The British Sundial Society

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FEBRUARY 1998

Front Cover: Sundial on wall of Schloss Bad Soden, Germany formerly in the Von Hutten family (Photo: D. A. Bateman)

'Mach es wie de Sonnenuhr, Zähl die heitren Stunden nur.'

(Do as the sundial does: count only the cheerful hours)

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BULLETIN

OF THE BRITISH SUNDIAL SOCIETY

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EDITORIAL

One of the delights of the study of sundials and gnomonics is the large number of related topics with which it can overlap; astronomy and astro-navigation, spherical geometry and physics, architecture and garden design, history and archeology, and several more. This diversity of peripheral topics is paralleled by the diversity of interests of the readers of the Bulletin. A diallist who cannot enthuse over an elegant ivory diptych dial from Nürnberg may rejoice in a neat little computer program for laying out declination lines on a curved surface. Another reader hastily turns the pages of trigonometrical equations in order to get stuck-in to a fascinating account of mass dials in Suffolk. The editor must therefore do a balancing act, to make sure that in every issue of the Bulletin there is something for everybody, and that no one aspect of gnomonics will become over-emphasised, to the exclusion of others.

In recent weeks, after editing in quick succession articles on 'Portable dials in the Roman Empire', 'Sundials in a medieval cloister in Italy', a sundial found by archeologists in France, and another dug up in Jugo-slavia, a sundial made before the adoption in Britain of the Gregorian Calendar, 'Four eighteenth century meridian lines in Rome', and 'Ancient Egyptian Shadow Clocks,' I was left with an uneasy feeling that perhaps the Bulletin was becoming overloaded with History. A quick survey of the contents of recent issues showed that sometimes as much as one-third, but never as much as one half, of the articles in any one issue of the Bulletin is devoted to historic dials or the historical aspects of gnomonics. This gave some indication of the amount of historical material which might be appropriate, as an outline for current editorial policy.

So it is especially gratifying to be able to publish in this issue some good forward-looking articles on new designs for dials. Apart from John Singleton's ingenious modification of the analemmatic dial to accommodate a fixed gnomon, there are two highly original designs which are totally independent of the 'art of shadows': Allan Mills' polarised-light dial, and C.M. Lowne's reflecting dial. Let us rejoice in the recognition by the Sundial Society that, (in the words of one of our members) dialling is 'an area for new developments rather than simply one of historical research, preservation and nostalgia'.

THE SELLOTAPE SUNDIAL

A MODERN VERSION OF WHEATSTONE'S POLARIZATION DIAL OF 1848

ALLAN A. MILLS

Using the Sun to measure the passage of time basically involves noting its position in the sky as the day (or year) progresses. However, the Sun is too bright to look at directly, and there are no convenient graduations in the sky, so it is usual to make use of shadows falling upon calibrated dials for this purpose. This simple technique has given rise to the remarkably diverse types of sundial that generally form the subject of this journal.

However, any other method for accurately determining the position of the Sun in the celestial sphere should serve the same purpose. In 1848 Charles Wheatstone[1] showed how to use the polarization associated with the blue sky to find the azimuth of the Sun and so, with proper orientation and calibration, to determine the time of day. His instrument is therefore a true sundial, but is unique in that it looks towards the north and is not dependent on shadows. Consequently it can work when the Sun is behind a cloud, or even below the horizon! Using the instrument is simple enough, but rather extensive and sophisticated optics are required to explain its operation - far beyond the simple projection of a shadow.

THE NATURE OF LIGHT

From the standpoint of classical physics, light consists of electromagnetic waves whose vibrations are transverse to the direction of propagation.[2,3,4] Frequency of vibration (ω) is the most fundamental characteristic, being related to wavelength (λ) and velocity (v) in a given medium by the relationship:

$$v = \lambda\omega$$

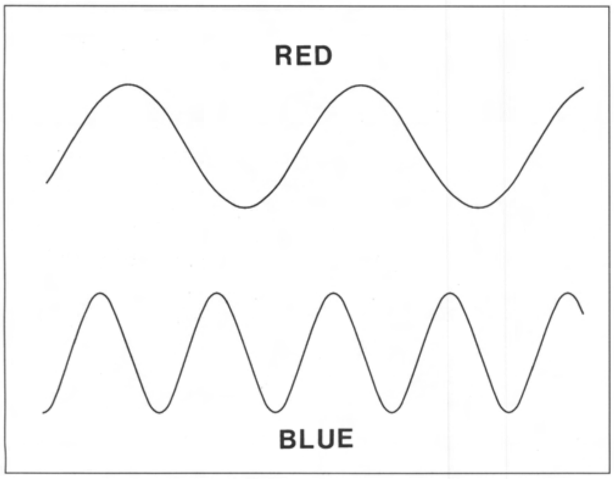

Fig. 1 Conventional representation of light waves

The velocity of light is a maximum in vacuum, where it approaches 300,000 km/sec. In real media (particularly transparent solids) the velocity is reduced but the frequency remains unchanged, so the wavelength is proportionally less.

Light waves are conventionally represented by sine waves, as in Figure 1. The red end of the visible spectrum contains the lower frequency waves of longer wavelength: the blue end is of higher frequency and shorter wavelength. However, with most thermal sources (including the Sun) the plane of vibration must be thought of as taking up every possible orientation with respect to the direction of propagation. Light of any frequency with its vibration confined to a single plane is said to be linearly polarized. This refers to the displacement of the electric vector when viewed along the axis of propagation: the older term 'plane polarized' is less commonly used nowadays.

POLARIZED LIGHT

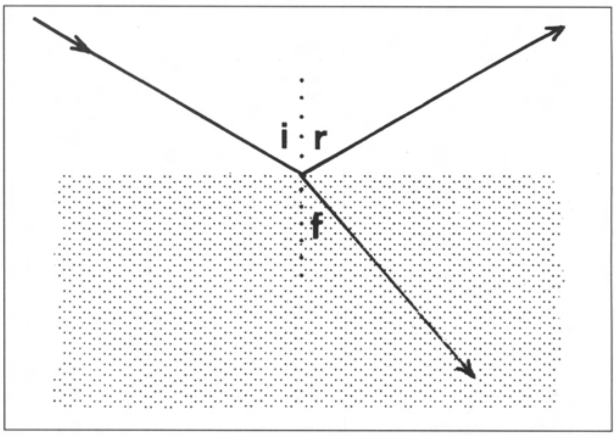

Fig. 2 Reflection and refraction of light

There are three main ways by which ordinary light may be converted into polarized light:

Reflection and refraction

A beam incident upon a transparent medium such as water is, in general, partially reflected and partially refracted (Figure 2). The laws governing this phenomenon are:

a) For reflection

$$i = r$$

These angles are always measured with respect to the normal at the surface.

b) For refraction

$$\frac{\sin i}{\sin f} = \text{constant.}$$

This constant is known as the refractive index (η), and is a measure of the reduced velocity of light in the medium. Both the reflected and refracted rays contain a percentage of polarized light. Brewster showed that this content attains a maximum (approaching 100% in the reflected beam) when the angle of incidence is such that:

$$\tan i = \eta.$$

For water of refractive index 1.33 this optimum angle of incidence is 53°. Glass and perspex have higher refractive indices around 1.5, so their 'Brewster angles' are approximately 56°.

Brewster's relationship applies only to reflection by insulators. Reflection from metals (e.g. conventional silvered mirrors and front-surface aluminised mirrors) gives rise to the more complex elliptical polarization.

Birefringence and dichroism

Water, being a liquid, is optically homogeneous: light is not affected by the direction of travel within it. Glass is really a supercooled liquid, so the vitreous state is similarly uniform (unless it is strained, when a directionality is introduced). Crystalline solids, however, may well have an internal structure that is more easily traversed in one direction than another: they are said to exhibit double refraction or birefringence. An unpolarized incident beam will then give rise to two internal beams polarized at right angles to each other. Calcium carbonate or calcite (especially in the form of the transparent and colourless crystals known as Iceland spar) is a well-known example where this birefringence is so pronounced that two well-separated beams are produced by quite a short pathlength within the crystal. The classic Nicol prism was cut from Iceland spar in such a way that one beam was directed to the side and absorbed by a coating of black paint, whilst the other continued and was emitted as a 100% linearly polarized beam. Its intensity can never exceed 50% of the original light.

A dichroic crystal is both birefringent and coloured, but exhibits so much greater absorption along one axis that the beam traversing the latter is effectively eliminated. Tourmaline is a natural example; the man-made iodosulphate of quinine (herapathite) is another. It is difficult to grow large crystals of these complex substances, so they remained optical curiosities until Land discovered how to embed vast numbers of microscopic crystals of the last-named within a sheet of nitrocellulose and then align them by stretching the plastic. Some years later he obtained improved results from stretched polyvinyl alcohol films dyed with iodine and then protected by lamination between sheets of cellulose acetate-butyrate (CAB).[5] This became well-known as 'Polaroid' polarizing sheet.[6]

Polaroid may be visualised as a very closely spaced 'picket fence' filter. A sinusoidal beam of light incident upon it will be absorbed in one direction, but the emergent beam will be highly linearly polarized in the direction of the vertical spaces between the posts of the fence. Additional losses by absorption reduce the intensity below the theoretical maximum of 50%: the most used grade of Polaroid (HN32) passes 32%. This filter is said to act as a 'polarizer'. A second Polaroid acts as an 'analyzer': set parallel to the first it passes the linearly polarized light, but when turned through 90° the effect of the 'crossed' gratings is to block the beam.

Polaroid sunglasses incorporate lenses oriented vertically to block the horizontally-vibrating polarized dazzle produced by reflection from water, vegetation and road surfaces.

Scattering

Rayleigh showed that the familiar blue sky is a result of scattering by the molecules of the air, the degree of scattering being inversely proportional to the fourth power of the wavelength. The blue end of the spectrum is therefore preferentially scattered out of the incident beam, the remainder giving the reddened Sun associated with the direct view at sunset. The blue sky is really of quite low intensity: it is just that we view it against the blackness of space.

Preferential scattering of blue light may be demonstrated by shining white light down a long glass tube containing a very dilute solution of sodium thiosulphate acidified with a few drops of dilute hydrochloric acid. Sulphur is slowly released in colloidal form and for a while (before the particles grow too large) the tube appears bluish from the side and reddish when observed end-on. If the blue light is viewed through a Polaroid sheet it will be found to be partially polarized, the degree of polarization reaching a maximum at 90° to the main beam.

POLARIZATION OF THE BLUE SKY

The blue sky is similarly polarized as an inherent property of the scattering process that produces it.[7,8] By the first decade of the 19th century it had been established that:

a) The *direction* of the polarization at any point in the sky always tends to be perpendicular to the plane

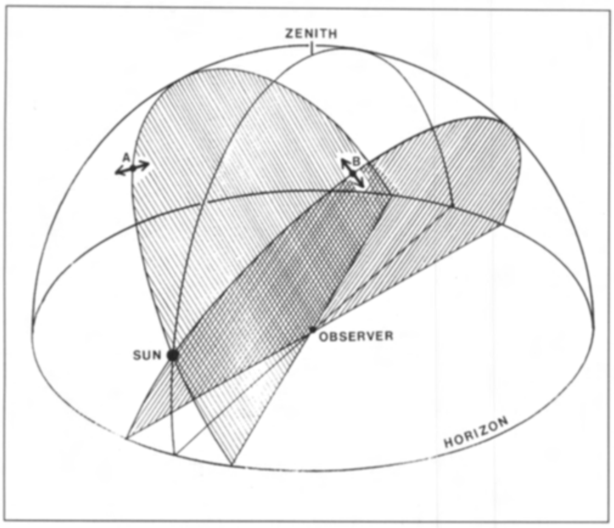

Fig. 3 The direction of polarization of light from any point in the sky (e.g. A or B) is in general perpendicular to a plane containing that point, the sun, and the observer.

connecting that point, the Sun, and the eye of the observer (Figure 3).

b) The *intensity* of polarization (i.e. the proportion of polarized light in the total light) reaches a maximum at 90° to the Sun. (See the experiment described above.) This is represented in Figure 4 by the relative lengths of the double-headed arrows signifying the polarization vector (Figure 4).

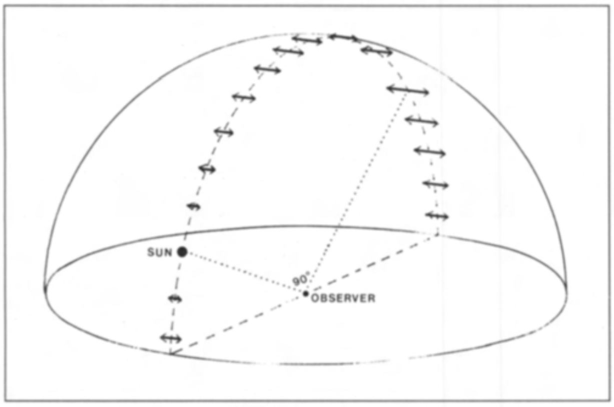

Fig. 4 Relative intensity of the linearly polarized component along the great circle bounding a plane connecting observer, sun, and a set of points in the sky.

Moisture, pollution and other factors reduce the proportion of polarized light from the blue sky so that it is never more than about 75% - and usually considerably less in British skies!

MOVEMENT OF THE POLARIZATION PATTERN

As the Sun moves across the sky the associated polarization pattern moves with it. This is most clearly demonstrated if we make the northern celestial pole our 'point in the sky', for the Sun (whatever its declination) circles about this point at a uniform velocity of 15° per hour, making one apparent revolution in the 24 hour day. The plane is therefore carried round at the same rate, passing successively through the imaginary hour circles. This motion is diagrammed in Figure 5. It will be apparent that only at the equinoxes, when by definition the Sun is 90° from the poles, will the maximum of the polarization pattern coincide with the pole. Nevertheless, a sufficiently sensitive method of delineating the direction of polarization could in principle give the local apparent solar time to an observer at a given location: we have the potential for a great sundial around the northern celestial pole, where the Sun itself can never reach. Similar reasoning applies in the southern hemisphere. The usual shadows are not involved, although - like the gnomon - the axis of the 'polarization sundial' must be fixed in the direction of the celestial pole.

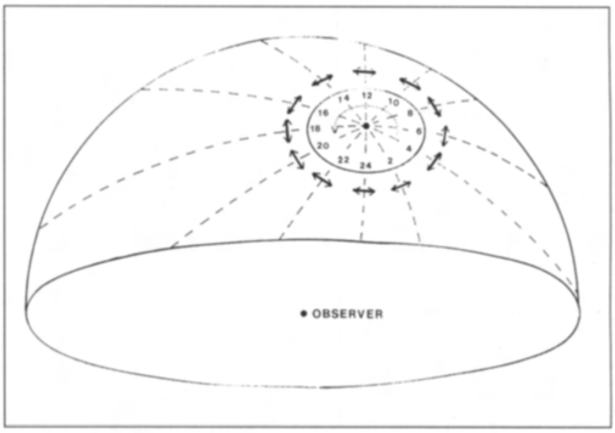

Fig. 5 The plane containing sun, observer and celestial pole rotates uniformly about the last-named, making one turn per 24 hours in an anti-clockwise direction. The major polarization vector is always at 90° to the plane.

QUALITATIVE DETECTION OF THE PRESENCE OF POLARIZATION

The partial polarization of light from the blue sky is easily demonstrated by viewing through a piece of Polaroid whilst turning the latter in the hand. The resulting change of intensity of the transmitted light with position of the Polaroid analyzer is obvious, but complete extinction is never achieved. This phenomenon is sometimes employed by photographers to increase the contrast of white clouds, for the light from these is substantially unpolarized and so remains unaffected.

Finding the *precise* direction of vibration of the polarized component of the total light is less easy. Looking through a piece of Polaroid towards the (predetermined) celestial pole on an average sunny day, it proved impossible to locate the position of maximum extinction (at right angles to the plane of polarization of the polarized component in the incident light) to better than ±20°. This is inadequate for reasonable timetelling or navigation: an improved method of setting the analyzer is essential.

IMPROVING SENSITIVITY

The eye/brain system is not good at remembering and mentally comparing varying intensities, such as those produced in the above experiment. It is, however, very well adapted to matching the intensities and/or colours of two fields presented side-by-side.

This desirable situation may be achieved by arranging for the plane of polarization of a segment of the field of view seen through an appropriate instrument to be subjected to an additional rotation, whilst the light in the remaining field proceeds unchanged. The two areas will then appear of equal intensities (or identical colours, see below) when the instrument has been so turned on its axis that the plane of polarization of the incident radiation falls exactly along a bisector of the two fields in the eyepiece. Devices of this nature are sometimes called 'polariscopes'. A simple form for use with a polarization dial is described by Colchester.[9]

CELLOPHANE AS A ROTATOR: THE SELLOTAPE POLARISCOPE

The transparent film known as 'Cellophane' is made by stretching a film of regenerated cellulose, and is characterised by surface striae parallel to the extrusion direction. This stretching induces birefringence, just as in the stretched polyvinyl alcohol film used in Polaroid. Incident light therefore travels in two orthogonal directions at different velocities: 'slow' parallel to the striae and 'fast' across them.[10,11] However, no iodine or other dyestuff is present, so both components are transmitted.

The phase difference between the emerging components depends on the degree of stretching and the thickness of the Cellophane film - it appears to be manufactured in several gauges. 'Sellotape' consists of Cellophane coated with an adhesive, but the latter is readily removed by rubbing with petrol on a tissue. The resulting 0.029 mm thick Cellophane (measured over 16 layers) is said to be optimal for making polariscopes.[12] (The plain Cellophane used for wrapping boxes of chocolates etc. would be more convenient but is significantly thinner, one sample being found to be 0.018 mm thick. 'Scotch Tape' is a similar cellulose product, but I have not tested it.)

If a strip of Sellotape-derived Cellophane is slid in along a diagonal between crossed squares of Polaroid it will appear to 'scrape away the darkness' to appear white. This is because the phase difference between the two emerging components is close to half a wavelength for all but the extreme ends of the spectrum, and this leads to an apparent rotation of the recombined beam through 90° (refs. 2 - 5). It is therefore passed by the crossed analyzer, and the eye interprets the depleted light as white. Conversely, if the polars are made parallel the Sellotape assumes the complementary colour, in this case purple from the admixture of light from the ends of the spectrum. (The 0.018 mm Cellophane appears amber between crossed polars, blue when they are parallel.)

These intriguing effects are the result of selective interference, and the colours are much more intense and varied with several superimposed layers of Sellotape or Cellophane.[8,13,14] Thin sections of many rocks and minerals exhibit the phenomena very well, which therefore constitute an important diagnostic technique for the petrologist. For this reason the clearest explanations tend to be found in textbooks intended for the geologist rather than the physicist. That by Gay[15] is recommended. Examination with a laboratory spectroscope of Sellotape's purple colour between parallel polars showed a broad absorption band centred in the green: it is therefore said to act as a 'half-wave plate' for green - but is very unselective in single thickness, so the emerging light appears white rather than greenish to the eye. Multiple layers (which may be angled to each other) 'sharpen' the absorption bands and produce purer colours.

Returning to the sky polariscope, all that is required to give a great improvement in sensitivity is a strip of Sellotape at 45° to the analyzer, permanently installed on the sky side so that both may be rotated together as a unit.[8] Equality of intensity between the two fields will be produced when the assembly is at 45° to any linearly polarized portion of the incoming light. The vibration direction of the latter will coincide with the length of the Sellotape strip. 'Light' and 'dark' matches will be displayed alternatively every 90° when such a polariscope is turned through 360°.

WHEATSTONE'S POLARIZATION SUNDIALS

Following this long preamble we are at last able to appreciate the genius of Wheatstone. Speaking at the 1848 meeting of the British Association for the Advancement of Science[16] he described not one but two polarization dials. Cellophane was not of course available, so he utilised thin sheets cleaved from selenite (a hydrated calcium sulphate) to provide the rotation of part of the field necessary for sensitivity. Being comparable with several layers of Sellotape, reddish and greenish pastel tints at varying intensities were produced rather than shades of grey. Polaroid, too, had yet to be invented, so the more accurate

Fig. 6 Wheatstone precision polarization sundial, by W.H. Darker of Lambeth. The cone is 25 cm long. (Wellcome Collection, Science Museum, London.)

of Wheatstone's instruments embodies a Nicol prism as the analyser. It has already been described elsewhere,[17] together with details of a modern reconstruction reproducing the characteristic conical shape. This results from the need to mechanically link the selenite or Sellotape films with the rotatable analyzer. An example made to Wheatstone's design by W. H. Darker of Lambeth is in the Wellcome Collection at the Science Museum, London (Figure 6).
Wheatstone also exhibited at the same 1848 meeting a

Fig. 7 Wheatstone folding-type polarization sundial. The base is 13 x 11.5 cm. Old Royal Observatory, Greenwich.

smaller and simpler folding form of polarization sundial (Figure 7). It consisted of a fixed semicircular fan of 15° sectors of selenite arranged to face the celestial pole. The emergent light was analysed by reflection at the Brewster angle from a sloping piece of black glass, the time being indicated to within $^1/_2$ hour by the sector exhibiting the most intense reddish tint. The simplest way of demonstrating and understanding this instrument is to cut twenty-four 15° sectors of Sellotape in the manner diagrammed in Figure 8. Arrange these in a circle on a piece of glass, hold up out-of-doors to face the pole of a clear blue sky, and view through one lens of a pair of polarizing sunglasses. You will see a cross made up of comparatively dark sectors and, at 45° to it, another cross consisting of the brightest sectors. Turning the analyser alone through 90° interchanges the dark and light crosses. This pattern rotates anti-clockwise as the day advances. Fixing the analyser above and in a given direction with respect to the Cellophane collage, and adding numerals to correspond with one arm of a chosen cross, would therefore form the basis of a time-telling instrument. (One can usually estimate the time well enough to know which of the two orthogonal indications is relevant.) Sticking several layers of Sellotape one above the other will mimic

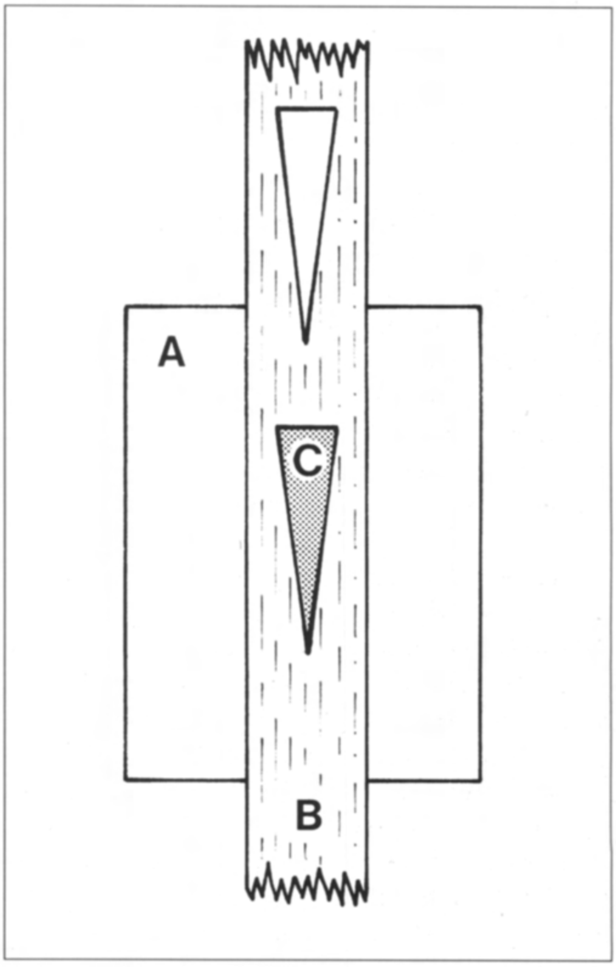

Fig. 8 Method of cutting 15° sectors from Sellotape. A: sheet of glass rubbed with silicone furniture polish; B: 1" wide Sellotape; C: aluminium template, used to guide a very sharp craft knife.

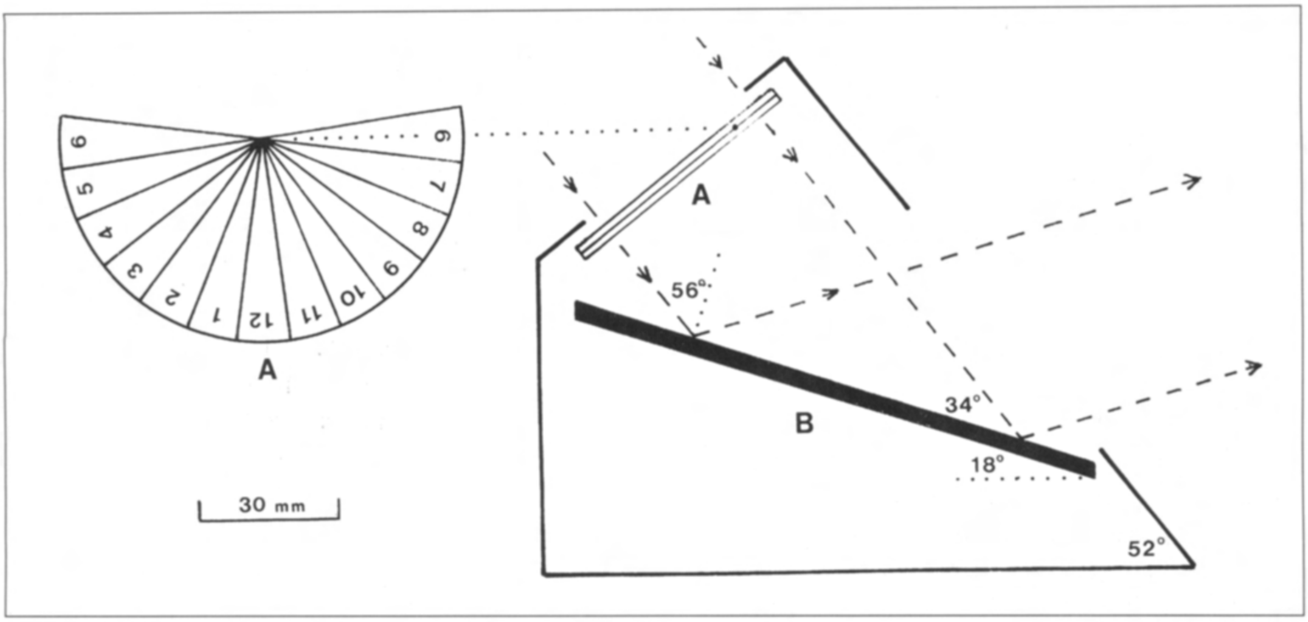

Fig. 9 Scale diagram of the 'Sellotape Sundial'. 'A' represents the fan of Sellotape sectors; 'B' the rectangle of glossy black Perspex. The latter is 100 mm wide.

Wheatstone's fan of pretty colours - but the penalty is that you will then have to explain where they come from! These polariscopes may also be tested and demonstrated with the partially-polarized light coming from a reading lamp reflected at a low angle from the top of a desk.

For a more refined instrument I decided to use sectors cut from a single thickness of Sellotape, producing a pattern in shades of grey against the blue sky. A fan of thirteen 15° sectors was laid down on one of the 1.5 mm clear Perspex windows shown in Figure 9, carefully rolling the tape to minimise the entrapment of air bubbles. Then, to avoid the long-term oxidative degradation associated with most adhesive tapes, a few drops of 'boiled' (i.e. artists' drying-type) linseed oil were placed on top of the fan before lowering the Perspex cover into place. A small weight was placed on top, and ten days allowed for residual air bubbles to disappear and the oil to harden around the edges of the sandwich. It was then mounted in a plywood box cut to the latitude angle (Figure 10). Following Wheatstone's design, a rectangle of 3 mm polished black Perspex set at the Brewster angle was employed as the analyzer. Inverted

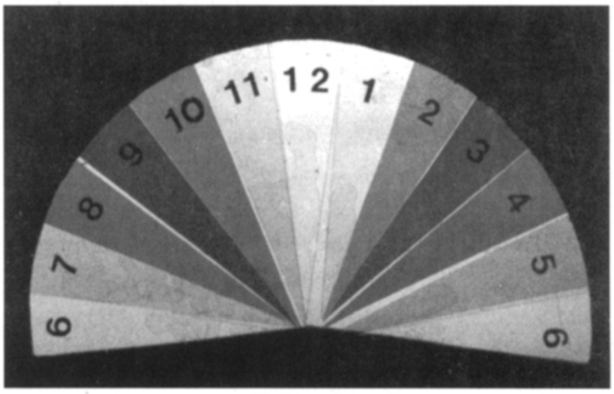

Fig. 11 Appearance of the dial when set towards the pole of a blue sky at 12 noon local apparent time.

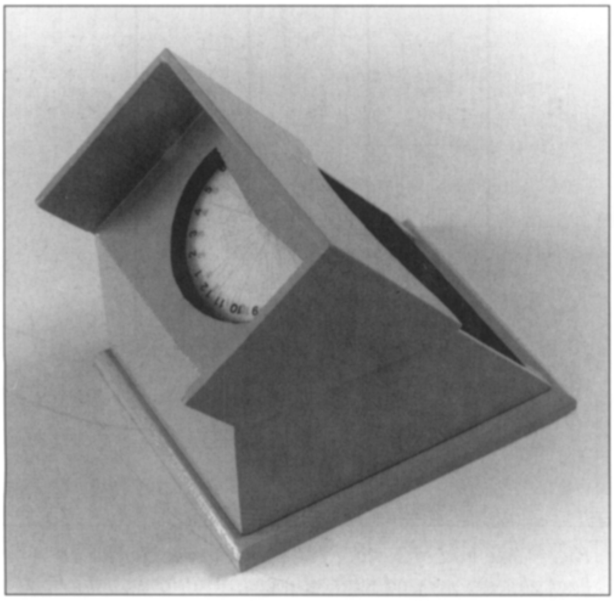

Fig. 10 External appearance of the 'Sellotape Sundial'.

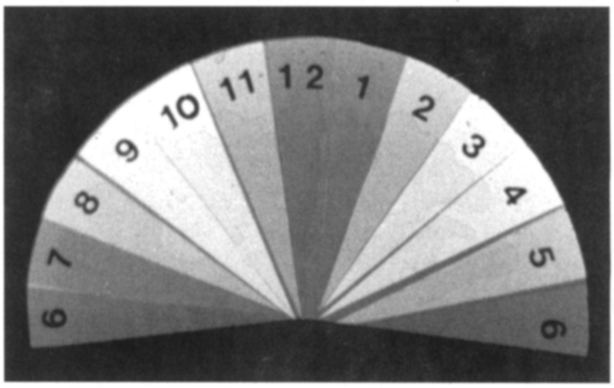

Fig. 12 Appearance at 9.30 p.m. on a day in July. The Sun had set, and no shadows were visible in the dusk.

numerals (Letraset) were placed so that they appeared correct in the reflected image, with '12' at the apex of the arc. The hour was indicated by the brightest sector; the half-hour by the equality of two adjacent sectors (Figures 11 and 12).

FURTHER DEVELOPMENTS

These polarizing dials are effective when directed towards the northern celestial pole on a temporary mounting outdoors, or through an open window. The blue sky does not have to be entirely cloudless. Unfortunately, closing the window is likely to cause anomalies as a result of superimposed polarization following reflection/refraction by the vertical glass. Perhaps a dial could be contrived on the inside of a domed or angled skylight that permits a more-or-less perpendicular view of the pole star at night? It might look good with sectors of Cellophane (or stretched Cling-Film[4,13]) varnished-on in multiple layers to give chosen interference colours. Cleaved muscovite mica is another possibility, and should be more resistant to degradation. A 'stained glass window' would be less exacting. The collage could be viewed through a fixed piece of Polaroid, or laminated directly with the latter.[14,18] I do not, however have any information on the durability of Polaroid towards long-term exposure to sunlight. It's probably none too good, so how about reflection from a pool or a polished slab of black marble on the floor?

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6. Obtainable in the U.K. from Optical Filters, Unit 36, Princes Estate, Summerleys Road, Princes Risborough, Bucks HP17 9PX. Tel: 01844 260 377. The most-used HN32 linear polarizer, laminated in CAB and 0.03" thick, is about 40p per square inch. It is best to obtain two squares, say of 2" side, both with an edge parallel to the permitted polarization direction. Check by examining a low angle reflection from a shiny non-metallic surface, such as the top of a desk.

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SUN COMPASS BASED ON AN ARTEFACT FOUND AT UUNARTOQ FJORD, SW GREENLAND

MARGARET FOLKARD & JOHN WARD WITH INTRODUCTION BY MARGARET STANIER

INTRODUCTION

During the Middle Ages the Norsemen sailed the North Atlantic on frequent and regular voyages to settlements in the Scottish Islands, Ireland and the Faeroes; and to more distant outposts including Iceland and southern Greenland. Indeed the Norsemen were the first Europeans to see the continent of North America. Bjarne Herjulfsson saw it by chance in 986 A.D. when blown off course on a voyage to Greenland, and a generation later Leif Eriksson organised a successful voyage of discovery in two vessels.

Navigation on the Norsemen's voyages was by dead reckoning. The crews were able to judge the speed of their vessel with sufficient accuracy, and direction was found by sun and stars. Many of the longer voyages were undertaken in spring and autumn when both sun and Polaris would be visible at these high latitudes. Much use was made of latitude sailing, a device used for centuries before and since, by vessels out of sight of land: sailing coastwise north or south by landmarks until the latitude of the destination is reached, then turning due east or west and maintaining a constant latitude till landfall. Thus for the Norsemen, Bergen was the starting point for Hvarf in Greenland along latitude 60°N, Stad for the Faeroe Islands on 62°, Trondheim for Iceland on 64°. A constant latitude was maintained by observation of the altitude of noon sun, and of Polaris at night. (Marcus[1]) The Norse crews must have dreaded fogs and thick weather when sun and stars might be invisible for days.

During excavations in 1948-51 in south-west Greenland at a settlement site called Narsarsuaq near Uunartoq fjord, a team of Danish archeologisits headed by C.L Vebaek unearthed (among much else) a wooden half-disc bearing a central hole[2] (Fig.1). Regularly arranged notches had been cut around the diameter, spaced in such a way that there would have been 32 in the original in the complete disc. The material was later identified as Norway Spruce (Picea abies) and the test by carbon 14 gave the date as approximately 985-1015 A.D. This half-disc, now in the Danish National Museum in Copenhagen, and originally described as a 'sun-ray disc, use unknown' was subsequently identified as a 'bearing dial' by Sølver[3].

The instrument when intact might have had a handle below the plane of the disc and a central pin above it. Sølver envisaged that the navigator would stand close to the helmsman with his steering-oar at the vessel's starboard quarter and would hold the bearing dial horizontal. If at dawn the azimuth of the sun is known to be north-east the navigator takes a bearing on the sun on the centre of the dial, turning the dial so that the north east notch points to the rising sun. The dial is now a true compass enabling the navigator to 'divide the horizon'. The course is set and the helsman can maintain the proper course by wind and seaway. A bearing on Polaris could be taken at night. A series of small cuts on the surface of the wooden disc may perhaps be the markers for the 'North' notch on the perimeter. (Fig.2)

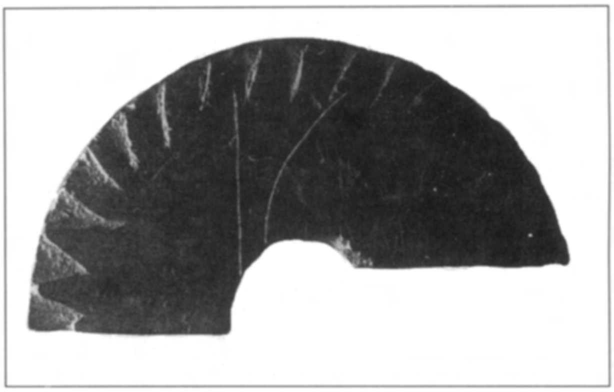

Fig.1 Wooden half-disc found during excavation at a Norse settlement near Uunartoq fjord, SW Greenland. (Photographed by Technical Department, Danish Criminal Police, Copenhagen; 'gnomon lines' have been highlighted)

In 1978 a Swedish astronomer, Dr. Curt Roslund, examining a photograph of the half-disc from the Museum in Copenhagen, noticed two lines on the surface, which might be interpreted as declination lines: 'gnomon lines' as they were called. Roslund, who had an interest in astro-navigation, asked permission to examine the original disc, and was able by microscopic examination to show that the lines had been cut into the wood at least twice. The implication was that these lines were intentional, not mere random scratches made before or while the half-disc had been buried. One of these lines was almost straight , the other deeply curved. They could be interpreted as declination lines for equinox and summer solstice, and closer inspection and calculation revealed that these were indeed the appropriate equinox and solstice lines for the latitude 61°N: These lines were the loci of the shadow of the tip of the pin of the bearing dial at that latitude on those days. The navigator, keeping the dial horizontal (whether by floating on water or by other means, Fig. 3) had only to

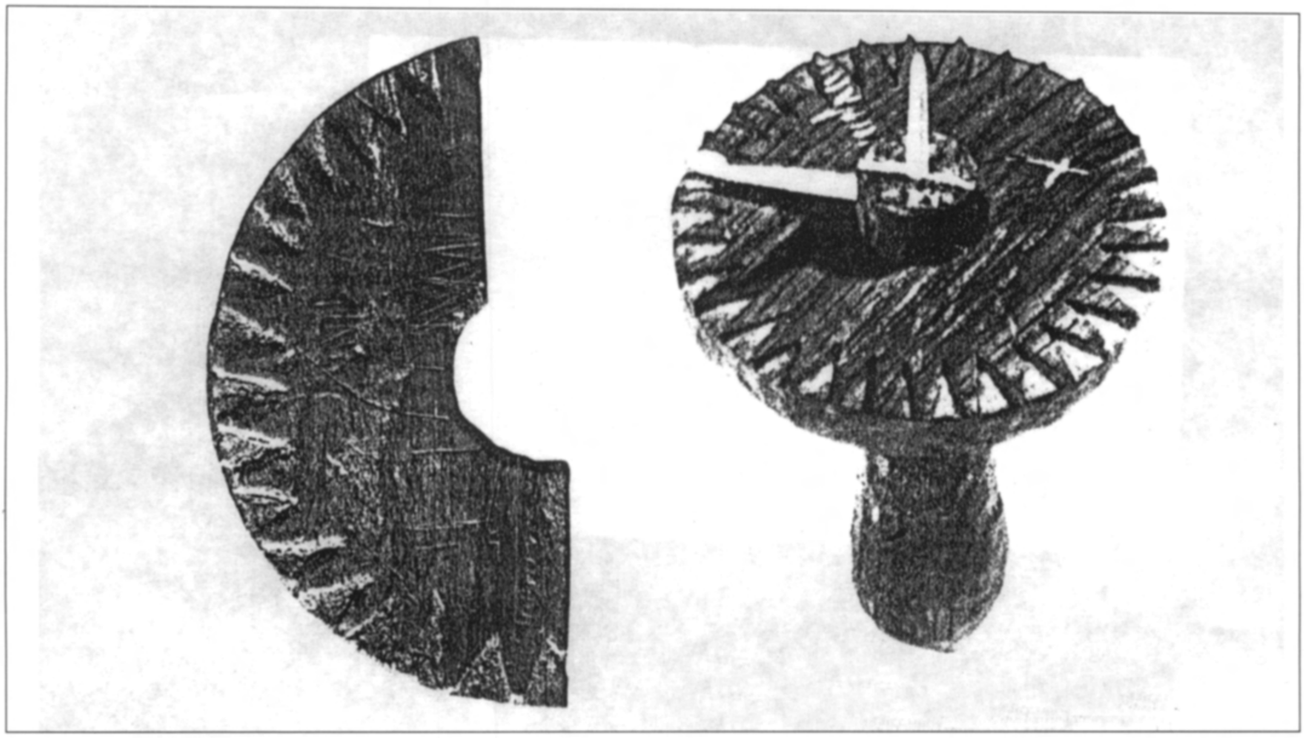

Fig.2 Half-disc and possible reconstruction of complete disc, suggesting its use as a bearing dial. (from Sølver, 1953)

turn the dial until the shadow of the tip of the pin fell on the line, and the dial became a true reading compass. The calibration of the compass could thus be carried out at any time of the day when sunshine was available, not just at dawn when the sun's azimuth at rising was known, as Sølver had envisaged (Vebaek & Thirslund[4], Thirslund[5]).

In fact, a declination line is precisely correct for only one day of the year. (Fig.4.). However in practice a line could be used for a week or two either side of the equinox or summer

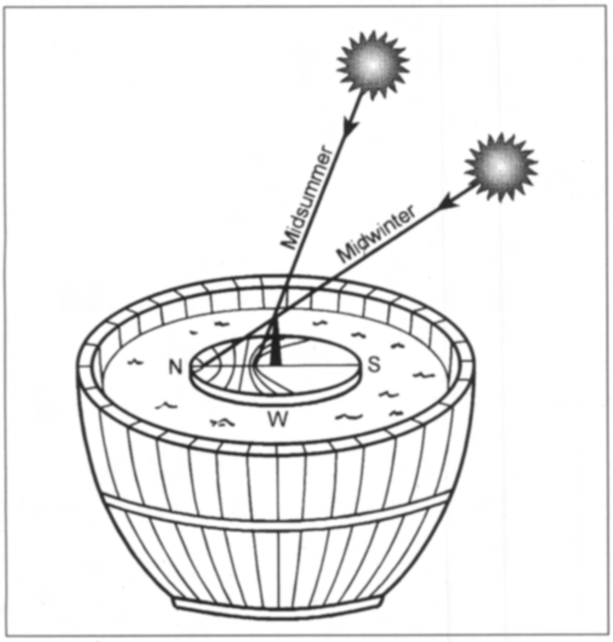

Fig.3 Possible means by which a wooden disc could be kept horizontal on a vessel at sea. (from Vebaek & Thirslund,1992)

solstice. During the morning this inaccuracy would cause the vessel to be steered (say) slightly too far south of her time course, and during the afternoon slightly too far north of it. The zig-zags thus sailed would form only a small addition to the length of the voyage.

A number of experiments confirmed this interpretation of the use of the Uunartoq disc. In 1988 Thirslund[5] made numerous 'replica' discs based on the archeological finding but for appropriate dates and latitudes, and invited a group over 100 yachtsmen to test them out on board their craft during yacht races round Fyn and Zealand. (The discs were kept horizontal, not by floating on a water surface as suggested in Fig.3, but by being fixed to the top of a cork which was then inserted into a empty bottle which was allowed to swing freely.) A similar dial was also made for a North Atlantic crossing in the Norse replica vessel 'Gaia' in 1991. The discs performed well in both these tests: the true compass bearing could be attained within 2° or 3°.

In recent years several replicas of ancient vessels have been built and sailed: the 'Golden Hinde' of Drake, Cook's 'Endeavour' and the 'Mathew' of John Cabot for example. Navigation in such replica vessels is of course carried out by modern means: satellite fixes, radio beacons and the like. However a few replica instruments (astrolabe or backstaff perhaps) are also carried on board to enable the crew to try their skills; members of the crew are pleased if using such equipment they attain an accuracy within 2° of the true position. When Commander Bill McGrath (U.S. Navy) proposed a re-enactment of Leif Eriksson's transatlantic

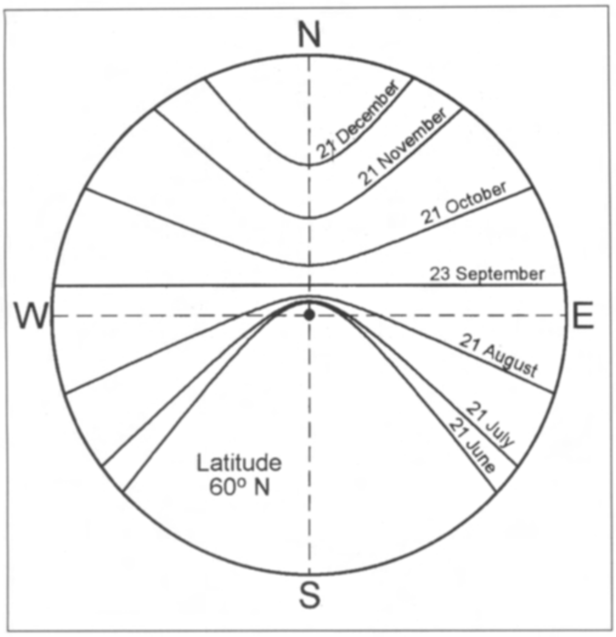

Fig.4 Configuration of declination lines on a horizontal surface on various dates of the year.

voyage, he asked the authors of this article to make sun compasses based on the artefact from SW Greenland.

THE MAKING OF THE SUN COMPASSES

Imagine a circular disc of wood about 300-400cm in diameter and about 25mm thick. In the centre of the disc is a vertical pin (or gnomon or nodus) about 50-100mm high. The disc can be floated either in sea or in a barrel of water on board the ship. When the sun is shining, the central vertical gnomon casts a shadow onto the horizontal wooden disc floating in the water. This was used for finding direction assuming an approximate knowledge of the date and hour of the day.

The curved lines engraved on the wood showed the locus of the gnomon's shadow tip brought about by variations in the sun's azimuth and altitude angles. These positions vary with both latitude and date.

There was no way that these lines could be calculated by the Norsemen of long ago. However, all they had to do to make these lines was to plot, by direct observation, the gnomon's shadow position for a given day of the year and at the proposed departure location (and hence latitude).

Nowadays, this type of calculation can be done quite readily with the aid of a pocket calculator or computer. As experienced gnomonists we were able to compute the shadow positions for a range of latitudes between 60° and 70° North. Different heights of gnomon were made, to maximise the shadow length and hence the accuracy of the sun compass.

We then made a set of nine discs, using narrow boards of Norway spruce, which were glued together with waterproof glue before being machined into discs 400mm in diameter and 25mm thick. Using tape we attached the computed paper plots onto these discs.

A leather stitch-marking wheel was then firmly pressed through the paper to mark the wood with the required curves and lines. The paper was removed and the lines were better defined with carving tools, and darkened using an ordinary lead pencil.

Finally the discs and gnomons were coated with a mixture of beeswax and turpentine in order to make them quite waterproof. Fig.5 shows a completed disc.

To save packing space aboard a small boat, the gnomons were made demountable with the aid of a screwed brass joint similar to that used for joining the two halves of a snooker cue.

We delivered the discs to Lieutenant Commander Bill McGrath (USA Navy) who will be the navigator for a proposed re-enactment voyage to America by the Norsemen about 1000 years ago. If all goes well the voyage will begin on 22 June 1996 from Bergen in Norway. A single boat will be rowed and partially sail-assisted across the Atlantic Ocean, veering towards Iceland then on to Greenland and finally to America.

We wish them *bon voyage*

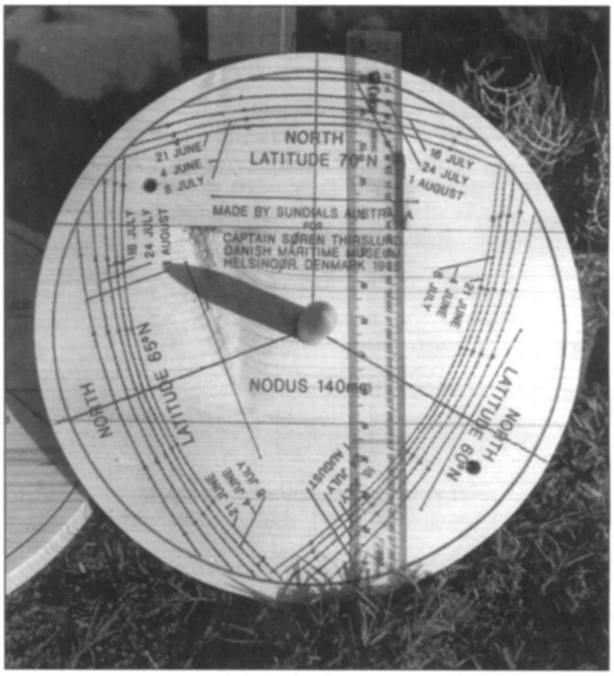

Fig.5 Compass disc designed and made by authors

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2. C.L. Vebaek: 'A New World Benedictine Nunnery before the days of Columbus: excavations in S.W. Greenland' *Illustrated London News,* **220,** 763-765, (1952)
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A CUSHION SUNDIAL

NICOLA SEVERINO (ITALY)

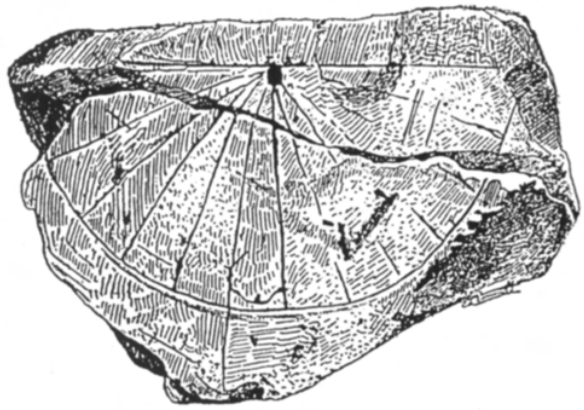
In Bulletin Archeologique, No 3, published in 1896, I found, on page 318, a remarkable written account by Theophile Eck[1]. Close to the Cemetery area of Aubigny-en-artois and about one mile for the town of Aubigny, there is a locality by the name of "Bourbon". Here, in October and November 1895, many sarcophagi were discovered. These were in good condition and had not been violated.

In a tomb of the VII or VIIIth century was found, in 1895, the skeleton of an old man which was accompanied by many brass objects. His skull rested on an old sundial stone! The horizontal sundial had hour lines spaced at 15°, all converging on a large gnomon hole through which the line of 6-0-6 passed. The hour lines were for indicating astronomical hours and not temporary hours. This is a very important discovery for the history of gnomonics, for in Europe the astronomical hours do not appear until about the 17th century.

This sundial is therefore a unique example of a sundial with markings for the astronomical hours. Such a form of dial is not mentioned by the Venerable Bede in his writings.

It is not possible to determine from the gnomon hole if the dial was fitted with a polar orientated gnomon or a vertical gnomon. If it was intended for a gnomon parallel to the terrestrial axis, it is another important example in the history of gnomonics. The polar oriented gnomon was unknown to the European diallists until XV-XVIth century.

The sundial from the tomb at Bourbon was incised on a white stone. Its present whereabouts is unknown but it may be located in the Museum at Constantinople (today's Istanbul). On page 320 in Theophile Eck's article note "Au musée d'Epinal on voit un cadran solaire en bronze de l'epoch galle-romaine. Suivant M. Baltazzi-Bey, le musé de Constantinople aurait reçu en 1895, avec de nombreux objets, un cadran solaire en marbre blanc de Séleucie. [At the Epinal museum one can see a bronze sundial of the Gallic-Roman period. According to M. Baltazzi-Bey, the museum at Constantinople had received in 1895, a sundial in the white marble of Séleucie]. I have described this dial in my book 'Storia della Gnomonica' p.48.[2] The significance of this sundial may never be known. Why should it be placed under the head of an old man? Perhaps he was an old diallist. Perhaps it was a symbol of passing time, and the mortal time of the man. We may not know, but seemingly the old man wished to take with him to his tomb, his sundial and the time of his life!



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BOOK REVIEW

BIBLOGRAFIA DELLA GNOMONICA
Nicola Severino

In two volumes of 361 pages and 101 pages, no illustrations. Paper covers with front plastic guard. A4 format. Privately published in Roccasecca, Italy, July 1997. Price in Italy about 100 dollars from Nicola Severino, Via Lazio, 6, 03030 ROCCASECCA STAZ (FR)), ITALY.

The first volume of this work, "Checklist of dialling References" contains a general catalogue of works and articles printed from 1500 - July 1997, a total of about 9950 titles. The entries are in alphabetical name order where possible; many of the items lack the name of the author and are entered under "anonymous". A proportion of the entries have the title translated into English, plus comments on the book, or on the author of the work. Otherwise the entry is merely a short title form of record purposes.

Many of the older dialling works have very long titles indeed and so it is impracticable to render these in full. Furthermore, with such a large number of entries, it has been impossible to inspect each item, and so the recorded information of other bibliographers has been used after checking.

In the past, bibliographers often used a selected or abbreviated part of a title, leading to confusion and giving the impression that two or more titles were in being, when in fact it was merely one work. Again, with authors who have Latinised forms of names, this can give the impression of two or more separate authors, for example John Hollywood becomes Sacrobosco. This is clarified in the entries wherever possible.

For researchers this is a larger collation of dialling works than ever before assembled but the entries are only intended to lead the reader to a given work and its details. For actual research work it is necessary to refer back to the original sources, wherever possible, to be certain of accuracy.

The second volume "Sezione Riviste" (Magazine Section), carries on to include the more ephemeral dialling material, namely that in magazines, periodicals, newspapers, etc. The entire contents of the Nederlands Sundial Society's

Bulletin *De Zonnewijzerkring* is recorded in this section, plus the dialling contents of Antiquarian Horology, Antique Clocks, Bulletin of the British Sundial Society, Bulletin of the SIS, NAWCC Bulletin, Patents for Inventions in connection with sundials, the contributions of the BSS Chairman, and the other similar items. This represents a vast amount of effort to collate dialling items from a multitude of sources.

It is an unfortunate fact that most dialling biblographies have faults, errors of omission, and shortcomings. The idea is to present the information, as accurately as possible, in a convenient manner for consultation as possible. Alas, in this work, there is a combination of Italian texts and English, so to the average English speaking reader, the Italian parts will be a complete mystery. Without English translations of the entries, those in Italian will be useful only to Italian speaking diallists. There are many misprints, and as many of the comments to the entries run on directly from the entry itself, there is clouding of the clarity of the individual entry.

One of the main faults in the entries in the main catalogue is that where a author has many entries, these have not been put into any kind of order. The convention is that these should be placed in chronological order, for often someone consulting such a bibliography may have the date of the material he is searching for. It is the duty of a bibliographer to reduce the amount of time and effort spent in searching to the very minimum, and present the data so that the searcher knows when it is no longer worth-while continuing the search. But where there are several pages of entries in higgledy-piggedly order, each separate entry must be consulted to be certain that nothing has been missed. The reviewer, from personal experience, knows just how frustrating this can be.

In the second volume, the absence of headings detailing the contents of each page is another frustration. One has to go back to the start of the entries for a periodical to be certain of knowing where the entries have come from, eg *Antiquarian Horology, Antique clocks,* and so on. Had all the pages had explanatory headings, this would have been much more helpful. The NAWCC entries have been divided into two parts; the second part has not been identified at all until the end. The American list of Patents for sundials has the heading for the table at the bottom of one page, with the table on the following page, whilst the list of British Patents is completely unexplained and untitled as a section.

It would be easy to go on in this vein, but the whole work indicates a hasty approach to collation and careless editing. The reviewer will say no more about these faults, nor of any misprints.

It is a very great pity that the largest gnomonics bibliography in the world has so much wrong with it. For those with an extensive dialling knowledge and experience, it will not matter too much. For beginners it could be very confusing.

It is certain, that when one comes to projects of this dimension, very few persons are equipped with all the necessary knowledge to bring it to fruition single-handed. Such complicated collations of material need more than one pair of eyes to identify failings of presentation and editing, especially in a language foreign to the compiler.

But the crunch point is that in a Reference Work, the absolute requirement is for complete accuracy as far as is humanly possible. Once doubt sets in about accuracy, implicit trust is lost for ever. No one can ever enjoy eating a curate's egg.

No true bibliography of dialling works has ever appeared, nor it is ever likely to do so. What we have in the main, are lists of book and article titles with few factual adornments. The true bibliography would be of little use to the dialling enthusiast anyway, for it would contain much redundant information, and the compiler would have to examine not only the works in all their published forms, but their later editions and reprints. The reviewer cannot think of a single person in the dialling world who could, or would, undertake such an enormous task, and of what interest would it be to the average gnomonist if it appeared? The cost of such a work would be far beyond what most enthusiasts would be prepared to pay. The reviewer has many bibliographies but the factor of usage is very low indeed.

With the present Bibliografia, it is the only dialling collation of the size in the world, and as half a loaf is better than no bread, those who require such reference sources have no option but to acquire a copy. No doubt the compiler, when he has had time to think about things, will make the extra effort to transform a mediocre offering to one worthy of the respect of his fellow diallists. The first requirement is an improvement in presentation, secondly an English edition for English speaking gnomonists.

For better, or for worse, English is the universal language of the modern world. There are more English speaking gnomonists in the world than all the other languages put together; their needs are therefore paramount.

For personal reasons the reviewer wishes to remain anonymous.

ANALEMMA

JOURNAL REVIEWS

CHARLES K. AKED

COMPENDIUM

Volume 4, No 3 issue, for September 1997, commences with an article "Floating Gnomons from Down Under". The reviewer does not find it an entirely convincing theme. Of much more interest is the answer to Edward Hauxley's Challenge, given by the ubiquitous Fred Sawyer. It is pleasing that at least one BSS member sent in a correct solution: Mr Peter Lamont, our oldest member.

One of the lecturers at the 1997 BSS Conference at Newton Rigg, Mr John Davis, quite took the reviewer by surprise with what he could do with his Psion Organiser in respect of dialling problems. He submitted an article " The Psion Organiser - The Dialist's Friend," which covers the ground of the talk at the BSS Conference, but which the reviewer found more easy of assimilation in reading the article. a very ingenious exposition.

"The Gnomonicum", the subject of the next article, is a multi-faceted sundial designed by Lothar Loske, and is in Frankfurt, Germany. It is meant as an educational facility. Mine is a personal comment only, but it does not appeal to me with its over-ornamentation and complexity.

Next Fred Sawyer (who seems to pop up here, there and everywhere in the Compendium), deals with the contents of Digital Compendium for the programs PLTMGR and POP and how to make the best use of them.

We have now got to the VIIIth part of the series "Error Analysis of the Horizontal Sundial" by Lauresch and Edinger. This surely must be the definitive analysis of this aspect of gnomonics. The current theme is the case of the dial tilted in the east/west direction. This is followed by a short poem on the base of a stone pedestal of a sundial in front of Wellesley College, Wellesley MA; and a three page review of Denis Savoie's *Gnomonique Moderne*. Two of Sawyer's puzzles based on the material in the book are included as inserts in his review.

William S Maddux contributes "The Meridian on the Shortest Day..." in the design and construction Forum moderated by Robert Terwilliger, an excellent practical article for finding the meridian. Yet another quiz from Fred Sawyer, this time on solving the home port of a Captain Emerson from the remnants of an old dial which once stood in front of the captain's home. This will entertain the more erudite readers of Compendium for some time.

There are several pages on Letters, Notes, Email, Internet, containing many points of interest, and the solutions to the two puzzles from the material of *Gnomonique Moderne.* The In Memoriam feature gives good appreciations of Richard L. Schmoyer and Roderick Sheldon Webster. Both had had long useful lives and turned to dialling around 1960. Mr Webster and his wife became caretakers of the scientific collection of the Adler Planetarium in Chicago from 1962-1969; they were then appointed curators of the collection. The dial collection of the Adler Planetarium is the largest in North America. Finally a page of the Equation of Time and Solar Declination at noon Eastern Time for October - December 1997 completes the issue.

Compendium has become an authorative disseminator of dialling knowledge. It is well worth subscribing to if you are really interested in gnomonics. The Digital version includes dialling programs, plus the contents of the bulletin. Personally the reviewer finds it easier to read the text from the printed page rather than a computer screen, but younger members may not find it so.

DE ZONNEWIJZERKRING

Bulletin 97.3 for September 1997 contains the usual feast of delights for the gnomonist, opening with the details of the 21st June 1997 Zonnewijzerkring excursion. The reviewer was surprised to see his short note on the Queens' College Sundial on pages 3-4. It was really on the observations of Dr Marinus I.Hagen in respect of the dial for he was much more perceptive than the majority of us. This extract showed how much the Dutch journal would be improved if the text was set, for the article was a facsimile copy of the original in BSS Bulletin 97.2.

R. Sanders writes of an isocline sundial based on the work of Professor Freeman, giving a full mathematical analysis. P. Oyen writes on the Polar sundial with hour and date lines, again with a mathematical supporting outline and two tables.

Erich Pollähne, a well-known visitor to BSS Conferences, writes on a Time Monument, a very elaborate monumental sundial. The reviewer's tastes are for simple concepts. This is a most elaborate affair I think; one could easily spend a whole day trying to understand all the details.

F. J de Vries details a sundial with Babylonian and Italian hour lines, with details of how to construct these; followed by the description of one of the projects for the Sundial Park in Genk, Belguim, the idea of Javier Moreno Bores of Madrid. It is a bifilar sundial with a cylinder.

Arnold Zenkert writes of parallel "Winkels"; the reviewer's lack of knowledge of the Dutch language does not allow him to give further details.

An article is included on pathfinder methods using various methods to obtain the direction of north. This is a compilation of the methods published in the past issues of the Bulletin. The compiler is J Kragten.

The feature " Sundials in the Netherlands" by Wiel Coenen gives details of six examples but only one diagram. Following this are illustrations of the Este cylinder dial recently reported on by Mario Arnaldi; these seem out of place but only because it belongs to item 1254 in the literature review by D Verschuuren, and this is several pages later. This review covers many journals of which English diallists have no cognizance. The BSS Bulletin is analysed in great detail, plus the Clocks Sundial Page contributed by our Chairman Christopher Daniel, ending on the contents of NASS Compendiums for March and June 1997. It is a splendid compilation of the contents of all the European dialling journals. If all the back copies of these reviews were brought together, it would form a valuable reference work in its own right.

It would be helpful if it was possible to give short resumées of the articles in English, for this is the universal language of the present-day world.

OXFORD TODAY

This journal, which appears three times a year, happens to carry a sundial-related article in the Michaelmas Term issue: Volume 10(1)pp. 14-17.

'The Measure of the Universe' by Georgina Ferry is about the Museum of the History of Science, Broad Street Oxford; and the article concentrates on artefacts related to dialling and calendars. There is an excellent colour photograph of the only known example of a spherical astrolable in the world. A geometrical quadrant made by the incomparable Christopher Schissler of Augsburg in 1579 is shown in colour, albeit on too small a scale to allow distinguishing of its main features. Similarly a pocket sundial photographed in black-and-white made by Paul Reinmann in 1612 is in exquisite detail but too small. Another photograph shows young visitors closely examining an armillary sphere. On the front cover is a magnificent colour photo of an astrolable but no reference to this could be found within.

The article is a 'puff' for the Museum of the History of Science which has just won a grant of 1.2 million pounds from the Heritage Lottery Fund to build an extension. Of good general interest, the article is another reminder of the wonderful collection of portable dials and astrolabes held in the Museum, second to none in the world. The previous management seemed to discourage visitors, with awkward hours of opening, under-staffed, and generally disapproving of anyone entering the place. This is all changing under the guidance of Jim Bennett, the present Keeper, and the future looks bright for the Museum, housed handsomely in the oldest purpose-built museum building in the country.

THE POULTON HALL SUNDIAL

J. MIKE SHAW

When I joined the British Sundial Society, one of the first things I acquired was a copy of the Sundial Register. I was quite surprised to find that there were no sundials whatsoever recorded on the Wirral peninsula. I imposed upon myself the task of seeing how many I could find. I knew that it was no use looking East of Chester - there lies "Somerville Country", and they are all already in the bag!

I had the usual immediate success with churchyards, and then started to knock on the doors of likely-looking old houses and halls. In doing so, I have met some really interesting and very kind people - and I have always been shown the greatest of courtesy. Most in this area are horizontal, but I have managed to find two Pilkington-Gibbs. However, I found a very interesting horizontal dial within the walled garden of Poulton Hall, Bebington.

Poulton Hall lies on high ground, entirely surrounded by trees, and is not visible from the surrounding roads. It is unusual in that the present hall lies on the site of a former castle, and has been the uninterrupted home of the Lancelyn-Green family for 905 years!

The dial is in the centre of a well cultivated walled garden and is in "reasonable" condition. It is a fine example of engraving. There is no maker's name on the dial, but the

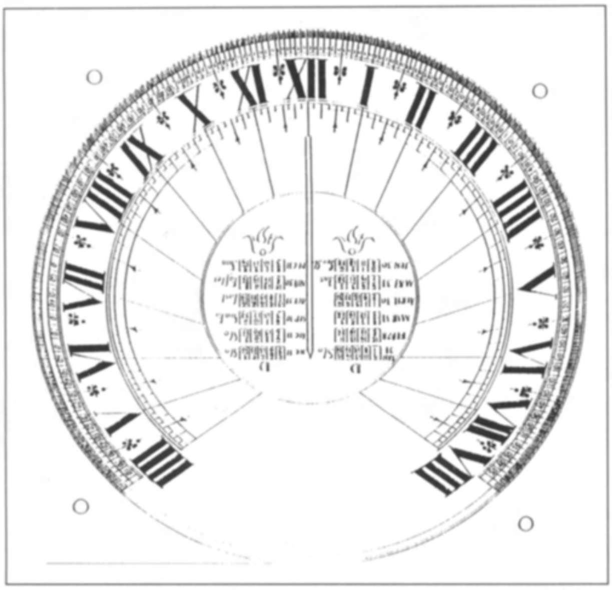


Fig. 1 Drawing of dial face.

letter D is found twice, once above each set of tables. The dial is very similar in execution to one found at the "Mollington Bannastre" Hotel near Chester, which is marked as "Dolland, London". The Dial is marked in minute increments around the circumferance, but, unusually, there has been no allowance for the thickness of the gnomon. There is some evidence that the current gnomon may be a replacement.

A sketch of the face of the dial is shown as Fig. 1.

An unusual feature of the dial are the sets of tables on either side of the gnomon. These are reproduced in tabular form as Fig. 2. They are clearly Equation of Time tables for setting the clocks in the Hall and the adjustments are given for weekly intervals, to the nearest minute. However I was puzzled that they did not agree with "my" Equation of Time table, even though I live within 2 seconds on longitude.

Jan	9	11	13	14	15	Slo
31	1	8	15	22	29	
Feb		15	14	13	11	
28		5	12	19	26	
Mar		9	7	5	3	
31		5	12	19	26	
April	1	1	3	4	4	
30	2	9	16	23	30	
May		4	4	3	2	Fas
31		7	14	21	28	
Jun		0	1	2	4	Sun Slo
30		4	11	18	24	

Jul	5	6	6	5	3	Slo
31	2	9	16	23	30	
Aug	4	2	0	2		Slo
31	6	13	20	27		
Sep	4	7	10	11		Sun Fa
30	3	10	17	24		
Oct	13	15	16	16	16	Fast
31	1	8	15	22	29	
Nov	15	13	11	8		Faster
30	5	12	19	26		
Dec	5	1	2	5		Sun
31	3	10	17	24		

Fig. 2 Tables from dial face

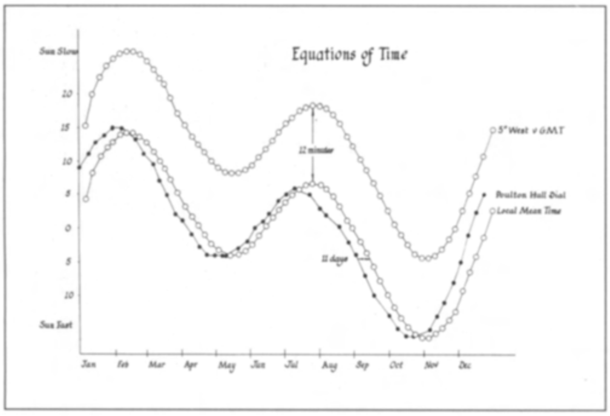


Fig. 3 Equations of Time

Poulton Hall lies within about 200 metres of 3 degrees West.

Knowing that a picture is better than a thousand words, I plotted the numbers from the tables onto a graph. This is shown as Fig. 3. The upper line is "my" E of T, which incorporates the longitude correction. The lower "open dot" graph shows the E of T for local apparent time, and the Poulton Hall dial clearly approximates to this line. However, it is not quite a match - the non-smoothness is due to the tables giving adjustments only to the nearest minute. Closer examination shows that the tables are offset

Fig 4 The sundial in its garden setting

from current Local Apparent Time by 11 days. So the dial has been in position since before the introduction of the Gregorian calendar - 1753 in Britain. The family records show that the walled garden was constructed ca 1702. As the dial is a centrepiece of the garden, it seems likely that it is contemporary. It has stood the test of time having been protected from the public for all these years. Fig. 4 shows the dial in its setting.

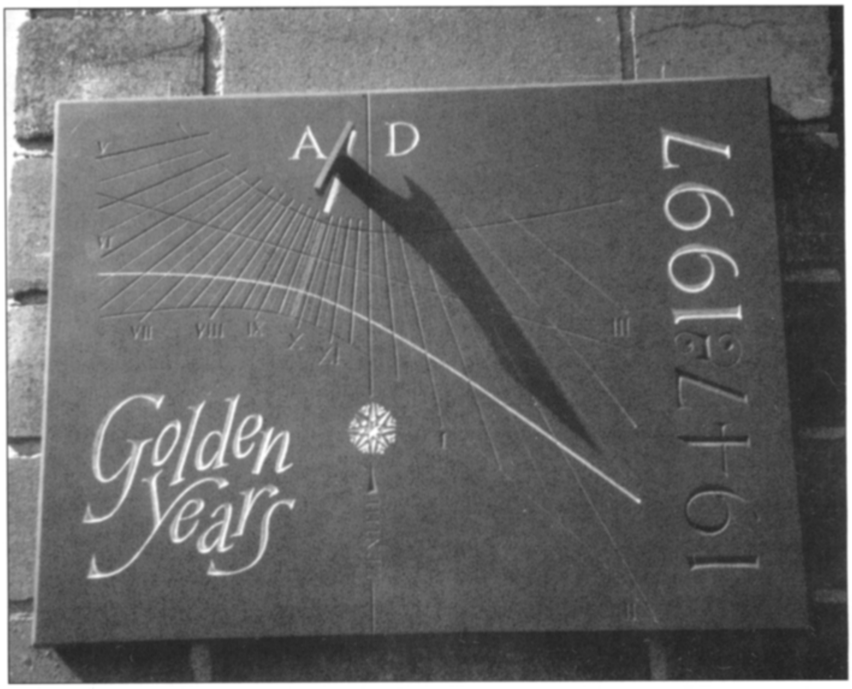
As a footnote, on the surface of the dial some disgruntled former owner has scratched the words "15 minutes slow". If only he had consulted with the BSS, we could have told him it was only 12!

A GOLDEN WEDDING DIAL

This year my wife and I celebrated our Golden Wedding Anniversary on 9 August, and I decided to commemorate the event by making a vertical declining dial (26°30: East) for the wall of our home. The principal features of the dial are the relevant dates, the line of declination marking the point which the tip of the gnomon's shadow reaches on 9 August (the golden line) and the Zenith or noon line is marked with a golden sun. The lines for the equinoxes and the soltices are also shown, and the dial is divided into quarter hours.

The material of the dial is Welsh slate, measuring 16ins. by 12ins. The gnomon is of brass (lacquered to preserve its colour); the carved lettering is guilded with loose leaf. The initials 'A' and 'D' at the top refer to our names, and the photograph was taken about 15 August.

Alan Smith



SUNDIALS PAINTED IN THE CLOISTER OF AN ITALIAN MONASTERY

MARIO ARNALDI (ITALY)

INTRODUCTION

In the cloister of the Convent of Saint Dominic at Taggia in Italy, there is a very interesting group of sundials. Painted at the beginning of the 16th Century, and recently restored by the writer, they add a number of elements that help us to understand the history of medieval time-keeping.

THE MONASTERY AT TAGGIA

Taggia was in medieval and renaissance times an important city of the region of Liguria in Italy. Now it is a small village situated between the sea and the mountains. The Romans called the area 'Tabia fluvius' and in early medieval times the place grew to great importance because of its position. The Benedictine monks founded there a number of churches and a monastery. They taught the population the practice of planting olive trees, and in the mountains they managed many chestnut woods. Their monastery and churches were frequently destroyed by African pirates, and almost always the pirates killed all the monks they found. At last the community left. But the city continued to keep an important name throughout the renaissance, and in the 15th century a new need of faith inspired a Dominican monk to found a new church there.

In the year 1459, after preaching in all Lombardy, Tuscany, Naples and Sicily, the blessed Cristofero from Milan came to Liguria. He started to preach in Genua and then moved westward coming to Taggia. There the people loved him so much that they would not let him leave without the promise of the foundation of a Dominican convent. So with the help of all the population the holy man bought the land and started to build the church and convent.

The church was consecrated in the year 1490, but the complex needed more buildings and the entire monastery was finished around the first years of the 16th century. Inside the cloister, six sundials were painted: one small dial on a wall facing east, and two on the church wall facing west, of which only traces remain. But the most interesting sundials are in a group on the wall facing south.

DESCRIPTION OF THE SUNDIALS

The entire group consists of three dials as shown in Fig.1: two in the upper part, a planetary dial superimposed on a dial with Italian hours; and one in the lower part working with French or European hours[1]. Of the pair of superimposed dials, some of the 'planetary' hour-lines are marked with large (arabic) numerals, and some of the 'Italian' hour lines marked with smaller numerals. In the past, the sundial group has suffered restorations; the last and worst was done about 25 years ago. The restorer made many mistakes such as reconstruction of signs and words without a precise knowledge of gnomonics. His worst action was to reconstruct the entire plaster; so now we do not have the original paintings on the wall. But fortunately he saved the exact drawing, or what remained of it, and he repainted on the new plaster.

The group of painted instruments was of great utility for the monastery at that time. In the years when the sundials were designed, people in Italy followed the 24-hour clock, the so-called 'Italian hours', starting their computation from sunset. Yet the Church continued to follow the canonical hours as before. This explains why the monks designed a sundial with planetary (seasonal, temporary) hours superimposed on an Italian hour dial. With a single glance, the monk appointed to sound the bell for prayer could see the exact time for the Divine Office even in the civic way of time-keeping. Later, after the Napoleonic War, the new method of counting time, the European way, was used all over Italy; and again the monks added another sundial below the first two.

We know much about the Italian hours and more about the European hours. The most interesting instrument of the entire group is the planetary sundial working with unequal hours. Many diallists, heirs of Galileo and Copericus, think that sundials of this kind are not of great gnomonic interest. However we cannot forget the past: from Roman times throughout much of the medieval period such dials were constructed. Often diallists (of whom I am one) try to look at medieval sundials with logical eyes. But we forget that they were used almost solely by monastic communities. Laymen did not need them much as they knew the time by experience. But the monk must know the time as exactly as possible because he has to pray at the right time. The Taggia Sundial shows us very interesting aspects of such times of prayer.

RESTORATION OF THE DIALS

Before the last restoration (made by the writer in August of 1996) the dial face showed many errors created unintentionally by the last restorer. One of these was the wrong reconstruction of the phrase at the top of the dial. Because of some gaps, he wrote the mysterious words '*TANETAR VEL CANONIOH* ' which means nothing. To find the right sentence was easy. The arrangement of the words suggested '*PLANETARIU VEL CANONICU*' or better, ' *HOR PLANETARIU VEL CANONICU* ' which means ' Planetary Sundial or Canonical'. Actually the sundial is neither, but a mix of the two. The divisions of the hours are the classic twelve temporary ancient spaces. It omits only the line of the first hour, because the church throws its shadow on the dial face at that moment.

Below the lines on the right, there were before restoration a strange semicircular sequence of signs. People imaged different meanings for them, but looking more clearly we were able to see similarities to symbols well known to gnomonists, the symbols of the planets. So we can read from above to below the Sun, Mars, Jupiter and Saturn symbols. Going on to the missing half circle we would have

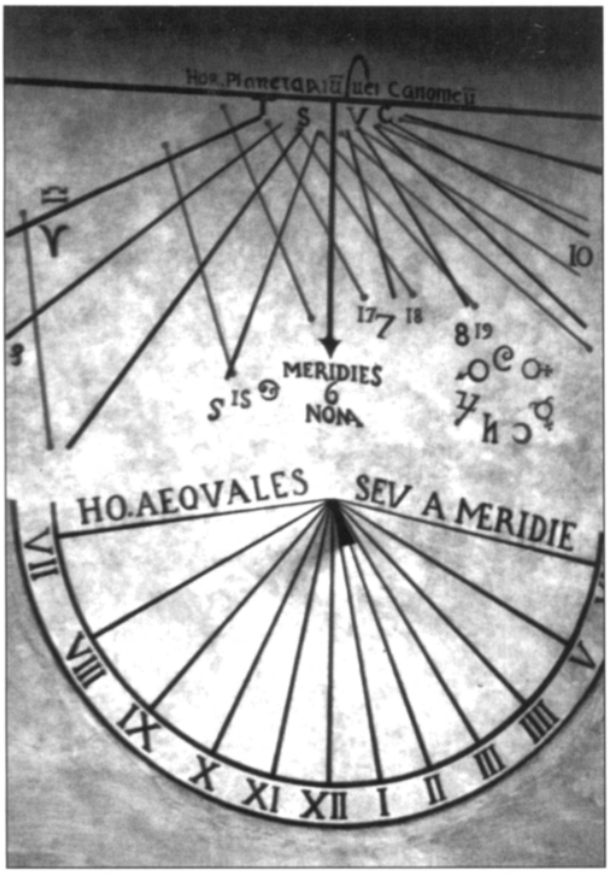


Fig.1 Three sundials on the south- facing wall of the Monastery at Taggia. On the upper part of the wall are two superimposed dials, one showing Italian hours, the other showing planetary hours. Below these, there is a dial showing European hours. There is also a circle of zodiac signs. On the upper dial pair, some of the Italian hours are marked by smaller (arabic) numerals: 15, 17...etc. Some planetary hours are marked by larger numerals: 6, 7...etc.

read the later signs: the Moon, Mercury and Venus, closing the entire ring. The circle of planets explain the words '*Hor Planetarium*' and represents a table for the government of the luminaries upon the Earth and Mankind. No surprise should be felt at this: even religious people believed in astrology.

We can see that the hour lines are numbered in the normal ancient sequence from zero to twelve; many of the numerals are missing now. We also read near the base of gnomon the canonical moments of prayers: the capital letters T,S,V,C for Tertia, Sexta, Vespers and Compline. But we have in this dial an interesting note. Under the midday line, painted as an arrow pointing down, there are three items. The first is the word 'meridie' meaning 'midday'; the second is the number six, that means the sixth temporary hour, and the third is the word NONA, that means the Office of Nones. All these three items signify the same astronomical moment of time,the noon hour . Here in this article I wish to suggest another route of research: study of contemporary writings and chronicles. Many writers used to include in their tales or reports a mention of time and hours, and this leads to interesting findings.

DAILY OFFICES OF THE CHURCH

Many ancient people used to divide the daylight into twelve equal parts and this way of measuring time continued until the Middle Ages. Dividing daylight, whether longer or shorter, into twelve parts would always bring midday to the end of the sixth hour. But what about the word NONA, the Office of Nones? It is known that this office was (originally) celebrated at the ninth hour of the day, half way through the afternoon. The names of the Divine Offices in fact came from the hours of their celebration: *Prima* (Prime) from the first, *Tertia* (Terce) from the third, *Sexta* (sext) from the sixth, *Nona* (Nones) from the ninth. After these were the Offices of *Vespera* (Vespers) at sunset, *Completorium* (Compline) one hour after sunset, *Media Nocte* at midnight.

The monks of Egypt in the Middle East had only two moments in prayer together, morning and evening. The way of life was inherited by monks of Europe of the 4th and 5th centuries but with new rules: they prayed at *Matutinam, Secunda, Antert, Tertia, Sext, Nona, Vespera, Midnoc.*

Saint Benedict of Norcia created for monks a rule which was used by almost all monastic houses in Europe from the fifth century onwards. He wrote that brothers must pray seven times in the day and once in the night: *Vigiliae, Laudes, Prima, Tertia, Sexta, Nona, Vespera,* and *Completorium.* Later Saint Benedict defined Vespers and

Compline in such a way they became day's hours; he said that Vespers must be brought forward so they did not need candles to see; and the Saint explains that this must be adopted throughout the year. We know that later even Compline was recited when it was still daylight. Now we see why V (Vespers) and C (Compline) are placed so early on the Taggia dial. Indeed we see on this dial that all the canonical hours are moved forward. Saint Benedict also prescribed the time for eating, for every liturgical season. The brothers could eat only after Nones, but they were allowed to celebrate Nones a little earlier. Slowly the bringing-forward of the Office of Nones caused it to lie on the sixth hour of the day. We have evidence today of this custom in the English Language and in German too. In fact Englishmen identify midday with the word 'Noon' or 'Noontide' and Germans say 'Nonzeit' for 'Mittag'[2] .

TERMINOLOGY OF HOURS FROM LITERARY SOURCES

We know that in Germany this custom was established in the 13th century[3] and we may guess that the same happened in other countries of Europe. In Italy we may surmise that this process took place a little earlier, but it is hard to find documents to prove it. One of the most important witnesses to this custom was the great poet Dante Alighieri who wrote, between 1304 and 1307, a work in four treatises called "Convivio'[4]. In this work Dante writes of the philosophy and science of this time. In the third treatise he wrote about the canonical hours and compares them to the equinoctial hours. In the 4th treatise he wrote: 'Concerning the division of the day, we have to know that the Church uses the seasonal hours, that are twelve every day, longer or shorter according to the sun. But the sixth hour, that is midday, is the noblest and most virtuous of all the day, and the Church puts close to it all the Offices, from every part, that is earlier or later, as far as possible. The Office of Terce they recite at the *end* of the third hour, but Nones and Vespers they recite at the *beginning...* ' So we are now sure that in the 13th century in Italy the Church used to say Nones around midday and at the same time we know that Vespers was moved to the former place of Nones, the ninth hour. Dante explains that in his time the day was divided into four parts named Terce, Sext, Nona and Vespers; these parts were sub-divided, making in all eight day-divisions; see Fig.2. But while Dante says that this custom was only for the Church, other writers and chroniclers indicate in their writings that the Church's customs were adopted by laymen as normal time terminology.

Here are some examples selected from Italian literature, enabling us to recognise the use of the word 'Nona' as Midday. Boccaccio, in the Decameron, Tale 3 for Day 8[5], wrote '.... and all the rest of the morning (Calandrino) passed searching for his friends (Bruno and Buffalmacco). At last when it was almost the hour of Nona, he remembered that they were working in the monastery of Faenza's women, in spite of the great heat..' And later,

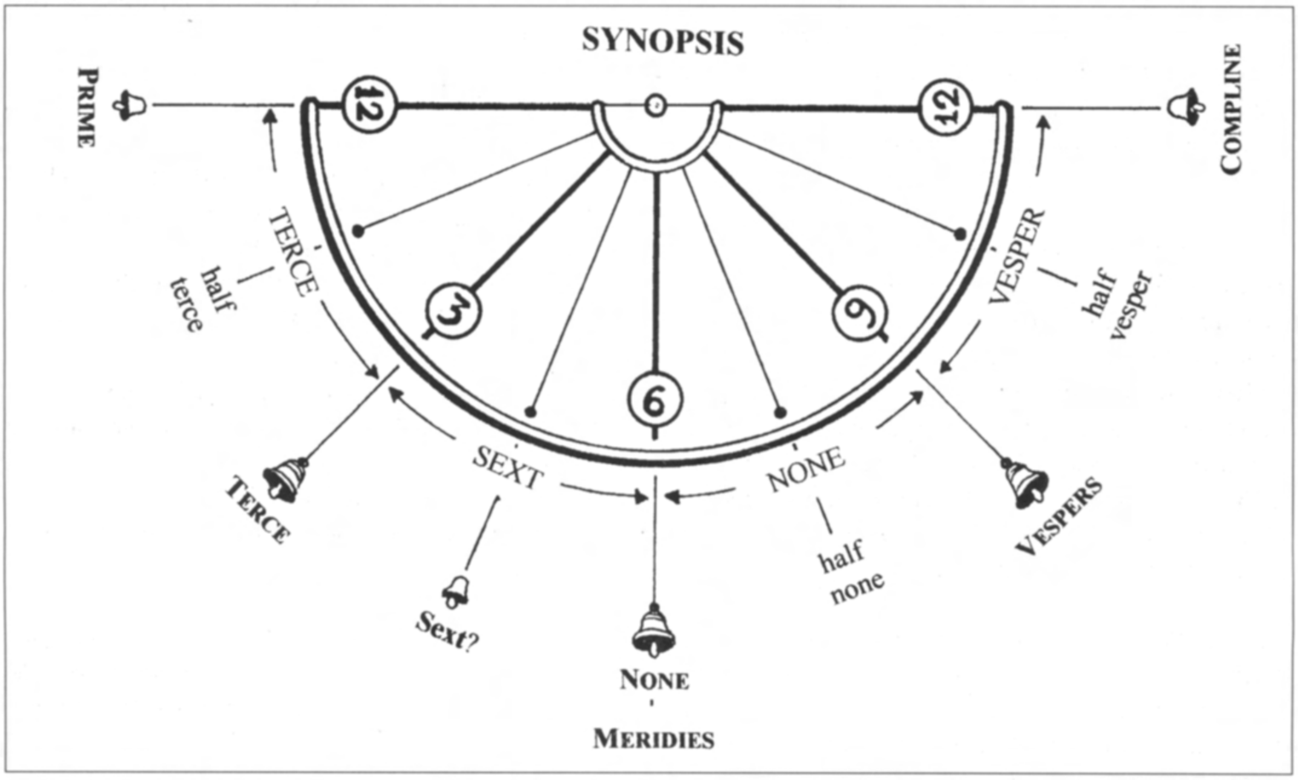


Fig.2 The division of the day in 13th century Italy, according to Dante's 'Convivio'.

Bruno points out that..

'.... the sun is high in the sky'. They are clearly talking about midday. The friends who met for telling tales in the 'Decameron' told the tales between Nona and Vespers. The teller of the Tale 10 on Day 5 starts: ' I hope that the tale will not be heavy, because to tell it well I need to say much;
if you look at the sun you will see it in the middle of the sky'.

The monks took their first meal after Sext or after Nones, but because Nones came close to the sixth hour, the liturgy of the Roman Church and the custom of laymen became the same. So when we read about lunch it is often associated with Nones. A.F.Grazzini[6] wrote in the 16th century a book of twenty-two tales, in one of which we read: '...Lady Mea and her daughter left early last morning, and near Nona they arrived near .. where a priest was saying Mass. They were welcomed by him and they remained for lunch.'

One of the best comparisons between midday and Nones was given by Bilfinger, who made use of a number of chronicles assembled by A.L.Muratori in the 18th century, all of which gave eye-witness accounts of the total eclipse of the sun of June 1239. This was a great event, seen over a wide area, and records are easy to find in many chronicles. Here are some descriptions of the event. 'In this year 1239 3rd of June, there was a great eclipse of the sun, that lasted from the sixth hour until the ninth and the stars were visible in the sky'. 'In that year, Friday, the sun became dark at Nones time, and they saw the sky with stars'. 'In that year, the sun was eclipsed at midday, until the hour of the Vespers'. This shows that 'midday', the astronomical event, and 'the sixth hour', and 'Nones' the sacred Office, are the same thing, and indicate the same moment, as on the Taggia dial.

As we have seen, Dante Alighieri in the 'Convivio' describes the division of the the day in his time, and explains the division into four parts, called Terce, Sext, None and Vespers. These parts were often called 'hours', and this custom survived into the 16th century. For working people, the end of each of these four periods were the times to eat. We can read in 'Il Fuggilizio' by T Costi[7] who lived in the 16th century that woodcutters have their breakfast at Terce, the lunch a little before midday, a small meal at Vespers and supper in the evening.

But because our sundial is purely for convent use, I wish finally to recall the words of Abbot Calmet in his "commentary on the Rule of Saint Benedict'[8]: ' Nowadays (1751) almost everywhere they chant Vespers at 3p.m., but during Lent we moved the celebration before midday so that we can eat at noon.' As for Terce, that also moved its position in the 16th century, from the third to the second hour.

All these changes were confusing, especially when we realise that the way of computing hours changed many times in Italy. That is why scholars such as Regiomontanus wrote conversion tables computed for all the year. Our dial does not need them as the canonical hours are superimposed over the Italian hours. The Taggia sundial at this point seems to divide the canonical day into six parts, and this maybe explains why many Italian monastic dials are divided into six, as one of the later canonical customs.

PRESENT PRACTICE

Nowadays very few of the religious orders follow the right times of the Divine Office. The extreme inconstancy of the canonical hours , and the changed conditions of the time system and the way of life, caused modern monks and priests to decide almost by themselves when to recite the Offices, depending on their engagements during the day. Nowadays generally the Matitudinum and the Laudes are recited between midnight and midday and in some cases they can be anticipated in the afternoon of the day before; Terce, Sext and Nones in the morning; during feast days and in Lent Vespers is recited before lunch and on all other days they recite Vespers and Compline in the afternoon. They can recite the Office entirely in the morning when they wake up, or in the evening when they go to bed, and who knows, they may take a look at a plastic 'Swatch' chronometer.

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ANALEMMATIC DIAL WITH A FIXED GNOMON

JOHN SINGLETON

The analemmatic dial normally comprises a set of hour points lying on a horizontal ellipse, and a movable vertical gnomon, positioned on the minor axis at a point dependent on the date (or the sun's declination). Instead of moving the gnomon we can move the ellipse, or more practically use a family of shifted ellipses - see Fig. 1 (and Ref. 1). However the resulting dial is difficult to use in the region where the ellipses cross. To overcome this problem the ellipses may be scaled so that, instead of crossing in the six o'clock regions, they all touch at midnight - see Fig. 2. The hour lines are still straight, but instead of being parallel they radiate from the point where the ellipses touch.

For zero declination, the ellipse is described by $x/b = \sin H/\sin ø$, $y/b = 1+\cos H$ where the gnomon is at (0,b) and H = hour-angle, ø = latitude. For other declinations, the scaling factor is $1/(1+\cot ø.\tan D)$. The hour lines lie at angles T (measured from noon) given by $\tan T = (1-\cos H)/\sin H.\sin ø$.

REFERENCE

1 Drinkwater, P.I. An analemmatic dial on a vertical plane. B.S.S. Bull. 89.2 2-4

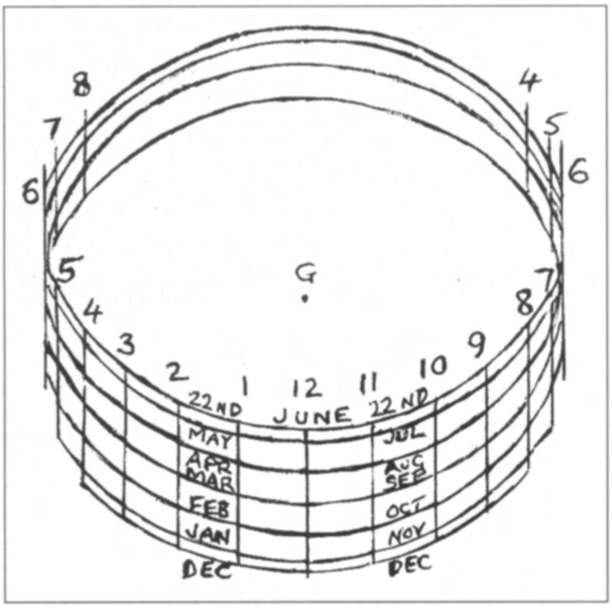

Fig. 1. (Ø = 51.5°N)
Family of shifted ellipses

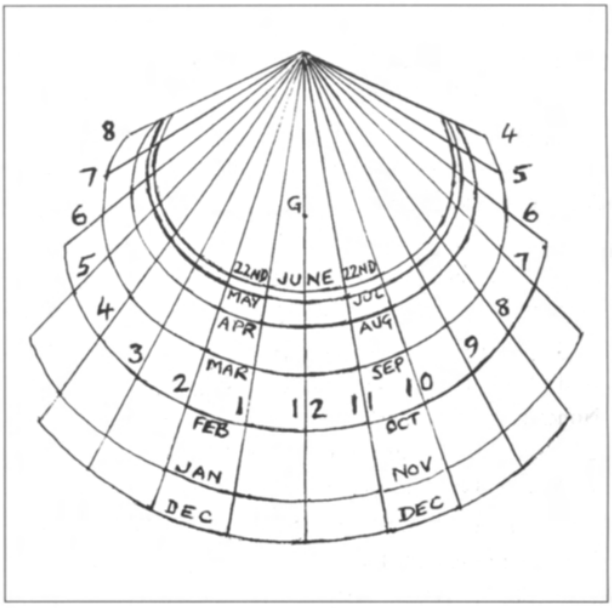

Fig. 2 (Ø=51.5°N)
Ellipses touching at midnight

A 19TH CENTURY VERNACULAR HORIZONTAL SUNDIAL FROM OUTBACK AUSTRALIA

JOHN PICKARD

INTRODUCTION: A RUSTY SHEET OF STEEL

Legislation passed in the Colony of New South Wales in 1861 allowed smallholders to select parcels of land and settle on them[1]. In the semi-arid far western regions of the (present) state, most of these settlers failed. The maximum size permitted by the legislation (640 acres) was simply too small for commercial survival. Today, the ruins of houses, huts, wells, fences, yards and gardens on these blocks provide mute testimony to the heartbreak of failed attempts to settle a harsh environment. I have been studying the archaeology of these sites in an effort to understand the consequences of the legislation in this semi-arid landscape.

Kalyanka Station is a medium sized property for this region. Its 89,100 acres (36,058 ha) contain many of these original smallholdings. The small town of Wilcannia lies within *Kalyanka*. In the late 19th century, Wilcannia was a thriving river port and the bustling commercial centre for the region. Many settlers selected their blocks close to the town.

Consequently I have focussed my research on this property. While examining the ruins of a house on Portion 64, Parish of Wilcannia, County of Young (latitude 31° 30.7' S, longitude 143° 19.4' E) I found a rusty piece of sheet steel with a strange radial pattern of markings lying on the ground (Figure 1). On closer examination it appeared to be a homemade sundial. As I have been unable to find any records of vernacular dials from 19th century Australia, the dial represents an important addition to our knowledge of dials in Australia. Here I describe the dial and consider its origins

DESCRIPTION OF THE DIAL

The dial is laid out on an irregular rectangle 182 mm long x 152 mm wide of galvanised steel sheet (known colloquially as "galvanised iron") 0.42 mm (0.0165") thick (Figures 1 and 2). The sheet is slightly bent and distorted. Marks on the edge of the sheet show that it was cut to shape with a cold chisel rather than with tin snips. The morning end of the sheet is rounded in an arc approximately 150 mm radius. Originally the dial was attached with 14 cut tacks hammered through the sheet. Ten tacks remain in their holes. Four holes along the noon line were probably used to attach the gnomon that is missing.

An irregular line of prick marks or dimples, apparently formed with a nail, centre punch or similar tool, marks each hour-line (0600 h to 1800 h). A very few dimples actually pierce the sheet. The 1200 h line is marked as two parallel rows of dimples approximately 6 mm apart suggesting that the gnomon was similar width, say $^1/_4''$. Ten of the 14 hour-lines have 6 dimples. The 0600 h, 1500 h and 1700 h each have seven. The location of the additional dimple in the 1700 h suggests a mistake in marking out, or in punching the dimple. The 0800 h line has eight dimples. The spacing of the dimples is irregular in most lines, and most are not in straight lines.

An irregular circular mark on the top face of the sheet at the approximate intersection of the 1200 h and the 0600 - 1800 h lines appears to have been used as the centre for semi-circles marking the inner and outer limits of the hour-lines.

ANALYSIS OF THE DIAL

To determine the original latitude for which the dial was designed, I measured the angles between the hour-lines and the noon lines. The projections of the hour-lines clearly show that the laying-out of the dial is extremely poor (Figure 2). Virtually none intersects with the junction of the noon lines and the 0600 h - 1800 h line. The calculated latitude varies for each hour-line (Table 1). Using the morning hours only, the mean calculated latitude[2] is 23.46°, and for the afternoon

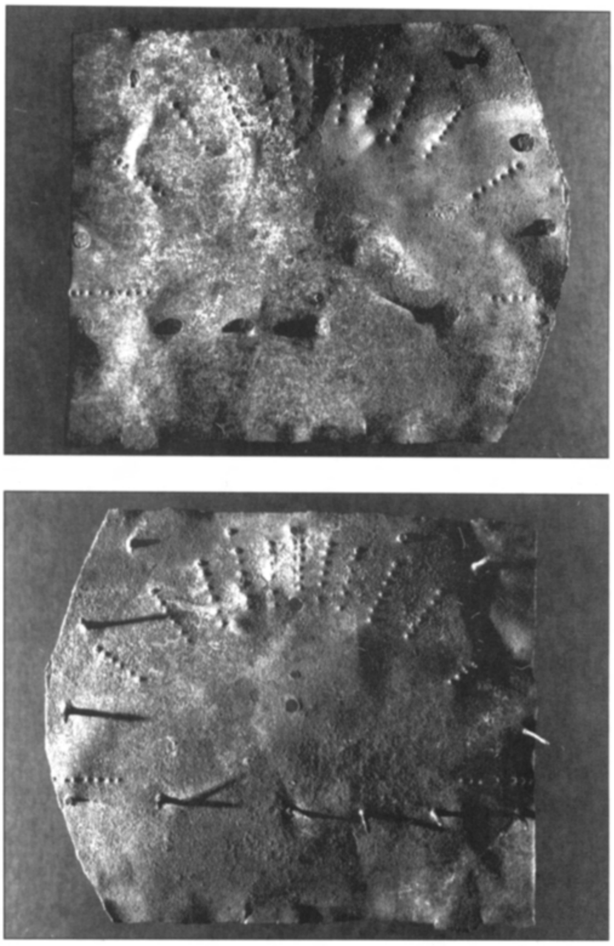

Fig.1 Photographs of face (upper) and obverse (lower) of the dial showing hour-lines marked by dimples, tacks, and holes used to fasten gnomon.

hours, the mean is 25.49° (omitting result for 1300 h, which is clearly aberrant). The overall mean latitude is 24.36°. As the latitude of *Kalyanka* is 31.52°S, it is unlikely that the dial was made for this location.

If we compare local apparent time hour angles calculated for latitude 24.36° with the angles on the dial, then the errors are quite variable (Table 2). There is no real evidence of a systematic error, although the afternoon errors are more consistently negative. From this, we can conclude that the hour angles were slightly inaccurately determined, but that the laying-out itself was rather poor (Figure 3). Virtually none of the lines comes from the correct origin, and it is difficult to imagine how or why this was done so poorly. Indeed, one could be forgiven for thinking that the dial had been marked by the *"...thumbnail dipped in tar"* immortalised in Banjo Patterson's classic Australian poem *Clancy of the Overflow*[3].

ORIGINS OF THE DIAL

The calculated latitude is approximately 800 km north of *Kalyanka*, suggesting that dial may have been made in Queensland, and brought south to *Kalyanka* at some stage by one of the selectors of this block. Galvanised iron was the raw material for myriad tasks in early rural Australia: roofs and walls of huts, water troughs, garden fences and kitchen implements. Struggling farmers and graziers used galvanised iron and fencing wire to make or repair items they could not afford to buy. Thus there is a strong heritage of using the material for almost any task.

The alternative that the dial was made for latitude 24.36° N is unlikely. This latitude covers regions such as the Sahara Desert, Arabia, India, and Mexico. In none of these regions was galvanised iron a widely used material in the late 19th century. However, latitude 24.36°S also passes through the Transvaal of South Africa. Like the rural areas of Australia, galvanised iron was widely used for all manner of things.

If the dial had been originally set up as a vertical dial, the latitude would be about 66°. This is nonsensical for the Southern Hemisphere, and extremely unlikely for the Northern Hemisphere.

One possible way to resolve the origin of the dial is to consider the origins of the settlers. Despite a detailed search of the surviving documents in the NSW State Archives, I have not been able to uncover any personal details on the holders of the block. Thomas William Barnes selected a 180 acre (72.85 ha) piece of land on the plain a few miles north west of Wilcannia on 4 May 1882. He applied for a Conditional Purchase (CP) under Section 14 of the Crown Lands Alienation Act of 1861. Why he selected this block we will probably never know. There is no surface water, ground tanks (dam-like structures to retain water) leak, and the vegetation would barely support 1 sheep on 12 acres. He lodged his application at the local Land Office in Wilcannia. A surveyor was duly sent to survey the block, which was given a formal title: Portion 64, Parish of Wilcannia, County of Young. Barnes' application was granted as CP 82/17. These details are recorded on the plan (registered number 87-1991) prepared by the surveyor.

Barnes sold Portion 64 (with three other nearby blocks of land) to George Hunter Doake and August Christian Geyer on 27 April 1888. Doake sold out to Geyer in 1897, who in turn, sold to a Mrs Byrnes in 1898. Eventually the barren nature of the land defeated the settlers who forfeited the land through non-payment of interest.

The records provide no personal details of any of the holders. There is no information on their origins, previous residences, occupations, etc. It is unlikely that anyone who knew enough gnomonics to lay out a horizontal sundial would make it for the wrong latitude. Thus I believe that it was made for central Queensland, and brought to Portion 64 by one of the early settlers in the late 19th century.

DISCUSSION

As a relic of science in the colony, the dial does not increase the reputation of local scientists. However, I believe the dial itself and its location are compelling evidence that a scientist or skilled tradesman did not make it.

The dial is a very interesting relic of vernacular Australia. Other early Australian sundials are considerably more formal. They are bronze and slate with elaborate engraving and gnomons. In marked contrast, the *Kalyanka* dial is homemade. It does not take too much imagination to picture a mathematically-minded person, perhaps a school teacher, an educated drover, or remittance man, squatting in the burning sun of central Queensland laying out the hour-

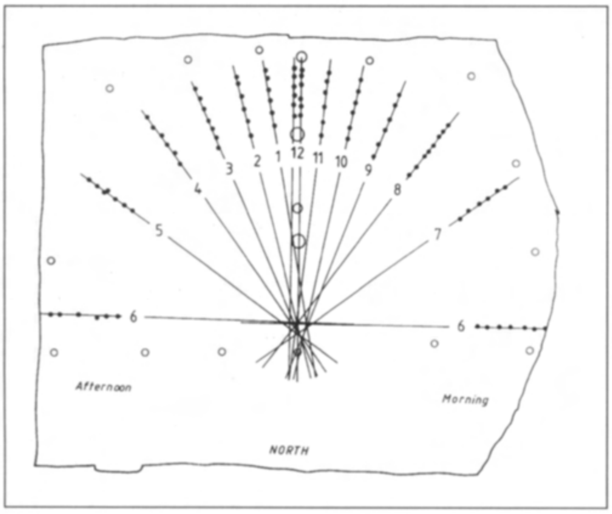

Fig. 2 Drawing of dial showing dimples and projection of hour marks back to the origin of the dial. Note that the projections do not meet in a regular manner as required by gnomonics.

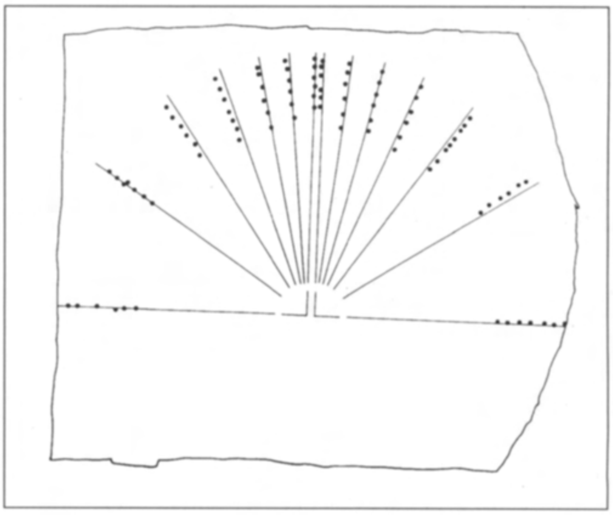

Fig. 3 Drawing of the dial overlain with hour-lines calculated for latitude 24.36°, and drawn from origins at the junctions of the 1200 and 0600 – 1800 h lines.

lines on a scrap of rusty galvanised iron and then punching them with a nail. A wooden gnomon would be added, and the dial tacked to a stump outside the kitchen door of the family hut. Here it told local apparent time, which was probably sufficient in early outback Australia. The discrepancies with local standard time would have been irrelevant in the days of horses, long distances and little interaction with the centralised government.

Later, when the family moved to Kalyanka to take advantage of the cheap land, the dial would have been taken along. Did the settler know enough gnomonics to reset the dial correctly? Did he add a wedge beneath the dial when he set it up some 7° further south? We will never know.

ACKNOWLEDGMENTS

I thank Mark Etheridge and Mog Davies, owners of *Kalyanka* Station for their kindness in allowing me to work on their property. I have returned the dial to them as part of the heritage of their sheep station. A Macquarie University Research Grant (The archaeology of the Robertson Lands Acts of 1861) has supported the research reported here. Effy Alexarkis (Design and Visual Production, Macquarie University) produced the superb photos of what my field assistant (and son) Tom Pickard described as "a rusty old piece of scrap iron."

TABLE 1. ANALYSIS OF HOUR ANGLES TO DETERMINE LATITUDE OF DIAL.

Hour	*Calculated hour angle*[1]	*Measured hour angle*[2]	*Calculated latitude*[3]
0600	90.0	90.0	-
0700	62.9	54.0	21.64
0800	42.2	36.4	25.24
0900	27.6	21.3	22.99
1000	16.8	12.3	22.25
1100	8.0	6.5	25.16
1200	0.0	0.0	-
1200	0.0	0.0	-
1300	8.0	10.0	41.15
1400	16.8	15.0	27.65
1500	27.6	24.5	27.11
1600	42.2	36.3	25.12
1700	62.9	54.5	22.07
1800	90.0	89.3	-

Notes

1. Calculated assuming latitude = 31.52°S (see text).

2. Measured between hour-line and appropriate 1200 h line.

3. Calculated using the equation: sin (latitude) = tan (time) / tan (hour angle)

Mean calculated latitude

Using morning hours only	23.46°
Using afternoon hours only (omitting result for 1300 h)	25.49°
Overall mean latitude	24.36°

TABLE 2. COMPARISON OF MEASURED AND CALCULATED HOUR ANGLES FOR LATITUDE 24.36°

Hour	*Measured hour angle*[1]	*Calculated hour angle*[2]	*Difference (calc – meas)*
0600	90.0	90.0	0.0
0700	54.0	57.0	3.0
0800	36.4	35.6	-0.8
0900	21.3	22.4	1.1
1000	12.3	13.4	1.2
1100	6.5	6.3	0.2
1200	0.0	0.0	0.0
1200	0.0	0.0	0.0
1300	10.0	6.3	-3.7
1400	15.0	13.4	-1.6
1500	24.5	22.4	-2.1
1600	36.3	35.6	-0.7
1700	54.5	57.0	2.5
1800	89.3	90.0	0.7

Notes

1. Measured between hour-line and appropriate 1200 h line.

2. Calculated using the equation: tan (hour angle) = tan (time) /sin (latitude)

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REFLECTING SUNDIALS

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INTRODUCTION

For a practical sundial, it is necessary to arrange that the light from the sun shall give an indication of the time of day upon some suitable graduated surface. This is essentially a problem in optics and as such is capable of a number of solutions. Of course the simplest and most common practice is to allow the shadow of some object (a gnomon) to fall on the recording surface where the time is indicated by the transition from light to shade. Another simple method is to arrange for the sunlight to pass through a small aperture so that the resulting bright spot indicates the time. This arrangement is used for example in the Daniel 'dolphin' dial at the National Maritime Museum and in some types of noon marker. From a purely optical viewpoint these shadow-casting methods have little interest: they rely on the fact that by the laws of geometrical optics the sun, the gnomon and its shadow must all lie in one plane.

REFRACTING SUNDIALS

A step in optical sophistication can be taken by arranging for the sunlight to be refracted by passage through a lens. This may give improved accuracy: the focused image of the sun will be better defined than the edge of a shadow. Some types of heliochronometer use lenses, for example an instrument by Wheatstone[1]. A small cannon which is fired at noon by the heat of the sun's image is another example[2].

The Campbell-Stokes sunshine recorder, with a spherical glass ball for a lens, is a refracting sundial. The daily record strips of prepared paper on which the image of the sun burns a trace are graduated, so that the times of sunshine can be determined in addition to the duration. Other types of refracting dial exist, and evidently they are not uncommon.

A problem with any simple image-forming system is that it will only produce a good image when the light source is on or near to the optical axis of the system. Off-axis images will suffer aberrations to a greater or lesser degree. In the Wheatstone heliochronometer, the body of the instrument is arranged to rotate about an axis parallel to that of the earth to follow the sun in hour-angle (which provides a measure of the time) and the changes in the sun's declination can also be accommodated, so that in use the image of the sun is always on axis. The spherical ball of the sunshine recorder has no unique axis, so that whatever the sun's direction the image quality is the same. It does, however, have severe spherical aberration and only the core of the image (passing through the centre of the lens) burns the trace on the recording card.

REFLECTING SUNDIALS

In contrast to refracting sundials, those which operate by the reflection of sunlight seem to be rare. By a reflecting dial, I imply one which uses a concave mirror to concentrate the light into an image. This excludes the type described by Waugh[3], in which the spot of light reflected by a small horizontal plane mirror indicates the time on a dial drawn on the ceiling. This may be considered as a variation on an aperture dial.

The remarks above concerning poor off-axis image quality apply with equal or greater force to reflecting systems. The approach I have adopted is to take some advantage of the aberrations to produce dials with unusual properties. All the dials I shall describe use a concave part-cylindrical surface to reflect the sunlight. The term 'cylindrical' does not necessarily mean that the cross-section of the reflector is an arc of a circle (this is a 'right-circular cylinder'): the section may take the form of some other mathematical curve.

To understand how the reflecting surface operates, it may be imagined as being made from many narrow segments parallel to the axis of the cylinder, each segment so small that it may be regarded as plane and joined at a slight angle to its neighbours. When the cylinder is placed in sunlight each segment reflects a line of light on to a plane surface

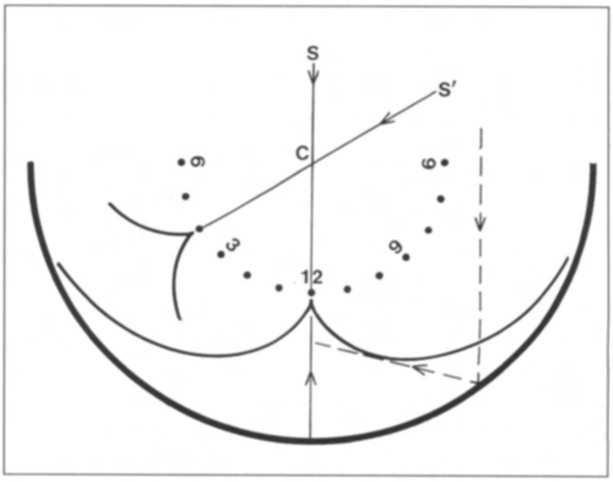

Figure 1. Right-circular cylinder and its reflected caustic.

which is at a right angle to the cylinder axis. The reflected light obeys the 'law of reflection', namely that the angle of reflection is equal to the angle of incidence, both being measured from the normal (the direction at a right angle) to the surface at the point of incidence. Because the reflector is curved the angles of the normals vary with respect to the incoming light and the reflected lines will overlap to form a pattern.

As with all optical instruments which form an image of the sun, care must be taken to ensure that there is no chance of damage from concentrated light and heat in the image, either to the instrument itself or the eyes of the observer. These dials are quite safe in this respect.

A 'RIGHT-CIRCULAR CYLINDRICAL' DIAL

It will be simplest to start with a right-circular semi-cylinder as shown in section in Figure 1. The pattern formed by the reflected light is indicated and will be recognised as that seen on the surface of the contents of a straight-sided cup or mug when held in sunlight. The characteristic shape of the reflection is known as a caustic and the point where the two curved sides meet is called the cusp. The normals to the cylindrical surface all radiate from the axis of the cylinder (C in Figure 1) so that a ray of light which passes through the axis is reflected back upon itself and forms the apex of the cusp. The cusp thus points back at the source of light, S in the figure.

The dashed line in Figure 1 represents an incoming ray of light, parallel to the one which passes through the axis. After reflection, the ray is tangential to the caustic, which can be regarded as the envelope of the reflections. Near the cusp the rays pass through the caustic and emerge from the other side, but they are then spreading out and no longer overlap. The cusp appears half-way between the reflector and its axis.

If the direction of the light source changes, a ray with a different angle will pass centrally and the position of the cusp will alter. Such a change in source position from S to S′ is indicated and shows that, as seen from the centre of the circle, the change in the angle of the cusp will be the same as the angular change in position of the source. This raises the possibility of constructing a sundial using a reflecting cylinder, by providing it with a graduated screen to show the caustic and to indicate the time by the position of the cusp. The axis of the cylinder points to the poles of the sky (it is parallel to the earth's axis) and the screen is perpendicular to the axis, in the plane of the equator: the dial is therefore an equatorial sundial. As the cusps are formed half-way from centre to edge, the time marks lie on a circle of half the radius of the cylinder and are spaced at intervals corresponding to 15° per hour as measured at the centre. Hourly time-marks are indicated in the figure.

My first attempt to make such a dial is shown in Figure 2. The reflecting surface is half a biscuit tin, still attached to part of the bottom to hold it to the correct shape. The recording screen was cut from a sheet of clear plastic, ground on one side with fine grinding paste to give a matt translucent surface. It is held in the reflector with cyanoacrylate adhesive. The time marks (hours only) are rub-down lettering. The dial is carried on a wooden mount at the latitude angle. In the photograph the cusp of the caustic indicates about 9.10am.

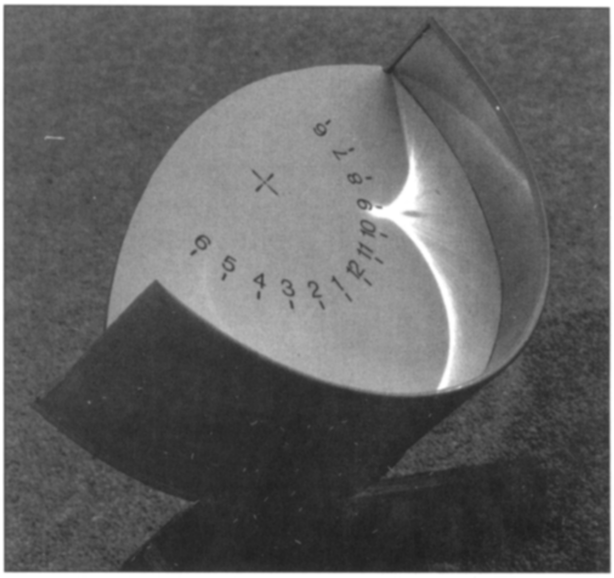

Figure 2. Right-circular cylindrical sundial.

Two points concerning the operation of the dial will be apparent. In the first place, the caustic will not appear when the sun is in or very near the plane of the screen, which will happen at the equinoxes. Secondly, if the reflector is carried above the screen only, time will not be indicated when the sun is below the plane of the screen, between autumn and spring equinoxes. Not much can be done about the first defect (a common failing of equatorial dials) but the second can be obviated as in my dial by extending the reflector below the screen. In the winter the caustic is thrown up on to the underside of the translucent screen and can be seen from above as readily as in the summer months. In either case the caustic will give a time indication in hazy sunshine when the diffuse shadow of a gnomon might be unreadable.

THE CYCLOID AS A REFLECTOR

My interest in reflecting dials was aroused by a passage in a book by Ball[4], in which the problem is introduced as an examination question:

A sundial is constructed of a reflecting cylinder whose cross-section is a cycloid, mounted upon a card so that the generating lines of the cylinder are parallel to the earth's axis and perpendicular to the plane of the card, whilst the axis of the cycloidal cross-section lies in the plane of the meridian. Prove that, if the distance between the extremities of the cycloid on the card be provided with a proper uniform graduation the cusp of the caustic due to the reflection of the solar rays will always indicate apparent solar time.

The concept of a sundial with an evenly-spaced straight-line graduation was most intriguing! Unfortunately, tests with a cycloidal dial made in this way soon showed that it could not possibly work in the way described: the cusps were neither evenly-spaced with time nor did they lie on a straight line.

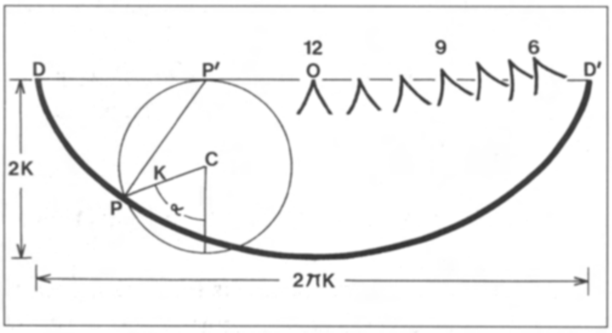

Figure 3. The cycloid and the cusps of its caustics.

A cycloid is the curve traced out by a point on the circumference of a circle which is rolled along a straight line: a stone caught in the tyre of a moving vehicle describes a succession of cycloids. On the left-hand side of Figure 3 the circle whose centre is at C rolls along the line DOD′. The point P is on the circumference and the normals to the cycloid are given by the line joining P to the point of contact P′ of the circle with the straight line. The right-hand side of Figure 3 shows the position of the cusp of the caustic for every hour from 6am to noon. It is obvious that the cusps are not equally spaced and (except near noon) they lie outside the straight line joining the ends of the curve. The cycloid is not wholly a failure, however, the outer edge of the caustic where it crosses the straight line does move uniformly with time. These are the points where the light rays which are reflected normally intersect the line. Evidently the setter of the examination question did not realise that in the case of a cycloid the cusp of the caustic (unlike that of the right-circular cylinder) is not formed by light reflected normally. Formulae for the cycloid and other curves are given in Appendix I.

It does not seem possible to derive a curve which will give straight-line uniform motion of the cusp. In relation to the cycloid, such a curve would have to be of steeper curvature to reflect the cusps into a straight line, but to make them evenly spaced would need less curvature, two mutually incompatible requirements.

THE PARABOLIC REFLECTOR

If the dial properties are relaxed to accept either uniform motion of some part of the caustic other than the cusp or non-uniform straight-line motion of the cusp itself, some solutions are possible. The first alternative has already been found for the cycloid as discussed above. Another curve having this property is the parabola shown in Figure 4. At noon the reflected light focuses into a bright spot on the axis of the curve. With the sun out of the meridian the inner edge of the caustic indicates the time on a scale which is very nearly uniform, and the caustic itself develops an attractive curved shape which starts tightly curled near noon and expands with increasing hour-angle of the sun. Some of the curved caustics are shown in Figure 4. Figure 5 is a

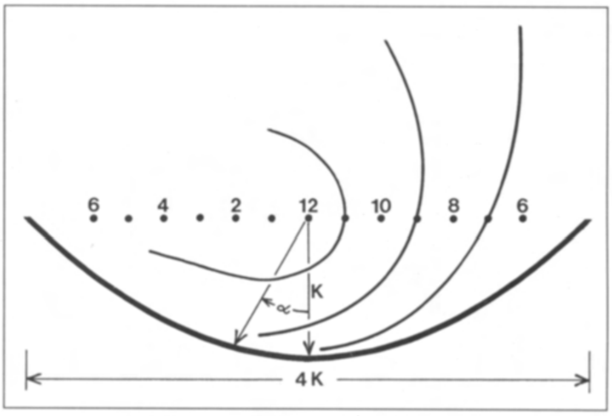

Figure 4. Parabolic curve and some reflected caustics.

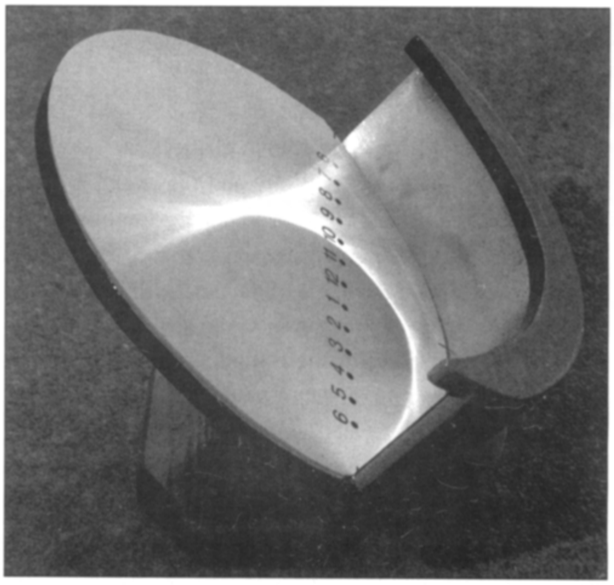

Figure 5. Dial with parabolic reflector.

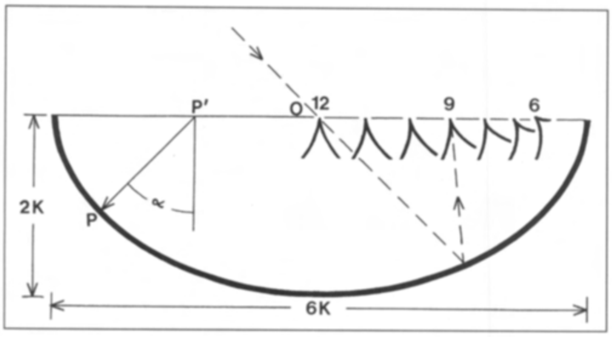

Figure 6. The 'sundial curve' and its caustics.

photograph of a dial with a parabolic reflector, showing the caustic at about 10.20am. This dial is single-sided and shows time only from spring to autumn equinoxes. To show the extent of the caustic, the base of the dial is larger than it need be just to show the time.

Details of the construction of my prototype dials are given in Appendix II. Being made of materials such as hardboard and sticky tape they are strictly indoor window-cill or outdoor fair-weather dials.

A 'SUNDIAL CURVE'

The curve shown in Figure 6 provides the other alternative of non-uniform linear motion of the cusp of the caustic. It bears a superficial resemblance to the cycloid but, as suggested above, has a stronger curvature. The line PP′ moves along the base line, turning through an angle and shortening as it does so. The reflected caustics for every hour from 6am to noon are shown in Figure 6. The cusp moves along a straight line (except that at 6^h hour-angle the cusp falls very slightly outside) but the motion is not uniform with time, the hourly positions get closer together with increasing distance of the sun from the meridian.

This curve can be used in another way. The light which forms the apex of the cusp passes through point O, the axis of the curve, as shown by the dashed line in Figure 6. If a translucent screen pierced with an aperture on this axis is mounted across the reflector, light entering through the aperture falls on the reflector and focuses as a bright line on the screen indicating the time on an appropriate scale. The time marks are the same distance from centre as those for the cusp of the caustic. Figure 7 shows a dial made in this way. Sunlight enters through the slot in the centre of the scale and focuses as a bright line, in this case showing a time just after 11am. With changing declination of the sun throughout the year the line appears in differing positions on the screen, being high in the winter and low in summer. The photograph was taken in mid-August. Time is shown continually throughout the year except for a short interval either side of noon at the equinoxes when the line disappears from the

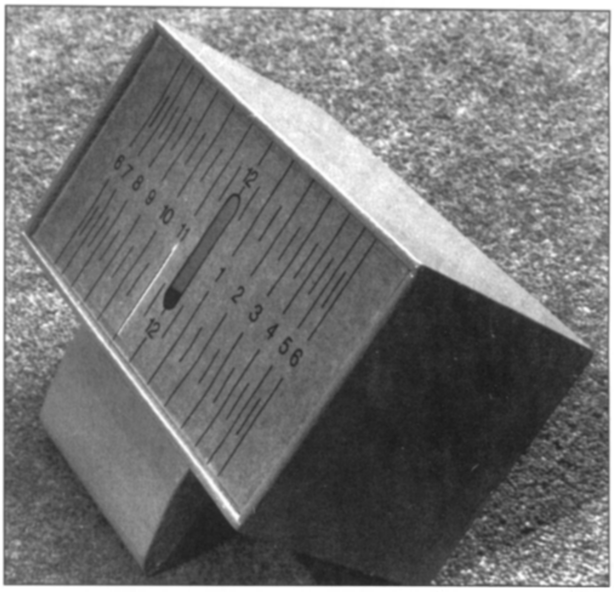

Figure 7. Aperture dial using the sundial curve.

screen, being reflected straight back out through the aperture.

This shape does not appear in a published collection of reference curves[5] and it may justifiably be claimed as the 'sundial curve'.

DIAL WITH SMALL SEGMENTAL REFLECTOR

A reflecting dial of a different type is shown in section in Figure 8. The reflector is a small segment of a cylinder of

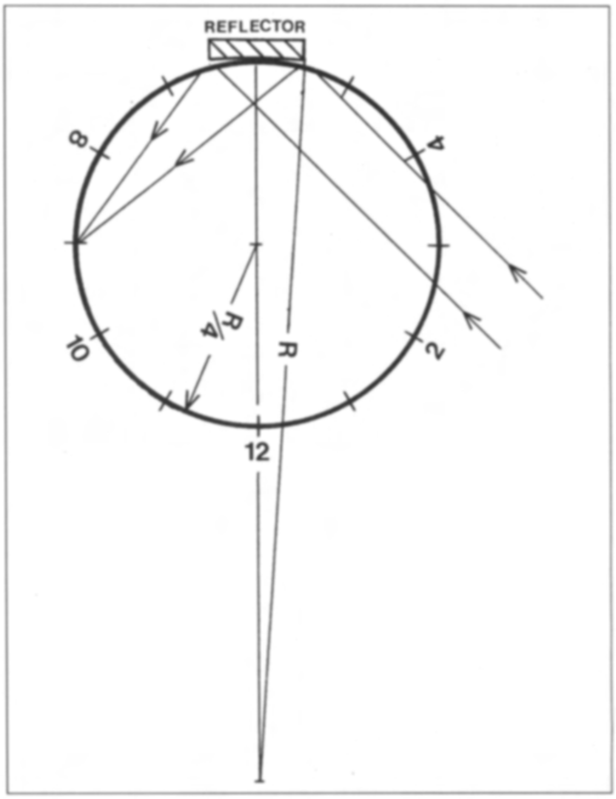

Figure 8. Diagram of small-segment cylindrical mirror dial.

relatively long radius (R) which focuses the sunlight as a bright line on the recording surface. This is a complete cylinder with a radius one-quarter that of the reflector and held in contact with it. The surface of the small cylinder is ground to make it translucent and provided with time marks. As measured at the centre of the small cylinder, the hour marks are 30° apart, not 15° as in a normal equatorial dial. The focused line is in fact a small part of the caustic of a full semi-circle, and its distance from the reflector varies as the cosine of the angles of incidence and reflection. Thus the focal position traces out a circle. If the reflector is made too wide aberrations will broaden the focused image, but in the proportions shown in Figure 8 the dial will perform satisfactorily. In the photograph of Figure 9, the indicated time is about 2.23pm.

CONCLUSION

So far as is known, the dials mentioned here (with the exception of the cycloid) have not been described before.

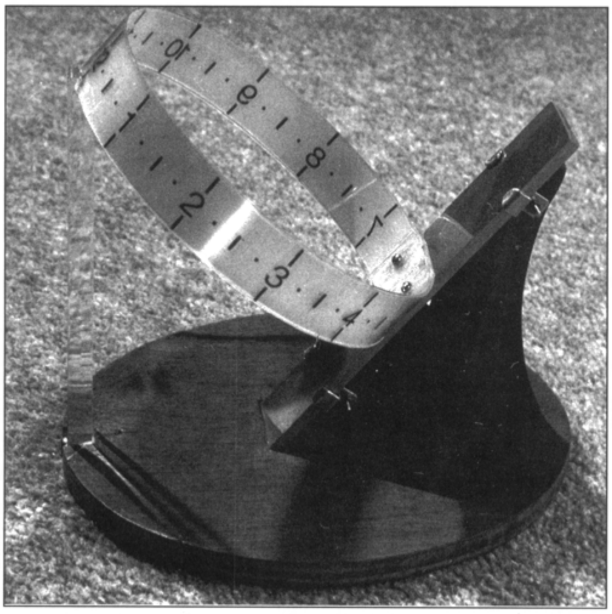

Figure 9. A small-segment mirror dial.

There may well be other curves with interesting caustics or focusing properties, and my search for them continues.

APPENDIX I: FORMULAE

In the following formulae the shapes of the various curves are given in x,y co-ordinates to enable them to be plotted on squared paper for construction. The factor K is a dimension which can be chosen to give the required size of the reflector. The curves are of course symmetrical on either side of the centre or 12 noon position and only require the calculation of half the curve from the origin or centre to the limit of the curve. The positions of the time-marks are designated x_T and y_T and are calculated for the sun's hour-angle H at 15°/hour. Although most of the dials are graduated from 6am to 6pm, the practical limit of time registration is 5 or at most $5^1/_2$ hours (H=75° or $82^1/_2$°) either side of noon, an adequate range for a window-cill dial.

Right-circular cylinder: no formulae needed as the shapes of the reflector and the graduated scale are those of semi-circles.

Cycloid: in Figure 3, the cycloid is described by the point P on the circumference of the circle as it rolls along the line DOD′. If the radius of the circle is K and it turns through an angle α, the cycloid is given by:

$$x=K(\alpha+\sin\alpha) \quad \text{(limits of } \alpha\text{: } \pm180° \text{ or } \pm\Pi \text{ radians)}$$
$$y=K(1+\cos\alpha)$$

In the equation for x the value of α is to be entered in radians ($\alpha^{rad}=\pi\alpha°/180$). In forming the curve, the circle turns through a complete revolution, so the distance DOD′ is 2πK. The positions of the cusp of the caustic are given by:

$$x_T=K(H+\sin H-0{\cdot}0432\sin^3 H) \quad \text{(H in radians)}$$
$$y_T=-0.125K(1-\cos 2H)$$

and the positions of the outer edge of the caustic on line DOD′ are:

$$x_T=0.0349K\text{x}H \quad \text{(H in degrees, limits } \pm75°\text{)}$$

Parabola: referring to Figure 4, the curve is given by the expressions:

$$x=2K\tan(\alpha/2) \quad \text{(limits of } \alpha\text{: } \pm90°\text{)}$$
$$y=K(1-\tan^2(\alpha/2))$$

and the position of the time-marks by:

$$x_T=K(\sin H/(\cos^3(H/3))$$
$$y_T=0$$

As mentioned earlier the time scale is very nearly uniform and for a small dial it will be satisfactory to take:

$$x_T=0.0174K\text{x}H°$$

The error is less than a minute over the range 7am to 5pm.

Sundial curve: in Figure 6 and working from the centre O as origin, the generating line PP′ moves along OD turning through angle α as it does so. The distance (OP′) travelled is K(2sinα) and the length PP′ is K(1+cos²α). The x,y co-ordinates are then:

$$x = K\sin\alpha\,(3+\cos^2\alpha) \qquad \text{(limits of } \alpha\text{: } \pm 90°\text{)}$$
$$y = K\cos\alpha\,(1+\cos^2\alpha)$$

The formula for the time marks is rather complicated:

$$x_T = K(2\sin H + 0.457(1-\cos H)^2/\sin H)$$
$$y_T = 0$$

Dial with small-segment reflector: as mentioned earlier, the cylindrical reflector has four times the radius of the small cylinder forming the screen whose time marks are spaced at 30° per hour as measured from the centre. The practical limit of time shown is from 7am to 5pm.

APPENDIX II: CONSTRUCTIONAL DETAILS

All the dials need reflecting surfaces which conform accurately to the shapes given by the formulae. Except for the biscuit-tin model, this is done by plotting the calculated co-ordinates at suitable intervals on squared paper, drawing a smooth curve and sticking the plot on to hardboard. Cutting carefully around the curve with a fretsaw produces concave and convex sections which are stuck on to hardboard leaving a narrow blind groove between them so that a flexible reflecting surface can be slid into the gap. One such assembly forms the base of the dial, and another similar curved groove forms a support for the top of the reflector. Top and bottom supports are held apart by lengths of dowel rod. It is essential that the two grooves are as accurate as possible and mounted precisely one above the other. Errors in the reflecting surface are doubled in the reflections and the shape of the caustic will be adversely affected. As a guide, a reflector of about 150mm between the ends (as mine are) should conform to the correct shape to within about ±0.3mm. The height of a reflector above and below the equatorial plane needs to be sufficient to show the full extent of the caustic at the sun's maximum declination of $\pm 23^1/_2°$. The tangent of this angle is 0.43, so the reflector height can conveniently be made half of the maximum throw required to show the full caustic on the screen. The reflectors are made of flexible sheet plastic about 0.3mm thick cut to fit the distance between the grooves on top and bottom supports. To make it more reflective, thin aluminised self-adhesive tape is stuck to the plastic. Before final assembly the squared paper is cleaned off and white paper with the necessary time graduation is stuck on to the base. Of course for southern-hemisphere use the time graduations would need to be the reverse of those shown in the figures. The final step is to provide a suitable mount to hold the dial at the correct latitude angle, and a coat or two of model-makers enamel finishes the dial off.

The small-segment reflector was made by grinding one side of a section of aluminium strip to a cylindrical shape with abrasive paper on a former of a convenient radius (another biscuit tin!), and then polishing it with a cloth lap and metal polish on the same former. The cylindrical screen is a strip of plastic, ground to make it translucent, provided with time scales in rub-down lettering and bent into a cylinder. A transparent acrylic support bracket (which does not show well in Figure 9) from the base helps to hold the strip to the correct shape.

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FOUR MERIDIAN LINES IN ROME

NICOLETTA LANCIANO

The four meridian lines under consideration were traced in the late 18th and early 19th century. Two were the work of Monsignor Filippo Gilii, another is located in the astronomical observatory in the Calandrelli Tower, and a fourth is in the private apartments of the Orsini family, known today as the Palazzo Taverna.

This is a report on the progress of the ongoing research being done on these meridian lines aimed at gathering further and more precise information on their history, and the feasibility of the proposal to repair them and clean their gnomonic apertures. This study is being carried out as part of the effort to safeguard and enhance the scientific patrimony of Rome, as well as in connection with the history of science.

THE MERIDIAN LINE IN THE VATICAN TOWER OF THE WINDS

The most famous meridian line is located in the Vatican Tower of the winds. Fr. Ignazio Danti had it traced in 1579 in connection with the calendar reform under Pope Gregory XIII. But another meridian line was traced on the second floor of the same tower, by Msgr. Filippo Gilii, who was also responsible for the one in St. Peter's Square described below. Msgr. Gilii was director of the Vatican Specula from 1800 to 1821.

Gilii's Vatican line is still intact, but its gnomon is closed. Carved in white marble, the signs of the zodiac, also in marble, are carved along both sides. A marble circle in the floor indicates the 'vertical point', the point above which the gnomon aperture is situated.

Carved in the marble in front of the sign of Cancer, to the south, are the words 'AD OBLIQ. ECLIPTICAE GR 23° 27′ 54″. This is the measurement of the obliquity of the ecliptic that was used to trace the line. The line is divided into 20cm units, indicated by notches. The Arabic and Roman numerals '7000' and 'VII' are carved near the sign of Cancer, and the numbers '46,000' and 'XXXXVI' close to Capricorn. The entire line then, measures 7m 80cm (A small portion of it is shown in Fig.1). On the small terrace adjacent to the hall where the line is situated, there is a sundial on the wall facing east, also the work of Msgr. Gilii. Made in 1797, its gnomon is badly in need of repair.

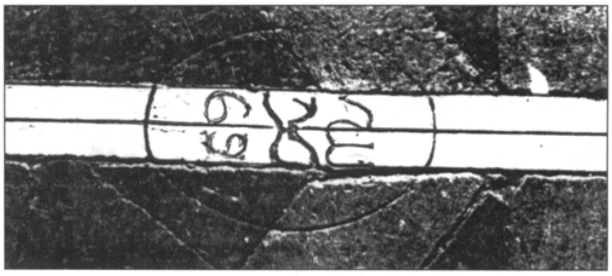

Fig.1 A Zodiac Symbol on Gilii's meridian line, Vatican Tower of the winds.

THE MERIDIAN LINE IN ST. PETER'S SQUARE

Unlike the other three Meridian lines under consideration in this report, which make use of direct sun rays, this one uses the shadow of a vertical gnomon, the obelisk at the centre of the Square. (See Figs 2 and 3).

Many people are aware of the two points in St. Peter's Square marking the 'centre of the colonnades' which are mentioned in most guide-books. Many of us also remember the circles carved round the base of the obelisk with designs of the various winds according to direction. Few people however remember having seen or stepped on other circles

Fig.2 St. Peter's Square, from above.

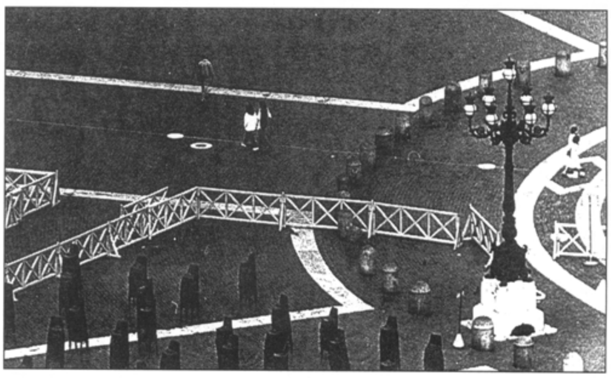

Fig.3 A part of St. Peter's Square to the north of the obelisk.

Fig.4 Circle on the meridian line, St. Peter's Square; the Cancer zodiac sign.

with designs similar to those of the winds, giving the dates when the sun enters into the different signs of the zodiac, a veritable solar calendar. To the north, i.e. to the right if we face the basilica, towards the papal rooms, between the obelisk and just beyond Maderno's fountain, there is a line in white marble with circles at regular intervals. The circle closest to the obelisk has the following words: 'Solstice in Cancer, 22 June'; then 'Leo, 23 July; Gemini, 22 May; Virgo, 24 August; Taurus, 21 April; Libra, 24 September; Aries, 21 March; Scorpio, 24 October; Pisces, 29 February; Sagittarius, 23 November; Aquarius, 21 January'.; and last, the one nearest the colonnades reads: 'Solstice in Capricorn, 22 December' (Fig.4 shows the 22 June circle)

The following explanation is given in *The Historical Dictionary of Ecclesiastical Knowledge, Vol. 48 p. 195, (Gaetano Moroni, Venice, 1847):*
'In 1817 under the care and direction of the Vatican astronomer Msgr. Filippo Gilii, a meridian line was traced in the area of the square closest to the papal palace, marking the monthly and daily movements of the sun at noon, for which the obelisk serves as a gnomon. A short distance from it is a white circle inlaid in the pavement, indicating the point from which, looking at the colonnade, it is possible to see only one of the four lines of columns which compose it'.

We would expect the line, which falls exactly along the North-South meridian, not only to pass through the centre of obelisk, but also through the centre of the fountain. In fact, the the whole Piazza seems to be perfectly symmetrical. But as can be seen in the photograph, the meridian line is asymmetrical with respect to the colonnade, the obelisk and the fountains. The 'centre of the colonnade' in fact is 50cm from the meridian, which is about a 5 degree angle from the North-South meridian parallel to the facade of the basilica and the line uniting the centre of the colonnade with the obelisk. (See Drawing, Fig.5)

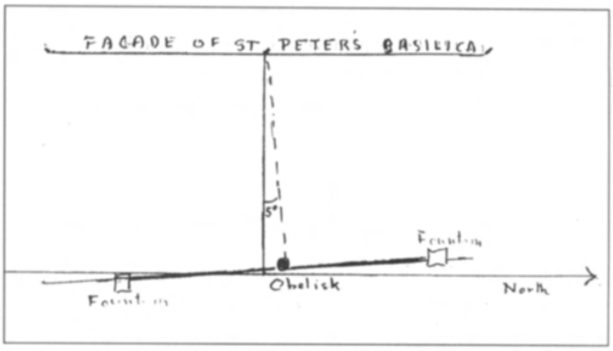

Fig.5 Diagram showing 5° offset in line of meridian and fountains.

In fact in 1585 Bernini found the obelisk and the facade of the basilica already finished, so the obelisk is not perpendicular to the central point of the facade, (the main entrance). When Bernini was considering how to arrange the colonnade he took as his axis the line between the obelisk and the main entrance, and situated the fountain on a line perpendicular to it. (see Fig.5). This explains why the meridian line is offset in relation to the fountain and the centre of the base of the obelisk.

The meridian line indicates twelve noon local solar time, and often disagrees with the bell and the tower clock which run according to conventional time. This is because of Rome's geographical position, and the methods for telling time.

THE MERIDIAN LINE IN THE CALANDRELLI TOWER

In the tower commissioned by Cardinal Zelada called the Calandrelli Tower, situated at the south-east corner of the Roman College belonging to the Society of Jesus, there is an observatory created by Guiseppe Calandrelli. As Director of the Observatory he spent a great deal of time there, but because of its high and narrow shape it vibrates violently and is not suitable as an observatory. The meridian line located in one of its small rooms was traced in 1797, as indicated on a marble slab. Its gnomonic aperture is now closed, but its position at about 4m 31cm from the floor is clearly visible. The unit of measurement is 43cm, a tenth of the height from the floor to the gnomonic opening. At the beginning of the line, near the vertical point, the words 'DECIMA GNOMONIS ALTITUDO' have been carved. The line does not fit in the small room, and part of it is on the wall. Numbers are carved at each notch, the numbers along the wall indicating points at which the sunlight coming through the gnomonic hole intersects it at 43cm intervals. If it could fit on the floor it would measure 946cm. (43 x 22). The 12 signs of the zodiac are carved in marble along it. Fig.6 (a) and (b) show the outside of Calandrelli Tower, and the meridian line on the floor and wall.

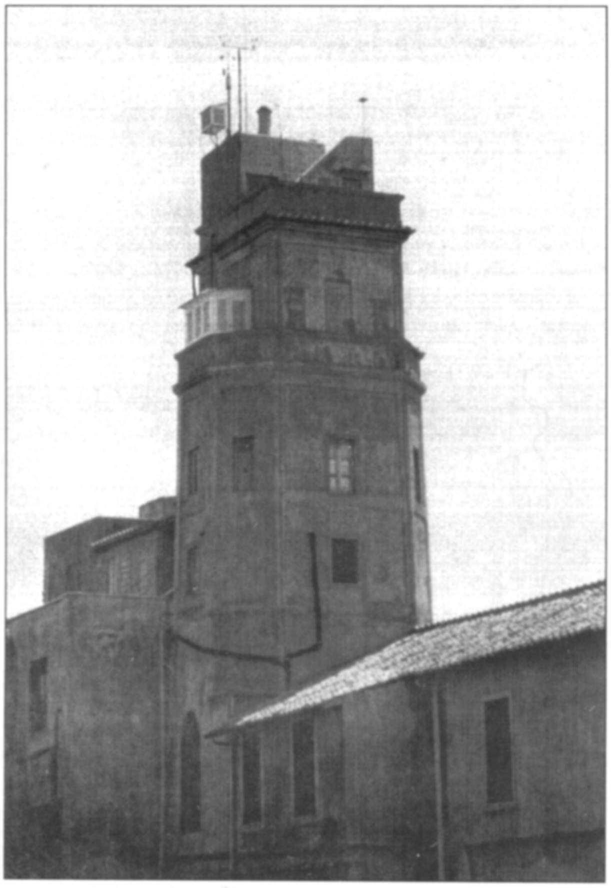

Fig.6 (a) View of Calandrelli Tower.

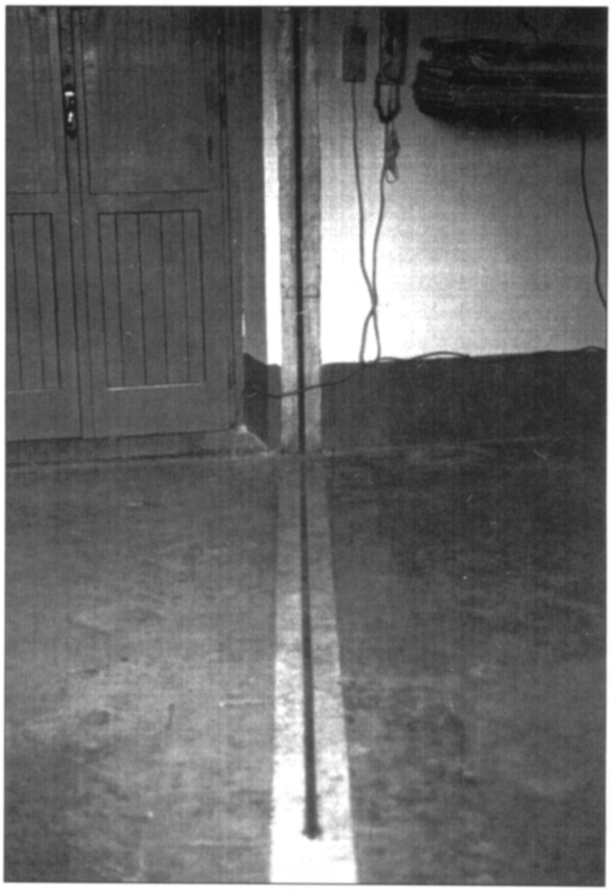

Fig. 6 (b) The meridian line in the Calandrelli Tower, floor and wall.

THE MERIDIAN LINE IN THE PALAZZO TAVERNA

The Institute of Architectural Research is located on the first floor of Palazzo Orsini, known today as Palazzo Taverna, at the corner of Via Orsini and Via di Panico. In the room said to be that of Ocresia, containing frescos depicting scenes from Greek mythology and Roman history (painted by Liborio Coccetti between 1810 and 1816) there is a very simple and well-preserved meridian line probably placed there for decorative purposes. A bronze plague gives the name of the person responsible: 'Mario Gabrielli fece MDCCCXXIX'. The line is 5.4m. long and is composed of 2.5cm. bronze strips laid in a 20cm strip of white marble in a floor of terra-cotta tiles. The gnomonic opening is closed but it is possible to see traces of it from the courtyard outside. The 12 signs of the zodiac are indicated by small incisions carved in the bronze and the symbols are carved in the marble. (Fig. 7) Since the room is used quite often for meetings and exhibitions the meridian can be viewed quite easily, but the fact that it is constantly being trodden-on is a threat to its conservation.

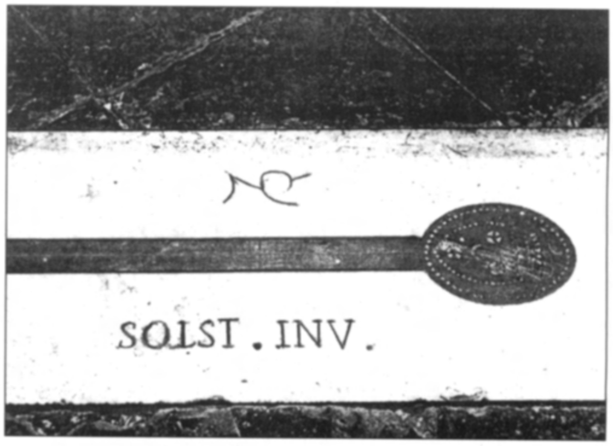

Fig.7 Line in Palazzo Taverna: zodiac symbol.

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F. Mangianti & M. C. Beltrano: *Il Collegio romano [The Roman College : 100 years of meteorological observations]* Rome, 1990

F. Foresta Martin, N. Lanciano & P. Lanciano: *Dalla Terra ala Galassie [From Earth to Galaxies]* Rome 1993

N. Lanciano, Dipartimenti di Matematica,
(Universita degli Studi di Roma 'La Sapienza')
P. Aldo Moro 2, 00185 ROMA, ITALY

READERS LETTERS

'UMKHONTO WE LANGA' AGAIN

I should like to comment on the article by R.P.M. Holliday (South Africa) with the title 'UmKhonto we Langa' in BSS Bull 97.1. It is especially for Historical interest that I write.

In 1910 the Dutch Author W.E. van Wijk wrote a series of articles on gnomonics; in one of these he stated the same objection to a horizontial dial as Mr. Holliday, namely the fact that the scale for reading the time is not linear. Van Wijk mentioned a solution of the problem described by the Dutchman J.A.C Oudemans in 1901. Oudemans' artcle is in French, and is entitled 'Curva Gnomonica'. It is part of a book 'Archives neerlandaises des scinces exactes et naturelles'.

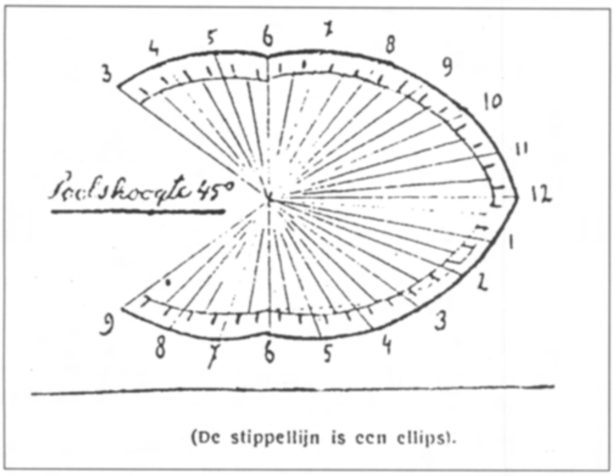


Fig. 1 From Van Eijk, 1910

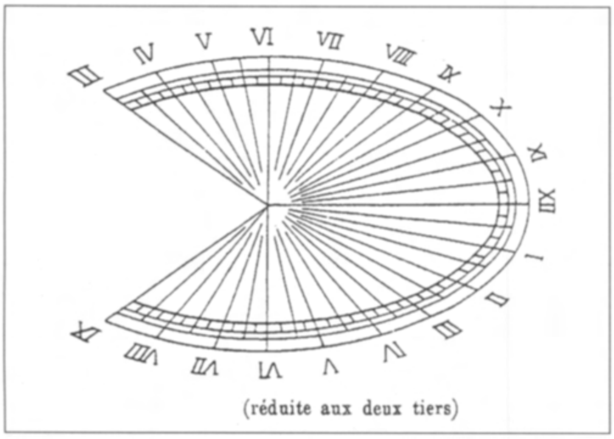


Fig. 2 From Oudemans, 1901

The mathematics give by Oudemans are different from those by Holliday, but the result is the same: a linear scale along a 'spear'. It is very nice to see that after about 100 years the same problem arises. Is history repeating itself?

I wonder if the term 'Curva Gnomonica' is used for the first time by Oudemans or if this term is used earlier in gnomonics; if so by whom? And was it for the same curve?

References

W.E van Eijk: *De Natuur 1910*

J.A.C. Oudemans: 'Curva Gnomonica' *Archives neerlandaises des Sciences* exactes *et Naturelles Serie II, Tome IV* Matinus Nijhoff La Haye 1901.

F.J.de Vries,
Van Gorkumlaan 39,
5461 WN EINDHOVEN, Netherlands.

IDENTIFICATION SOUGHT

I recently obtained the photograph (below) of a horizontal sundial flanked by two gentlemen. Alas, it came with no information at all, so I have no idea where it is. Can anyone identify it, please? The dial is horizontal with a fretwork gnomon. It is mounted on a octagonal pillar, presumably of natural stone, with distinctive interlaced braidwork on the central cylindrical column. It appears to be set in a large forested area. There are no obvious inscriptions on the stonework. The date I estimate to be around 1940. The gentleman on the left is well dressed and wears fashionable spats and carries a trendy 'Homberg' type hat; the style appears to me to be Edwardian or just post Edwardian, but the gentleman on the right appears to be rather more 'modernly' dressed. Any help in identifying the location would be greatly appreciated.

Peter Tandy
74 Old Bedford Road
Luton, Beds LU2 6PD

AN APPRECIATION

After seeing the first two copies of the BSS Bulletin without the onerous task of preparing it for publication, I would like to congratulate the new Editor of the Bulletin for the very high standard she has achieved. She has even published articles which I could not sort out to my satisfaction. BSS members should be truly grateful that such a competent person has been found to do the work, for the Bulletin is the British Sundial Society's only central theme binding the membership together. Well done Dr. Stanier and may you continue at this high standard for a very long time.

C.K.Aked

("Approbation from Sir Hubert..." Ed.)

SCHNEIDER'S 'ULTIMA NONNA'

I would like to contribute to the discussion on the interesting article 'Ultima Nonna' by D. Schneider. (BSS Bull. 97.4)

About the meaning for Dante of the symbolic number nine, all this is fully explained about him in the 'Vita Nova' and in the 'Commedia'. For him, 'nine' means perfection, infinite wisdom, miracle of God. The number nine is called 'Friend of Beatrice' by the Poet. The number nine appears several times during Beatrice's life. It looked like an exception when Beatrice died. Indeed the real death date was June 8th 1290 just after sunset. The arabic calendar having the beginning of the day at sunset (later called italian hours) was for Dante a solution for his problem. Dante was a staunch Christian but he was well acquainted with Islamic culture and was favourably disposed towards arabic learning especially in astronomy and philosophy. D.G. Rossetti was a great artist but a poor diallist. He was several times wrong in painting sundials but the greatest mistake was to allow the sundial to operate after sunset.

Reference:

G. Ferrari & N. Severino: Appunti per lo studio delle meridiane arabe, Ferrari, Modena, Italy 1997

E.G.A. Marianeschi,
Via Aulo Pompeo 6, 05100 Terni, Italy

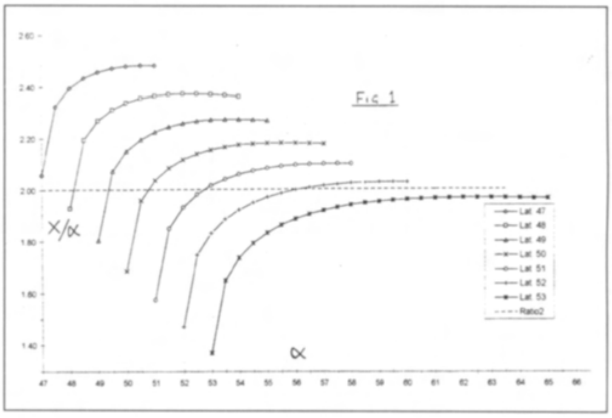
DESERT ISLAND DISC (LOSURE)S

When designing my origami Sun calender (Bulletin 97.4), whilst it was clear that a 2-piece instrument could be made for any latitude up to $66^{1}/_{2}{}^{\circ}$, I suspected that there might well be some limitation on the latitude for the 1-piece Calendar. However, not possessing a computer, I did not do calculations for latitudes other than my home ($51^{1}/_{2}{}^{\circ}$).

Fortunately, a fellow member Brian Russ has subsequently set his computer to work on the problem, and produced a very revealing set of curves (Fig 1.). They show that the conditions for a 1-piece instrument ($\alpha > \phi$ and $x/\alpha = 2$) can only both be satisfied between latitudes $47^{1}/_{2}{}^{\circ}$ and $52^{1}/_{2}{}^{\circ}$ - a surprisingly narrow range within which my home is fortuitously situated.

So, unless you are lucky enough (?) to be shipwrecked in the Aleutian Isles, for instance, you will need to make your Sun calendar from 2 pieces (as also will British members north of Birmingham and most Americans, for example).

I do apologise to anyone who may have been struggling to find a solution to the "1-piece" equation $x=2\alpha$, for a particular latitude where no such solution exists. However, the 2-piece instrument works just as well and the calculations are certainly easier, as you don't need to solve $x=2\alpha$. You will, though, need to provide "bend-back" glueing tabs along lines OA and OB of facilitate fixing to a base. On the other hand, you may have already been given a calendar for Christmas...



John Moir

NEWS FROM YUGOSLAVIA

A BSS member Milutin Tadić has sent a reprint of his article: Publication of the Astronomical Observatory of Belgrade No.56 (1997), pp31-42. The English translation Abstract reads as follows

Project of a Catalogue of Yugoslav Sundials

Milutin Tadić (Faculty of Sciences, Pristina, Yugoslavia)

Twelve years ago astronomers accepted an idea to elaborate a catalogue of the sundials. The catalogue has not been complied so far because of the known circumstances-the country of twelve years ago does not exist any more. Now, it is not hard to compose the catalogue of our sundials. First, the unexpected number of our sundials is not great; second, there are some European catalogues and one should only follow their example. In that sense, following European experience, it seems most practical to form a section for Gnomonics in our Astronomical Society and entrust it with the realisation of such a catalogue.

The number of sundials will not be nearly the number of sundials in the West European countries. But the existing Roman sundial from Sirmium and the medieval sundial from the monastery at Studenica are in themselves sufficient reason for starting on our catalogue.

M.Tadić, Karadordeva 90/9, 36000 Kraljevo, Yugoslavia

One of the illustrations from M. Tadic's article is shown below.


М. ТАДИЋ

ЈЕДАН ТИ ЈЕ ОД ОВИХ ПОСЛЕДЊИ!
EGY EZEKBOL VEGORAD!

Слика 5.

Сунчаник је конструисао српски монах Јован Јулијан Чокор, половином XIX вијека.

Литература: Јовановић, Д.Б.: 1985, Јован Јулијан Чокор, *Зборник радова VII националне конференције астронома Југославије*, Београд.

И тако даље... у овом тренутку познато нам је двадесетак наших стационарних сунчаника.

8. КАКО РЕАЛИЗОВАТИ НАЦРТ КАТАЛОГА?

Обзиром на невелик очекивани број наших сунчаника, неће бити тешко обликовати каталошке јединице, систематизовати их, уредити и одштамати каталог. Проблем је у томе што немамо потпуну евиденцију о нашим сунчаницима. У западноевропским земљама информације су скупила удружења љубитеља сунчаника, преко својих чланова[2].

Примјер добре организованости може бити British Sundial Society (BSS) које сада има скоро хиљаду чланова. BSS постоји тек десетак година, али

[2] Занимљив је примјер Чешке. Тамо је проф. др Лудвик Муха ангажовао своје студенте. Његови дипломци су каталошки обрадили сунчанике на простору цијеле Чешке Републике, по административним јединицама.

40

SUNDIAL 'WHEEL'

Forty years ago, during the excavation of the medieval dining room of the Orthodox monastery Studenica (Lat. 43°29°`, Long. 20°32') in Yugoslavia, there were found four marble fragments of a sundial. Connecting the fragments made $^3/_4$ of a marble wheel. The reconstructed sundial-wheel is shown is Fig. 1.

The radius of the wheel is 28cm, and 6cm thick. The diameter of the opening is 12cm by 4cm. From the edge of the opening there is engraved a concentric groove 6mm wide. The gnomon is missing. One cm from the circle the engraved hour lines are placed at $^1/_4$ hour intervals: the full hours are 67mm, the half-hours 40mm and the quarter-hour 23mm. Each full hour is marked by Roman and Arabic numerals side by side, height 13mm. Part of the dial plate is preserved, from 5.30 a.m. until 5.30 p.m.

Question to readers of the B.S.S. Bulletin: If it is a sundial, how can we explain why it is made as a wheel? How did it look in its original complete shape?

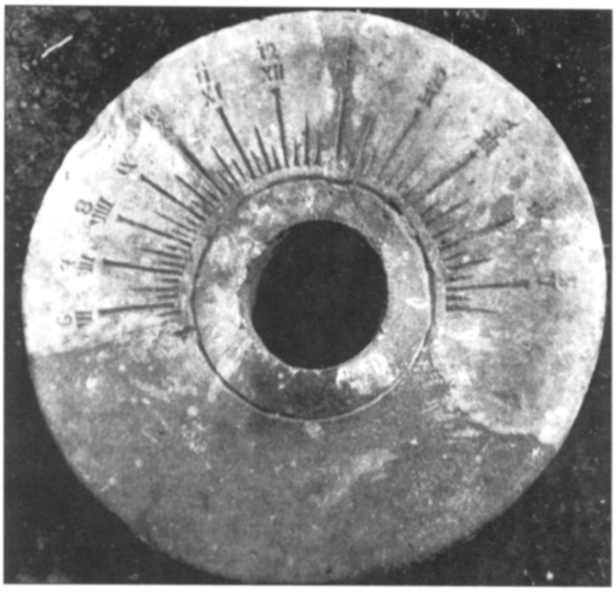


Fig. 1 Sundial wheel from Studentica, Yugoslavia

M. Tadić
Kanadordeva 90/9, 36000 Kraljevo, Yugoslavia

EDITOR'S NOTES

1. *'Time Trail' at the Old Royal Observatory, Greenwich, 20 Sept 1997* The British Sundial was represented at this function, in which many organisations participated, by Maurice Kenn of West Wickam, Kent. Mr. Kenn reports that the visitors included Australians, Americans, Japanese, Sri Lankans and others. After working their way through the clocks, watches, surveying instruments, telescopes, navigation... the visitors seem relieved to find themselves among 'Simple Sundials' which they could understand and make for themselves!

2. *Cordierite* Peter Tandy whose letter commenting on the suggested use of cordierite as a 'sunstone', early aid to navigation, appeared in Bull. 97.4, has supplied a formula for this complex magnesium-iron silicate: (Mg Fe) 2 Al_4 Si_5 O_{18}

3. *Postal Addresses* In the June 1998 issue of the Bulletin and thereafter, the postal address of the writers of contributions to the Bulletin will appear at the end of each item, unless the writer informs the Editor at the time of submission of the article that he/she does not wish this arrangement. The printing of addresses will enable readers who wish to make contact with writers to do so.

4. *Volume and page numbering* A revised system of volume and page numbering for the Bulletin is under consideration and will probably be announced at the 1998 Annual General Meeting. One purpose of the revisions is to simplify Bulletin entries in reference lists.

5. *Correspondence* Mr. C. K. Aked has asked that readers should be reminded that all contributions and correspondence relating to the Bulletin should be sent to the Editor (Dr. M. W. Stanier, address inside back cover), and not to him.

CORRIGENDA

1.Ultima Nonna?

This article, in Bull. B.S.S. 97.4. 5-7, was printed exactly as received by the present Editor. The author has pointed out an error on p.6, second column. The sentence starting 5 lines below Fig.3 should read: 'It was necessary to verify that in the XIII century hours were counted *from sunset, although in more recent times they were counted* from sunrise (Babylonian hours)'

The author also states that he should have spelt the title of this article "Ultima Nona" - "Last Nine".

2. Ancient Sundials of Ireland

This article, in Bull. B.S.S. 97.4. 13-20, contains a number of errors described by the author as 'small but important'. Readers are invited to correct their copies according to the list below.

p.15 column 1 3rd paragraph: for 'Machaio' substitute 'Machaoi'

p.15 column 2 line 32: numbers should read '...108, 132, 150..'

p.17 column 1 line 2: numbers should read '...30, 90, 150,'

p.17 column 2 line 6: Saints' names should be Maelchethair and Brendan

p.17 column 2 line 32: Should read '...divisions are 45, 87, and 135 degrees.'

p.18 column 1 line 3: should read '...and celebrated at the ninth hour, or between the ninth and the beginning of the night.'

3. Origami Sun Calendar

This article in Bull. B.S.S. 97.4, 36-39, contains a few small errors as printed

p.37 column 2 2nd para, line 3: for X substitute α

p.38 Formula… (1) should read: $AB = 2l \sin\alpha \sin \text{Arc} \cos (\cot\alpha \tan \phi)$……(1)

p.38 Add 4. Glue to base making AB = 58mm

The Editor is sorry about the necessity for these corrections. She hopes eventually to arrange for the authors to read their articles in proof, but this is difficult, particularly for overseas authors.

DIAL DEALINGS

MIKE COWHAM

This is the first of a new series talking about some of the dials that have recently been offered for sale. I have also included brief details of forthcoming sales and fairs that may be of interest to dial collectors. Even if you can not afford to buy the dials offered, these sales are ideal places to get to know your antique dials. You will be able to handle and examine them in a way that is impossible in many museums. You will learn from this about the various dials, how they are used, about their makers, their engraving styles, and armed with this knowledge, you should be in a better position to spot a wrong one in the future.

One of the best sources for dials for a private collection are the various auction houses. Most of these hold regular sales throughout the year. In the UK, there are four major salerooms, all in London, that regularly have sundials on offer. These are Christies South Kensington, Sotheby's, Phillips and Bonhams.

Other good sources include specialist dealers, of which I will give more details in a future issue, and fairs, such as the Scientific & Medical Instrument Fair held twice each year in London.

There were two exceptional sales towards the end of last year, one from Sotheby's and one from Christies. In just one sale of instruments, Sotheby's managed to offer a total of 26 dials. These ranged from basic 'Butterfield' dials that sold for about £500 to a superb polyhedral dial by Danfrie that made a staggering £280,000.

The dial that particularly interested me in this sale was a walking stick dial. Fig.1. The silver handle of the stick acts as the gnomon, throwing its shadow on a silver vertical pillar dial complete with a perpetual calendar engraved on its shaft. A walking stick dial is quite unusual, and this one more so in that it was made by a York silversmith. It was signed and dated *J Mann fecit 1679.* This attracted collectors of not just scientific instruments, but walking sticks and silver. York silver of this period is particularly rare. It exceeded its estimate of £3000 - £4000 and made a healthy £14,000.

A French sundial signed *Rousseau Jnv Fec*, c1770, in the form of a large pocket watch was sold for £20,000, five times its estimate. Fig.2. It was similar to, but larger than, the one sold in Time Museum sale in 1988.

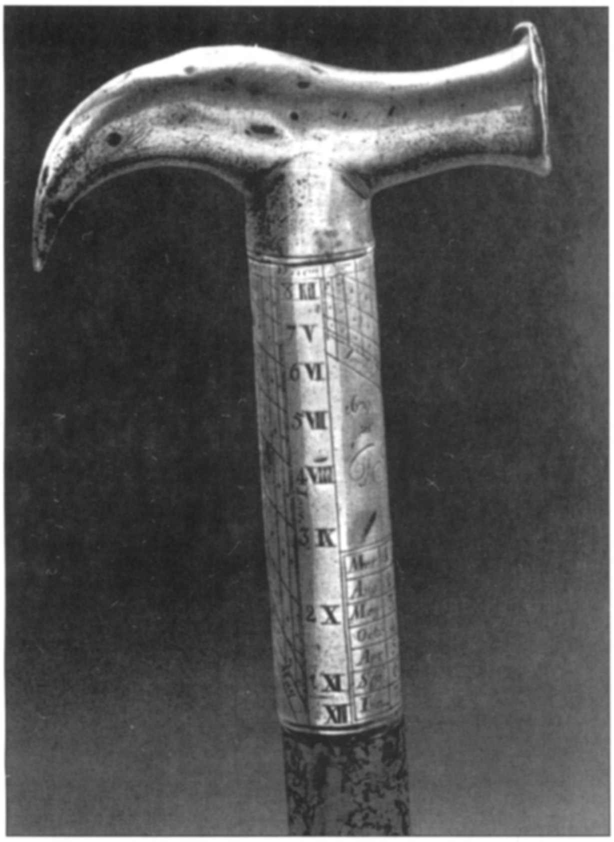


Fig.1. Walking Stick Dial. Sotheby's.

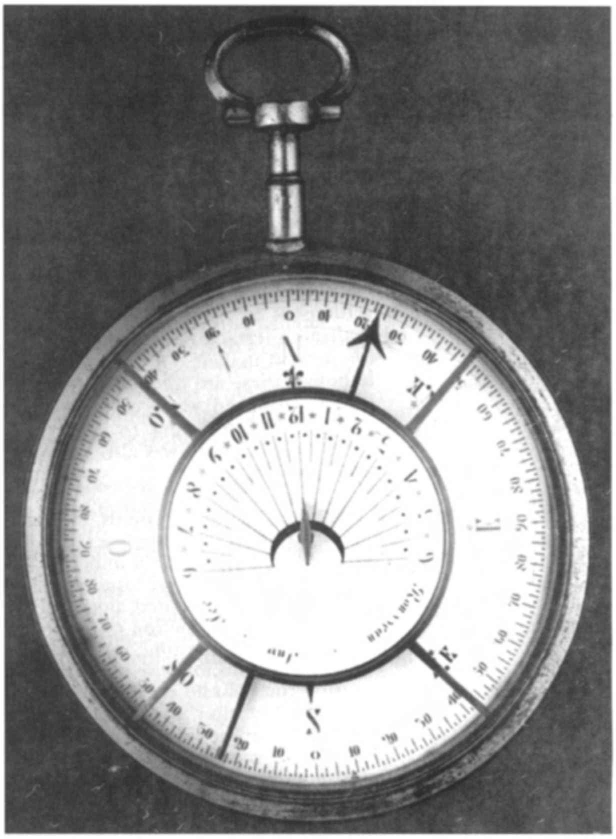


Fig.2. Dial in the form of a large Pocket Watch. Sotheby's.

There were several early and important dials in the sale. These were mostly gilt brass and from famous makers with estimates between £20,000 and £60,000. I would like to take three of the less expensive dials from this sale and describe in more detail.

The first was a brass ring or poke dial signed *I.A.M. 1693.* This maker is untraced, but there are two other, virtually identical dials known, one in the British Museum dated 1688 and one in the Manor House Museum in Bury St. Edmunds dated 1695. There are also a few others in European museums as recorded by Zinner.[1] If any reader can proffer a possible identity to 'I.A.M.', I will be pleased to hear from them. The dial sold for a reasonable £1250.

Fig.3. shows a string gnomon tablet dial by Marcus Purman of Munich. It was signed and dated **M*P 1593.* Purman is well known for his dials and other instruments, although his output of dials was quite small. This dial is of gilt brass with a silvered dial plate. One nice feature is its plumb bob that is nicely held in approximately its correct hanging position by a small support ring. This stops it falling around and scratching the dial plate when in transit. Its outer case was delicately engraved with foliate and floral scrolls. Its sale price was £8,000.

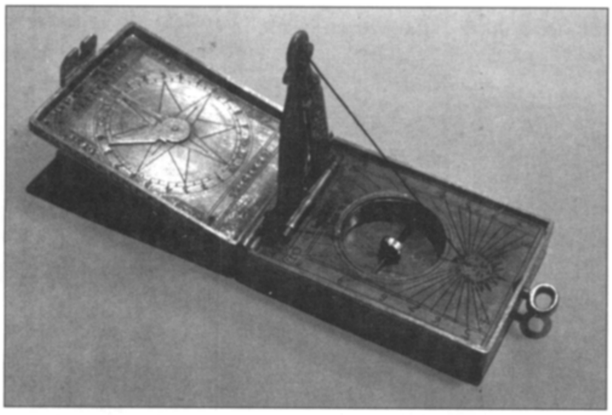


Fig.3. Tablet Dial by Marcus Purman. Sotheby's.

The last one was a small oval silver dial in a pair case made in about 1680. This was not illustrated in the catalogue, and hence was probably overlooked by many potential buyers. In addition to that, its gnomon was missing. Although it looked at first sight very similar to many French dials of around 1700, it was catalogued by Anthony Turner as an English dial. Furthermore, the dial was held in its case like a pocket watch, and could be released by a small catch. With it opened up to show the back of the dial plate, it revealed some fine engraving on the back of the compass bowl and a beautifully shaped gnomon spring. Fig.4. Yes! This must be English work. I wonder how many sale viewers found this catch and opened the dial? It made a modest £800.

Fig.4. Back of dial plate on oval silver dial. Sotheby's.

Christies South Kensington sale on 27 November had several fine dials. In particular they were offering three cruciform dials. Over the last 15 years at least, I don't recall having seen more than one or two of these dials for sale, and to have three in one sale is exceptional. One of these was carved from ivory. It shows the crucified Christ on its top surface and the Virgin with child on the other. The hour markings were on the arm edges as usual. Inside were some of the original bone relics fitted into some small circular cells. It was unsigned and undated but is possibly Flemish from 16th. Century. It sold for £9,200. The other two cruciform dials were of brass. Again these were unsigned, but one was attributed to Adrianus Zeelst of Louvain by its style and form of engraving. It was dated 1593, and the other, thought to be Spanish, 1648. The Spanish dial, Fig.5., was particularly crisp due to the fact that it came with its own original brass case. These fine dials made £17,250 and £18,400 respectively.

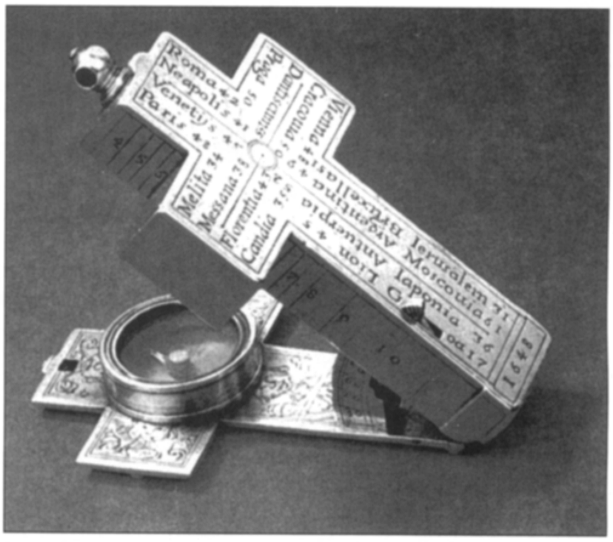


Fig.5. Spanish? Cruciform Dial. Christies.

Although not exactly a sundial, Christies sold a 19th. Century Snuff Box, Fig.6. signed *GAUCHERON composuit,* with a perpetual calendar on both top and bottom faces. This calendar was particularly complex, and it included on its underside an equation of time table showing the correct time at noon given by a sundial. This was a nice object selling for just £402.

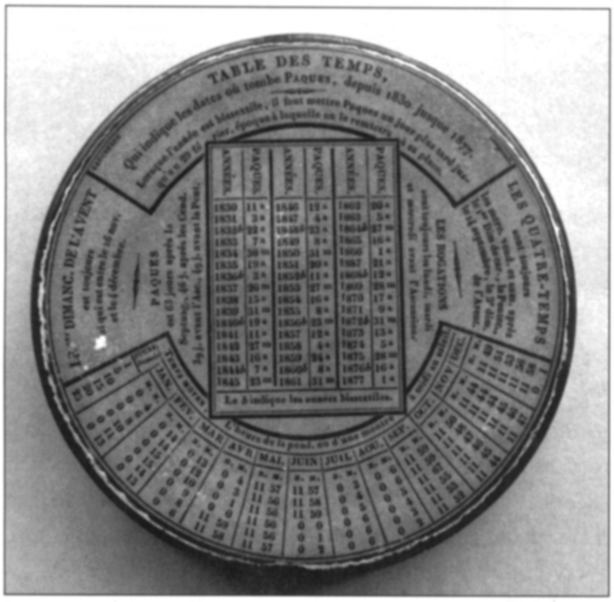


Fig.6. Perpetual Calendar on a Snuff Box. Christies.

Christies sale on 13 March 1997 offered three 'reproduction' dials, two of which were made by BSS members, Brookbrae Ltd. During the last year I also saw a Brookbrae dial at an antique fair where the dealer was offering it as 'an early 20th Century dial'. Luckily I was able to 'put him right' about this. Even so, it was a well-made dial and was certainly worth his asking price.

Phillips have had three Clocks & Watches sales that have included dials during the year. Phillips generally offer dials of more modest values and a bidder there would have had the opportunity to pick up a brass 'Butterfield' for £700 and an Augsburg dial for £800. Two ring dials were offered, both with missing suspension loops, one selling for £680 and the other for just £90! I did not see these dials so I am unable to comment about their condition or authenticity, but the dial at £90, if it was 'right', would have been an excellent 'starter' for any collection.

The Scientific & Medical Instrument Fair is staged in London twice each year. Several dials are regularly to be found there, particularly garden dials. There are two dealers who regularly offer the finer pocket dials. These are Tesseract from New York, and Bertrand Thièbaut from Paris. A dial sold by Tesseract in October made by Johann Martin of Augsburg was of particularly fine quality. Fig.7. It is a relatively simple dial but exquisitely made, with a gilt main plate and silvered chapter ring. Johann Martin worked with Johann Willebrand in Augsburg, and between them they turned out the best dials at that period. This dial was obviously made for a customer in Naples because 'Napoli 42' dominates its list of towns, all of which had Italian spellings. The Instrument Fair is also a good hunting ground for books on dialling. Rogers Turner Books have a regular table with several good books on dials and dialling, but you should also check out Turret House Books for the occasional dialling work.

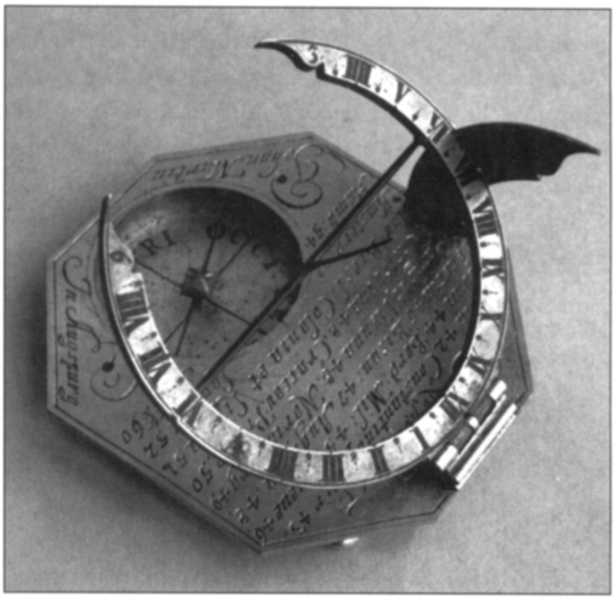


Fig.7. Augsburg Dial by Johann Martin from the Scientific Instrument Fair.

FORTHCOMING SALES IN 1998.

Christies South Kensington.

8 April	28 May
16 July	17 December

Sotheby's

7 March	30 September

Phillips

10 March

Bonhams

Three Scientific Instrument sales each year.

Scientific & Medical Instrument Fair.

The Radisson SAS Portman Hotel,
Portman Square, London W1.
Sunday 26 April 10:00 - 16:00
Sunday 25 October 10:00 - 16:00

Ref.1. ZINNER, Ernst. Deutsche und Niederlandische Astronomische Instrumente des 11. - 18. Jahrhunderts.

I would like to thank Sotheby's, Christies and Tesseract for their permission to use the photographs of their dials.

A PLEA FOR A NEW LOOK AT ROMAN PORTABLE DIALS

KARLHEINZ SCHALDACH

In the Bulletin No. 94.2, René R.-J. Rohr[1] gave a short introductory study on 'Portable Sundials in Ancient Rome'. The present text which is based on that article tries to find new answers to old and new questions on that theme, these questions being closely connected with the find of a Roman cylindrical sundial, as it was reported a short time ago by Mario Arnaldi and this author.[2,3] This find casts new light not only on the history of this type of sundial but also on the genesis of portable sundials in Roman times. It also corroborates some ideas which motivate the author to plead for a new look at portable sundials.

What we know for sure at the moment is the following:

1. There are 19 sundials known from Roman times that can be classified in 6 types (the names given closely follow the article by Rohr; Types III and V are new):

   I. The Ham Dial of Herculaneum (see Fig. 1).
   II. The Mayence Dial (see Fig.5 in Rohr's article).
   III. The Cylinder Dial of Este with two gnomons (see Fig. 2)
   IV. The Herapel Type (6 examples are known, see Fig. 4 in Rohr's article)
   V. The Ring Dial of Philippi (see Fig. 3) described by Gounaris[4]
   VI. The Bratislava Type (9 examples are known, see Fig. 6 in Rohr's article).

2. The sundials were made from the 1st to the 6th century A.D.

3. The Western Roman Empire finds are older than the Eastern Roman Empire ones.

4. All finds are made of bone or bronze.

5. Many of the dials of Types I to IV are not very well made, a calculated error of more than thirty minutes not being unusual.

Points 1 to 3 are not conclusive; they give no more than the present level of research. Point 1 is connected with point 4. As dials were probably not intended to survive for centuries under the ground, some might have been made of wood. This would explain why the number of finds is so small. Looking for an explanation for point 5, one could take comfort in Seneca's statement that philosophers agree more often than clocks, which implies that in his days such errors were common. But this argument cannot really satisfy, particularly since we know that sundials were improved upon if a defect was discovered - which means that there really was a lively interest in indicating time as precisely as possible. In any case it is unnecessary to have recourse to an argument based on social aspects whenever one does not know which way to turn in an individual instance.

Of course it is natural that individual opinions depend on the 'consciousness' of social conditions, but the same is true for the wish of an owner to have a timepiece indicating time with the highest possible precision - let alone the small size of the object and the intricacies of timekeeping. Since there were stationary sundials available for comparison in every town, at times in several places, the owners of timepieces ought to have noticed occurring inaccuracies. But perhaps there was no real interest in precision on the part of the owners of pocket dials, who rather tolerated the inaccuracy of the pieces since additional facilities provided by these objects were much more important to them. Was it possible at all, by means of these objects, to carry out other things than measuring the time? In this context we also have to ask ourselves what kind of individuals or professional groups could be particularly interested in sundials.

Before the discovery of object Type. III (found during excavation of a physician's house) nothing was known about the owners of such dials. When discussing astrological devices on dials of Type VI, Field[5] wrote: 'We must ask ourselves why sundials themselves were made. To

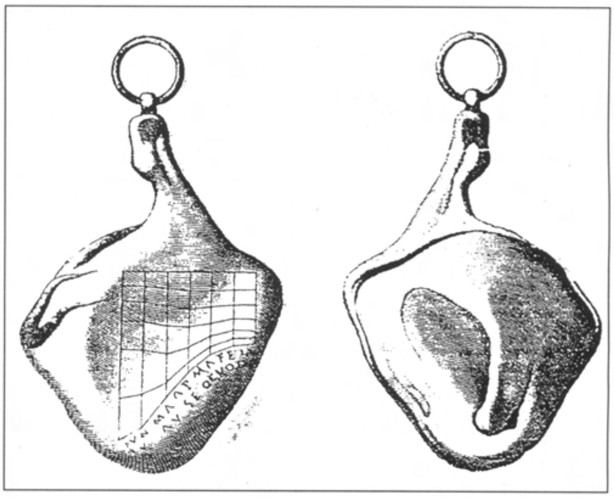


Fig.1 The 'Ham' of Herculaneum

answer such a question requires a grasp of the nature of Byzantine society, to which I can make no claim. Byzantinists have, however, suggested to me that portable sundials may have had a military application. The London sundial-calendar might then be the commander's dial, with gearing that would enable him to decide, for example, whether that night's Moon would be large enough to allow scouts to spy out the terrain'. This argument is rather sophisticated. An astrological device mainly serves astrological purposes. We know that for both Byzantine and Roman nobility, astrology was important. Therefore and because all portable sundials not only show the hours of day but also incorporate a calendar, they could very well serve as astrological instruments. This statement is supported by the fact that the owner of find Type. III was a physician, and since in those days medicine was very much connected with magic and astrological practice, the conclusion suggests itself that the sundial was not only a time-telling instrument but also (or even more) an astrological one.

Both from the simple texts of folk astronomy which are preserved to us and from the much more subtle texts dating from Antiquity we learn that not only the day but also the hour of birth are important for the life of an individual, that the efficiency of certain plants differs according to the time of day and according to the seasons, and that this efficiency additionally depends upon the phases of the moon, the position and the brightness of the sun, etc. This is the very reason why we may expect that a surgeon is particularly interested in an astrological device that he can always carry with him. This would also explain why, in those days, precision of chronometry was not as important as it is today. It was the mystical object and the astrological practice that gave those owners power, and not the exact dates.

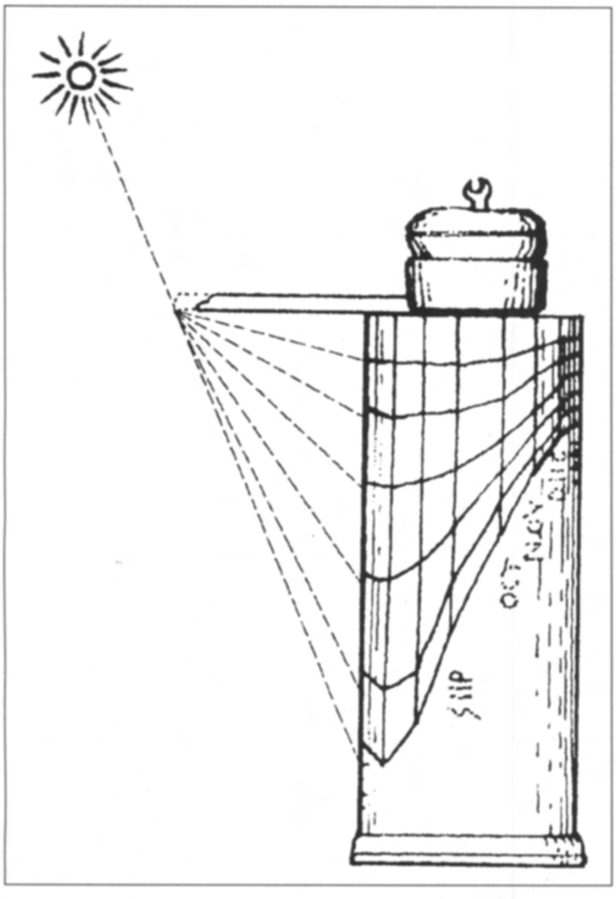


Fig.2 Sketch of the Cylinder dial of Este with the shorter gnomon, drawn by M. Arnaldi

In the course of their research on Greek horoscopes from between 400 B. C. and 800 A. D., Neugebauer and Van Hoesen[6] only incidentally found references to instruments: water clocks (clepsydras) and an astrolabe The fact that references to instruments in general are very scarce does not speak against the use of portable sundials in astrological practice. Nor do I consider the surgeons as the only professional group to use instruments. I could imagine that besides the astrologers themselves even educated laymen belonging to different professional groups did see more in such a dial than a mere instrument for timekeeping.

Regardless of this presumption there remains the fact that the precision of the markings on many portable sundials leaves much to be desired. This problem leads us to the question how these incorrect markings for the hour lines and the months were generated. This question is of particular importance for the Types I to IV which will be the main theme of the following lines.

My starting point will be the supposition that these small watches were not made by astronomers nor by individuals endowed with a particular understanding of gnomonics but rather by craftsmen, who were accustomed to working in base metal.

No written testimony on how these instruments were made has come down to us, but in book 9 of his *De Architectura,* Vitruvius writes: "Many also have left instructions for making hanging portable dials (viatoria pensilia). From such works anyone who wishes can find instructions, provided he understands the drawings of the analemma (dummodo sciat analemmatos descriptiones)."

Here he probably refers to the analemma outlined by himself, an analemma being - in Vitruvius' own words - 'a theoretical figure used for the construction of sundials which helps us, by means of an architectural procedure and of some circular movements with compasses, to form a concept (conceptio) of the structure of things under the starred sky.' Can we assume that in those days ordinary craftsmen understood such an analemma?

Vitruvius himself says 'Providing he understands.' That he himself had problems in understanding the portable dials is evident from the way he presents them to us. His note on these dials follows a list of dial types, which makes us think that these notions were valid for all types but travellers' dials. Accordingly, not a single name of any type of traveller's dial would be known to us; we would only recognise the comprehensive type name *viatoria pensilia*. But we have to ask: Does an expression like *pro pan klima,* which occurs in the list, also designate a stationary dial?

In order to settle this question it is important first to discuss the meaning of the notion *klima*. Originally the term klimata (pl. of klima) designated imaginary lines on the surface of the earth along which the longest day of the year embraced 13, $13^{1}/_{2}$, 14, $14^{1}/_{2}$, 15, $15^{1}/_{2}$, and 16 equatorial hours. But quite soon it also designated narrow stripes to the north and to the south of these lines. Within these seven climates the most important localities of Antiquity were situated, so that it became widespread usage to mention the climate in order to mark the position of one locality or another.

Whereas in Greece this procedure belongs to a tradition which may be traced back to Eratosthenes, the Romans handled the climates in a very arbitrary way. As a significant example I mention Plinius Secundus who in his *Historia naturalis* dealt with a notion of climates that stems from astrological sources. His way of using this notion may be described as follows: The whole earth was reduced to the parts inhabited by the Romans and the seven narrow stripes were transformed into seven broad contiguous zones. Besides the 7-sector-division there was a 5-sector type and an 8-sector one. There is no uniform concept recognisable any more on the Roman side, but there remains the common interpretation of the notion of climate as embracing localities and landscapes situated more or less along the same geographical latitude. Thus *pro pan klima* means both 'for every climate' and 'for every locality.'

But if such a designation is to make sense, it can only be applied to a portable dial, i. e. a traveller's dial. A stationary dial may only be used for the geographical latitude for which it had been calculated, but never 'for every climate'. Vitruvius did not recognise that, since he mentions the notion of *pro pan klima* in a wrong context. But if even he came into difficulties here, what can we expect from ordinary craftsmen? So we may suppose that in the practice of constructing portable sundials the way of procedure was not the construction of individual sundials. Rather we have to think of buyable models and written instructions containing simple drawings which enabled the user to copy the plan and thus to construct the dial true to the scale. According to the concept of the climates, seven or eight of these drawings would have sufficed to construct sundials for every zone of the Roman Empire. I think that the Vienna dial of Type IV has been constructed following such an esquisse. This dial contains four loose plates with grids on both sides for Alexandria / Aegyptus and Africa / Mauretania, Hellas / Asia and Hispania, Roma and Ancona / Tuscia, Gallia and Britannia / Germania, thus covering nearly the whole of the Roman Empire.

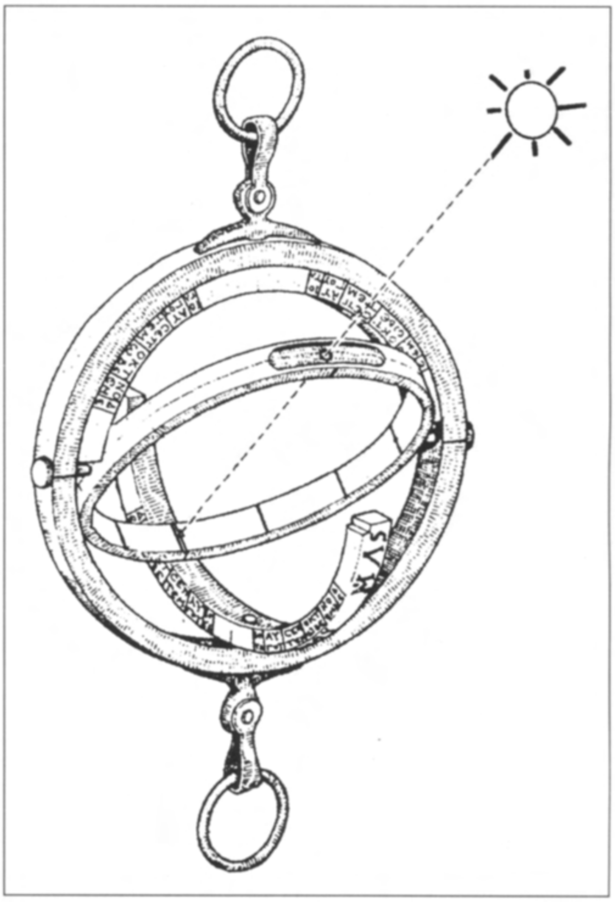


Fig.3 The Ring Dial of Philippi (Northern Greece)

Thus the majority of the portable sundials have probably been constructed by craftsmen following patterns available either as models or in the form of drawings in handbooks. As in those days the world was divided into a limited number of climates (between five and eight), we cannot expect more than eight different drawings for every type. Ensuing from this statement, there is another statement to be made. Since copying and proliferating these models and drawings continually caused new mistakes, an increasing inaccuracy occurred with the dials of Types I to IV, as these could relatively easily be copied from older drawings, thus avoiding costly constructions. This means that the later the date of a portable sundial, the more inaccuracies have to be taken into account.

Another way of determining the age of such an object is

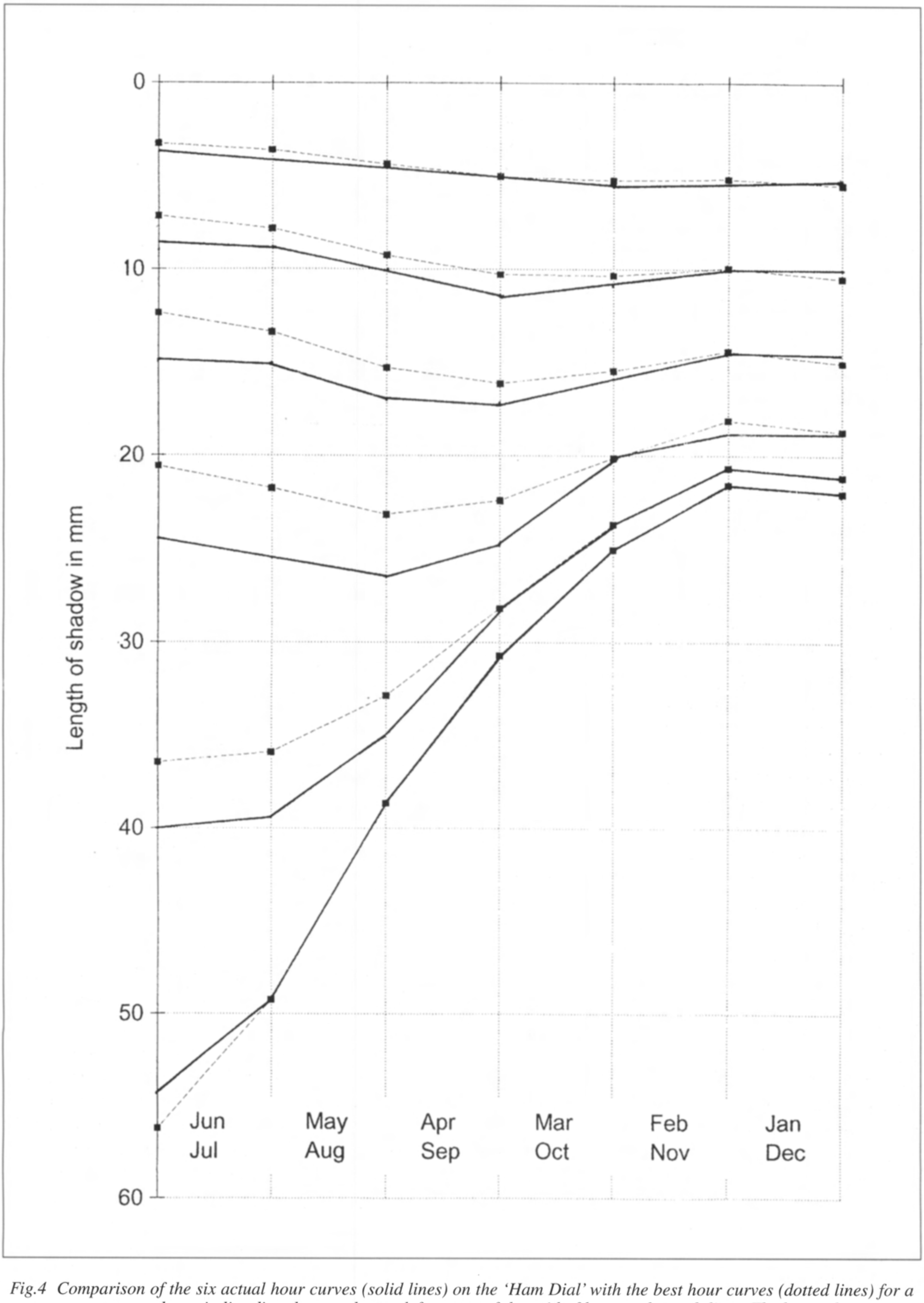


Fig.4 Comparison of the six actual hour curves (solid lines) on the 'Ham Dial' with the best hour curves (dotted lines) for a gnomon whose tip lies directly over the top left corner of the grid of hour-and-month lines. The best values are calculated for a vertical tip distance of 14cm and for latitude 38°N.

provided by the inscriptions. The following has to be stated here: originally every month line marked the entrance of the sun into a new zodiacal sign. Subsequently, however, the difference between month line and zodiacal sign has been neglected and the beginnings of the individual sectors were marked by the month names. Later the sectors themselves were marked by the month names. Thus seven month lines imply six month-sectors, every sector standing for two months. This shifting can be perceived properly if we compare the Ham Dial (Type I) with the Cylinder Dial (Type III). Whereas on the Cylinder the beginning of each sector is marked, the Ham already shows the more 'modern' version of paired months. Yet this does not imply that the grid from which the Cylinder of Este has been derived is older than the one from which the Ham of Herculaneum has been derived. I rather suggest that, as I explained above, the drawings have been handed down untested. Merely the way of marking the dials was adapted, in the course of the centuries, to the standard of the day.

Especially the dials belonging to Type VI show this shifting from marking the limits of a zodiacal sign to marking the limits of a month. Whereas the Western Roman Empire pieces bear the names of the solstices, the Eastern Roman Empire pieces show the month names, which means that the Western Roman Empire ones are older.

In the case of the Western Roman Empire pieces of Type IV the dates of the solstices tell us about the date of origin of the underlying drawings: VIII K IAN (December 25) and VIII K IVL (June 24) These dates correspond to a vernal equinox on March 24, a date which was valid only in the 2nd century B. C., although it continued to be accepted as reliable for centuries afterwards. If we suppose, however, that the prototype of this dial has been constructed by an astronomer aware of the shifting of the vernal points, we can assume that it has been constructed in the 2nd or, at the latest, in the 1st century B. C. At any rate, the pieces belonging to the type VI category found so far are all of a more recent date, the Eastern Roman pieces only dating from the period between the 4th and the 6th century A. D.

Finally we have to note yet another peculiarity occurring above all on the dials of Type IV: All these pieces seem to be characterised by an angle of 24° for the obliquity of the ecliptic, although the correct value for the 6th century should be closer to 23,5°. Supposedly simplicity and a way of thinking deeply rooted in tradition were the reasons for this state of affairs. Taking into account the small size of these objects, the error resulting therefrom is practically irrelevant. However, one ought to bear it in mind in case of re-examination, and one should always use the traditional value of 24° for calculations.

It was under these circumstances that the Cylinder of Este has been defined, and in the end the authors came to the opinion that the two gnomons of the dial 'were used at different times of the year, and that it was made for and used in the region in which it was discovered, rather than being designed for use at two different latitudes'[2]

The Ham Dial may be newly defined in the same manner. This means that the values underlying the calculations of the limits of the months were the following: 24°, 20.6°, 11.7°, 0°, -11.7°, -20.6°, -24°. On condition that the missing tip of the gnomon once was located in a particular distance directly above the top left hand corner of the grid of hour lines and month lines, I calculated the best approximation to the existing grid for a distance of 14 cm and a geographical latitude of 38°(Fig. 4). I do not try to relate the determined latitude to a distinct locality, but I prefer to ascribe it to a climate, say, Hellas (=Athens) / Asia. At any rate the opinion current so far, namely that this dial had been calculated for Herculaneum, cannot be accepted, as some authors have claimed. (De Solla Price, [7])

Both the Cylinder Type and the Ham Type are probably later developments of a prototype, i. e. of a simple cylindrical sundial with a very narrow bundle of the hour lines for winter time. To remedy this state of affairs, these two brilliant solutions were found. Compared with the rest of the portable dials, the errors one encounters on these two types are surprisingly small. This either means that the lines of the grid have been constructed or that they were conscientiously copied very closely to the original, and this again would mean that these grids were relatively recent inventions at the time when these instruments were constructed.

Most ideas that always do precede scientific discoveries went the way of oblivion; some, however, maintained their ground. Likewise, in the case of portable sundials of Classical Antiquity, the appearance of new finds will show whether or not the ideas elaborated above will persist.

ACKNOWLEDGEMENTS

I am especially grateful to Mario Arnaldi who found the Cylinder in the museum of Este, gave me valuable information on the Ham and inspired many ideas I elaborated above, and to Kurt Maier who translated this article into English.

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K. Schaldach,
Breitenbacher Str. 33a,
36381 Schlüchtern, Germany

ON THE BOOK OF DIALS

In these bright days of Science when our Times
We mark by clocks, chronometers, & chimes,
Our fathers antique Dials are well nigh
Neglected and forgot, as things gone by;

The slab of stone fixed on the Church's wall
Whose iron fingers made a shadow fall,
In hours if sunlight on its figur'd face,
With Holy motto suited to the place:

Or Dial stucco'd o'er the Council door.
Where the grave elders of the town of yore
Met to deliberate; or the Templar's Inn
of Court or College Quadrangle within;

Or grateful column of the sculptur'd stone
with plate of bronze for sun to shine upon,
Wherewith our ancestors were wont to adorn,
Their carriage entrance, or their Garden lawn.

All, all, were fading with the decaying fate,
Their sentences of truth obliterate,
When thou hast haply brought again to view,
These time revealers in a form so new,

Brighten'd their grounds that now no more they fail,
To all who ask, to give their truthful tale,
Rewrite in freshest figures the wise words.
The Stony tablets or the brass records,

Recall'd with skilful pencil in his prime,
"The honour'd figures of old Father Time",
His scythe, his hour glass, and his lack of hair
In front, not back, for none can hold him there,

Warm are our thanks, for great has been our pleasure
To see so gracefully employ'd thy leisure,
But if thy Dials tell us, after all,
We are but shadows on Life's sunny wall,
They not less point us, with a hope as bright,
To that good land above, where all is light.

H.V.J. Pegli - 1866. From a manuscript found inserted in a copy of The Book of Sundials by Mrs Alfred Gatty. 1872 1st edition. G.W.S. Miskin, 23rd, October 1997.

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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.
   Articles may vary in length, but the text should not exceed 4500 words, about three-and-a-half pages in the Bulletin.

2. Format: The preferred format for text is typescript, double-spaced, A4 paper; or on disc, 'microsoft word' or 'ASCII', with one printout.

3. Figures: For photographs, black and white prints as large as possible up to A5 size; colour prints are also acceptable if they show sufficient contrast. Slides and transparencies are ~~not satisfactory~~ also acceptable. Drawings and diagrams should be in clear black lines on white paper.

4. Each figure illustrating a article should carry on the back the author's name and title of the article (in abbreviated form); also a number, indicating its relative position in sequence in the text: (Fig.1, Fig.2...etc)

5. Captions for the figures should be written on a separate sheet, in numerical order. They should be sufficiently informative to allow the reader to understand the Figure without reference to the text.

6. Notes are best avoided: it should be possible in a short article to incorporate into the text all the background information which the reader needs, to understand the article. If notes are used, they may be referred to, in the text as (Note 1,) (Note 2) in brackets; then listed at the end of the article, after the 'Acknowledgments' and before the 'References'.

7. Acknowledgments: These should be as brief as is compatible with courtesy.

8. References: Sources are referred to in a text by a superscript number. They are listed in numerical order under the heading 'References' at the end of the article.
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   For books: Author's name; Title of book, in italics; Name of publisher, Place and date of publication.
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   Examples:

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   D. Colchester: 'A Polarized Light Sundial' *Bull.BSS.* **96.3** 13-15 (1996)
   A.A. Mills: 'Seasonal Hour Sundials' *Antiquarian Horol.* **19,** 142-170 (1990).
   W.S. Maddux: 'The Meridian on the Shortest Day' *Compendium, Journ. NASS.* **4,** 23-27 (1997).

   If you simply wish to give a short list of books associated with the subject of this article, this may be given at the end of the article under the heading 'Bibliography', using the convention as given for 'Books' above.

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