlit World Globe of Seattle', and it is illuminated within to show the sunrise line or *terminator*. Strictly speaking the sunrise line is only one half of the terminator (which for want of a better word I have re-named the *soloriensorbit* since the other half of the globe-encircling terminator is the *sunset* line. This sunlight world globe is furnished with an electric motor so that as it rotates once in every 24 hours so the sunset/sunrise line moves over its entire surface. An observer is able to time sunrise/sunset at any moment by means of a 24-hour time-scale ring that surrounds the globe in the plane of its supposed orbit round the 'sun'. The soloriensorbit continues to circle the globe accurately and continuously throughout the 365 days of the year by means of a dial that is manually set to the current date.

Clearly the movement of the real sunset/sunrise line would be reversed if the earth's rotation on its axis was reversed. However, I am left with the problem of how to reverse the electric motor attached to my globe so that in turn it also revolves in the opposite direction.

Just in case this calamity should happen, for whatever reason, are there any consequences (apart from the extinction of the human race) that we have not anticipated?

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ERRATUM

'Something Unsuspected, But Not New, In Darkest Scotland' (BSS Bulletin 18(iv), p.162, Dec 2006).

In the caption to Fig. 1, the word 'direction' is incorrect. The arrows show the approximate positions for Figs. 2 & 4. The author is not responsible for the error.

Death at the Sundial

"Above him, at the angle of the steep green bank of the terraced garden, was one of those small picturesque surprises common in the old landscape gardening; a kind of small round hill or dome of grass, like a giant molehill, ringed and crowned with three concentric fences of roses, and having a sundial in the highest point in the centre. Kidd could see the finger of the dial stand up dark against the sky like the dorsal fin of a shark, and the vain moonlight clinging to that idle clock. But he saw something else clinging to it also, for one wild moment- the figure of a man.

Though he saw it there only for a moment, though it was outlandish and incredible in costume, being clad from neck to heel in tight crimson, with glints of gold, yet he knew in one flash of moonlight who it was. That white face flung up to heaven, clean shaven and so un-naturally young, like Byron with a Roman nose, those black curls already grizzled - he had seen a thousand public portraits of Sir Claude Champion. The wild red figure reeled an instant against the sundial; the next it had rolled down the steep bank and lay at the American's feet."

From, "The strange crime of John Boulnois", a Father Brown story, by G.K. Chesterton. That is a good description of the garden feature, the mount , or mound, the correct place for your garden sundial.

contributed by Roger Bowling

THE VERTICAL SUNDIAL OF THE CHURCH OF THE DORMITION OF THE VIRGIN AT AGIA TRIAS IN THE ARGIVE PLAIN

E. TH. THEODOSSIOU & A. DAKANALIS

INTRODUCTION

A significant, well preserved vertical sundial of medieval Byzantine Greece can be found today at Argolis in the village of Agia Trias. Agia Trias is the name used today for a large village in the Argive plain in Peloponnese, which was, in past times, known as Merbakas. It is the seat of the municipality of Midea and rests very near to the famous ancient city of Mycenae and between Argos and Nauplion. another two other historical ancient cities. Agia Trias, Argos and Nauplion form an equilateral triangle, with Agia Trias on its northern apex.

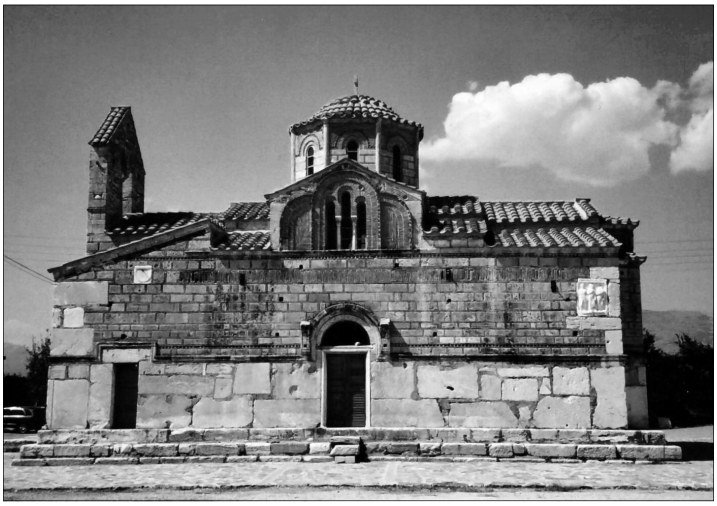


Fig. 1. The Byzantine church of the Dormition of the Virgin (Church of the Koimesis) at Agia Trias. The vertical sundial (left) and the three saints marble slab (right) can be seen.

In this village, our interest is focused on the well-known Byzantine church of the Dormition of the Virgin (Church of the Koimesis), which was built in the 13th century and is shown in Fig. 1. The church of the Dormition of the Virgin is a domed cross-in-square church of the composite four-column type, with a narthex and porches, which is the main characteristic of the Medieval Byzantine churches of Argolis. The wall masonry is pseudoisodomic in the lower section and 'cloisonné' in the upper part. The façades are decorated with a wide variety of brick ornaments. The historical church was built on a stone crepis and dates to the end of the 12th century or early 13th century. The church's interior is decorated with Byzantine murals and its main characteristic element is its ceramic meander shaped decor.

Later, in 1687, it became the Metochion (Dependence) of the Convent of Saint Theodossios in Nauplion, and it was given over by the Venetian admiral Francisco Morozini (1618-1694) to the Bishop of Rethymnon Athanassios Chortatzis, who was in Peloponnese at the time. In June 1825, the monastery must have been destroyed when Argos was set on fire by the Egyptian general Hibraim, ally to the Turkish occupation forces.

The historical monument has been repaired twice, in 1855 and in 1912. Restoration of the church as well as cleaning and revealing murals is currently in progress. Excavations carried out in 1989 and 1990 have brought to light the Crypt under the Sanctuary of the church, the stylobates of the original Econostates and the graves inside the church and the narthex, dated to the late Byzantine period.

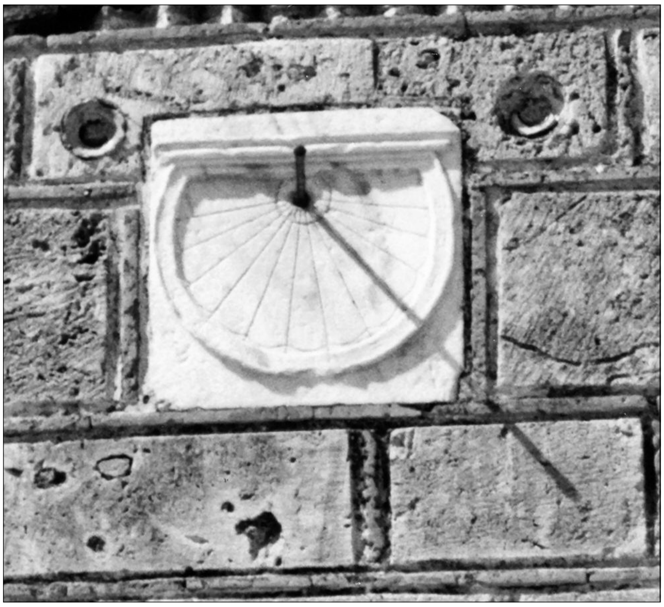
A few years ago the church was used as the cemeterial church of the village of Agia Trias. Now it is a well preserved monument standing beside the main road. This Byzantine church, known as the Church of Merbakas, was studied by the German archaeologist Adolf Struck (1909)[1], who also explained the place-name 'Merbakas'. According to the German archaeologist, this name apparently derives from the Latin Archbishop of Corinth, Wilhelm von Moerbeke (Guillaume de Moerbece, William of Moerbeke, Brabant 1215-Corinth1286).

William of Moerbeke, scholar, Orientalist and philosopher, was a Flemish cleric whose Latin translations of the works of Aristotle and other early Greek philosophers and commentators played an important part in the transmission of Greek thought to the medieval Latin West. William of Moerbeke stayed at the Papal court at Viterbo, where he completed several translations of ancient Greek scientific documents in Latin. It was there where he completed the work of Claudius Ptolemy (2nd century AD) 'Book of Anallema' in Latin.

THE VERTICAL SUNDIAL AT THE CHURCH OF THE DORMITION OF THE VIRGIN AT AGIA TRIAS

Based on the translation of Claudius Ptolemy's work 'Book of Anallema' from William of Moerbeke, which explains the method of projecting conical parts on a flat surface (essentially how to create a sundial), it is our belief that the

Archbishop knew of this technique. Since the Church of the Dormition of the Virgin at Agia Trias (λ = 22° 48′ E, *f* = 37° 44′ N) is mentioned as the church of Merbakas and is dated to the 13th century, it is quite possible that its builder was the Archbishop of Corinth, and as he knew of the method of making sundials, perhaps he placed one – as it used to be done in the West and not in Greece – on the southern side of the church.



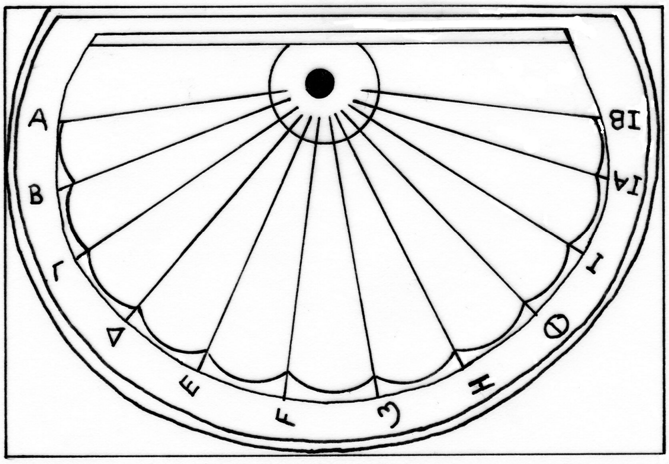


Fig. 2. The vertical sundial of the Church of the Dormition of the Virgin at Agia Trias.

Indeed, there is no reference to the history of the whole monument (monastery, main church, cemetery), which is dated only on the basis of the excavation data and the architectural form of the main church. It is therefore possible that it is connected with the antiquarian Archbishop of Corinth, William of Moerbeke. The objection is based on the fact that the church abides by the Byzantine construction standards. Perhaps the Archbishop might have found the church already built and added the sundial or he respected the Byzantine tradition or perhaps the Greek architect and builders were trained in this way of building. Either way it is our belief that, if it was not only due to the church itself, then this sundial designed and manufactured by Moerbeke, is the reason that the church and the whole village were named this way.

This vertical sundial is one of the very few – only seven – Medieval Byzantine sundials that were discovered last century by the architect, archaeologist and professor of the Athens University Anastassios Orlandos (1887-1979) and these are listed at his *'Byzantine Monuments in Greece'*.[2]

By observing the historical church it can be seen that the vertical sundial of white marble has been placed over the entrance to the narthex (see Fig. 1). This is an element that connects it to the notion of entering or exiting from one world to the other. We should not forget that Byzantine motif in church-building is cross-shaped, inscribed in a square and the center is dominated by an elevated cupola.

The church of this motif combines all the elements of Byzantine culture and Christian symbolism, where the church is thought as a miniature of heaven and the earth. The shape of the cross symbolizes man's salvation, with the churche's floor resembling the earth and the roof resembling heaven. The sanctuary marks the border between heaven and earth, while the dome symbolizes God descending to the world.

On the other end of the southern side of the church, rests another white marble slab built into the wall, Fig. 3, depicting three saints (or perhaps apostles).

Fig. 3. The white marble slab of the three saints or Apostles.

The vertical sundial (Fig. 2) is a carved semicircle on a square white marble slab. On its centre rests a small circle, whose centre bears an iron – now rusted – gnomon. The hour-lines, twelve in number, start from the base of the gnomon and do not end on the outer circle, but on a circle of a smaller radius. On the formed ring is marked out the numbering of the hour-lines, which follow the ancient Greek method of using the capital letters of the Greek alphabet: A, B, Γ, Δ, E, F, (maybe Z but this is missing), H, Θ, I, IA, IB. Part of this beautiful – and perhaps one of the most ancient – vertical sundial of Byzantine Greece decoration, is its eleven cyclical sections which are bound by the arcs of a circle. The Greek numbering of the hour lines means that this sundial is older than the vertical sundial at the Hossios Lukas Convent at Boeotia[3], which bears Arabic numbers.

Knowing that the Arabic numbering system was introduced in Europe by the Italian mathematician Leonardo da Pisa Fibonacci (1179-1250 AD), in the 13th century, and that it must have been at least a century before it became widely accepted, we conclude that the sundial must date at least to the 13th century.

This sundial should normally bear a horizontal line which resembles the horizon, while at noon the Sun's rays should fall upon its vertical line, perpendicular to the horizon, which would of course note the 6th hour. However, in a sundial like this, placed on a wall with an orientation of true south, it is not possible for the sunlight to fall on the horizontal line. It is probably for this reason that there is no horizontal line, and the hour line of the F hour is not perpendicular to the theoretical line of the horizon.

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SOLAR & LUNAR DATA 2007

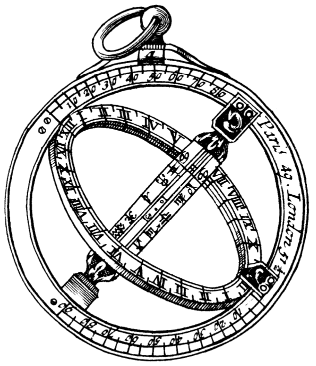
	April			May			June			
Day	Declination	Transit	Moon	Declination	Transit	Moon	Declination	Transit	Moon	Day
1	4°30'10"	12:03:58		15°02'55"	11:57:08		22°02'31"	11:57:46	○ 01:04	1
2	4°53'17"	12:03:40	○ 17:15	15°20'57"	11:57:00	○ 10:09	22°10'30"	11:57:55		2
3	5°16'19"	12:03:23		15°38'45"	11:56:54		22°18'06"	11:58:04		3
4	5°39'15"	12:03:05		15°56'17"	11:56:48		22°25'19"	11:58:14		4
5	6°02'05"	12:02:48		16°13'33"	11:56:43		22°32'09"	11:58:25		5
6	6°24'49"	12:02:31		16°30'33"	11:56:38		22°38'34"	11:58:36		6
7	6°47'27"	12:02:14		16°47'17"	11:56:33		22°44'36"	11:58:47		7
8	7°09'57"	12:01:57		17°03'44"	11:56:30		22°50'15"	11:58:58	☽ 11:43	8
9	7°32'21"	12:01:40		17°19'54"	11:56:27		22°55'29"	11:59:09		9
10	7°54'37"	12:01:24	☽ 18:04	17°35'47"	11:56:24	☽ 04:27	23°00'18"	11:59:21		10
11	8°16'45"	12:01:08		17°51'23"	11:56:22		23°04'44"	11:59:33		11
12	8°38'45"	12:00:52		18°06'40"	11:56:20		23°08'45"	11:59:46		12
13	9°00'37"	12:00:37		18°21'39"	11:56:20		23°12'21"	11:59:58		13
14	9°22'19"	12:00:22		18°36'20"	11:56:19		23°15'33"	12:00:11		14
15	9°43'52"	12:00:07		18°50'41"	11:56:20		23°18'21"	12:00:23	● 03:13	15
16	10°05'16"	11:59:53		19°04'44"	11:56:20	● 19:27	23°20'44"	12:00:36		16
17	10°26'30"	11:59:39	● 11:36	19°18'27"	11:56:22		23°22'41"	12:00:49		17
18	10°47'33"	11:59:25		19°31'51"	11:56:24		23°24'15"	12:01:02		18
19	11°08'25"	11:59:12		19°44'54"	11:56:26		23°25'23"	12:01:15		19
20	11°29'07"	11:58:59		19°57'38"	11:56:29		23°26'06"	12:01:28		20
21	11°49'37"	11:58:46		20°10'00"	11:56:33		23°26'25"	12:01:41		21
22	12°09'55"	11:58:34		20°22'02"	11:56:37		23°26'19"	12:01:54	☾ 13:15	22
23	12°30'01"	11:58:23		20°33'43"	11:56:42	☾ 21:03	23°25'48"	12:02:07		23
24	12°49'55"	11:58:12	☾ 06:36	20°45'03"	11:56:47		23°24'52"	12:02:20		24
25	13°09'36"	11:58:01		20°56'01"	11:56:53		23°23'31"	12:02:33		25
26	13°29'03"	11:57:51		21°06'38"	11:56:59		23°21'46"	12:02:46		26
27	13°48'18"	11:57:41		21°16'52"	11:57:05		23°19'37"	12:02:58		27
28	14°07'18"	11:57:32		21°26'45"	11:57:13		23°17'02"	12:03:11		28
29	14°26'05"	11:57:23		21°36'15"	11:57:20		23°14'03"	12:03:23		29
30	14°44'37"	11:57:15		21°45'23"	11:57:28		23°10'40"	12:03:35	○ 13:49	30
31				21°54'08"	11:57:37					31

Summer solstice 2007: June 21st, 18:06

Data kindly supplied by Fiona Vincent. The lunar data and times of the solstices have been added as a result of reader feedback.

DIAL DEALINGS 2006

MIKE COWHAM



The year 2006 had fewer sales than usual due to several factors, perhaps most notably the lack of interest from the market. However, there were still a few exceptional items offered and I will describe some of these together with a few of the more affordable items.

On the 28th of June at Christie's New York, in their sale 'The History of the Book', was *Le Manuel des Marchans moult utile a trestous* published in Gent in 1545 (Fig. 1). This was a merchant's reference book with information about values (with illustrations) of the many coins in circulation, a calendar, list of fairs etc. It had been rebound later in the century and several fine watercolour paintings were added at the front and back. What is of interest to us was that set inside the front cover was an early sundial in gold, signed on the frame by the goldsmith *B. V. DER CLOESEN.* Inside the back cover was a simple balance in silver. The date of the book is 1545, the year in which the Mary Rose was sunk in the Solent, so I had to see if this dial was anything like those found on board. The dial is early and, like the Mary Rose dials, probably originates from Nuremberg. However, according to the auction notes, the book was rebound around 1600, so this dial will date from that period. (The Mary Rose dials were wooden with small inbuilt compasses and small metal gnomons.) The book was estimated at $20,000 - $30,000, a fine sum, but made a staggering $156,000 including buyer's premium. Agreed, it was a rarity and a most desirable item, having survived for almost 500 years.

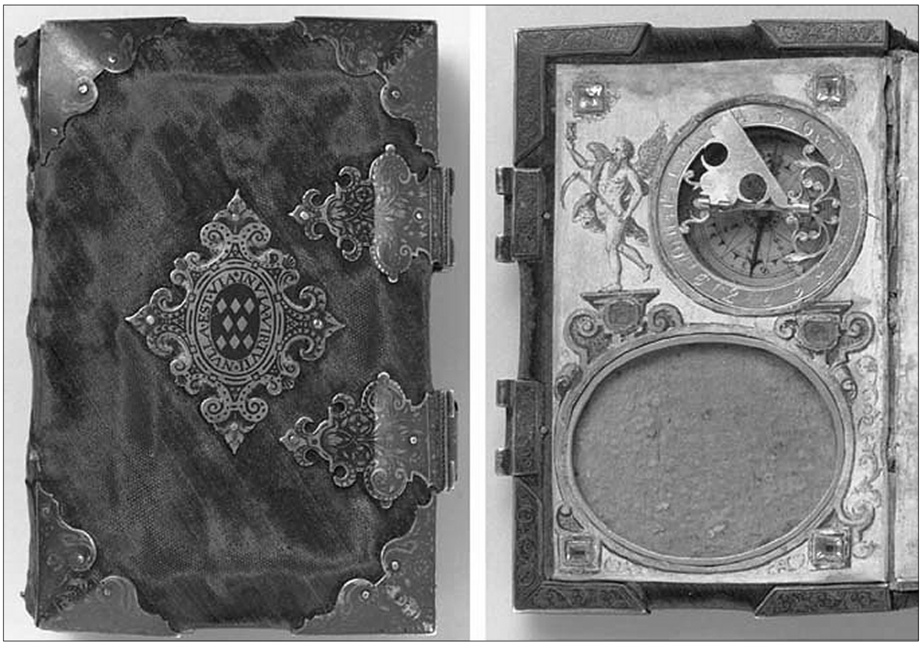
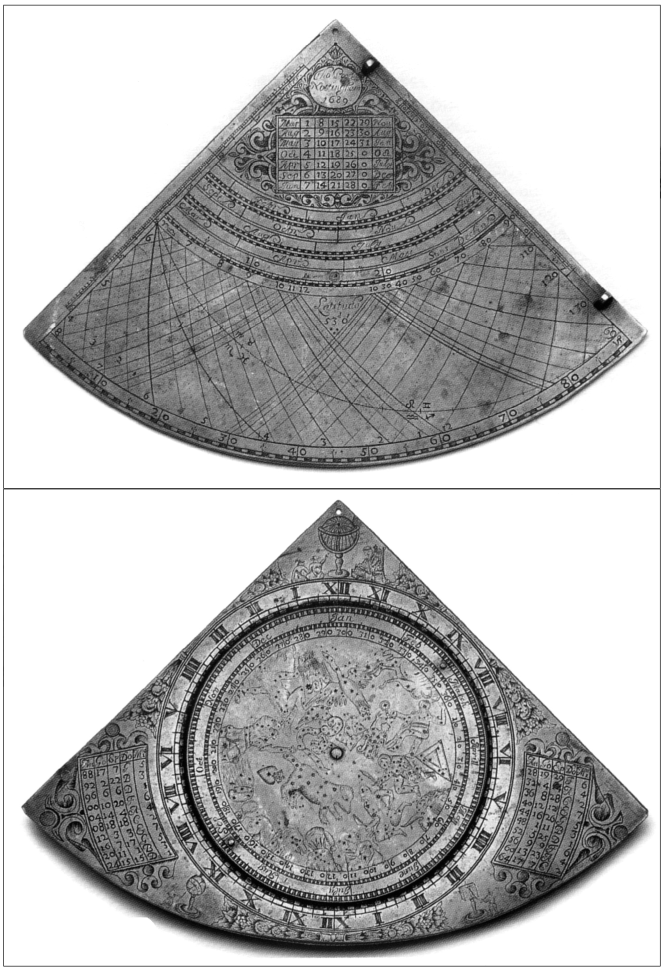


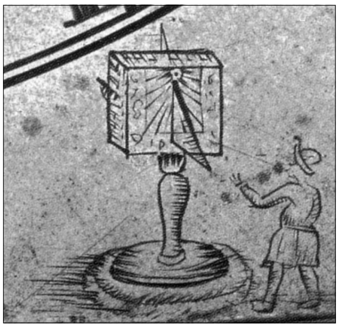
Fig. 1. Book of 1545 with sundial.

Fig. 2. Perpetual calendar sold by Rowley's.

An interesting perpetual calendar (Fig. 2) came up at a fairly local sale to me. It was at Rowley's of Newmarket. It is English and is dated around 1700. However, it has many differences to other calendars of the period. It consists of three brass discs with a diameter of 4.25cm, pinned together. On one side is a disc 1 - 31 (days of the month) that may be set against the days of the week engraved below. Interestingly, Sunday is signified by an image of the Sun instead of the more normal letter *S*. Below that is a list of months of the year listing their number of days. The other side is a little more interesting. At the top is a similar scale to that on the first side but with two numbers in place of the days, set vertically above each other. Either side of the aperture are the initials *H* and *W*. These are the times of High Water (at a port not specified but may have been London). Therefore the upper number is the day of the Lunar Cycle and the number below the time of High Water in hours. No minutes are recorded so the 48 minute daily difference means that some adjacent pairs of days will have the same time for the tides,



Above: *Figs. 3 & 4. The two sides of the quadrant by Tho: Poole, Nottingham.*



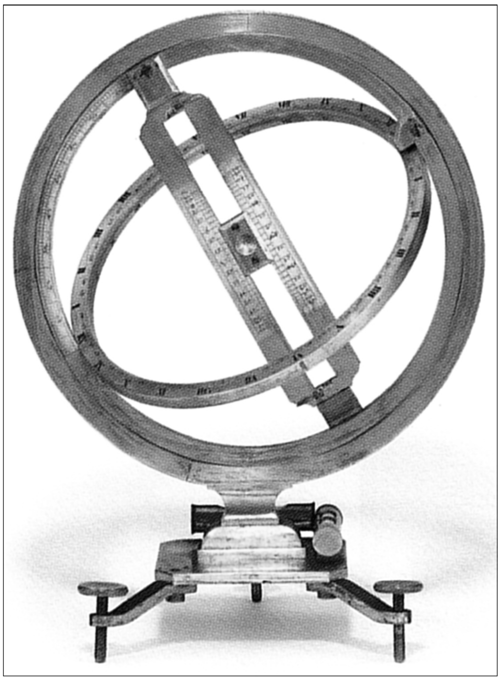
hence the pair of 7s below numbers 5 and 6. Below this is an aperture showing graphically the Phase of the Moon. The table beneath shows the times of Sunrise and Sunset (R and S) for each of the months of the year. It is a fascinating calendar and was sold for £2000, well above its £100 - £150 estimate.

In the sale at Christie's South Kensington on 25 October there were several dials offered. The object that really took my fancy was a small brass horary quadrant, made by *Tho: Poole Nottingham 1689* and made for *53^d 0'*. Figs. 3-6. It is very unusual and it is not often that provincial instruments of this complexity are to be found. On the front, in addition to the more normal scales, is a calendar square to assist with finding the day of the week for any day in each month. On the reverse is a fine map of the heavens showing various constellations on a volvelle for converting sidereal to solar times. This side too has calendrical information with dates from (16)88 to (17)64 with Golden Numbers, Epacts and Dominical Letters. In the spaces left, the quadrant is decorated with scrolls and small drawings so that there is virtually no wasted space at all. Of particular interest to us is a charming picture of a man standing beside a cube dial (Fig. 6). The quadrant made the sum of £14,400 including buyer's premium, midway between its estimates.

Standing ring dials are quite rare and are usually made by the very finest makers. The one in this sale (Fig. 7) differed from most in that the ring dial itself is not removable from its stand. It therefore looks a little strange at first glance, not having the normal suspension loop on top. However, it is well mounted on three screw legs and with the two spirit

Right: Fig. 7. Unsigned standing ring dial.

Below left: Figs. 5 & 6. Signature on quadrant and man looking at a cube dial.



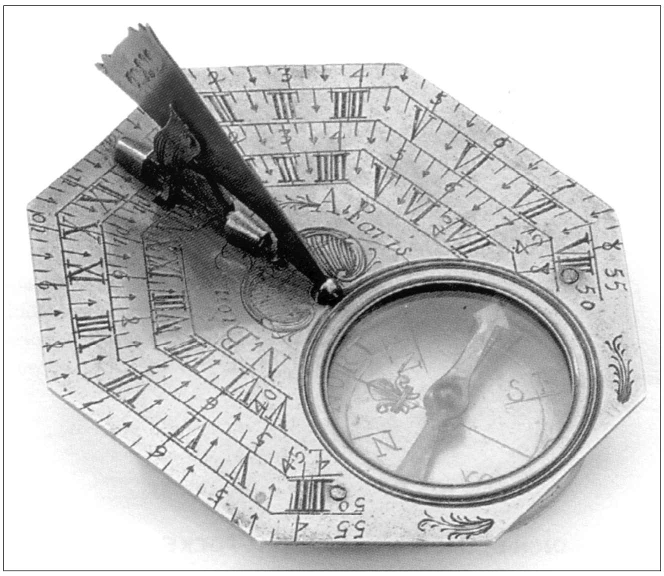
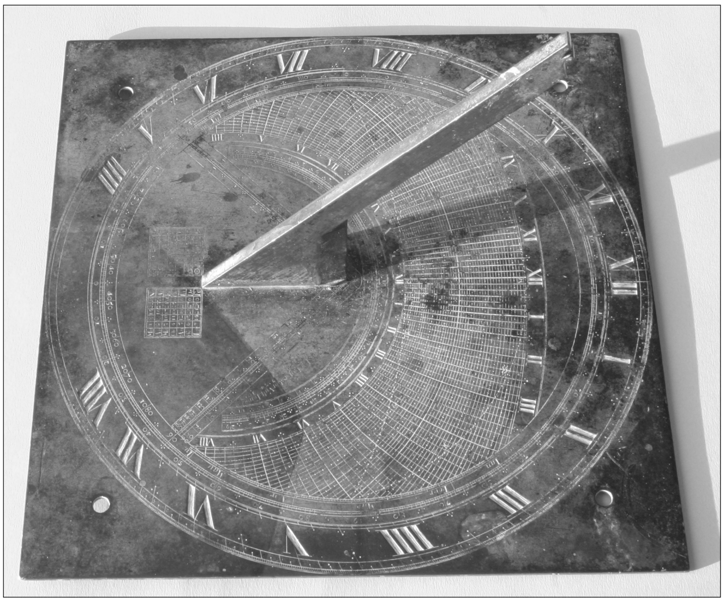


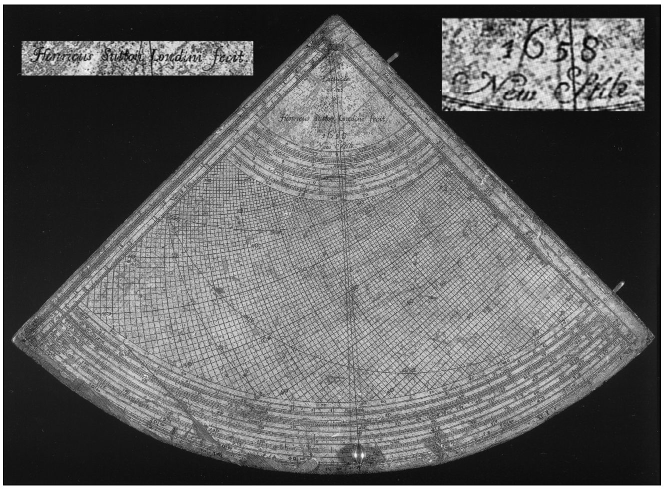
Fig. 8. Brass Butterfield dial by N Bion of Paris.

Left: Fig. 9. Wooden diptych dial.

Right: Fig. 11. Unsigned double horizontal dial.



Below: Fig. 10. New Style quadrant by Henry Sutton, 1658.



levels it would perform quite accurately. If only it had been signed.... It therefore sold for a mere £3,360.

A Butterfield dial (Fig. 8) signed by N Bion of Paris also sold at reasonable price - just £504, perhaps half of the usual rate. However, what is not clear from the catalogue or even the photograph is the dial's condition. Its gnomon has been replaced by a plain piece of brass, not even adjustable for latitude. The compass needle is also a replacement. This goes to show that it is not always safe to buy at a sale without viewing the goods, or at least getting an honest condition report from the auctioneers. I guess that this dial will be restored and may appear again at some time later.

An unsigned German diptych dial (Fig. 9) with paper scales pasted on the wooden base sold for an exceptionally high figure (for this type of dial). These dials were produced in quantities in Germany in the 19th century. The paper coverings tend to suffer from wear but this dial was in fairly good condition. It made £720 including buyer's premium.

In Christie's 'Landmarks of Science' sale on 13 December they were offering mostly books and manuscripts of famous persons, such as Darwin and Einstein. There were a few tools and instruments and one quadrant in particular took my attention (Fig. 10). It is one of just a few known by Henry Sutton that consist of paper scales pasted onto a wooden base. Because of their fragility, few have survived. This one was dated 1658, similar to one that I have already described.[1] However, I suddenly noticed that beneath his signature were the words *'New Stile'* (sic). This was at a time when we, in Britain, were still using the 'Old Style' or Julian Calendar. In fact it was nearly a century later before we adopted the 'New Style' or Gregorian calendar in 1752. My first thoughts were that Sutton had made this for a continental customer but then it was marked with the latitude of London, 51° 32'. These were not *rich mens' toys* and would have been used by someone in astronomy. It is possible that the owner was working with a colleague in Europe and needed the same calendrical information. I was able to get photographs of both quadrants and study them in detail. It appears that the same printing plate was used for both. The only change was the set of scales nearest to the apex. Therefore, he may have printed a large enough batch of the Julian plates then could have erased this scale, hammering from the back to raise the surface, before re-engraving this portion, in a similar way to Walter Hayes.[2] (This too was a re-used plate originally by Sutton.) The estimate for this quadrant was £12,000 - £18,000, which I thought was rather high and in the event it was not sold.

The Catalogue of London Book dealer, Sokol Books, showed the 1627 edition of Thomas Fale's book *Horologiographia*. Their price for this volume was £3,950. This is the third and probably the rarest edition of this 1593 work. Later editions were more numerous, my own copy dated 1652 was purchased at less than one quarter of this figure.

The Scientific Instrument Fair, held twice yearly in London (April & October), always manages to bring out a few interesting dials. Dealers attend from several countries and

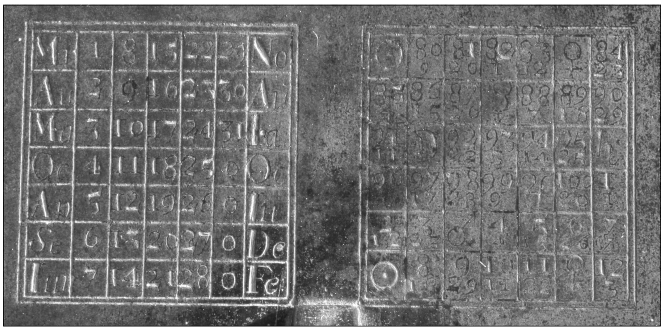


Fig. 12. Perpetual calendar information on the double horizontal dial of Fig. 11.

bargains are occasionally to be found. Several dials attracted my attention at the fair of 29th October. The first that I saw was a Butterfield *type* dial made, not in brass or silver, but of brightly coloured and decorated enamel on a metal base. This was being offered by Paris dealer Bertrand Thiébaut. Its gnomon was fixed but it had three chapter rings for different latitudes. Stuart Talbot, formerly of London but now residing in Freiburg in Germany, often has an interesting dial or two. On this occasion he had four. One was a rare double horizontal dial, c.1680, unsigned but in excellent condition (Figs. 11 & 12). It was obviously by one of the famous makers of this type but which one it is difficult to decide. Hopefully, detailed analysis of engraving and punch marking styles will eventually supply this information. One unusual feature of the dial is a perpetual calendar for the years 1680 to 1712, presented as two square tables. Stuart also had a very fine 6" universal equinoctial ring rial by *J Sisson London.* This dial was complete with its original fishskin case. A small 4" Horizontal Dial was signed simply '*I*N* 1678*', probably made by John Nash. His final dial was interesting, being a magnetic compass dial similar to one I have illustrated[1], obviously London made but for a lower latitude. On close inspection it was soon clear that this too was a Southern hemisphere dial. It was reasonably priced (for such a rarity) in the low hundreds.

ACKNOWLEDGEMENTS

I would like to thank the following for allowing me to use their photographs: Christie's New York for Fig. 1; Rowley's, Ely for Fig. 2; Christie's South Kensington for Figs. 3, 4, 5, 6, 7, 8 & 9; Christie's King Street, London for Fig. 10; Stuart Talbot for Figs. 11 & 12.

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1. M Cowham: *A Dial in Your Poke*, Cambridge (2004).
2. M Cowham: 'An Interesting Compass by Walter Hayes' *Bull SIS.* **81, pp.** 8-9 (June 2004).

Redacted

Birthday Dial

Our member Dr John Lester had a milestone birthday recently and was presented with this cake, made by Sue Dowker of Ackenthwaite, Cambria. The cake looks to be quite well delineated as a vertical south dial although it might possibly slide off the plate when put on the wall. But surely it should show 'temporary' hours?!

EARLY FRENCH 'SHELL' DIALS

MIKE COWHAM

Many years ago I bought the book 'Die Sonnenuhr' by René Rohr and in this is the photograph of the early mass dial at La Chaise Dieu in the Auvergne. Later on I was able to visit La Chaise Dieu and see the dial (Fig. 1) for myself. It is incised into the stone with its now-filled gnomon hole in the mortar above. The cross section of its carving resembles a corrugated iron sheet or perhaps more precisely a scallop shell. This dial has always intrigued me and about a year ago I was staying in Gigondas in Provence (where they make my favourite wine) and decided to look at the small Chapelle St Cosme just outside the village. Here I found another dial but this time much more interesting (Figs. 8 & 9).

Having now found these two dials I contacted Denis Schneider of the French sundial group. The Gigondas dial was new to him but he was able to tell me of some others of a similar type that are still to be seen in France. Armed with this information we travelled to France for a holiday but carefully arranged our route to pass the various dials that he had given us.

The first, at Meung-sur-Loir, near Orléans (Fig. 2), was a little different but could still be identified with the others. Another, at Thiers in the Auvergne (Figs. 4 & 5), showed similar features but has a further two 'segments' above the horizontal line. The most interesting of this type, at Cruis near Digne les Bains (Fig. 11), we left until last. On the way there we found a church at Montverdun sitting high upon a hill and this too had a dial (Fig. 6) with similar characteristics but with the full 24 hours of segments included.

Denis had sent me a photograph of the Cruis dial and having seen this I really wanted to see it for myself. He told me that the dial is now kept inside the church and as we approached (on a Sunday) I began to get the feeling that the church just possibly could be locked. I was right, and enquiries to several of the villagers failed to tell us how or where we could get the key. So, disappointed, we had to leave without seeing the dial at first hand. However, Denis's picture showed it in reasonable detail so we made a vow to return again to try to see this dial. I have since found out that the key may be obtained from the Marie but as we visited on a Sunday the Marie was closed! I have also included a further dial that we found on this trip at Fenioux in Charente-Maritime (Fig. 3), ostensibly a standard mass dial but upon closer inspection it seems that the eight divisions are also shaped a little like flower petals, so it could be related to the others. Another dial at Uzeste in

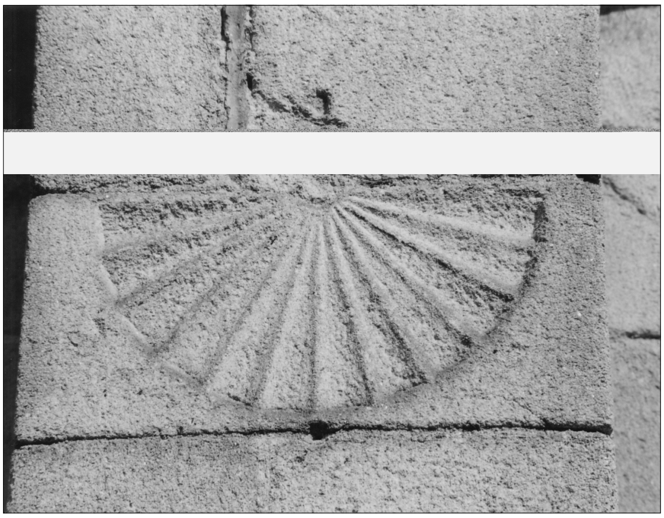


Fig. 1. The early 'shell' dial at La Chaise Dieu (Dial 5).

Gironde (Fig. 7) has been included because of its similarities to some of the others.

A later trip to Provence in October 2006 gave us the opportunity to try to see the Cruis dial again. This time, after yet another abortive attempt (we arrived in the afternoon and the Marie is only open mornings!) we were eventually able to gain access to photograph and measure the dial.

During our stay in Provence we were guided to two more of these dials, one at Boulbon, (Fig. 12), and another on a private house (once a chapel) near Apt (Fig. 13). A further dial, at Lafare, (Fig. 10), close to where we were staying, appears to be of a similar type but is now considerably worn by the actions of the weather.

What have all of these dials got in common? To be honest we probably have two different types here, those carved into the church walls and those carved on a stone and inserted later. However, they are all quite early, probably dated between 1050 and 1200AD, so almost contemporary with our Anglo-Saxon dials and probably made before most English mass dials. As with our Anglo-Saxon dials the numbers of 'hours' vary from dial to dial. On some of these dials the 'hours' are not indicated by incised lines but by raised sections, which show the time at the start and finish of each hour (e.g., 8½ to 9½, or as we would say 'in the ninth hour') unlike our present notation that shows the time of the actual hour itself. In almost all cases these French dials were mounted quite high on their respective buildings. It would have been quite difficult to read some of them from the ground without binoculars or a telescope (neither of which existed at the time that the dials were made). Why were they mounted so high? We can only speculate but a

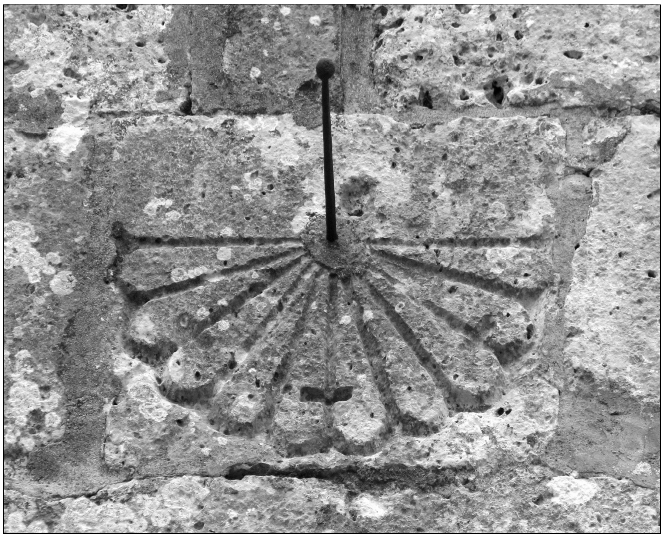


Fig. 2. The dial at Meung-sur-Loire with its 10 segments (Dial 1).

likely reason is to keep the dials above the levels of surrounding trees and buildings to ensure a clear shadow from sunrise to sunset, summer and winter. Anglo-Saxon dials too were originally mounted quite high on the walls of our churches. We are lucky that in France few of these dials have been repositioned, unlike those on English churches. It is only in recent years that they have started to restore their churches and they are now much more sensitive to retaining the old features.

DIAL DETAILS

There are 11 dials described in this article so to avoid confusion I have numbered each one consecutively from North to South and used the same numbering on the later distribution map (Fig. 14).

Dial 1. (Fig. 2.) The dial at Meung-sur-Loire is exceptionally high, about 11m. The dial face has 10 lobes or perhaps 'petals' and it must have been carved before being incorporated into the building, as its 'petals' stand proud of the stone itself. Note the cross marks at noon (Sext) and in the morning (Terce) and afternoon (Nones) similar to many of our Anglo-Saxon dials, but note that these are not exactly at the mid points of these periods.

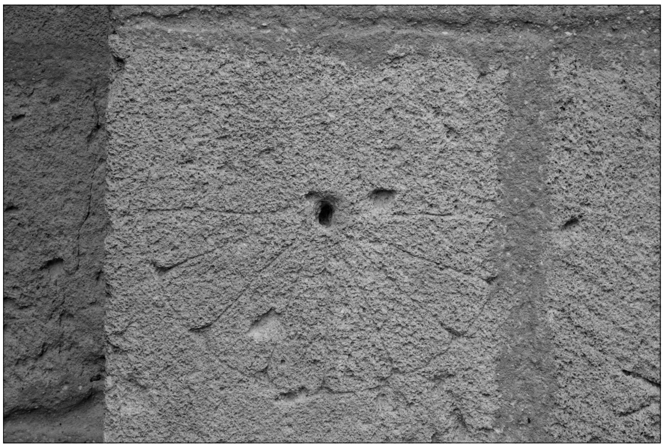
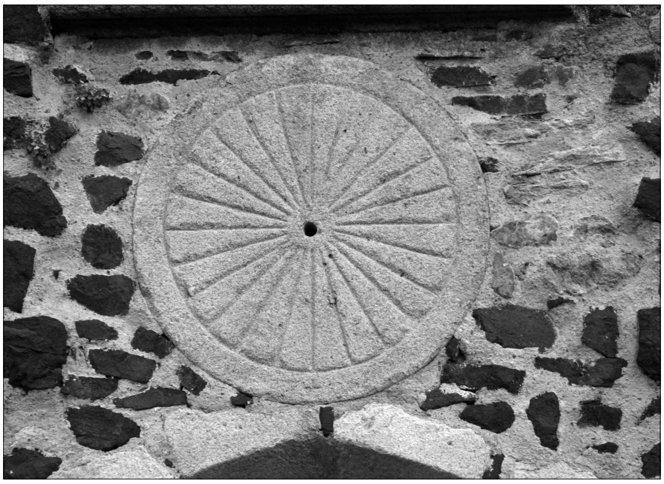


Fig. 3. The dial at Fenioux with its 8 interestingly shaped segments (Dial 2).



Top: Fig. 4. The dial at Thiers with 11 segments (Dial 3).
Centre: Fig. 5. The dial at Thiers rotated and stretched to show how it may originally have looked (Dial 3).
Bottom: Fig. 6. The dial at Montverdun with 24 segments (Dial 4).

Dial 2. (Fig. 3.) I have included the Fenioux dial because I think that it is related to the others, but perhaps somewhat

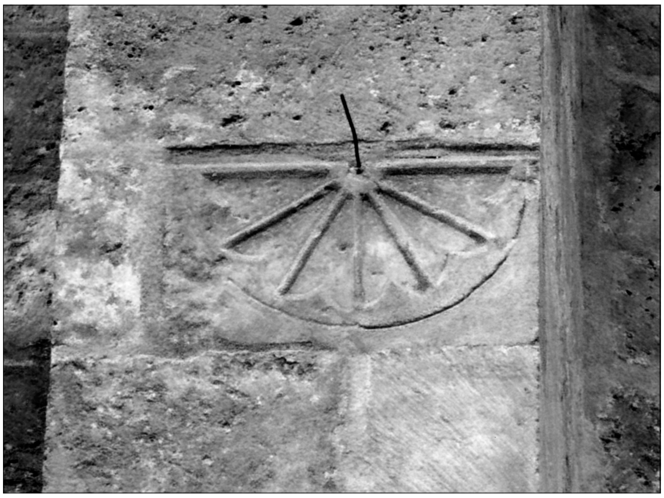


Fig. 7. The dial at Uzeste, not quite shell-like but more like the dials of Hesse in Germany (Dial 6).

later. This dial has been incised into a buttress, not very deeply, but the petal-like segments are quite clearly seen. This dial is relatively low at about head height and at first glance appears to be a standard mass dial.

Fig. 8 (below) and Fig. 9 (right). The 11 segment dial at Gigondas, mounted very high on the wall of the Chapelle St Cosme (Dial 7).

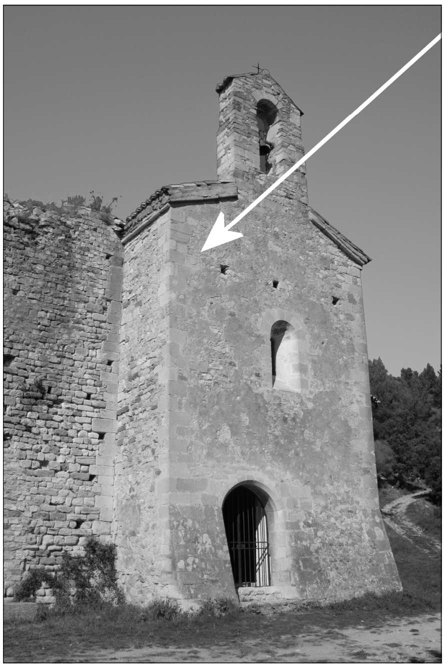
Dial 3. (Figs. 4 & 5.). The Thiers dial is about 8m high but is quite difficult to see as there are tall buildings close to the south side of the church. The dial is quite similar to that at Meung but it is carved into a cylindrical stone, which has since been turned such that the dial is no longer horizontal. This was probably done so as to 'arrange' a vertical line at noon. Note too the later semi-circular stone shelter that has been placed above it. This dial has just nine 'petals' below the horizontal line and two others above that are, of course, unusable in a vertical dial. Above the dial is a crescent, perhaps representing the moon lying on its back.

Dial 4. (Fig. 6.) The monastery church at Montverdun sits high on a hill overlooking the town. It has a circular dial with a full 24 divisions, now positioned above a later Gothic window. It shows no further divisions or any inscriptions but appears to have a '+' incised at its lowest point.

Dial 5. (Fig. 1.) The dial at the fine abbey church of La Chaise Dieu certainly resembles a fan, perhaps more than a shell. It clearly has 12 equal divisions and was probably incised directly into the buttress on which it now stands. Unusually, it is mounted fairly low down, just above head height, so this dial would have been easy to read, unlike many of the others in this study.

Dial 6. (Fig. 7.) The dial at Uzeste in Gironde is divided into just 6 segments. Although not quite shell shaped each segment is well defined and it is very similar to some of the German dials from the region of Hesse.

Dial 7. (Figs. 8 & 9.) The Gigondas dial was clearly cut into the stone before being incorporated into the building. It is only about 0.3m in diameter but is mounted around 7m above ground level. Even with a 300mm telephoto lens the



dial can not be made to completely fill the camera frame. It is divided, unusually, into 11 sections giving it a most attractive shell like appearance. Beneath the dial are inscribed the words **SOL--** and **LVNA** and below these **OROLOGIVM**. It is therefore interesting to speculate on how this dial could have been used for lunar purposes. It is feasible that it could be used around full moon (assuming that it was possible to read it from ground level) where the shadow would be near verti-

Fig. 10. The badly weathered dial at Lafare (Dial 8).

cal at midnight. Each day the moon rises about 48 minutes later but each division on the dial represents about 65½ minutes. However, when this dial was made almost 1000 years ago the difference of 17½ minutes per day, especially at night, would have been of little consequence.

Dial 8. (Fig. 10.) The badly weathered dial at Lafare is mounted directly above a small slit window. It appears to have 10 divisions but, like its nearby neighbour in Gigondas, it may have 11 divisions.

Dial 9. (Fig. 11.) The Cruis dial has to be the most interesting of all of these shell dials. The stone is about 0.8m square with the dial itself about 0.5m diameter. The dial is surrounded with various decorations and some text. It is possible to make out the word '**hoRILoGIo+**' across the top of the dial. Above this is a line of writing possibly '**ABB… Eclesia Aerecto**'. Other writing on it shows **(AQUI)LA** for the eagle at the top left, **LEO** for the lion at the top right, **BASILICVM** placed almost vertically near to the plant on the lower right (probably the herb basil) and **AGN(US)** on the left where the stone is damaged, but this may have been a lamb holding a flag. The dial is well incised into its stone, which is only 9 cm thick and it obviously was not part of an existing wall. The dial is probably the earliest of those mentioned in this article with an estimated date of 11th century. It has 11 segments but those at the sunrise/sunset points are only half divisions keeping the noon line vertical unlike that at Gigondas. The dial was unearthed in 1967 in a local garden near to the church but it is not known if it originally came from this church. Being buried for so long has protected it from the elements but some damage has been caused, particularly to its lower left-hand corner.

Fig. 11. The dial from Cruis with its 'beasts' and various insriptions. Note also that its 11 segments have been halved at dawn and dusk (Dial 9).

Dial 10. (Fig. 12.) The church of St Marcelin at Boulbon has a shell dial situated above its south door. It is divided into 12 equal divisions. In addition to this dial are to be found over 16 'scratch dials' all over the south face of the building. Most of these have only 4 segments and were probably used for determination of services, different ones being used for the different seasons.

Dial 11. (Fig. 13.) About 6km south of Apt on a ridge high above the valley, with a fantastic view of the region, is the former chapel of Notre Dame de Clermont, now a private residence. On the south side of the chapel wall is a rather small shell-type dial, again with 11 divisions. It is unusual in that these divisions stop at least one hour from the nominal 6am/6pm horizontal. Beneath the dial are the remains of a decorated border and there are traces of possible numerals at the noon and 3pm positions.

DISTRIBUTION OF SHELL DIALS

The map, Fig. 14, shows the locations of these 11 dials scattered across France. There is no clear concentration of them except that there appear to be more around the Auvergne and in Provence. I am sure that there are many more of these interesting dials to be found and hopefully within a few years I am confident that we will be able to double this listing.

Dials of this pattern seem to be unique to France but there are a few in Germany that are possibly related and I am informed that there are some in eastern Europe that I have not yet been able to examine.

Fig. 12. The dial at St Marcelin, Boulbon (Dial 10).

Fig. 13. The dial on the chapel of Notre Dame de Clermont, near Apt (Dial 11).

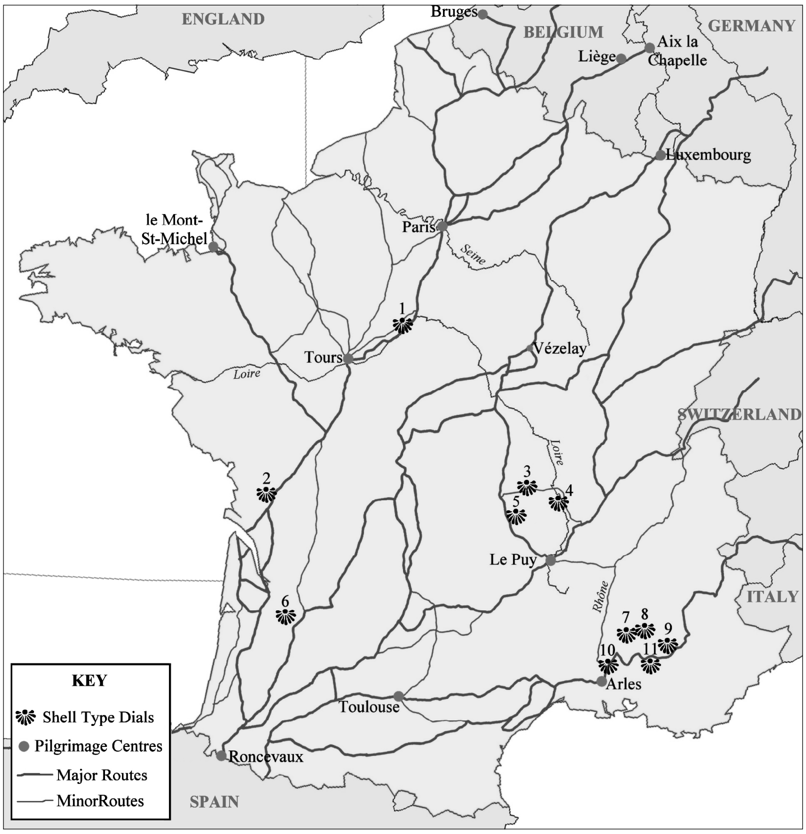


Fig. 14. Map showing the distributions of 'shell dials' in France superimposed on the major pilgrimage routes to Santiago de Compestela in Spain.

Note that due to the height of many of these dials, they were photographed from a rather low position thereby creating foreshortening in the vertical direction. This has been corrected for some of the illustrations used.

A suggestion has been made that these dials are in the form of a scallop shell. This is precisely the insignia of St Jacques. In the Middle Ages there were frequent pilgrimages to Santiago de Compostela where the remains of the saint were said to have been taken. I have added to the map the main routes across France taken by these pilgrims and it seems that the majority of these dials lie on, or very close to, one of these main arteries. Is it just coincidence or is there really a connection? It is difficult with such a small sample to be absolutely sure, but if more dials come to light on these routes it may be possible to make a positive connection with the routes of the pilgrims, who came from all over northern Europe.

DIAL CALIBRATIONS

Much has been written about early dials and the way that they are divided. Most, like these French dials, are divided into a number of equal parts. In the case of the earliest dials basic subdivision was used giving 2, 4, 8 and 16 divisions for the day. Some also used sub-multiples of 12. It is interesting here to see the use of odd numbers such as 9 and 11. The day is therefore reckoned such that the time is 'in a particular hour' and noon falls in the centre of the lowest division. This has been overcome at Cruis by making the first and last divisions only one half of the others.

The dials, being vertical and presumably exactly south facing, will only record 'hours' when the sun is positioned between east and west. These 'hours' will therefore vary in length considerably throughout the year by as much as 2:1 at these latitudes. This was not too important because the prime use for these dials was to record solar noon and to give an indication of the times for the various church services, usually mid-morning and mid-afternoon.

These dials were all constructed for use with horizontal gnomons (like our early Anglo-Saxon dials and later mass dials). The gnomons now fitted into some of these dials are unlikely to be original and are almost certainly modern replacements.

Dial No.	Location (Département)	Divs	Useful Divs	Hours each	Height AGL	Diam
1	Meung-sur-Loire (45)	10	10	1.2	c.11m	c.0.42m
2	Fenoiux (17)	8	8	1.5	est.1.6m	est. 0.25m
3	Thiers (63)	11	9	1.33	est. 8m	est. 0.6m
4	Montverdun (42)	24	12	1	est. 9m	est. 0.6m
5	La Chaise Dieu (43)	12	12	1	3.5m	0.48m
6	Uzeste (33)	6	6	2	unknown	unknown
7	Gigondas (84)	11	11	1.09	c. 7m	c. 0.3m
8	Lafare (84)	(10)	(10)	(1.2)	c. 4.9m	c. 0.36m
9	Cruis (04)	11	10 + 2 halves	1.09	-	0.52m
10	Boulbon (13)	12	12	1	c. 4.5m	c. 0.35m
11	Apt (84)	11	11	(0.9)	c. 5.3m	c. 0.2m

Table. 1. Details of the calibrations, heights above ground level and diameters for each of the dials listed.

I would appreciate information about further dials of this type that you may find when travelling around France.

ACKNOWLEDGEMENT

I would like to thank Denis Schneider for his invaluable help in locating these dials and for illustration Fig. 7.

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A UNIVERSAL ITALIAN AND BABYLONIAN HOURS ACCESSORY

CHRIS LUSBY TAYLOR

This paper is based on the author's presentation at the BSS Conference, Durham, April 2006

At our 2005 conference, Professor Karl Hofbauer[1] told us of Goethe's reaction when visiting Italy and finding the strange way they kept time. Instead of measuring time from midnight, as was done in Germany, they measured how much was still to come before sunset. This focus on the available daylight, rather than the irrevocably elapsed time, appealed on him and he saw in it something of the Italian character with its love of the evening. Indeed, before the almost universal availability of artificial lighting, the need to know how long you had before it would be dark must have been the prime motive for wanting to know the 'time'.

So, how can we measure how much time remains before sunset? When is sunset? It is when the sun is on the horizon. The horizon is in the horizontal plane. We can devise a sundial to show how much time will elapse until the sun is in any arbitrary plane, so we can certainly devise a sundial to show how much time will elapse before sunset.

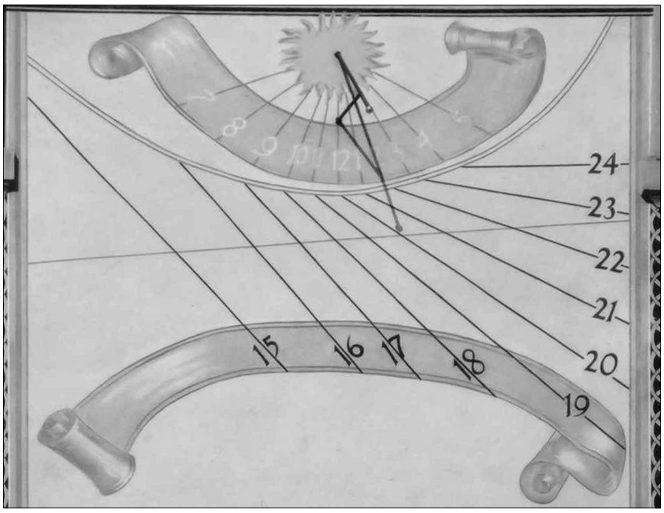

Fig. 1. Vertical Italian hours dial in Prague.

If we take some time, such as one hour before sunset and thus 23 hours after sunset yesterday, the sun must be in the plane we get by tilting the horizontal plane 15° anticlockwise about the polar axis. Regardless of the season and the sun's declination, it must be in this plane one hour before sunset. So if we place a nodus in this plane, its shadow on a horizontal or vertical dial an hour before sunset will, therefore, be on the straight line where this plane cuts the dial plane. Figure 1 is a vertical dial in Prague telling us it is about twenty and a quarter hours since the previous sunset, so we have 3¾ hours until sunset today.

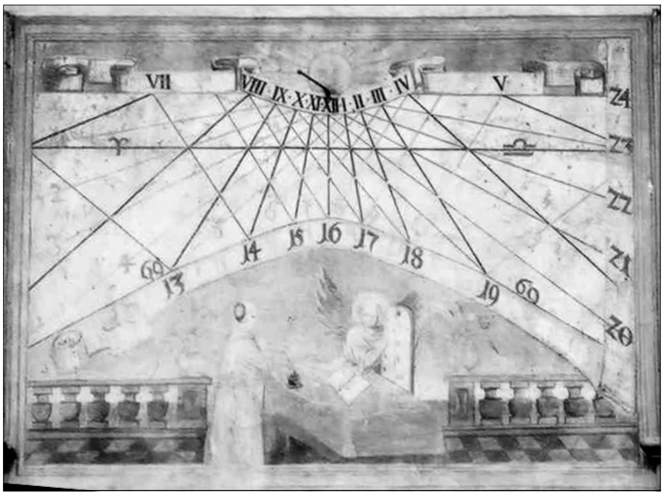

Fig. 2. Three sets of lines showing hours since sunset, midnight and dawn.

Just as we can find the plane that the sun is in one hour before sunset, so we can tilt the horizontal plane 15° clockwise about the polar axis to give the plane the sun is in one hour after sunrise. So, we can similarly mark the dial with lines showing time elapsed since dawn, known, for obscure reasons, as Babylonian hours. If we add conventional hours since midnight we get a complex but beautiful dial with three sets of intersecting lines, as in Figure 2 which is in the Klementinum in Prague. This is difficult to read. But there is a way to reduce the number of

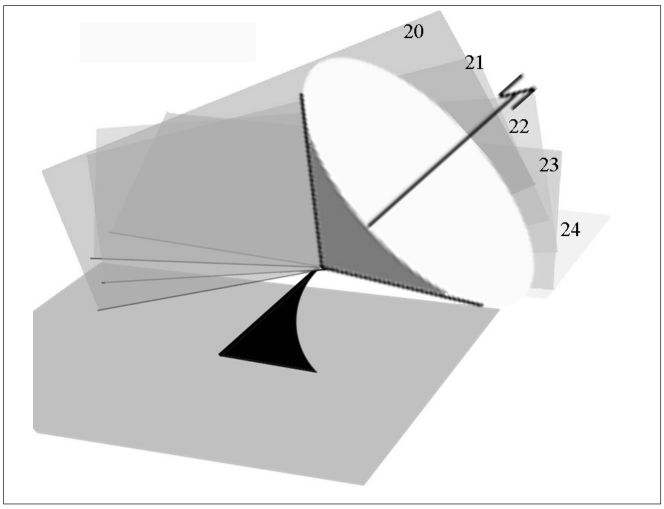

Fig. 3. Shadow planes through a nodus, 20 to 24h after sunset.

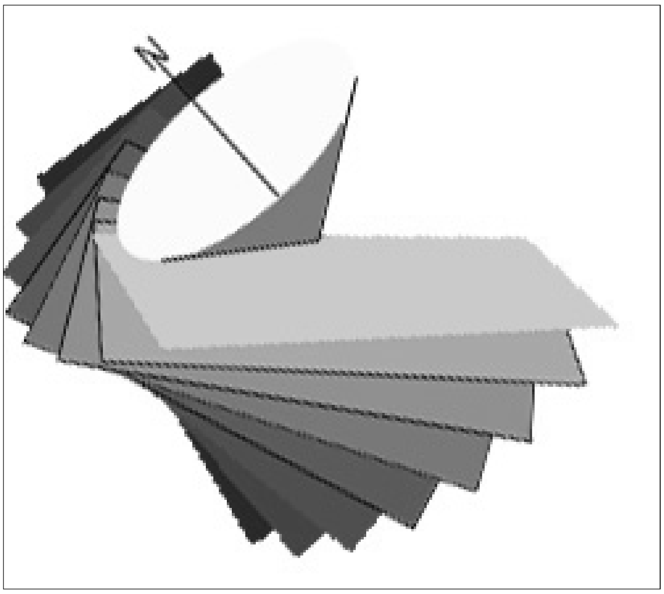

Fig. 4 The cone enclosed by all the shadow planes through a nodus.

lines. Look at the envelope, or space enclosed as we take a plane through a nodus, initially parallel to the horizon, and spin it around the polar axis. The envelope is two cones meeting at the nodus, as shown by Figs. 3 and 4. The apex angle of the cones is twice the latitude.

Instead of using a point nodus some distance from the dial to cast the shadow, we could use one of the entire cones. And, as the lowest part of the cone is horizontal, we can rest the cone on a horizontal dial, as has been done by Javier Moreno Bores with the dial in Genk shown in Figure 5.

The shadows of the edges of a cone resting on a plane are, clearly, straight lines radiating from the apex. So the Italian and Babylonian hour lines on this dial are radial, not skewed.

It isn't necessary to have both the complete cone and the full lengths of the hour lines. You could reduce the hour lines to a chapter ring, or keep them and reduce the cone to a conic section. Any shape gnomon that fits inside and just touches the cone all the way round will do. A sphere, for instance, as used by Fabio Savian's delightful frog in Fig. 6, which splits the dial down the middle and uses two hemispheres. A plane conic section works, also. A vertical or horizontal section through the cone could be used, but the most versatile is an equatorial

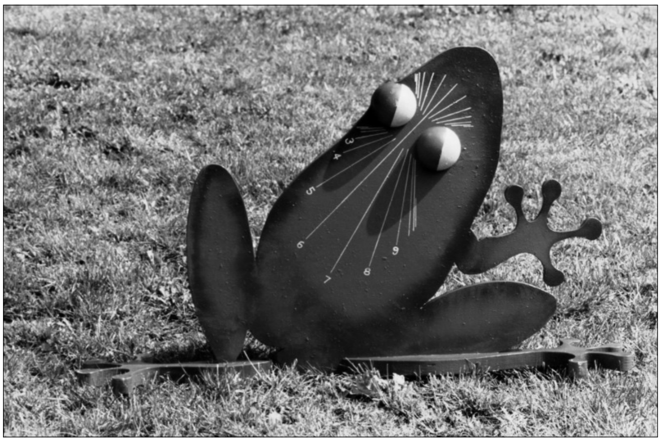

Fig. 6. Fabio Savian's La Rana dial in the form of a frog. Courtesy of Fabio Savian.

section as it is a circle. Imagine the Genk dial with the cone reduced to just its circular base. This circle touches the dial and its axis points to the apex of the cone it is standing in for, which is the point on the dial from which the Italian and Babylonian hour lines radiate.

By looking at this circular gnomon we can see how to draw the Italian hour lines. Fig 7 is the Genk dial, annotated with the relevant lines. O is the apex of the cone (hidden in concrete) and OK is the edge of the sunlit part of the cone, where the light kisses the cone to use Fred Sawyer's lovely term, so the edge of the shadow passes through H. The cone touches the ground at N. KH (not shown) and NH are tangents to the circular gnomon, center C, with radii CN and CK. So the triangles NCH and KCH are congruent, and angle NCH is half of angle NCK. At dawn, angle NCK is zero and it increases by 15° an hour, so NCH increases at 7.5° an hour. The length of NH is thus equal to NC.tan (*hour angle*/2). It is easy then to draw the hour line OH.

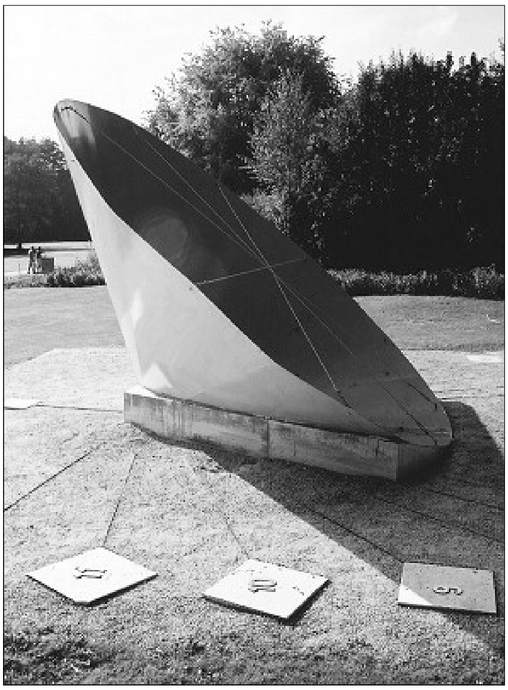

Fig. 5. Conical gnomon dial in Genk Sundial Park, Belgium. Courtesy of Frans Maes.

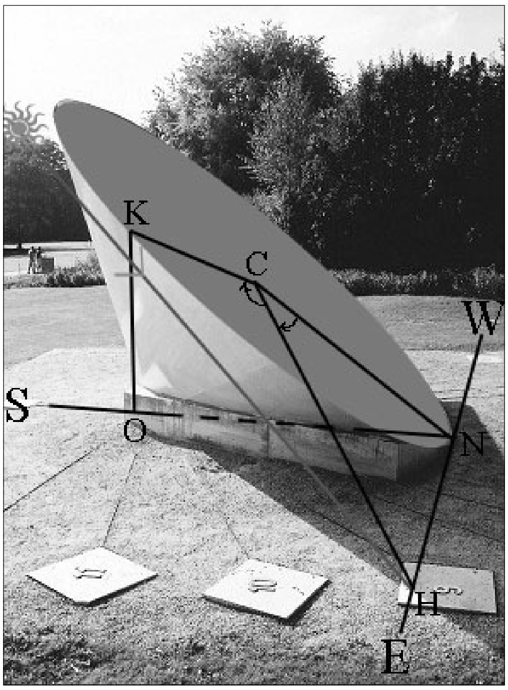

Fig. 7. The Genk dial showing how hour lines are derived. Courtesy of Frans Maes.

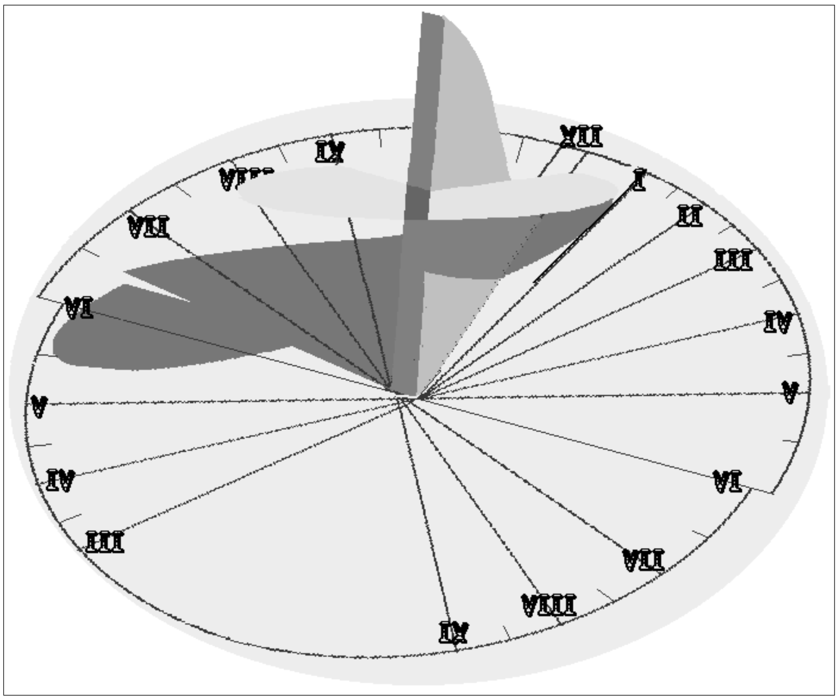

Fig. 8. A CD giving Italian and Babylonian hours on a standard sundial.

The hour lines of a conventional horizontal sundial can be drawn in an exactly similar way by imagining an equatorial circle surrounding the gnomon and touching the dial. The only difference is that they are drawn by using 15° per hour, not 7.5°. Thus, the hour lines of a horizontal dial with a conical gnomon resting on the dial are exactly the same as the half-hour lines of a conventional horizontal sundial.

So, if we can add a conical gnomon, or a section of one, to an existing horizontal sundial, we can use its existing hour lines to read Italian and Babylonian hours. All we need to do is double the time shown. We do not need any more lines, certainly not the confusing three sets of intersecting lines we saw in Fig. 2.

One way to add a conic section to an existing sundial is to use three quarters of a CD. Using a craft knife or a small hacksaw it is easy to cut a quadrant out of a CD. Note that this accessory – just three quarters of a CD – is universal in that it can be used with a horizontal sundial anywhere in the world. It needs no marks or graduations itself, relying on the existing hour lines on the horizontal sundial. Also, it is unaffected by the Equation of Time.

To use it, slip it over the gnomon with the shiny face upwards and adjust its angle so that the reflection of the gnomon seems to be continuous with the gnomon, with no kink – this ensures the CD is at right angles to the gnomon. Now slide it down the gnomon until it just touches the dial, as shown in Fig. 8. Hold it so that the shadow of your hand doesn't obscure the relevant part of the shadow of the CD.

A standard gnomon is a thickish plate with two parallel shadow-casting edges or styles. The east edge is used to read hours from 0 to 6, the west edge from 6 to 12. So it is with the CD – place it over the east edge to read Babylonian and Italian hours from 0 to 12, the west edge to read hours from 12 to 24. The shadow of the CD extends to the east and west of the gnomon. The Babylonian time is shown by the sundial's hour line that the shadow just reaches on the east side. Read the hour and double it. For instance, in Fig. 8, the shadow just reaches the 1 o'clock hour line. So, the Babylonian time is 2 hours since dawn. On the west side, the shadow reaches to about 5:25. Double this to give the Italian time 10:50. So, it is 10 hours 50 minutes since sunset yesterday and 13 hours 10 minutes until sunset today. We've already had two hours of day, so the day length is 15 hours 10 minutes.

If either hour is greater than 12, you must switch the CD over to the west edge of the gnomon to measure it. This is unambiguous – both edges will indicate either less or more than 12. Very often, and always in winter, you will find that you use the east edge for Babylonian hours and the west edge for Italian, unlike Fig. 8 which shows the east edge being correctly used for both.

So the full instructions for using the device are:

1. Place the CD over the gnomon, shiny side up, edge just touching the dial, angle adjusted to make the reflection of the gnomon appear in line with the gnomon. Centre the CD on the east edge of the gnomon to use the hour lines numbered up to 6, west for higher numbers. This should be obvious by looking at where the hour lines radiate from.

2. Find the time indicated where an hour line touches the edge of the shadow to the east of the gnomon. Double it to give the Babylonian hour: the time since sunrise. Think 'east = sunrise'.

3. Find the time indicated where an hour line touches the edge of the shadow to the west of the gnomon. Double it to give the Italian hour: the time since sunset yesterday. Think 'west = sunset'. Subtract from 24 to give the time to sunset today. Enjoy that time.

Two limitations in practice mean that the CD cannot be used with all horizontal sundials. The first is that the gnomon must not have supporting brackets jutting out above the dial. The other is that the hour lines must be drawn towards the foot of the gnomon. Some dials just have a chapter ring with hour marks instead of hour lines. This makes it difficult to estimate the time shown, although a straight edge laid from the foot of the gnomon, through the edge of the shadow to the chapter ring could be used.

Anyone making a horizontal sundial could add an equatorial disk or circle surrounding the gnomon so that the dial can be read for Italian and Babylonian hours as well as conventional ones. It should actually be two semicircles, one on either side of the gnomon, but they can be joined by a straight section the same length as the width of the gnomon. With this simple addition, the sundial becomes a permanent invitation to la dolce vita.

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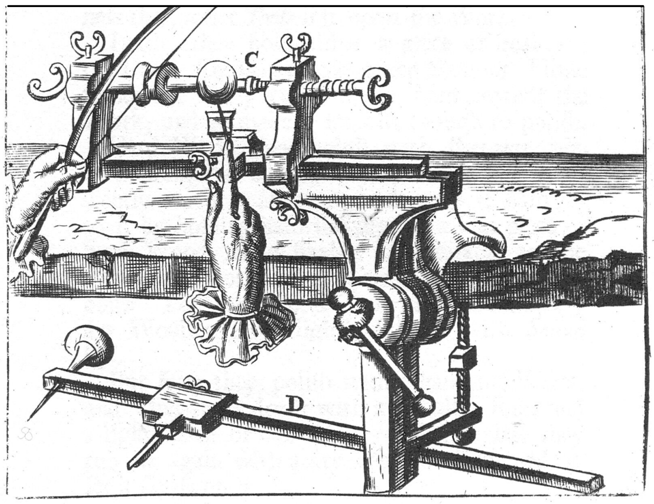
EXTRACT FROM JOSEPH MOXON'S 'MECHANICK EXERCISES'

JOHN DAVIS

Joseph Moxon (1627-1691) was a writer, publisher, mathematical instrument and globe maker and was also hydrographer to King Charles. He is best known to the dialling world for his book *Mechanick Dyalling* which showed how a sundial could be drawn on any plane using only geometry. He is also known for *Mechanick Exercises: or the Doctrine of Handy-Works* which was first published in 1678 and was the first English book to describe and illustrate the tools of various trades (smithing, joinery, bricklaying etc.) and explain their use from the point of view of the practitioner. It provides a valuable insight into 17th century technology. The following extract is taken from the section on turning.



Part of Moxon's Plate 16. The instrument described as a Sweep is at D at the bottom of the plate.

§ XIX. Of laying Moldings either upon Mettal, or Wood, without fitting the Work in a Lathe.

I Had, soon after the Fire of London, occasion to lay Moldings upon the Verges of several round and weighty flat pieces of Brass: And being at that time, by reason of the said Fire, unaccommodated of a Lathe of my own, I intended to put them out to be Turned: But then Turners were all full of Employment, which made them so unreasonable in their Prizes, that I was forc'd to contrive this following way to lay moldrings on their Verges.

I provided a strong Iron Bar for the Beam of a Sweep: (For the whole Tool marked in Plate 16, is by Mathematical Instrument-makers called a Sweep.) To this Tool is filed a Tooth of Steel with such Roundings and Hollows in the bottom of it, as I intended to have Hollows and Roundings upon my Work: For an Hollow on the Tooth, makes a Round upon the Work; and a Round upon the Tooth, makes an Hollow on the Work; even as they do in the Molding-plains Joyners use. Then I placed the Center-point of the Sweep in a Centre-hole made in a square Stud of Mettal, and fixed in the Center of the Plain of the Work; and removed the Socket that rides on the Beam of the Sweep, till the Tooth stood just upon its intended place on the Verge of the Work, and there screw'd the Socket fast to the Beam.

To work it out, I employ'd a Labourer, directing him in his Left Hand to hold the Head of the Center-pin, and with his Right Hand to draw the Beam and Tooth, which (according to the strength) he us'd, cut and tore away great Flakes of the Mettal, till it receiv'd the whole and perfect Form the Tooth would make; which was as compleat a Molding as and Skillful Turner could have laid upon it.

Having such good Success upon Brass, I improv'd the invention so, as to make it serve for Wood also......

The above transcription shows the original spellings but not the ligatures and italicisation of the original. It is highly likely that the "weighty round flat pieces of brass" were due to become horizontal sundials, perhaps even for the great makers such as Henry Wynne and his apprentice Thomas Tuttell with whom Moxon also co-wrote a dictionary of mathematical instruments.

The extract tells us several things about the practicalities of sundial making at the end of the 17th century. For example, it shows that it was common to cut a moulding on the perimeter of a dialplate and that there were lathes capable of doing this. The effects that the Great Fire of 1666 had on the trade is evident, as well as the ingenuity of Moxon in overcoming them.

Using the tool would not have been easy and it would have needed care to prevent the pivot slipping out of the hole in the plate centre and scoring the surface. It would be very interesting to try to identify a dial of this period which was produced by this method.

THE RESTORATION OF THE DIAL ON THE THOMAS PLUME LIBRARY, MALDON

JOHN DAVIS

Fig. 1. The sundial on the side of the Plume Library, before restoration.

The vertical sundial on the Thomas Plume Library in Maldon, Essex, has been variously recorded as being of wooden or slate construction. When I was asked by the local council to inspect it with a view to restoration on a dismal December afternoon in 2003, the first view from the ground was that either of these two materials could be correct: the dial was an unattractive grey colour with some hourlines just barely visible. (Fig. 1.) A hunt by the Town Clerk found a short ladder on an unattended building site which allowed for a slightly closer inspection. This showed that the dial face was actually of lead sheet on some form of backing with the lines shallowly cut into the surface and originally painted. The dial had the motto NON SINE LUMINE (*Not Without Light*) and a sun motif around the gnomon root with alternate straight and curly rays denoting the sun as provider of light and heat respectively. A report was duly written and the council set about raising the money for a professional architectural and sculptural restoration firm to put the dial back into good condition. The Essex Heritage Trust was the major supporter of the project.

Fig. 2. The statue of Thomas Plume outside All Saint's church, Maldon.

The Rev Thomas Plume (1630-1704) (Fig. 2) was a local Maldon man who was educated at Christ's College, Cambridge, and eventually (1658) became the vicar of St Alphege's church, Greenwich, at the period when John Flamsteed, the first Astronomer Royal, was establishing the Greenwich Observatory. He was also the Archdeacon of Rochester from 1679 until his death in 1704. He was a well-known figure and is mentioned in the diaries of Samuel Pepys and John Evelyn who both heard him preach at Greenwich. In his will, he bequeathed his library of 7000 books to Maldon for the use of the local clergy, gentlemen and scholars. He also gave an endowment to provide for the library's upkeep and 20 shillings a year for the purchase of new books. The brick library building is in the centre of Maldon and is now called the Plume Building. It was converted from a derelict church of which only the restored tower remains. The existing red-brick building was built by Plume to replace the nave, which had collapsed in 1655, over the period 1699-1704. It houses the books on the upper floor with the lower floor originally being used as the old Grammar School. In another bequest, of £1900, Plume founded the Plumean Professorship of Experimental Philosophy and Astronomy at Cambridge University, a post which celebrated its tri-centenary in 2004. One of the results of this post was the purchase of a number of astronomical instruments to furnish the Trinity College Cambridge observatory, including a telescopicum sciothericum made by John England.[1,2] Despite his association with Flamsteed and the chair of astronomy, books on dialling and astronomy are not particularly well represented in the catalogue of the library which contains volumes on topics such as theology, chemistry, medicine, history, travel and natural history and continues to be housed in the wonderful panel-lined library. Although there are standard titles by Leybourn, Gunter, Moxon and Oughtred, there are unfortu-


Fig. 3


Fig. 4


Fig. 5


Fig. 6

nately no early dialling treatises from, for example, Samuel Foster or John Blagrave.

The sundial on the Plume Library could well be contemporary with the building, or is perhaps just slightly younger.


Fig. 7

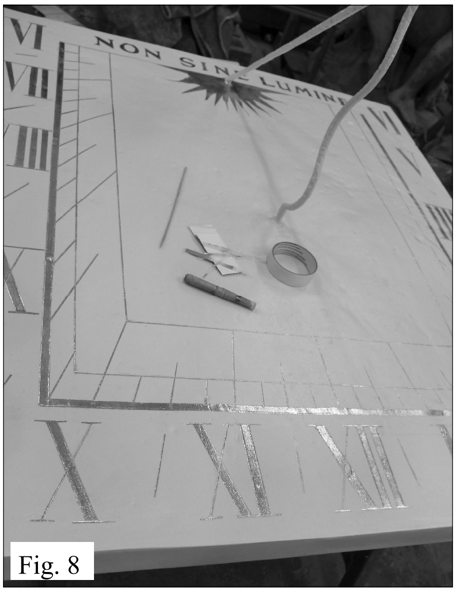


Fig. 8

Left, top to bottom:
Fig. 3. The unrestored dial. Note the holes in the lead and the rows of circular lead patches covering the nail heads.
Fig. 4. Soldering a lead strip on the top of the dial.
Fig 5. The top of the dial from the back showing an additional oak strip and the original wrought-iron centre hanger which also supports the gnomon root. Note the lead patch on the left.
Fig. 6. Lead infill in the holes on the front of the dial, before scraping back.

Above, top to bottom:
Fig. 7. Laying out the lines and lettering.
Fig. 8. Gilding the dial.

Lead dials of this type (as opposed to the modern cast-lead type) are rare but not unknown to the BSS Register. One example is at St Mary's church, Ellingham in Hampsire (SRN2916) and another, dating to before 1730, was on Hereford cathedral (SRN1000) although it is now kept in store.

The dial is 1225mm high by 1070mm wide by 70mm thick and is of a direct south design, being held to the wall with wrought iron brackets, canted out from the wall by around 75mm on its western edge. It was removed from the wall and taken to the workshops of Rupert Harris Conservation in London (Figs. 3-8). They have a substantial track record of dealing with lead statuary for the National Trust and

Fig. 9. The mayor of Maldon 'opening' the restored dial in September 2005.

other heritage bodies. It was discovered[3] that the dial was made by covering a set of oak boards, about 1" thick, by a sheet of 1/8" lead which was folded over the sides of the frame and attached with several rows of nails, the heads of which were neatly covered by circular lead patches. The lead was generally in good condition but there were several holes which had been made by squirrels gnawing at the lead, as evidenced by teeth marks. (Lead has a sweet taste and powdered lead was used by the Romans to sweeten their wine!) Damage to the framework in one corner allowed birds to access the interior and build a nest. Some of the oak boards had also been eaten away.

A section of well-seasoned oak was inserted to reform and stabilise the framework (Fig. 5). Lead sheet, soldered in from the reverse of the dialface, was used to repair the holes and the front surface then filled with lead and scraped to produce a flush surface (Figs. 4 & 6). A sacrificial strip of lead was added along the top edge of the dial to counter further squirrel damage (Fig. 4). The original wrought iron gnomon, which was only slightly corroded but well covered in a modern black paint, was straightened and welded before repainting.

The lead was painted by a sequence of acid etch primer followed by two coats of metal primer and three coats of normal exterior grade satin paint. Close examination of the dial face had shown that the sun motif, and perhaps the lines, lettering and numerals, had originally been gilded so this was restored using 24 carat, 18gm gold (Figs. 7 & 8). The background colour chosen by the conservators was an off-white. Whilst this shows a strong shadow it does not produce a strong contrast for the gilded lines and lettering.

The sundial was re-installed and officially 'opened' by the Mayor of Maldon at a ceremony on 29 September 2005 (Fig. 9). Although the dial is partially shaded by a large tree, it is a particularly fine feature on an historic building.

ACKNOWLEDGEMENTS

It is a pleasure to thank Mrs Helen Vincent (Maldon Town Clerk), Erica Wyllie (Plume Librarian) and Sally Bowling and Cathy Brown (Rupert Harris Conservation) for help in this project.

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COOKE'S NEW SUNDIAL AND THE BEADSMOORE HELIOCHRONOMETER

PETER LANE

Soon after joining the BSS I was made aware by a relative of the existence of a sundial owned by a Mr B. Beadsmoore. The sundial turned out to be a heliochronometer and was constructed by the present owner's great uncle, Mr Ernest Beadsmoore. Of particular interest is the fact that the dial was built as a result of his reading an article written by Professor W. E. Cooke, Government Astronomer of New South Wales, and published in *English Mechanics and the World of Science* magazine[1] in August 1924.

Ernest Beadsmoore was born at Woodhouse Eaves, Leicestershire. He followed in his father's footsteps by becoming a blacksmith and eventually worked his way up to being an enginewright working in various coal mines on the Nottinghamshire/Derbyshire border. In those days an enginewright was responsible for all mechanical and electrical operations at a coal mine. An accomplished engineer, he was a founder member of the Association of Mining Electrical Engineers. Away from his profession his hobby was model making. Inspired by the comprehensive article and instructions, Beadsmoore set about constructing his own dial.

The maker, Mr E Beadsmoore, with the instrument in his hands and a view of the stand from the SW.

Described by Professor Cooke as a 'New Sundial', the design, now apparently simplified, was based upon an earlier design which was circulated throughout Australia around 1913. The heliochronometer is not of the type manufactured by Pilkington and Gibbs who at that time were about to scale down production. It is a heliochronometer with an analemma, similar in concept to the one designed and built by L' Abbe Guyoux around 1827[2], but was constructed from wood and aluminium.

Having successfully produced and tested his heliochronometer, Beadsmoore submitted a letter to *English Mechanics*[3], some four months after Professor Cooke's original article. Beadsmoore explains,

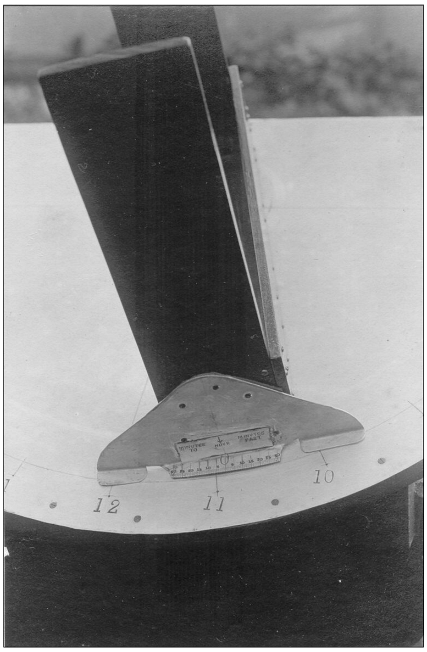
> *"Friendly assistance, with access to the Parish map, gave me a mark on a distant building as due North and likewise from the same source the exact latitude and longitude".*

Beadsmoore recognised the problems in calculating the date scale as the one in Cooke's article was for the Southern Hemisphere and goes on to explain his use of *Whittaker's Almanac* for declination readings and the equation of time. Following further use and testing of his dial, Mr Beadsmoore explains how he was assisted in its setting up by the local signalman providing 'Greenwich time'.

Beadsmoore lived and worked on the Nottinghamshire/Derbyshire border which at this time was heavily industrialised with coal mining, steel works and other heavy or intense industry contained within a densely populated railway network which operated 24 hours per day. In the final paragraph of his letter, he reveals the impact of his dial on at least part of the local workforce and comments,

> *"It is quite easy to read time to within half a minute and although surrounded by two railway systems and numerous works blowers and syrens, yet the vagaries of the numerous local correct times are perplexing and as it has already been possible to control the errors of one of the loudest local syrens, I feel my time has not been wasted".*

Some three weeks following the publication of Beadsmoore's letter, a further article by Cooke was published in the same magazine.[4] Entitled "A New Form of Sunclock", Cooke explains how he connected his original design to a clock face by a gear train in order to convert local apparent time to the national standard time. Given the name of 'Sunclock' and patented, he then goes on to describe the use of the sunclock to indicate true bearings, calculate latitude, show the times of sunrise and sunset and, in conjunction with an almanac, even the rising and setting of the planets. Surprisingly, he concludes by describing his invention as an "astronomical play-thing".



Far left: taking the time at 4pm, viewed from the NW.

Left: a close view of the minute scale at 5½ minutes to 11am.

Such was the impact of the 'Sunclock' that another article, in a later edition of the magazine[5] was submitted by Mr F. Hope Jones, Chairman of the BHI, where he states,

> *"It is rarely that one can see the development of an important invention rapidly unfolded before ones eyes".*

Whilst recognising the importance of Cooke's invention, *English Mechanics* also published a full article about Mr Beadsmoore's dial entitled 'The Cooke Sundial'[6], for which the maker received 27 shillings from the editor.

The alidade of the Beadsmoore heliochronometer, with pinhole and analemma, survives to this day although the pedestal and hour ring are now missing. However, all of Beadsmoore's paperwork, diary, calculations, photographs and magazine articles relating to his project have also survived and give us an idea of his thought processes as he produced his dial.[7]

Recognising that this was Beadsmoore's hobby, he seemed to take the project seriously and achieved considerable success. Even now, almost eighty years on, it is encouraging to see how the Astronomer for the Australian Commonwealth, by sharing his knowledge, managed to inspire an engineer who, notwithstanding the BBC's introduction of a standard time signal, could see the practical benefit of such an instrument.

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ACKNOWLEDGEMENTS

I am grateful to Mr Barry Beadsmoore for the loan of his great uncle's heliochronometer along with associated paperwork and photographs. The photographs were taken from originals by the professional photographer F.C. Helsby of Alfreton, Derbyshire.

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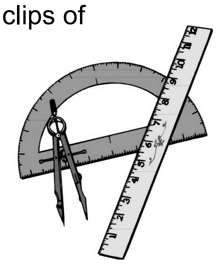
SUNDIALS SUFFUSE SECONDARY SCHOOLS

After a break of over a century, dialling is about to make a comeback into school mathematics. Peter Ransom, BSS member and teacher of mathematics at The Mountbatten School, Romsey, put in a bid to the DfES Bowland Initiative to develop work based on sundials for Key Stage 3 (11-14 year olds) pupils. Over 200 applications were made and Peter's sundial work was one of the final 23 that will be developed this year. After substantial trialling and evaluation all 23 'case studies' on mathematical applications will be made available for use in schools next year. Part of Peter's case study includes DVD clips of BSS members talking about how they use mathematics in their work. Peter said, 'Hopefully we will see an increase in sundial makers and BSS members in the years to come!



THE SUNDIAL IN LA SPECOLA MUSEUM, FLORENCE

STEFANO BARBOLINI, GUIDO DRESTI, FRANK KING & ROSARIO MOSELLO

INTRODUCTION

Many instruments have been used over the centuries to follow the course of the sun in the sky, whether to tell the time or to study astronomy. Particularly significant amongst these instruments is what is known in Italian as a 'meridiana a camera oscura'. The literal English translation, noon line in a dark room, is not common parlance in the dialling community. An alternative term, pinhole sundial, is proposed. This correctly implies that such a sundial incorporates a small hole through which an image of the sun is projected onto a dial. Pinhole sundials are particularly significant because of the studies which have been made using these instruments. These studies include determining the obliquity of the ecliptic and the retardation of the Julian calendar with respect to the astronomical cycle which led to the Gregorian reform. These topics explain the presence of such instruments in astronomical observatories and in Cathedrals.[1]

There are many pinhole sundials in Italy, owing to the Catholic Church's interest in the calendar, largely for fixing the date of Easter. There are some magnificent examples of these instruments in other European countries too.[2] A recent survey identified 43 pinhole sundials in Italian churches and monasteries, 28 in palaces and historic residences, 12 in astronomical observatories and 5 in universities and colleges.[3]

The historical and cultural attractions of Florence include a number of fascinating pinhole sundials: in the Cathedral, in the Church of Santa Maria Novella, in the Church of La Certosa, in the Ximeniano Observatory, and in the Pavilion of the Pitti Palace museum.[4]

This paper describes the pinhole sundial in the Grand-Ducal Astronomical Observatory in Florence which is also known as *La Specola*.[5] This dial is not accessible to the public at present and is relatively unknown even to Italian sundial enthusiasts. The paper gives an outline of the historical events which prompted its construction and subsequent abandonment, its recent rediscovery, and the inception of the restoration work.

LA SPECOLA

At the time of its inauguration on 21 February 1775, the name of the museum which is today known as 'La Specola' was The Imperial and Royal Museum of Physics and Natural History. It was founded by the royal family of Habsburg-Lorraine after the death of Giangastone, the last

Fig. 1. An 18th century print of La Specola, showing the octagonal tower above the Stork Room viewed from the Boboli Gardens.

member of the Medici dynasty, in 1737. The name 'Specola' (observatory) derives from the fact that the Grand-Ducal Astronomical Observatory was once housed here.

The building chosen for the museum was Palazzo Torrigiani in Via Romana, close to the Pitti Palace. This building (Fig. 1) dates from 1520, the year in which Bernardino Bini reorganized the surrounding fourteenth century houses into a single building. Palazzo Torrigiani was purchased by Pietro Leopoldo I of Lorraine in 1771 and radically refurbished and extended by the architect and engineer Gasparo Paoletti to fit it for its intended purpose. The innovations included new rooms for the museum, a small octagonal tower (2.9 m each interior side, 6.9 m between two opposite

Fig. 2. The octagonal tower and the Stork Room today, viewed from the south.

Fig. 3 (left). The Meridian Line, length 7.775m, with the winter solstice ellipse in the centre of the picture and the shutter and gnomonic hole near the ceiling at the top of the picture.

Fig. 4 (right). Close-up view of some of the storks.

walls) which was to house the meteorological instruments, and an adjacent room for the astronomical observatory (Fig. 2). The naturalist Felice Fontana was appointed Director of the museum, with Giovanni Fabbroni as his deputy.

In 1783 a number of instruments were ordered from the best craftsmen in London,[6] and between 1783 and 1784 Giuseppe Slop, an astronomer with the Pisa observatory, supervised their installation. However, the observatory did not come fully into use until 1808, when the astronomy professor Domenico De Vecchi gave his services free of charge.[7]

Around 1830 Giovan Battista Amici, an astronomer and above all a great technologist, was appointed as Director of La Specola. He brought with him a team of highly skilled specialized workmen, who were later to found the famous 'Galileo Workshops';[8] with their help he built a number of sophisticated astronomical instruments which he housed in the observatory.

When the new astronomical observatory was opened in Arcetri in 1872, all the instruments were transferred to the new building. However, in the old observatory, you can still see the 'Stork Room',[9] which is named after the plaster mouldings of storks which appear to support the ceiling (Figs. 3 & 4). Pillars which once supported instruments are still in place along with an instrument which by its nature could not be moved: the pinhole sundial, guarded for years only by the twenty storks above it.

THE RESTORATION OF THE SUNDIAL

The superb meridian line, crafted by Giuseppe Slop,[10] consists of a copper strip between two slabs of white marble set into the floor of the observatory. A silver thread runs along the centre of the copper strip. An inscription gives the date as 1784. Over the years, the instrument had practically disappeared under a thick layer of dust. There was apparently no gnomonic hole and there was a widespread conviction among experts and enthusiasts that the instrument could no longer work.

The sundial was restored to its former functional state in the summer of 2005 by one of the authors of this paper (Stefano Barbolini). The marble was carefully cleaned, as were the elliptical scagliola panels (artificial marble) containing the signs of the zodiac. At its extremities the copper strip broadens into ellipses which incorporate engravings of representations of the sun which were revealed on cleaning. These are at the points corresponding to the two solstices. Cleaning also revealed the silver thread and, fixed to the

Fig. 5. The vertical shutter, reconstructed in wood during restoration work, and the horizontal gnomonic hole through which the sun's image is projected onto the Meridian Line. The shutter was opened at night to permit the use of the quarantale (see text).

Fig. 6. The Meridian Line at noon. Note the wire which is suspended vertically above the meridian line. This serves as the string of the string-gnomon sundial.

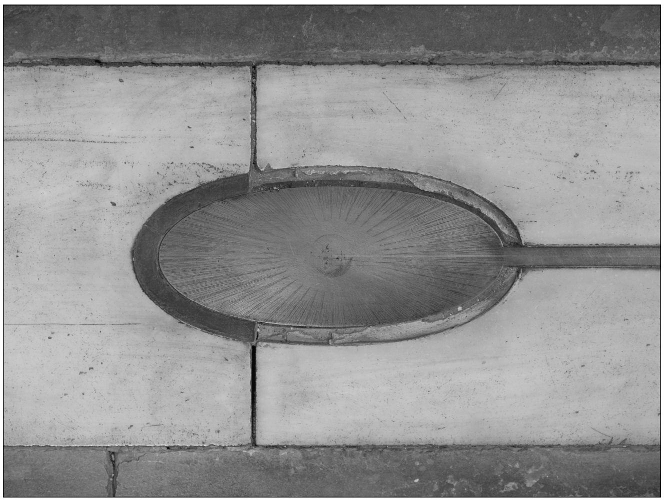


Fig. 7. The Winter Solstice Ellipse at the north end of the meridian line. Note the engraving of the sun and note that the silver thread embedded in the copper rod extends to the centre of the sun.

wall below a window opening, a thin horizontal sheet of silver. This sheet is pierced by the gnomonic hole, 3mm in diameter. The adjacent opening allowed too much light to enter for the hole to function, so a wooden window shutter (150mm × 135mm), as seen in Fig. 5, was constructed. This covers the opening but not the hole. The Specola sundial is a rare example of being a string-gnomon dial, meaning that it had a very thin wire (in the 18th century knotted hairs were used) stretched between two brackets about 60mm above the floor, perfectly level and aligned with the local meridian (Fig. 6). The south end of the thread is directly under the gnomonic hole. The evidence for this unusual and sophisticated device is a pair of metal brackets, one at each end of the meridian line. When correctly orientated, the wire and its shadow can be used in conjunction with a clock to determine the instant of solar transit. As the sun approaches the meridian, there is a moment of first contact when the light cone from the gnomonic hole first strikes the wire and casts a shadow. This shadow is tangential to the elliptical image on the floor. Later, there is a moment of last contact when the shadow of the wire is last seen on the other side of the image. The average of the times of first and last contact gives the instant of the sun's transit on the local meridian. This operation can be used to synchronize the clock with real local time. The peculiarity of this device is that it can also be used on an uneven floor. At present, however, there is only the meridian line with a silver thread 0.8mm across embedded in the centre of the copper strip. This silver inlay makes it easier to align the stretched wire which was suspended about 60 mm above the line. The floor itself is 24.65m above ground level and has shifted over the centuries both vertically and horizontally.

The silver thread was probably also used to determine the local magnetic variation, the angle between the meridian line and a magnetic compass needle. A triangle was constructed and the sides of this triangle were measured using vernier instruments which were accurate to one thousandth part of a Paris ligne (a unit of length, approximately 2.25mm).[11]

The oldest string-gnomon dial of which we have documentary evidence dates back to 1713; it was built by the French astronomer Josef Nicolas Delisle in Paris at the observatory of La Tour de Luxembourg. In Italy another sundial of this type can be seen in Bologna, in the tower of Palazzo Poggi, the ancient astronomical observatory of the city. There are also some instruments of the same kind in other European countries.[12]

The vertical shutter which can be opened from the inside (Fig. 5), together with the dowels set into the floor along the whole meridian line, suggests that

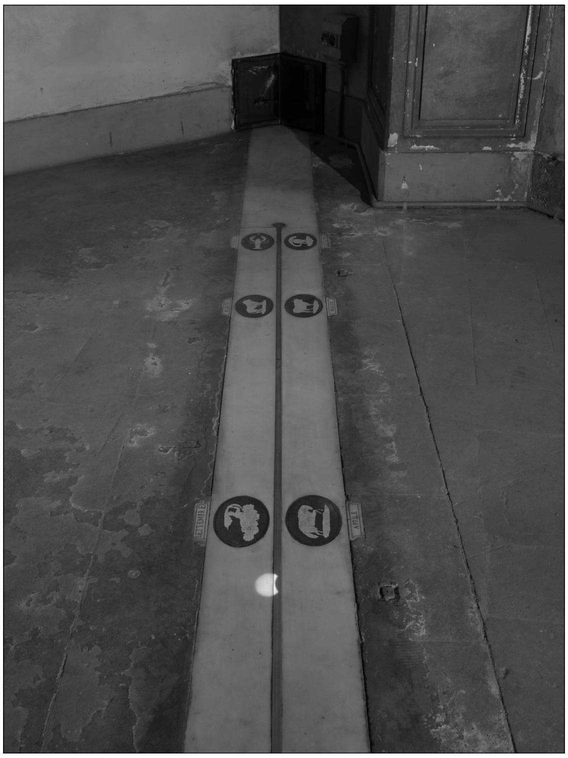


Fig. 8. Elliptical scagliola panels ornamented with Signs of Zodiac flank the meridian line. Photograph taken during the solar eclipse on 29.03.2006, at 13:30 Central European Summer Time (11:20 GMT).

another instrument, a *quarantale*, was used. This consisted of a transit circle telescope, aligned with the meridian line, which at night allowed the projection onto the meridian line of a star crossing the meridian and sighted through the open window. The telescope moved along rails fixed to the dowels which can still be seen. The iron brackets between which the string gnomon was stretched are soldered to the wall. Attached to these brackets are brass clamps which hold a fragment of wire 3mm in diameter. The purpose of these clamps is unclear. They may have been used in connection with accessories to the string gnomon or they may have been used in connection with the *quarantale*.

There is documentary evidence of the use of this instrument and that of the sundial in the old palace of Pietramellara (now Sassoli de'Bianchi) in Bologna, a city near Florence.[13]

Fig. 9. The bronze inscription near the Winter Solstice Ellipse.

No expense was spared in the construction of the Grand-Ducal observatory. The highest quality materials were used both for the plaster mouldings in the sundial room, which represent twenty storks in flight, and for the dial itself. The copper strip is not a continuous piece of metal, but is interrupted at points which correspond to the sun's entry into the various signs of the zodiac. The dimensions of the copper ellipses at the extremities of the meridian line match the sizes of the image of the sun at the solstices (Fig. 7). The elliptical panels set into the marble slabs are made of blue scagliola. Each has a sign of the zodiac drawn in white in the centre (Fig. 8). These panels are unconventionally arranged, each being placed in the middle of the period of the zodiac that it indicates and not at the beginning, as is usually the case. Next to the zodiac panels the name in Italian of the corresponding month is engraved in small marble rectangles. In the marble to the north of the ellipse for the winter solstice is a Latin inscription in bronze letters (Fig. 9):

LINEA MERIDIANA DUCTA IN OBSERVATORIO
REGII MUSAEI SCIENTIARUM FLORENTINI
PETRO LEOPOLDO IMPERANTE. MDCCLXXXIV.

"*This meridian line was laid out in the Observatory of the Royal Science Museum of Florence while Pietro Leopoldo was ruler. 1784*."

DIAL MEASUREMENTS COMPARED WITH CALCULATED VALUES

The positions of the first points of the signs of the zodiac on the meridian line were carefully measured and so also were the dimensions of the two copper ellipses at the extremities of the line. We compared the observed values with those determined by calculation.

The crucial datum point is the point on the floor perpendicularly below the centre of the gnomonic hole. The equally crucial base measurement is the height of the gnomonic hole above the datum point. For reference purposes the principal parameters of the dial are shown in Table 1.[14] For completeness, the values include the local longitude although this was not used in the calculations.

Dial parameters	
Latitude	43° 45′ 48″
Longitude	11° 14′ 40″
Altitude (m a.s.l.)	65
Height of the gnomonic hole (mm)	3278
Diameter of the gnomonic hole (mm)	3
Astronomical parameters in 1784:	
Obliquity of the Ecliptic	23° 28′ 11″
Angular diameter of the sun (summer solstice)	31′ 27″
Angular diameter of the sun (winter solstice)	32′ 31″
Astronomical parameter in 2006:	
Obliquity of the Ecliptic	23° 26′ 20″

The measured distances of the first points of the signs of the zodiac, along the meridian line from the datum point, are shown in the column headed A in Table 2. The equivalent calculated values were determined twice. First, the values appropriate to the year 1784 were calculated and these are shown in the column headed B. Secondly, the values appropriate to the year 2006 were calculated and these are shown in the column headed C. The differences between the two sets of calculated values are a consequence of the reduction in the obliquity of the ecliptic between 1784 and 2006.

The calculations take into account the corrections required for both parallax and refraction. The reduction in the obliquity of the ecliptic means that, had the line been set out today, the distance between its end points (corresponding to the two solstices) would be about 13mm shorter than the distance appropriate for 1784.

The differences between the actual measurements and those calculated for 1784 are shown in the column headed B-A. It is clear that there is a systematic difference of just over 22mm. This may be a consequence of movement of the floor (the dial is on the fourth floor of an ancient building),

Solar longitude	Signs of the Zodiac	Distances along the Line (mm)				Refs to Fig. 10
		measured values A	calculated values 1784 B	calculated values 2006 C	B-A	
90°	Cancer	1191	1212	1214	21	d
120°/ 60°	Leo/Gemini	1409	1431	1433	22	c
150°/ 30°	Virgo/Taurus	2048	2070	2071	22	b
180°/ 0°	Libra/Aries	3116	3138	3138	22	a
210°/330°	Scorpio/Pisces	4698	4721	4719	23	e
240°/300°	Sagittarius/Aquarius	6670	6693	6686	23	f
270°	Capricorn	7775	7796	7785	21	g

Table 2. Actual measurements compared with calculated values.

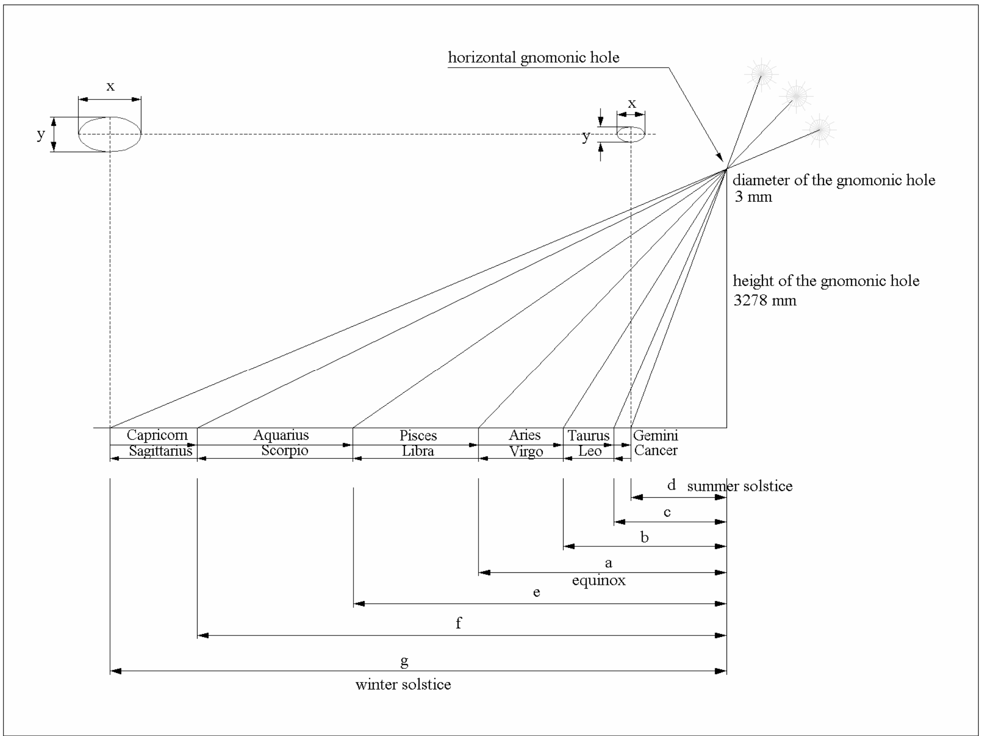


Fig. 10. Vertical section of the Meridian Line and the gnomonic hole.

	measured values (mm)		calculated values (mm)	
	major axis *x*	minor axis *y*	major axis *x*	minor axis *y*
summer solstice	38	35	37	35
winter solstice	210	85	209.3	83

Table 3. The 1784 dimensions of the image at the solstices; (x, y) values refer to Fig. 10.

or the use of different parameters in the calculations. Perhaps the most likely explanation is that the wall now leans inwards a little, so the gnomonic hole is about 22mm to the north of its original position.

Figure 10 shows a schematic vertical section of the meridian line. The positions of the first points as actually measured (the values in column A of Table 2) are shown to scale as is the position of the gnomonic hole.

As separate calculations, the sizes of the image of the sun at the two solstices in 1784 were determined and compared with the sizes of the copper ellipses at the extremities of the meridian line itself. If the gnomonic hole were a point, the theoretical shape of the solar image would be a true ellipse, being a section of a cone of light. The dimensions are easily calculated from the angular diameter of the solar disc, the distance of the hole from the centre of the image, and the apparent altitude of the sun.

The actual shape of the image is modified slightly because of the non-zero diameter of the hole. The minor axis is extended by the diameter of the hole, while the major axis is related to the same amount and to the tangent of the altitude of the sun.

Table 3 shows the dimensions of the major and minor axes of the copper ellipses and the major and minor axes of the corresponding solar image as calculated for 1784. The dimensions of the image at the solstices in 2006 were also calculated but the changes since 1784 are negligible.

CONCLUSIONS

Palazzo Torrigiani today houses the Natural History Museum of the University of Florence which was also founded by the Grand-Duke Pietro Leopoldo. The foundation was in 1775 but the nucleus of the Botanical Garden goes back as far as 1545. The Museum is laid out in six sectors with exhibits of exceptional scientific and historical value, and attracts thousands of visitors every year; it is still a centre for advanced research into nature and the environment. At present it is the leading natural history museum in Italy and one of the most important in the world.[15]

The old astronomical observatory has not enjoyed the same good fortune. One reason is that the narrow access to the Stork Room has meant that the room is generally closed to the public. Visits by small groups of people are occasionally organised on request. Happily, the museum authorities and Italian sundial enthusiasts are beginning to realise the historical importance of the dial in the magnificent setting of the Stork Room.

If you are fortunate enough to visit it and witness the passage of the sun across the meridian line, we guarantee that you will be thrilled by the experience, with its flavour of antiquity. It is fascinating to think that every day in this place of science, now dead and almost forgotten, a small aperture lets light into the dark so that the sun comes into contact with the copper strip placed there centuries before by the hand of man (thus Charles Dickens described the phenomenon when in 1844 he witnessed the passage of the sun across the dial in San Petronio in Bologna)[16]. The authors hope that an increase in the number of requests to visit La Specola by sundial enthusiasts from all over the world will help to speed its full restoration and access to the public in a setting which so perfectly combines nature, history, science and art.

ACKNOWLEDGEMENTS

We are very grateful to the administrators of La Specola Museum, in particular Dr Marco Borri and Dr Marta Poggesi, for giving us permission to survey the sundial and to take photographs. We are also grateful to the following who assisted in various ways with the data collection: Saulo Bambi, Fausto Barbagli, Lorenzo Chelazzi, Simone Contardi, Gianni Ferrari, Giovanni Garofalo, Gianna Innocenti, Anna Nistri, Alvaro Rinaldi, Annalisa Savastano, Thomas B. Settle, Giorgio Strano. We should like to thank Dr Luc Bodart for research into the architectural details. Sandra Spence translated the text from the original Italian, Dr Mara Miniati (Institute and Museum for the History of Science, Florence) and Dr Piero Ranfagni (Arcetri Observatory, Florence) contributed to the scientific revision of the paper.

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2. There are fine examples of pinhole sundials in Notre Dame and Saint Sulpice in Paris and in Saint Michel in Brussels. English examples are rare. The two in best condition are in the Bromley House Library in Nottingham and in the Custom House in Ramsgate. There are remnants of a pinhole sundial in Durham Cathedral. (Personal communication from Douglas Bateman).
3. G. Mesturini: ‘Meridiane a camera oscura d'Italia: aggiornamenti 2005’ (Pinhole sundials in Italy: supplementary information 2005), *Proceedings of the XIII National Seminar on Gnomonics*, Lignano Sabbiadoro (UD, Italy), 8-10 April 2005, pp.139-144 (2005).
4. For information about pinhole sundials in Florence see: M.L. Righini Bonelli and T.B. Settle: ‘Egnatio Danti's Great Astronomical Quadrant”, *Annals of the Institute and Museum for the History of Science*, Florence, a.4, n.2, pp.3-13 (1979); L. Ximenes: ‘*Del vecchio e nuovo Gnomone fiorentino*’ (Concerning Florentine Gnomonics, Old and New), Imperial Printing works, Florence, (1757).
5. Specola, from the Latin ‘specula’ (observatory) derived from ‘speciere’, to see, to observe. Today used for an astronomical observatory or an elevated place suitable for astronomical observations.
6. Among these makers of astronomical instruments were Dolland, Sisson and James Short (personal communication from Mara Miniati, Institute and Museum for the History of Science, Florence).
7. Details of the history of La Specula are in: G. Righini: ‘La tradizione astronomica fiorentina e l'Osservatorio di Arcetri’ (The Florentine astronomical tradition and the Arcetri Observatory), *Physis*, a.6, pp.133-150 (1962); M. Miniati: ‘Origini della Specola fiorentina’ (Origins of the Florentine Observatory), *Giornale di Astronomia*, pp. 209-220, (1984).
8. A company making precision instruments was founded in 1862 by the optician and mechanic Giovan Battista Amici (1786-1863) and the astronomer Giovan Battista Donati (1826-1873). The products of the company included instruments for teaching and for physics, geodetic instruments, balances, and instrumentation for telescopes. From 1896, under the engineer Giulio Martinez, the company began to extend its product range to include periscopes, projectors and maritime telemetry equipment. Today, the Galileo Workshops make optical instruments for military use and for space technology, and are among the major companies in Italy in this sector. The company library is of great interest.
9. In ‘theatrical style’, with the freedom of a stage set, far from the canons of the main trends in architecture. A visionary dimension which is found for example in the drawings of the revolutionary architect Lequeu.
10. Giuseppe Antonio Slop of Cadenberg (1740-1808) worked as an astronomer at the Pisa Observatory, initially as assistant to Tommaso Perelli, later succeeding him to the Chair of Astronomy at Pisa University. Slop of Cadenberg made a long series of observations and published six volumes of astronomical research undertaken at Pisa. (See M. Di Bono: ‘La Specola pisana (1735-1808)’, *Giornale di Astronomia*, 10: pp. 221-229 (1984); M. Di Bono: ‘Un secolo di astronomia a Pisa nelle vicende della Specola (1735-1833)’ (One century of astronomy in Pisa in the activity of La Specola), Bollettino Storico Pisano, 59: pp. 49-89, (1990).
11. Information obtained from a manuscript by J.N. Delisle in the Paris Observatory (C-2-14), dated March 1712 to April 1713, translated into Italian and discussed by N. Lanciano: ‘Le meridiane filari’ (String gnomon sundials), *Astronomia*, 10: pp. 5-9 and 1: pp. 5-9 (1990 and 1991).

12. Other string-gnomon sundials can be seen in Italy, for example in Bologna (Palazzo Poggi, bib. ref. Paltrinieri); in Europe there are examples in Hungary in the Archiepiscopal College of Eger Szabadsagter, and in the observatory of the Jesuits' Clementine College in Prague (P. Voit: '*Prazské Klementinum'*. Praha, p. 183 (1990); Z. Sima: '*Astronomy and Clementine*', National Library of the Czech Republic. Prague, p.124 (2001)).

13. G. Paltrinieri: 'Il Quarantale', *BSS Bull*, 93: pp.2-7, (1993). See also the description of the dial in the old Pietramellara Palace (now Sassoli de'Bianchi) located in Bologna and described by G. Paltrinieri and I. Frizioni: 'Meridiane e orologi solari di Bologna e Provincia' (Noon marks and sundials in Bologna and its Province), Artiere Edizionitalia, Bologna. p. 497 (1995).

14. The 1784 data were provided by the program GEFFEM written by Gianni Ferrari, Modena, Italy; those for 2006 are from the Italian Astronomical Association (UAI) Astronomical Almanac.

15. Web sites of the Museum: http://www3.unifi.it/msn/, http://brunelleschi.imss.fi.it/ist/luogo/museostorianaturalelaspecola.html

16. Charles Dickens: 'Pictures from Italy', in *Dickens, The works*. Ed. A. Lang, 34 vols, New York. Vol. 28, pp. 309-317 (1900).

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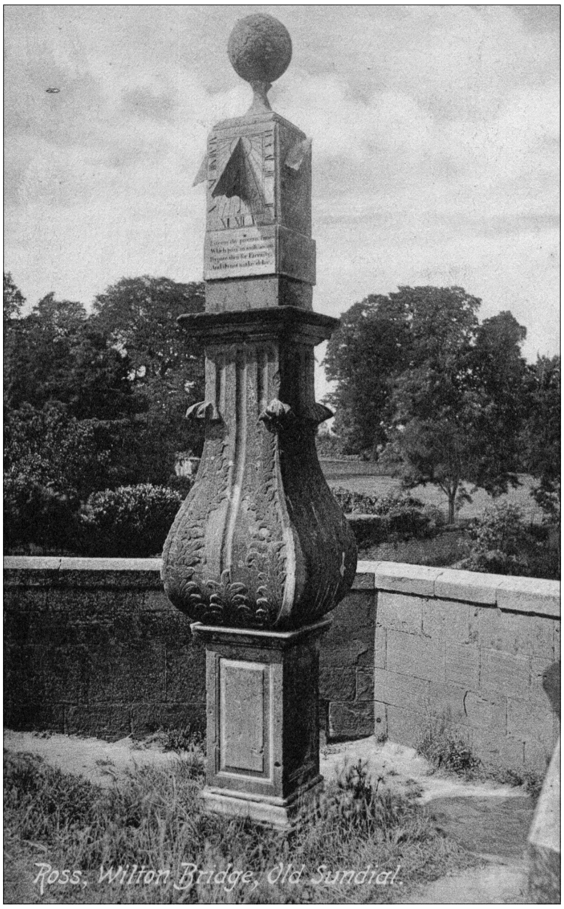
Postcard Potpourri 3 – Wilton Bridge, Ross on Wye

Peter Ransom

This striking dial still exists on the bridge that spans the River Wye, just north of Ross on Wye (Hereford and Worcester). I have a couple of postcards of the dial that date from the early 1900s and last November decided to pay it a visit since we were in the area. The accompanying pictures show the dial in situ and its current state. The first thing to note is the change in orientation! On the postcard the south face faces south (you can even see the shadow), yet today the north face points south – someone's put the dial back incorrectly sometime during the last century.



Today the motto at the bottom of the south face is not readable, but by scanning the postcard at a high resolution then enlarging the image the following verse can be determined:

Esteem the precious time
Which pass so swift away
Prepare then for Eternity
And do not make delay

Since this is such a visible dial I thought I would check the details in The Register, but it is not recorded there, so perhaps I should 'not make delay' and send in a record form! Old pictures on postcards can sometimes provide us with long-lost information.

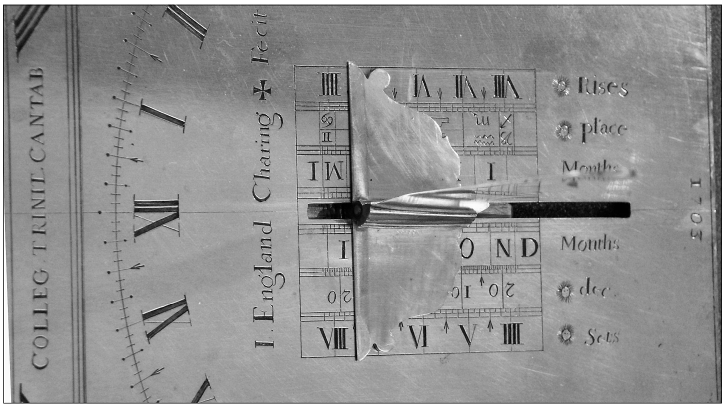
pransom@btinternet.com

THE SELF-SETTING PROPERTY OF DUAL SUNDIALS

MICHAEL LOWNE

INTRODUCTION

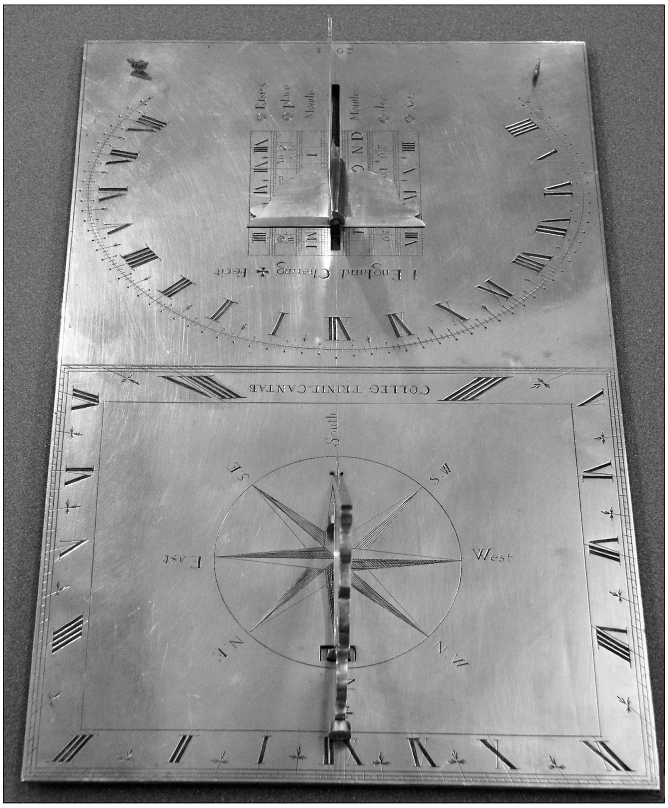
The self-setting property of a dual sundial arises from the ability to rotate the instrument until both dials show the same time, when it will in principle be in correct north-south alignment. Commonly, such a dial is a horizontal instrument consisting of a polar-gnomon dial and an analemmatic dial with a vertical gnomon which can be adjusted along the north-south line to allow for the changing declination of the sun throughout the year by correlation with the calendar date. Fig. 1 is a general view of a dual dial by John England dated 1703 and Fig. 2 shows the detail of the analemmatic dial adjustment for date. The cross-piece is set to the appropriate date on the date scale, which has the months indicated by their initial letters and is divided to five-day intervals except near the solstices. When correctly set the cross-piece also indicates the sun's declination, its zodiacal sign and the times of sunrise and sunset.



J. Davis

Fig. 2. Detail of the England dial of Fig. 1.

The dual dial was apparently first proposed by Thomas Tuttell and published by him in 1698.[1] He specifically mentions the self-setting property and indeed recommends the dial on that account. Modern authors refer to the property but seldom note that it is possible to obtain agreement between the dials at three different settings, only one of which will be correct: the dials will show the same time when set at equal time intervals before and after noon (for example 9am and 3pm), and at noon itself. It is of interest to examine the reliability of this method of alignment.



J. Davis

Fig. 1. A dual dial by John England, 1703. Courtesy of the Whipple Museum, Cambridge.

THE POLAR TRIANGLE

We start by explaining the astronomical parameters on which the operation of the majority of sundials depend. The symbol φ stands for the latitude, δ is the sun's declination positive to the north or negative to the south of the celestial equator and a is the altitude of the sun above the horizon. Fig. 3 represents the 'polar triangle' on the sky, whose apices are the pole P, the zenith of the observer Z and the position of the sun S at some particular time. Of the sides of the triangle, the arc PZ lies in the meridian and is the co-latitude (90-φ), PS is the complement of the sun's declination (90-δ) and ZS is the zenith distance (90-a). Of

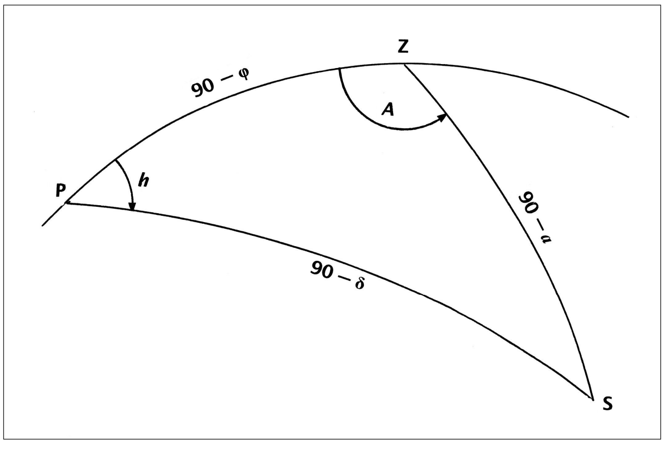


Fig. 3. The polar triangle.

the angles, that at Z is the azimuth of the sun A, the bearing measured from north, and that at P is the sun's hour-angle h which determines the time. The third angle at S between the hour circle containing the sun and the vertical is called the parallactic angle η and is generally of little use in gnomonics.

To find the time we need to determine h which expressed in time is the interval which will elapse before or has elapsed since the meridian passage of the sun. To do this four quantities are available, two of which can be known (φ, δ) and two which can be measured (a, A). But only three of these are needed, a fact which accounts in large measure for the variety of sundials with which we are acquainted. In our present interest the analemmatic dial uses latitude, declination and azimuth and is independent of altitude. As will appear later, the polar dial can be considered to use latitude, altitude and azimuth independently of declination. It is this use of differing parameters which makes the self-setting property possible. Of other dial types, many small portable dials use latitude, declination and altitude: being thus independent of azimuth they are useful for travellers in a situation where the north-south direction is unknown. The 'Astroid' dial[2,3] operates without knowledge of the latitude. Inasmuch as it requires the input of three angles (two known, one measured or one known, two measured) to show as output the hour-angle of the sun calibrated as the time of day; a sundial is an analogue computer.

We now proceed to examine each of the two dial types in the present application, to determine how their time indications are affected by rotation in the horizontal plane and to compare the two to test the effectiveness of the self-setting property.

Fig. 4 is a perspective drawing of the polar dial. N is a point on the gnomon with GN perpendicular to the dial plane and R is the root of the gnomon. GR is proportional to cotφ. The shadow of N falls at V on a time line T. With the sun at azimuth A and altitude a the angle RGV is A and the distance GV is proportional to cot$a$. A rotation of the dial I in its own plane will not alter the latitude nor the altitude of the sun and the shadow of N moves from V to V' on the time line T' and GV'=GV.

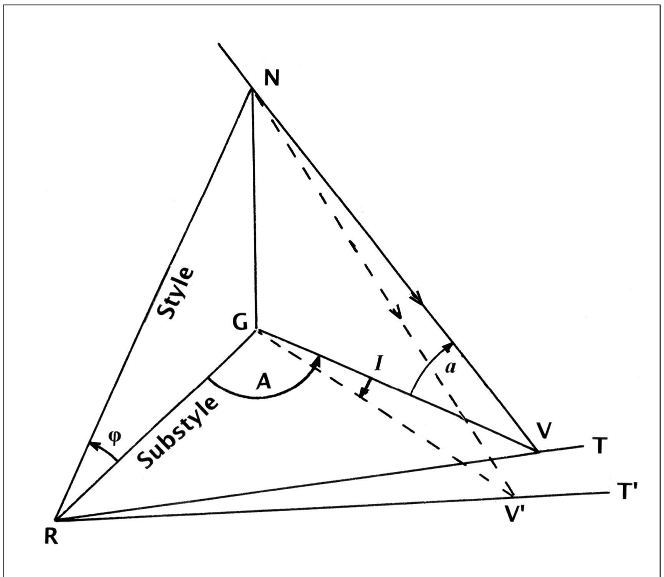


Fig. 4. Schematic drawing of a polar dial.

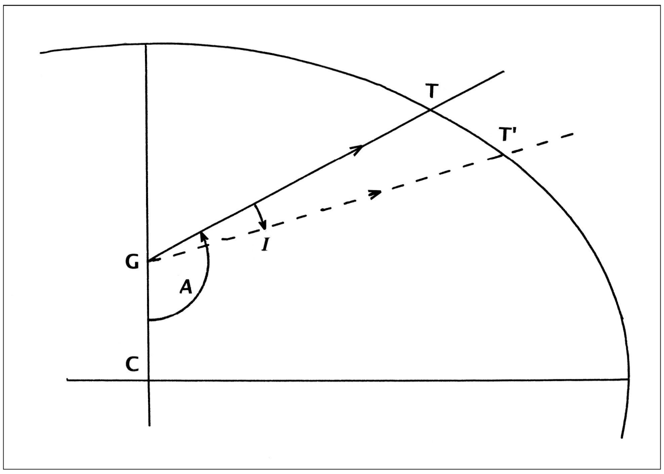


Fig. 5. Plan of an analemmatic dial.

Fig. 5 is a plan view of the analemmatic dial, with C the centre and G the foot of the moveable gnomon. The ellipse of the time graduations is indicated by the curved line. In use the distance CG is proportional to cosφ.tanδ and the gnomon shadow passes through a time mark T. In rotating the dial through an angle I, CG does not alter and the shadow now passes through time mark T'. Note that GT' is not equal to GT.

THE CALCULATIONS

Rotation about a vertical axis causes the time indications of both gnomon shadows to alter by different amounts. In determining the effectiveness of the self-setting property we need to find that amount of rotation of the instrument from the correct alignment which will give the minimum detectable difference between the time readings of the two dials and the time error which will result. Designed to be portable, dual dials are generally relatively small with time divisions no closer than five minutes, and some have only quarter-hour divisions. It does not seem likely that any time difference of less than about two minutes will be readily detectable and this value has been adopted for the comparison. For each dial an error in azimuth setting will produce false polar triangles with incorrect hour-angles h and wrong time indications. For the polar dial, the false h is found from an altered azimuth, retaining the latitude and altitude unchanged. That for the analemmatic dial is found from the azimuth altered by the same amount, retaining the latitude and declination. The two values of h are compared: unless a lucky estimate of the azimuth error (ΔA) has been entered their difference will not be the required two minutes (0.5°) but a revised value of ΔA can be formed from the

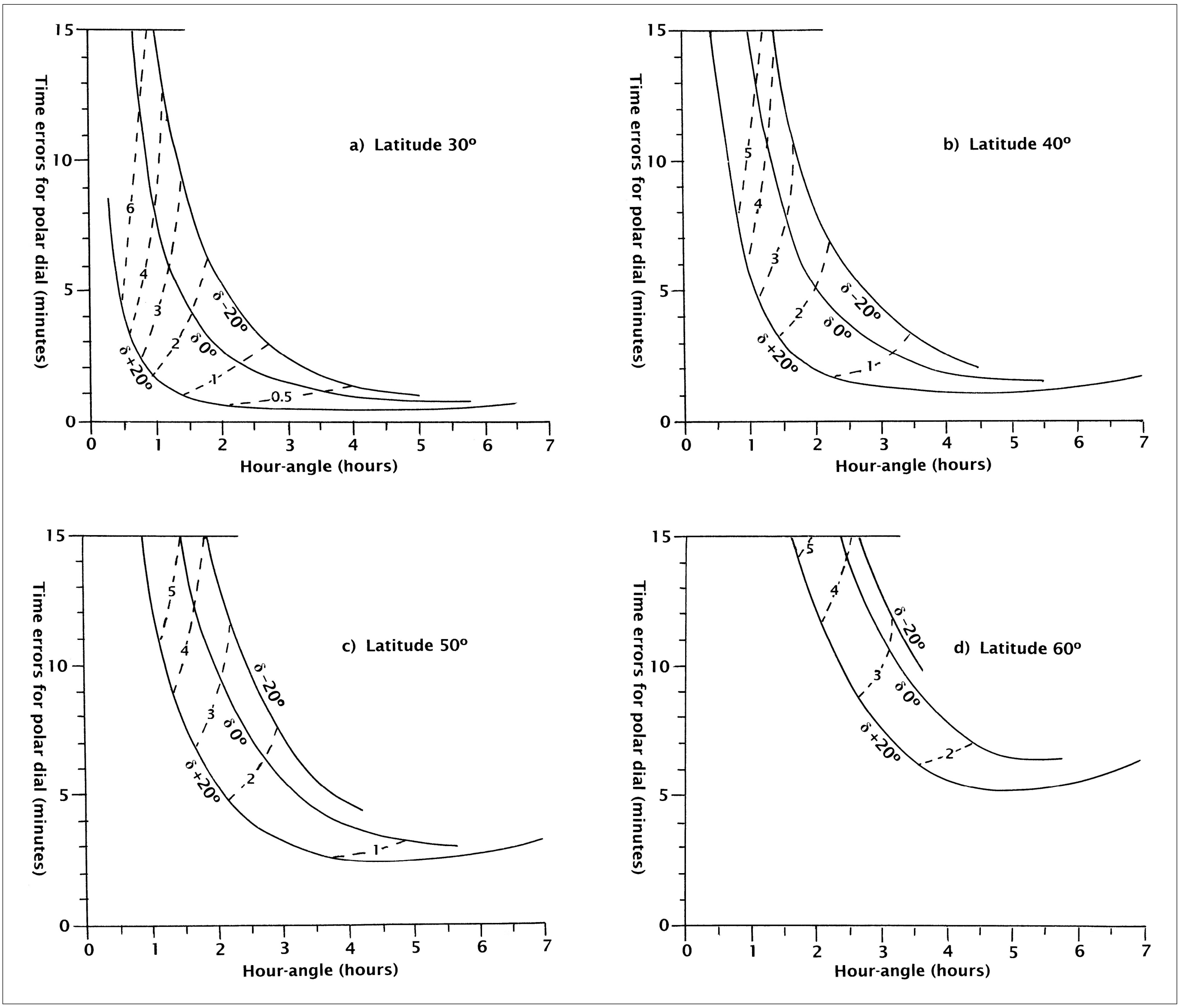


Fig. 6. Calculated time errors for 2 minutes difference between dials.

difference and new calculations made. More than one iteration may be needed to obtain the two-minute difference. From the final value of ΔA the time errors for each dial may be obtained. It is found that that the error of the analemmatic dial is always greater than that of the polar dial and that near to the meridian the errors obtained by rotation of the dial in opposite senses are not the same. The necessary formulae and an explanation of the method are given later. It is also possible to calculate the time errors by plane trigonometry, working in the dial plane: the results obtained are identical.

THE RESULTS

Figs. 6a-d present the results of calculations for four north latitudes (30, 40, 50 and 60°) and three declinations (+20, 0 and -20°) over a range of hour-angles expressed in hours. The graphs show the time errors of the polar dial for the adopted difference of two minutes between the dials: the errors of the analemmatic dial will always be two minutes greater. The dashed lines show the setting errors (values of ΔA) which give rise to the observed time differences. The nearer each curve lies to the horizontal origin of the graph the more sensitive is the dial to rotation under those conditions.

It is obvious that at low latitudes the sensitivity is good but becomes less and less with increasing latitude and is better at high declinations rather than lower. Also it is better at larger hour-angles than smaller: near noon the curves run off rapidly. If it is assumed that for small portable dials an error of five minutes in the indicated time would be acceptable, the performance can be assessed from the graphs. At latitude 30° and high declination, the time error would be greater than five minutes if the dial is set within half an hour of noon, at the equinoxes within about 1½ hours and at low declination about 2 hours. At latitude 40° the corresponding values are about 1, 2 and nearly 3 hours, and at 50° 2, 3 and 4 hours. It is virtually impossible to obtain an error of less than five minutes at latitude 60°.

In the time errors there is a dependence upon which way the dial is rotated to find the apparent coincidence of times. The difference between opposite rotations is marked at times near noon but becomes less with increasing hour-angle. Rotating the dial so that the gnomon shadows more nearly approach the noon line will give a larger error than if rotated the opposite way. The diagrams of Fig. 6 are drawn for the smaller errors.

The dependence of the sensitivity upon latitude, hour-angle and declination can be explained. At higher latitudes the polar gnomon becomes more nearly vertical and there is less difference between the angles of the two gnomons. With decreasing hour-angle the two gnomons approach the same plane (that of the dial meridian) and the gnomon shadows become more nearly coincident until at noon they do coincide. At high declinations a change of azimuth has more effect upon hour-angle than it would at low declinations and the sensitivity is thereby improved.

These results are also applicable to the double-horizontal sundial devised by William Oughtred[4], which combines a polar and an azimuth dial, although perhaps on the larger dials with closer time divisions differences of a minute might be detectable.

AN ALTERNATIVE SELF-SETTING DIAL

Sawyer[5] has described a dual dial consisting of two Foster-Lambert equiangular dials on the same dial plate. The two time calibrations are above and below centre with 12 noon at the highest and lowest points, the upper times running clockwise and the lower anticlockwise, from 6 am to 6 pm. The two gnomons are at 45º to the dial plate and mutually at 90º. Adjustment for the varying declination of the sun throughout the year is made by positioning the apex of the V between the gnomons at the appropriate place on the line joining the 12 noon marks. Suitable for use at any latitude, the dial is set so that when correctly oriented to the meridian the normal to the dial is directed to the celestial equator and the dial plane lies in the polar axis. In use the dial is rotated about a vertical axis until the gnomon shadows indicate the same time on both dials. My version of the dial is shown in Fig. 7 with both dials indicating just after 8:40 am (the inner shadows of the V). The declination calibration is visible alongside the central slot. The formula for this is $R\tan\delta$ where R is the dial radius from the centre. In Fig. 7 the declination is set to -5º.

No detailed calculations of the dial performance have been made; instead, the dial was mounted on a test rig which enabled it to be set correctly to the sky but turned about the vertical appropriate to a range of latitudes. These tests showed that this dial is significantly better in locating the proper orientation than the traditional dual dial described earlier. Within about an hour of 12 noon there is little improvement because then the two gnomons are more or less parallel to the direction of the shadows, as before. Away from noon, there is very little dependence on declination and the latitude dependence is much reduced because the angle between the two gnomons does not get smaller with increasing latitude. Typically, at low latitudes the two types of dial have much the same setting errors but in mid-latitudes the improvement is marked with errors of only a minute or two. At high latitudes the traditional dial is virtually useless but this dial can be set to give errors of just a few minutes.

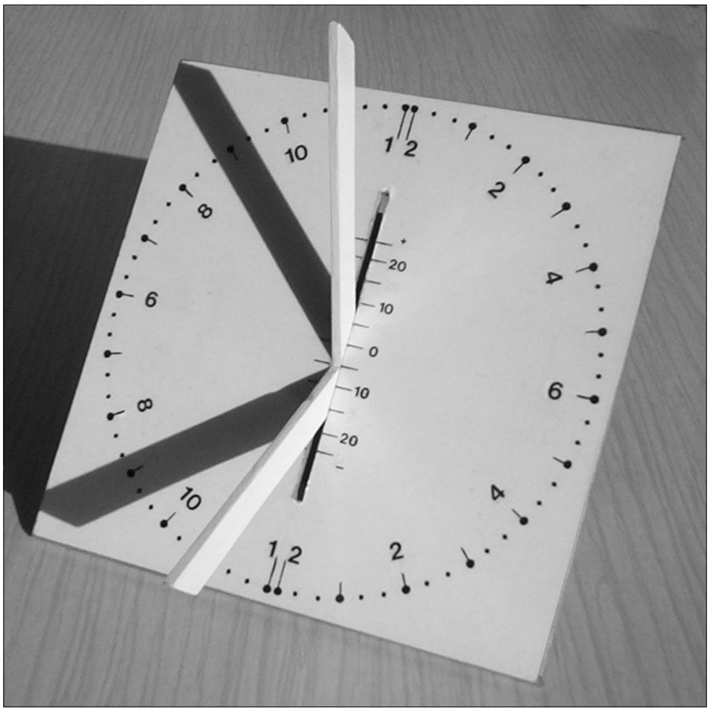


Fig. 7. A dual Foster-Lambert reclining dial.

The time indication from the shadow of the lower gnomon changes more slowly with rotation than that of the upper gnomon and is therefore the better indicator of the correct time. With twenty-minute intervals as on the dial in Fig. 7 the time coincidence can be set and read to two or three minutes, and with a dial divided to five minutes the precision could be within a minute. At hour-angles greater than about three hours the time shown by the lower gnomon shadow hardly changes with quite large rotations: this arises because the gnomon is more nearly horizontal. The shadow plane cast by it maintains much the same position in space and the time indication is mostly affected by the change in the intersection of the shadow with the dial plane. This effect is most pronounced at 45º latitude, when the lower gnomon is exactly horizontal. Under such circumstances when set for time coincidence the lower shadow will indicate time with as much precision as the calibrations will allow, but would require the declination to be accurately set and the dial to be placed on a good horizontal surface. Of course this dial still suffers from the ambiguity of equal time intervals before and after noon.

Rohr[6] provides an illustration of a fine dual dial of this type. It is carried on a mounting with a horizontal axis enabling it to be set for the appropriate latitude. Shadows are cast by the outer edges of the gnomons and the dials are separated to allow for this.

ALTITUDE DIALS

As mentioned earlier, there are types of dial which operate from the altitude of the sun and do not rely on being set to the meridian to tell the time.[7] Simple examples of these such as the latitude-specific pillar and Capuchin dials (generally divided only to hours) would be less accurate than a traditional self-setting dual dial. Precision altitude instruments such as the universal ring dial (adjustable for latitude) and the latitude-specific 'horizontal instrument' of William Oughtred[8] might well out-perform the dual dial, but (because of the variable altitude changes with change of hour-angle) they too are less accurate near noon, at low declinations and high latitudes, and are ambiguous at equal intervals before and after noon. The ring dial could generally be expected to be the more accurate as it operates directly from the sun's altitude, whereas the horizontal instrument involves two settings, one to measure the altitude and then to transfer this to the rotating alidade. A formula for calculating the likely errors of an altitude dial is given later.

CONCLUSION

The self-setting accuracy of the traditional dual dial leaves much to be desired, particularly near noon, at high latitudes and low declinations of the sun. The dual Foster-Lambert reclining dial is a decided improvement and additionally is adaptable for any latitude, but also suffers from poor performance near noon. Self-setting dials, although of limited use to travellers, are no substitute for a well-made and properly aligned conventional dial.

TRADITIONAL DIAL FORMULAE AND METHOD OF USE

Notation:

φ latitude, δ declination, h hour-angle (in arc),
a altitude, A azimuth, as before.
ΔA azimuth error, angle between the dial N-S line and the true meridian.
$\Delta A'$ revised value of ΔA for iteration
P, Q auxiliary quantities required in the calculations.
h'_p, h'_a false hour-angles for the polar and analemmatic dials respectively.
$\Delta h'$ difference between h'_p and h'_a
Δt_p, Δt_a time errors for polar and analemmatic dials, in minutes.
Δt difference in minutes between the two dials.

Equations:

$a = \sin^{-1}[\sin\varphi.\sin\delta+\cos\varphi.\cos\delta.\cos h]$ 1.

$A = \cos^{-1}[(\cos\varphi.\sin\delta-\sin\varphi.\cos\delta.\cos h)/\cos a]$ 2.

$P = \sin^{-1}[\sin\varphi.\sin a+\cos\varphi.\cos a.\cos(A-\Delta A)]$ 3.

$Q = \sin^{-1}[\cos\varphi.\sin(A-\Delta A)/\cos\delta]$ 4.

$h'_p = \cos^{-1}[(\sin a-\sin\varphi.\sin P)/\cos\varphi.\cos P]$ 5.

$h'_a = 2\times\tan^{-1}[\sin½(\varphi-\delta)/(\tan½(A-\Delta A-Q)\sin½(180-\varphi-\delta))]$ .... 6.

$\Delta h' = h'_a - h'_p$ 7.

$\Delta A' = 0.5\Delta A\ /\mathrm{abs}\Delta h'$ 8.

$\Delta t_p = 4(h'_p - h)$ 9.

$\Delta t_a = 4(h'_a - h)$ 10.

$\Delta t = \Delta t_a - \Delta t_p$ 11.

Equations 1-8 have input and output in degrees: results from equations 9-11 are in minutes of time. As the errors are symmetrical with respect to the meridian it is only necessary to calculate the results for positive values of h. For the opposite sense of rotation of the dial, take ΔA as negative. For southern-hemisphere use, keep the latitude positive but reverse the sign of the declination.

Method:

Select φ, δ, h, derive a and A from Eqs 1 & 2.

Select a value for ΔA (3º is convenient to start), derive P from Eq 3 and Q from Eq 4.

Calculate the false hour-angles h'_p and h'_a for each dial from Eqs 5 & 6.

Use Eq 7 to check the difference $\Delta h'$ between them. This is required to be 0.5º but will not be unless a lucky choice has been made for the value of ΔA. A revised value $\Delta A'$ is made using Eq 8. and the calculations iterated from Eq 3 to Eq 7. More than one iteration may be needed to obtain a value of 0.5º for $\Delta h'$.

Use Eqs 9 & 10 to obtain the errors of each dial in minutes of time and check with Eq 11 that their difference is 2 minutes.

It is possible to choose another value for the time difference by altering the numerical coefficient in Eq 8. For example, a coefficient of 0.25 will give one minute's difference.

Worked example:

$\varphi = +50º$ $\delta = +20º$ $h = 45º$ (3hrs)

$a = 43.560$ $A = 113.518$

First calc:	Iteration 1	Iteration 2	
ΔA = 3º	$\Delta A'$ = 1.205	1.251	
P = 21.385	20.551	20.572	
Q = 39.840	39.259	39.274	
h'_p = 46.791	45.722	45.750	
h'_a = 48.036	46.204	46.250	
$\Delta h'$ = 1.245	0.482	0.500	
Δt_p = 7.17	2.89	3.00	(mins)
Δt_a = 12.14	4.82	5.00	(mins)
Δt = 4.97	1.93	2.00	(mins)

From this it is seen that the initial estimate of ΔA = 3º gives Δt = 4.97 minutes. The first iteration with $\Delta A'$ = 1.205 overshoots slightly to give Δt = 1.93 but a second iteration with $\Delta A'$ = 1.251 gives the desired difference Δt = 2.0 minutes, with a time error of 3 minutes on the polar dial. These values agree with the plotted line on Fig 6c. In calculating a long run with the same declination approximate values of ΔA will become apparent from the sequence of values of $\Delta A'$ and appropriate estimates made.

For an altitude dial, the likely time error can be calculated from:

$$\Delta t = -4\cos a.\Delta a/\cos\varphi.\cos\delta.\sin h$$

where Δa is the altitude error and a is derived from Eq. 1.

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BOOK REVIEW

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ORIENTATION OF ST MARY'S CHURCH, STOKE D'ABERNON, SURREY

KEN HEAD

Introduction

Recent articles on church orientation in the Bulletin by John Wall[1] and Ian Hinton[2] prompted me to look again at the orientation of our own church of St Mary, Stoke D'Abernon. In previous articles,[3,4] I have described the replica Saxon sundial on this church.

There are two matters to consider.

* The orientation of the 7th century Saxon church itself, and its relationship (if any) to the direction of sunrise on the day of dedication.
* The possible reason for the misalignment of the 13th century chancel with the 7th century nave.

The alignment of the church building is shown diagrammatically in Fig. 1.

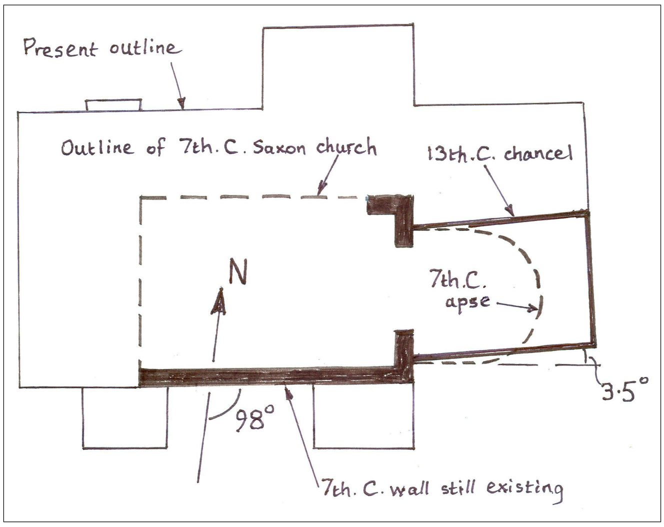

Fig. 1. Orientation of St Mary's Church, Stoke D'Abernon (simplified outlines).

Direction of sunrise

For both the above considerations, the relationship to the direction of sunrise on the festival day of the saint is relevant. At St Mary's we take this to be the Feast of the Annunciation ('Lady Day'), 25 March. So I calculated the sun's azimuth at theoretical sunrise (which I call A_s, measured *anticlockwise* from the south) for zero altitude (i.e. $a = 0$) over a range of 20 days from the vernal equinox, 21 March, using mean values of declination tabulated by Waugh.[5] These values of A_s are plotted graphically (upper line of points) against the day number in Fig. 2, where it can be seen that the relationship over this range is, for practical purposes, linear. The following equation provides a good approximation of the relationship.

$$A_s \text{ (in degrees)} = 90 + 0.6\,N$$

where N is the day number, counting from the day of the equinox as zero. In other words, the azimuth at sunrise increases by 0.6° each day, within these few days.

I also calculated the sun's azimuths on the same days when it is at an altitude corresponding to the local horizon, using the following equation kindly provided by Michael Lowne.[6]

$$\cos A_s = \frac{\sin\phi \sin a - \sin\delta}{\cos\phi \cos a}$$

in which a is the elevation of the local horizon.

The information from measurements made in 1965 (when this topic was discussed by the then Rector in the Parish Magazine[7]) was that the eastern horizon is at a distance of 1750 feet, rising 45 feet. This gives an elevation of 1.47°, which results in the perceived sunrise being later than, and a little to the south of, the theoretical sunrise. This value of a was inserted in the above equation, giving the sunrise azimuths shown by the lower line of points in Fig. 2.

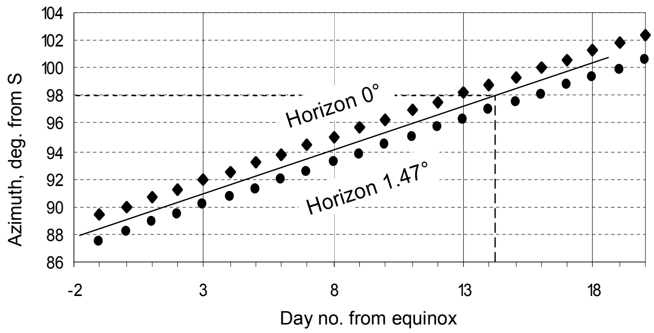

Fig. 2. Azimuth at sunrise on the 20 days following the vernal equinox, for level and elevated horizons.

Sunrise

We have to consider what we mean by sunrise. There are several criteria.

1. The instant when the centre of the sun's disc just coincides with the horizon when the observer is on a flat level plain. (position A in Fig. 3)
2. The similar situation when the horizon is elevated above the observer (position B).
3. The instant when the top edge of the sun's disc is just visible above a level horizon (position C).

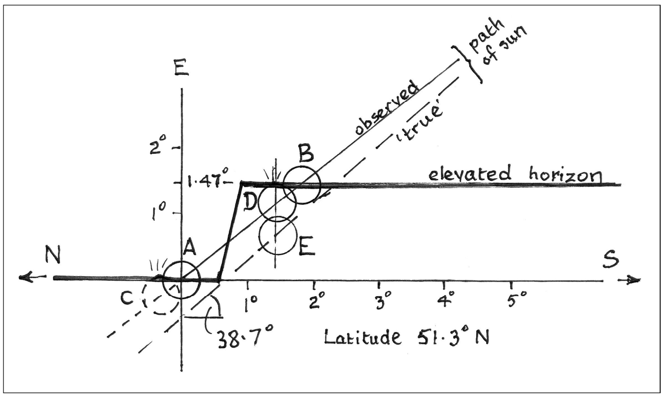

Fig. 3. Combined effect of elevated horizon and atmospheric refraction.

4. The same for an elevated horizon (position D).

The observed track of the centre of the sun's disc for the first few degrees of elevation after sunrise approximates to the full line in Fig 3, although it is actually a curve. The apparent diameter of the sun's disc is about ½°, so observing the top edge in effect lowers the horizon by ¼°.

None of the above criteria take into account the true ('astronomical') position of the sun. The observer sees only the 'perceived' sun, which is a little higher than the actual sun because of atmospheric refraction (Fig. 4). The difference amounts to approximately ½° for altitudes between zero and 1°, and thereafter decreases (Lowne[6]). The sun's true position corresponding to D in Fig. 3 is shown by E. The true path of the sun within a few degrees of the horizon is indicated by the broken line (in fact a curve), which at the equinox rises at an angle of (90^o – ϕ) at its intersection with the horizon.

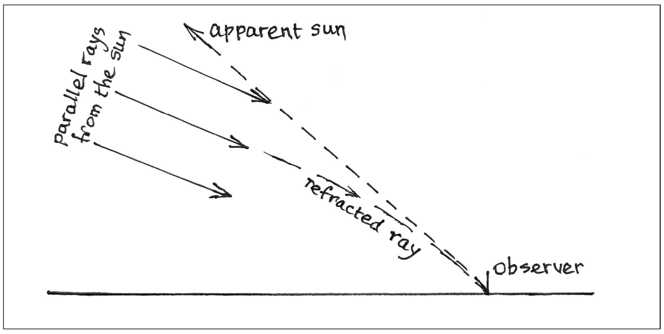

Fig. 4. Refraction of sun's rays by the atmosphere.

It is likely that medieval observers would use the first appearance of the upper limb of the sun as the instant of sunrise (criterion 4 above). This assumption, and also taking into account atmospheric refraction, is equivalent to lowering the actual horizon by about ¾°. The relationship between azimuth of sunrise as observed and date is therefore represented by the curve that is drawn about mid-way between the two sets of points in Fig. 2.

Church orientation

The axis of the nave of the church, looking east, lies at about N 82° E, i.e. its azimuth (using my sign convention) is 98° (see Fig. 1). From Fig. 2, this direction corresponds to 'theoretical' sunrise on day 13, or 3 April in today's calendar. If instead of 'theoretical' sunrise we use 'perceived' sunrise, taking into account the factors discussed above (radius of the sun's disc, elevated horizon and atmospheric refraction), the 'mid-way' graph gives sunrise at 98° on day 14, i.e. 4 April today.

The original church, of which the south wall still remains, was built by the Saxons towards the end of the 7th century. Because of calendar drift (explained by Hinton), there was a discrepancy of about 3 days at that time between solar date and calendar date, which means that perceived sunrise at 98° azimuth would have occurred three days earlier than 4 April, i.e. on 1 April. This date does not exactly agree with dedication on the Feast of the Annunciation (25 March, Lady Day), but it is within the 'octave' of that feast, i.e. within the period of eight days that include and follow the feast day. So we do have a reasonable agreement with a 'patronal saint' sunrise.

Misalignment of the Chancel

The present chancel replaced the original 7th century apse in the 13th century, i.e. six centuries after the nave was built (and at about the same time as the older of the two magnificent memorial brasses was made). The rate of calendar drift of 3 days in 4 centuries is equivalent to a discrepancy of 4.5 days in that time. From the relationship derived above, this gives a change in sunrise direction of $4.5\times0.6 = 2.7°$. The measured out-of-alignment angle is actually 3.5° (Fig. 1), so the relationship is not exact. However, the difference of 0.8° is equivalent to a change due to just over 1 day. Within a 4-year leap year cycle there could easily be a variation of 1 day in the date of the equinox. Since we do not know exactly in which year the chancel was built, we cannot be any more precise in our judgement. So I suggest that we can claim a very reasonable agreement with the idea of a re-dedication on or near the Saint's Day (25 March) as the reason for the chancel being out of alignment with the nave.

Alternative suggestion

There are several other dates in the Church Calendar devoted to St Mary, perhaps the most significant being her nativity. This is often taken to be 14 August, but at our church the alternative date of 8 September is commemorated. It occurred to me that this date is 14 days *before* the autumnal equinox, and therefore it would be reasonable to expect that the azimuth at sunrise on that day would be about the same as at 14 days *after* the vernal equinox, i.e.

the day referred to above. So could this be the day of dedication instead? I think not, because at that time of year the azimuth of sunrise is moving daily towards the south. If this date had also been used at the time of building the new chancel in the 13th century, it would have been out of alignment by about 3° towards the south, i.e. opposite to the actual direction.

Conclusion

These observations neither confirm nor disprove Hinton's assertion that the concept of 'saint's day' alignment is no longer valid. However they do show a reasonably close agreement to that idea in the case of St Mary's, Stoke D'Abernon, for both the original 7th century building and the out-of-alignment of the 13th century chancel.

ACKNOWLEDGEMENTS

I am grateful to Michael Lowne for his advice and valuable comments in preparing this paper. I would also like to thank the Rev Rosemary Mason for information relating to the commemoration of St Mary.

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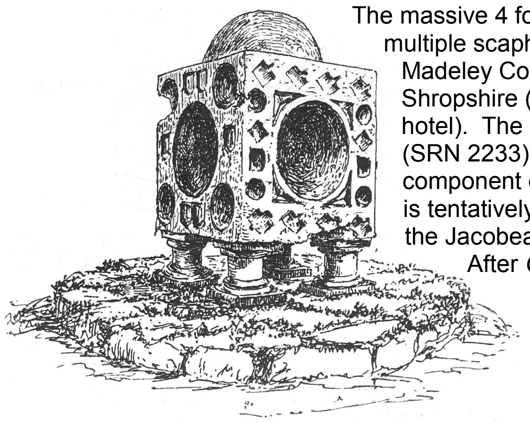

The massive 4 foot cube, multiple scaphe dial at Madeley Court Shropshire (now a hotel). The block (SRN 2233) has 56 component dials and is tentatively dated to the Jacobean period. After *Gatty*.

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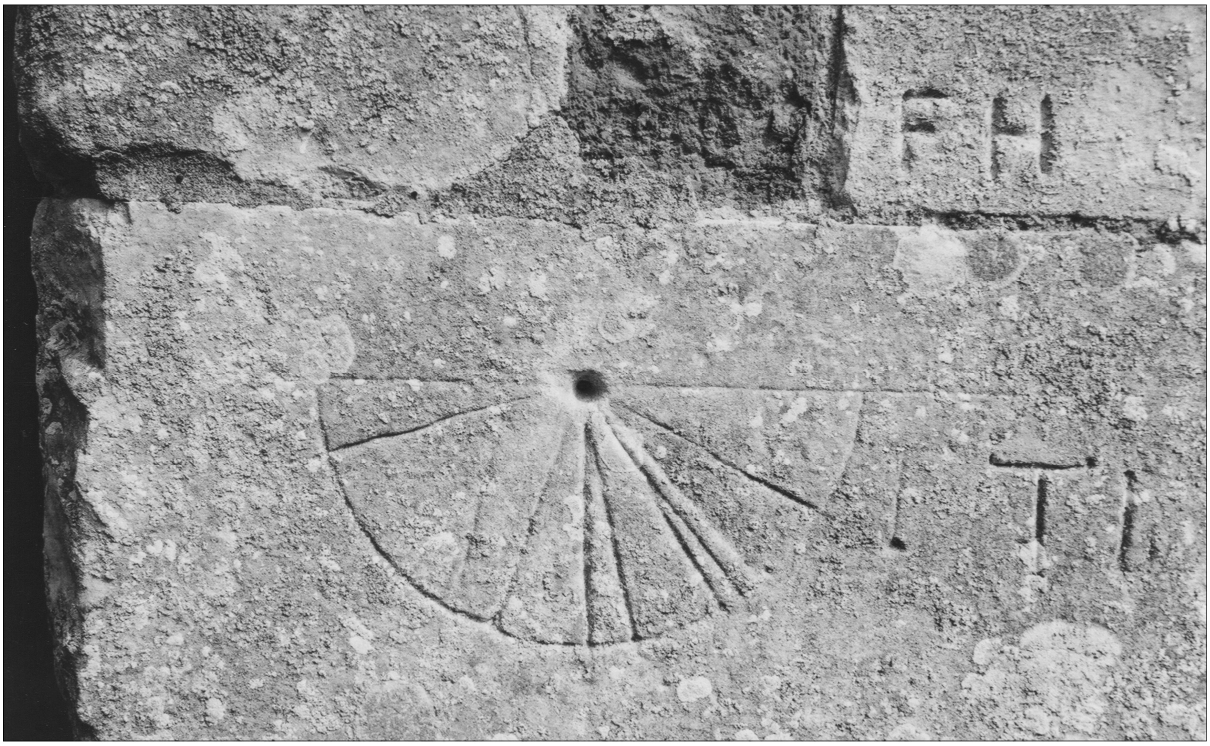
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