SCRATCH DIALS.

By BRIG.-GEN. J. W. S. SEWELL, C.B., C.M.G.

A considerable bibliography has grown up on the subject of the so-called scratch dials, otherwise called Mass Dials, or Incised dials, on the south walls of Parish Churches. Authors in the main have directed their attention to the problem of "*What* are these dials"? With considerable unanimity they have decided that the answer is "Sun dials." This answer is, without reasonable doubt, correct generally, but requires some qualification in respect of certain features found on some dials.

When however the further problems arise, *why*, *when*, and *how* these dials were constructed, the majority of writers become somewhat vague, even to the point of avoidance of these problems.

The trouble appears to be due, in part at least, to the fact that the majority of ecclesiologists evince extraordinary reluctance to credit bygone scientists with any knowledge which transcends that of the man of to-day who has received a normal education.

Before attempting to investigate any of the problems associated with Scratch dials, it is therefore necessary to recapitulate very briefly the history of the systems in vogue in ancient civilized states for dividing the twenty-four hours day into measured intervals.

The Egyptians of old divided the 24 hours into "night," from sunset to sunrise; and "day" from sunrise to sunset. Each of these periods was divided into 12 equal hours, regardless of the season of the year. It followed that the hours of day (in Egypt) varied in length from about 50 minutes, as now measured, at mid-winter to 70 minutes at mid-summer. Such "hours" are known as "temporary hours." At the equinoxes, clearly, the 24 hours were divided into 24 equal hours, as they are to-day. In consequence the present system of equal division at all seasons is known as that of "equinoctial hours."

It might reasonably be assumed that the introduction of any form of timepiece would necessarily involve the change from "temporary" hours to "equinoctial" hours. Curiously, however, this was not at first the case. The famous Clepsydra of *circa* 1400 B.C. has 12 scales marked on it, one for each month of the year, to enable the passage of night watches of 3 hours each to be observed.

In the last seven centuries B.C., there are records of sundials, of some sort. By the early part of the Christian era the science of gnomonics had been fully developed by the Greek astronomers. Ptolemy (*c.* 140 A.D.) in Book II of his *Almagest*, and more especially in his *De Analemmate* provided all the details of the science. Even after the destruction of the Library at Alexandria by the Moslems,

the remains of astronomical science were preserved by the astronomers of Baghdad; and, perhaps in lesser degree, in Byzantium. At any rate copies of Ptolemy's work remained after the destruction of the Alexandria library.

The Romans, however, had no use for sundials nor for equinoctial hours. Sundials which have been found in Rome and Pompeii were constructed for other latitudes, and were therefore useless as time pieces where they had been installed by the Romans. With the Romans "the sixth hour of the night" meant midnight; "the third hour of the night" the hour midway between sunset and midnight.

Of the methods of measuring time in this country prior to 1300 A.D., we know practically nothing. It is believed that the Anglo-Saxons divided "day" and "night" each into 8 equal periods; but we do not know whether these were "temporary" or "equinoctial" divisions of time. The somewhat legendary Alfred is said to have made candles for measuring intervals of time. It is possible, even probable, that the ordinary population relied on that instinctive knowledge of time, which animals possess; which indeed has not wholly been atrophied in man of to-day by our reliance on clocks and watches. Ecclesiologists cannot however tell us how priests of the Norman and early Plantaganet periods timed their "offices." Probably they used some form of time-piece, sand glasses or candles, for example, starting with a nebulously defined "dawn" as the zero hour of the day. It is, however, known that mechanical clocks were first introduced into this country towards the close of the 13th century. Thus we hear of a clock installed at Westminster in 1288, and of another at Canterbury in 1292. From this epoch, the consequential introduction of equinoctial hours necessarily followed; since clocks are designed only to indicate equal intervals of time.

In the Middle Ages, the general adoption and development of new inventions appear to have been very slow. For example, three centuries passed after the first use of cannon before the long bow and the cross bow were finally abandoned as infantry weapons. It is improbable that remote country parishes were provided with clocks much before the Reformation.

Later, evidence will be adduced in support of the generally accepted theory that scratch dials were used to indicate the time. Far less acceptable, however, is the usual assumption that they were used as time pieces. A Wireless signal from Greenwich is now given and used to indicate the correct Greenwich mean time, but such signals do not constitute time pieces in themselves. A clock, regulated by the time signal is necessary for the purpose of timing our actions. Similarly when a clock was first provided, some signal was required in order to know that the clock was keeping reasonably correct time.

In this climate a sundial must be a most inefficient timepiece. In the first place, at the best it can only indicate time during 12 hours, at the equinoxes. At midwinter, it can only register time during 8

hours of the 24. At midsummer, in the case of a vertical dial on a wall facing due South (the normal condition for a scratch dial) the sun will shine on the dial, in the latitude of Suffolk, from 7.20 a.m. to 4.40 p.m. In the second place, although we are not so wrapped in fog as foreigners think, yet there are numerous days, and many more part days, when the sun is obscured. A timepiece which only works spasmodically is almost worse than no timepiece at all.

From the first installation of clocks, however, until the installation of the electric telegraph brought Greenwich mean time to every village, a sundial did provide a crude method of checking clocks.*

Even if a nail was driven perpendicularly into a wall facing due S., and a plumbbob line drawn on the wall from the nail, the shadow of the nail would fall on that line at apparent noon. That however would not quite suffice. Although we usually get a spell of sunshine at some time during most days of the year, there is no guarantee that such a spell will occur at noon. Again noon may not have suited the Parish Priest as an hour for taking observations. If he knew the elementary laws of dialling, he would add a few more lines so that he might have the opportunity of checking his clock at other hours. Subsequent incumbents might add yet more lines; so that we should expect to find, as we actually do find, dials varying from some with only two or three incised radii to others which mark almost every half hour of the period from 6 a.m. to 6 p.m.

Clearly the disputable matter here is the suggestion that a Parish Priest did know the elements of dialling. The assumption is not necessary in quite that form. In the monastic orders, there must have been friars, as early as 1300 A.D., who had travelled to Byzantium and there imbibed the ancient lore of sundialling. Indeed, clearly, sundials in some form must have been installed by that date at Westminster and at Canterbury, in order to check the clocks installed. If, as seems probable, parish clocks had not been installed in the remote parishes before the Tudor period, any difficulty in assuming a knowledge of sundialling disappears: for by that epoch sundials were common; the works of Ptolemy had been translated and published; and "gnomonics" may well have been one of the studies at Universities.

Moreover, it is not necessary in any case to assume that the calibration of a sundial was carried out by the solution of spherical triangles, now a matter of elementary mathematics, but then requiring the use of some geometrical instrument similar to Ptolemy's analemma or some complex computations.

*The "crudity" lies in the difference between the "mean time" necessarily kept by a clock, and the "apparent time" kept by the sun. Under the best system of co-ordination of these two "times," mean noon, i.e. noon by the clock, must swing about 15 minutes each side of apparent noon, i.e. the hour when the sun is due South. It is, however, quite improbable that anyone would have been troubled by a difference of 15 minutes between the clock and the dial.

It was of course necessary to know that the gnomon must be fixed in the meridional plane, a quite simple construction in the case of a Church oriented E—W ; and that the style must be directed to the N. Pole of the heavens. Evidence is adduced later (*v.* Parham, *inf.*) which appears to show that the style employed probably took the form of an iron rod, about 1/6″ diam. at its point of fixture, and possibly widening towards its outer end. Calibration of the dial could have been executed empirically : that is to say if the constructor desired to indicate the 9 a.m. radius, he would observe the clock time when the shadow of the style fell on the vertical line (i.e. Sun noon) : 21 hours later by the clock he would mark the position of the shadow on the dial.

An attempt has been made above to offer, in accordance with the principle laid down many centuries ago, the simplest explanation consistent with the evidence as regards the problems of *why* sundials were constructed and *how* their calibration was effected. The answer to " *when* were sundials constructed ? " must clearly be : when the church clock concerned was installed ; the determination of the precise date of that event must be left to ecclesiologists. The answers given to the queries enunciated postulate acceptance of the theory, which may be regarded indeed as axiomatic, that many, if not most of these scratch dials were used at one time as sundials. Before proceeding to analyse any examples, however, it is necessary to advert to certain features which are not, *prima facie*, consonant with this accepted hypothesis.

(1) In a number of cases, one quadrant of the dial is calibrated to show angles with the vertical of 0°, 15°, 30°, 45°, 60°, 75°, 90°. Now these angles appear to indicate the knowledge that the Earth rotates on its axis at the rate of 15° hourly. But why show them on the dial ? To indicate that the hours measured by the sundial are equinoctial ? Surely a work of supererogation. To indicate the calibration which must be given to an equatorial sundial ? But such dials, although very simple do not appear to have been in vogue.*

(2) In a few cases the dials have no central hole ; that is to say, no sign of the fixation of a gnomon. Possibly a portable gnomon was employed, when it was desired to ascertain apparent time from such dials.

(3) In a number of cases, some radii are inscribed in the upper quadrants. Clearly the shadow of a gnomon cannot fall above the horizontal line, unless the gnomon is bent upwards from its pivot ; a most improbable arrangement.

Mr. Green (*Sundials, Incised Dials or Mass Clocks*) has animadverted, perhaps somewhat laboriously, against theories based on the hypothesis

*An equatorial dial consists of a dial perpendicular to the style, which as always, must be fixed parallel to the earth's axis. The dial will then be parallel to the equator. On it the shadow of the style will move through 15° hourly ; on the upper side in the summer half year ; on the lower side in the winter half year.

that the gnomon consisted of a pin driven perpendicularly to the surface of the wall, and that the inscribed lines represent the position of the shadow of that pin at a fixed hour for Mass, such as 9 a.m., at different seasons of the year. The unreliability of any form of sundialling in this climate as a guide to the hour of an action has been discussed above. These theories, further, in order to explain all the inscribed lines, even in the lower quadrants, require the assumption of 3 fixed hours such as 9 a.m., noon, and 3 p.m. They are in fact complex explanations, necessitated only by the assumption that the constructors of sun dials did not know that the style should point to the N. Pole of the heavens. This assumption is quite unwarranted, even if we superimpose another unwarranted assumption, namely that these dials were used as sun-dials before the Tudor period. There is ample evidence that scientists, for at least the last 4,500 years have been able to determine the position of the N. Pole of the heavens with reasonable accuracy, even at such a period as the 1st millenium B.C., when no bright star was within 6° or 7° of the Pole. In the Tudor period, with the present Pole Star 3° from the Pole, mariners determined latitudes with reasonable accuracy.*

The factual evidence inherent in these scratch dials is presented by Mr. Green in his work, as regards both quantity and quality, in a manner which cannot be too highly commended as an example of scientific labour and accuracy. In addition to numerous descriptions he has given half-tone photographs of nearly 90 dials ; comparison of these with his tracings shows that these photos were taken in such a manner as to avoid any appreciable photographic distortion of the angles : so that the angles can actually be read from the photographs, if so desired. He has further given tracings of 35 of these dials. 19 of these tracings are of dials on walls facing due South.

In Table I are given the graduations of ten dials on walls facing due South, taken from Mr. Green's collection. His figures have been changed so as to give the angles read by him on either side of the vertical line. In Col. 2 are given the correct graduations for a vertical sundial on a South facing wall in latitude 51° (the mean latitude for the Hampshire dials).

In Table II similar figures are given for some Suffolk dials, the mean latitude being taken as 52°10′. These were taken in most cases, with a celluloid protractor, direct from the dials. In consequence the same degree of reliability cannot be claimed as for the readings taken by Mr. Green from his photos and tracings.

These tracings show clearly a fact well known to any student of Suffolk dials, namely, that the radii are often blurred, and even crooked ; so that it is not possible in most cases to determine within one degree either way what graduation was originally intended. We may reason-

*It is worthy of note, when considering the astronomical science of our forefathers, that some churches (e.g. Orford) which have been rebuilt on Norman foundations, are nevertheless oriented E—W with considerable accuracy. It must be inferred that the Normans were able to determine accurately the position of the North celestial pole.

ably assume a small inaccuracy in inscribing the line of the gnomon shadow. In consequence a reading within 2° of the correct graduation may perhaps be taken as correct sundialling. That many of these dials were used as sundials is clearly evidenced by the remains of the tangs of the gnomons which are still extant in a number of cases : even where these have now disappeared, holes often remain which appear to have held these fixtures.

PARHAM.

The dial here is a veritable sundial.

The face is rectangular, and exhibits the correct shadow lines for hours from 6 a.m. to 6 p.m. The hours round noon are numbered in Roman figures, the outer hours in Arabic figures, thus : I, II, III, 4, 5, 6. The Arabic figured hours may represent later additions to the dial.

The stump of the original style is still extant—it consists of a wire, about 1/6″ to ¼″ in diameter, driven into the ashlar at about the correct angle (38° with face) : no doubt it was bent a little at the surface of the stone to give the exact " set." From the condition of the stump, it may be inferred that it is of almost pure wrought iron ; since there is little sign of rust. It may have increased in diameter outwards, as in the case of the still extant sundial on Aldeburgh Moot Hall, of reputed date 1650.

We must now consider those facts which are inconsistent with the sundial theory. Some minor matters are :—

(i) Many dials lie only about four feet from the ground. We might reasonably have expected the constructor of a sundial to place it somewhat above eye level, in order to preserve the gnomon from chance knocks by persons passing about the churchyard.

(ii) A considerable number are very small, 3 to 4 inches in diameter.

(iii) In some cases there is no gnomon hole ; nor, moreover, any filled-in hole.

More serious consideration must be given to the next two matters :—

(iv) The presence of " radii " in the upper quadrants.

(v) In the cases cited of dials on South-facing walls, it will be noted that the majority of graduations fall within the 2°, demanded as a " margin of indetermination," of the correct shadow angles. In most of the cases cited however there are one or two cases of graduations which are 3° or 4° from any correct shadow angle for hours and half hours. These have been italicised in the Tables. Any suggestion that a single quarter hour graduation was intended must be regarded as an attempt to force the facts to fit the theory. In particular, in Table I will be noted the persistence of a graduation of 61°—62°. In Table II there is a corresponding graduation of 58°—60°. Other inconsistent graduations are about 17°, 36°, 51°, 71°.

A possible explanation of all these inconsistencies may be afforded by the theory that the majority of these scratch dials as we now find

them constitute in fact palimpsests. This theory is moreover consistent with the theory of many ecclesiologists that the dials date from the construction of the church itself. Briefly this theory is that the original dials were made by the masons who built the church, and at a later date were adapted as sundials. This would, further, explain the crooked radii as attempts by the sundial constructor to amend a graduation which did not quite fit with the shadow angle, by working it over. It is also consistent with the fact clearly evidenced in Mr. Green's tracings that in most dials some of the radii emanate from different centres.

It is unnecessary no doubt to remind readers that from time immemorial, as far back certainly as the construction of the Pyramids of Egypt, masons have recorded dates and less intelligible marks on their work. It is perhaps less commonly known that they still use, in Malta, the face of a wall to construct working drawings of spiral staircases. The design of the tracery of a Gothic window requires setting off certain angles in order to produce what architects call "the element of the tracery." The master builder would inevitably draw these angles on any available dressed surface, such as ashlar quoins. Tracery varied, and Gothic windows also varied from the Lancet arch to the depressed arch. In the case of the equilateral arch with two mullions, an angle of 50° 29′ drawn from the springing of the arch, to the centre line defines the centre of curvature of the upper quatrefoil. Other angles define other critical points in ordinary tracery.

Having in view, however, the impossibility of accuracy in determining now the angle intended, it would be futile to pursue this hypothesis in detail. It is improbable that even laborious comparison of the dial angles with the elements of tracery of the windows of the particular church concerned would enable the hypothesis to be proved or disproved. We do not know now how the master builders of the 13th and 14th centuries carried out their geometric computations. It can only be observed that such computations must have been made; that they would have taken a geometric form; and that they would naturally have been recorded on dressed stones of the edifice by the master builder for the guidance of his masons. Moreover it will be clear that such records would sometimes involve the use of all four quadrants. It would be strange to the verge of the miraculous if some of the masons' angles did not approximate to some of the correct shadow angles of the 24 half-hours between 6 a.m. and 6 p.m. Mr. Green hypothesises that the dials were intended to represent divisions of the lower quadrants into the series 15°, 30°, 45°, etc., where each angle is one-sixth of a right-angle.

There is no doubt that some quadrants are so divided. His hypothesis would however be facilitated by remembering that the right angle is not the only angle which may be so divided. A fundamental angle is the unit of circular measure, whose arc equals the radius. This angle is clearly $360° \div 2\pi$ (approx.) 57°.3. Simple fractions of this angle will produce angles which approximate to the correct sundial angles, and

to the angles noted as inconsistent with sundialling, especially when we use our option to read the recorded angles from the vertical, or from the horizontal.

Table III will illustrate this remark: the angles in this table are expressed in degrees and decimals.

This Table of course represents the ease with which figures may be juggled. It is introduced merely to show by comparison with Tables I and II, that it is easy to hypothesise a mason's dial which could readily be adapted to the purpose of a vertical sundial; and would moreover then leave radii corresponding to those on the scratch dials which are inconsistent with sundial radii.

I have refrained from consideration of dials on walls which do not face due South, because such consideration involves further complexities in the comparison of the actual graduations with possible gnomon shadows. In general, however, the conclusions are similar; the dials may conceivably have been used in some way as sundials, but the inconsistencies are as marked, or even more so, as in the case of South-facing dials. Here also, in consequence, some additional hypothesis is required in order to explain all the graduations.

Reference must however be made to a dial recorded by Mr. Green at Chaddesley Corbett, No. 3, on a wall facing S.10 E, with graduations marked with Roman figures; of the hours presumably. At first sight this is obviously a sundial. Consideration of the angles made by the radii shows however that under no conceivable conditions can these radii have represented the hours indicated on a vertical dial. Mr. Green's photos and tracing show that the dial is on two stones; the joint being marked XII. The radii emanate from a centre below the (presumed) gnomon hole. The lines marked *VI—VI* are above the horizontal. It is in consequence not easy to determine the angles within 2°; but those given below are as read by Mr. Green :—

W. Quadrant.		E. Quadrant.	
Figure.	From vertical.	Figure.	From vertical.
IV	90°	IV	92°(?)
?	76°	V	79°
IIIV	64°	IIII	65°
IX	49°	III	50°
X	36°	II	36°
XI	16°	I	19°

Clearly if this dial was constructed after the stones were placed in the present position, the gnomon must have been constructed correctly: for only in that case would the noon shadow fall vertically on a dial facing S.10 E. In that case however the remaining radii do not even remotely represent the positions of the shadow at the hours indicated. Alternatively if the stones have been removed from some other derelict wall, which did face due South, it will be difficult, apparently indeed impossible, to find some erroneous arrangement of the gnomon which

would give the radii inscribed at any season of the year. If however a horizontal dial be constructed, with a vertical style, then in the latitude of Chaddesley Corbett (52°.20′), the shadow of this style will fall, at the equinoxes, on lines 19°, 36°, 50°, 65°, 79°, from the line pointing due *North*, at 1, 2, 3, 4, and 5 hours respectively before and after noon.

This coincidence is too marked to be accidental. It must be inferred that these two stones did form part of a horizontal dial constructed as hypothesised; and that they were subsequently used in the construction of the 14th century church wall. In the course of building the wall, the stone now on the West appears to have been redressed, and to have lost its relative position to the extent of about 2°. If this inference is correct, the Roman figures clearly cannot have been on the original horizontal dial: for the order of the hours is inverted; since the present W. quadrant must have been the N.E. quadrant in such an horizontal dial.

This dial provides, in any case, an object lesson which evidences that there can be no unique solution of the problem.

The general conclusion may be that the majority of these dials were originally constructed for purposes other than sundialling; but were subsequently adapted for use as such, when the necessity arose for a check on the church clock.

TABLE I.

HAMPSHIRE DIALS read by Mr. A. R. GREEN.

Hour Apparent Time	Correct angle of shadow Lat: 51°	Bramley	Bramley	Burghclere	Burghclere	South Hayling	Sherborne St. John	Sherborne St. John	Stoke Charity	Stoke Charity	Timsbury
	° ′	°	°	°	°	°	°	°	°	°	°
6.30	78.11										
7.00	66.56		68		*70*	*62*	*64*	*62*	*62*	*69*	*62*
7.30	56.39			58							
8.00	47.28	46	47		46				49		
8.30	39.21			*36*		39	41				41
9.00	32.11	31	31					32	34	34	
9.30	25.46				28		27				
10.00	19.58										
10.30	14.37	15	14			16			12		16
11.00	9.34				7						
12.00	0										
1.00	9.34		7								
1.30	14.37	15									
2.00	19.58		*17*								
2.30	25.46				25	26				26	
3.00	32.11		30				31	30			
3.30	39.21	38								41	
4.00	47.28	50	*51*		45						
4.30	56.39									57	
5.00	66.56		68		65	65	*62*	*61*			
5.30	78.11					77					

TABLE II.

SUFFOLK DIALS.

Hour Apparent Time	Shadow angles Lat: 52° 10′	Parham (1)	Tunstall (2)	Orford	Iken (3)	Cratfield	Dennington	Ubbeston
	° ′	°	°	°	°	°	°	°
6.30	77.53		77	76				
7.00	66.24		*61*	64			*70*	
7.30	55.58					57		55
8.00	46.44		48	48			48	
8.30	38.38				38	40		
9.00	31.31		30	33				*35*
9.30	25.12		26					
10.00	19.30			18	21	20		
10.30	14.15		14					15
11.00	9.20							
12.00	0							
1.00	9.20	10			11			10
1.30	14.15			14				
2.00	19.30	21	19					
2.30	25.12							
3.00	31.31	34	33	34				31
3.30	38.38						40	
4.00	46.44	48	48		44	*42*		
4.30	55.58				57			
5.00	66.24	66	*61*					
5.30	77.53		76					

NOTES.

(1) Radii for morning hours too worn for accurate reading of angles.
(2) Radii in W. upper quadrant, read from vertical: 21°, 39°, 61°.
Radii in E. upper quadrant, read from vertical: 20° 35°, 55°, 68°.
(3) Radii in W. upper quadrant, read from vertical: 69°, 80°

TABLE III.

CIRCULAR MEASURE (UNIT 57.°3).

Angle.	Set off from vertical.	Set off from horizontal, read from vertical.
	°	°
1/8	7.2	82.8
1/6	9.5	80.5
1/4	14.3	75.7
1/3	19.1	70.9
1/2	28.1	61.9
2/3	38.2	51.8
3/4	42.4	47.6
5/6	47.8	42.2
1	57.3	32.7

NOTE. The angles shown in this table should be compared with the angles actually shown on scratch dials.