ROBERT STIKFORD'S 'DE UMBRIS VERSIS ET EXTENSIS'

JOHN DAVIS

The manner by which 'scientific' sundials, designed for the local latitude and indicating time in equal-hours, were introduced into Europe in the early 15th century is a continued subject of debate. These dials gradually replaced the earlier Saxon and mass dials with their horizontal gnomons which showed unequal (temporary) hours but took no account of latitude.

The oldest extant scientific dial in the world with a polar-aligned gnomon is the one by Ibn al Shatir in Damascus, made in 1371.[1] Islamic dials showing equal hours date to well before this time, although they normally used a point nodus rather than a polar-aligned gnomon. King[2] states that the earliest explicit reference to a pole-style gnomon is by the Mamluk author Sibt al-Maridini who flourished in Cairo c.1460. The material in this treatise was not original and clearly the invention must have been earlier, though perhaps not by such a long time period as might be suggested by centuries of dial history in the Islamic world.

In Europe, these 'scientific' dials – termed 'modern' by Zinner[3] because they are the type still common – were reasonably well known in manuscripts of the mid-fifteenth century, as well as by a handful of extant examples.[4] But although it seems reasonable to suppose that the knowledge of how to design a scientific dial reached Europe by diffusion from the Islamic world, there is remarkably little evidence of this and it is still possible that the method was re-invented in Europe. The majority of the European manuscripts of the period describing how to design a dial – either horizontal or vertical – are very similar and quite short, using a geometrical method for producing the layout. This is in contrast to a typical Islamic text which is much more involved and uses detailed tabulated values to draw up their complex dials. The European manuscripts are clearly related to each other as scribes in the scriptoria of monasteries across Europe copied and recopied basic texts. This raises the questions: where did the original texts come from and what were they based on?

John Whethamstede

John Whethamstede (c.1392–1465) was abbot of the monastery of St Albans for two spells, 1420–40 and 1451–65.[5] This is the post which had earlier been occupied by Richard of Wallingford (?1292-?1336), builder of the famous St Albans astronomical clock, inventor of the *Albion* and perhaps the most accomplished English astronomer and instrument maker of the Middle Ages.[6] Both Whethamstede and Richard Wallingford had strong connections with Oxford, only 35 miles away and home of the 'Merton Calculators' at Merton College, responsible for the leading astronomical and calendrical research of the 14th century.[7] Whethamstede was not himself an astronomer but his writings indicate that he was interested in the subject and in the work of his illustrious forebears at the Abbey. His major legacy to history is a codex called the *Granarium* (a play on his name) originally written c.1430 and which was a compendium or encyclopedia of the knowledge of the time, drawing on the information in the extensive library at St Albans.[8] Various partial copies of this manuscript still exist, e.g. British Library MS Cotton Nero C VI part 1. Part of its contents is devoted to listing the inventors of a very wide range of items, including libraries, making fire and trousers (!) as well as various technologies such as the plough. In the key section on astronomy and astronomical instruments, Whethamstede draws on his own knowledge as well as that from the St Albans library when he writes on sundials:

> *Figuram in plano pariete, que docet per umbras horas diei certitudinaliter agnoscere, adinvenit primitus, quo ad horas inequales, Albategni secundum aliquos, Arzachel vero secundum alios; quo ad horas vero equales, adinvenit illam primitus monachus monasterii Albanensis, qui apud suos Robertus Stikford fuerat nuncupatus*
>
> [It was originally Albategni, according to some, or according to others, Arzachel, who invented the figure on the vertical wall which showed how to recognise accurately from the shadows the unequal hours of the day. With regard to the true equal hours, the first inventor was a monk of the monastery of St Alban, known amongst his colleagues as Robert Stikford.]

Thus, having attributed the design of sundials showing the old unequal hours to either Albategni (c.858-929), the famous Islamic astronomer better known as Al-Battani, or to Azarchel (1029-1087), the leading instrument-maker from Muslem Spain, he says that the dial for equal hours was invented by a monk from his own abbey, Robert Stikford. This is a very bold claim which must be treated cautiously as there are no other sources to support it and it could well be that this Stikford, not previously known to the world of science history – he appears only as a footnote in North's work on Richard of Wallingford – merely copied the information from an earlier source. Nevertheless, it is extremely important as it shows that there was knowledge of equal hour sundials in England before 1430. Whethamstede was clearly aware of Arab astronomy yet did not know of their pole-style dials.

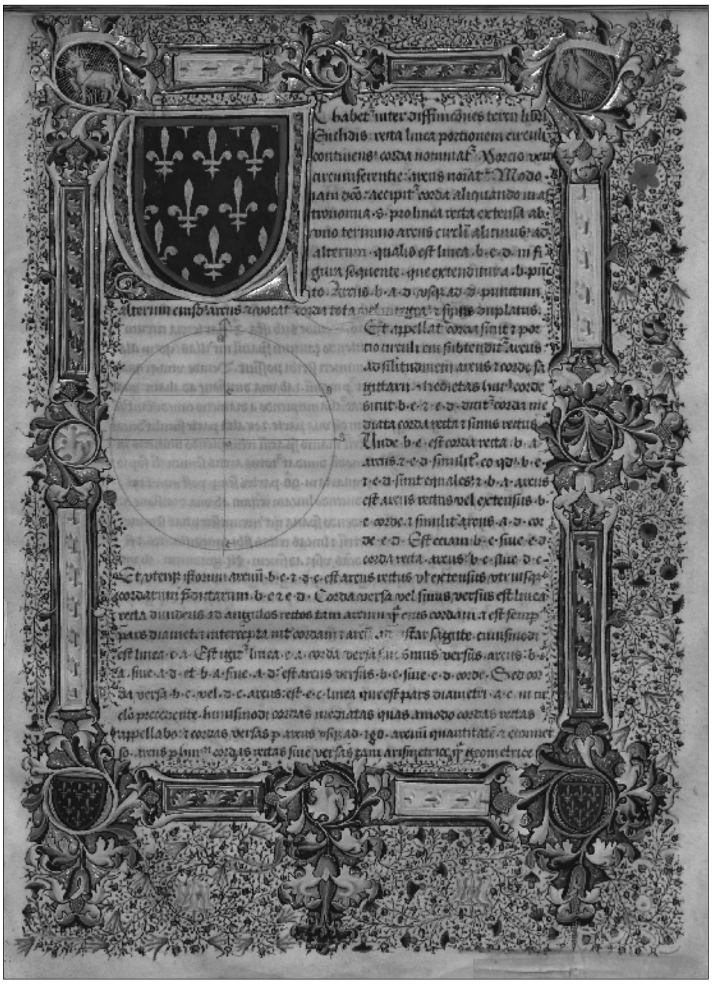


Fig. 1. The beautifully-illuminated first page of the Biblioteca Ambrosiana copy of Stikford's 'De Umbris...'. *Ambr. & 201 bis sup, f.80r. © Biblioteca Ambrosiana, Milan.*

Robert Stikford

Robert[us] Stikford[e] is mentioned four times in the roughly contemporary *Gesta Abbatum*[9] for St Albans over the period 1396–1401 where he is described as the *tertius prior* in lists amongst many other monks. This relatively senior position in an establishment of around a hundred monks suggests that he was not a young man at that time.[10] His origins are unknown though it is noted that there is a village of Stickford near Boston in Lincolnshire with a 13th century church.

His work was unknown to history until quite recently (2005) when a previously-overlooked manuscript in the Biblioteca Ambosiana in Milan was discovered. The manuscript,[11] which is described in general outline by Anna Bellettini,[12] includes a treatise called *De Umbris Versis et Extensis* (roughly 'On the motion of shadows', and shortened to *De Umbris* in this article) by Robert Stikford. It seems to be a copy of a large astronomical codex which was given by Whethamstede to the Duke of Bedford around 1430. John, Duke of Bedford (1389-1435) was the third son of King Henry IV and brother of Henry V. He was Regent of France (Governor of Normandy 1422-32) under his nephew, Henry VI, and an important commisioner of illustrated manuscripts. He is known to have visited St Albans in June 1426 and thus Whethamstede, as an abbot seeking political favours for his establishment, promised to have a copy of an astronomical codex prepared for him and it seems this included Stikford's *De Umbris*.[13] Whethamstede later regretted the high cost of the book.

The manuscript is not an autograph one so we do not know when Stikford's original, which is presumed lost, was written. The best guess must be in the period 1396–1401 for which we have evidence of his existence but clearly it must be before 1426 and thus earlier than the simple dialling manuscripts described above. Thus Stikford is exactly contemporary with Geoffrey Chaucer whose *Treatise on the Astrolabe* was written in the early 1390s. Whereas Chaucer wrote in English, Stikford used the standard Latin of the academic and monastic world.

In contrast to the rather short (one or two folios only) dialling manuscripts of the mid-fifteenth century which are relatively common, Stikford's treatise is quite extensive at 28 double-sided folios. The Ambrosiana copy is a high-quality production, with illuminated capitals and wonderfully controlled calligraphy, again in contrast to the scrawling run-of-the-mill dialling manuscripts half a century later.

A key passage of the *De Umbris* (f. 86r) reads:

> *Nos autem ad presens principaliter intendimus scribere quod nos cum labore, Deo - cui gratias - inquisicionem nostram ad propositi nostri methodum dirigente, per racionem invenimus, videlicet qualiter superficiebus planis perpendiculariter super circulum emisperii elevatis et immobiliter situatis ad latitudinem 51 graduum et 50 minutorum, que dicitur esse ville Oxonie latitudo, hore equales a meridie vel media nocte possint cognosci per umbras.*
>
> ['However, we now in the first place intend to write what with difficulty we (God, to whom thanks, directing our enquiry into our proposed method) have found by reasoning, that is to say just as a flat surface raised perpendicularly above the circumference of the hemisphere and immovably placed at latitude 51 degrees and 50 minutes, which is said to be the latitude of the city of Oxford,[14] so the hours from midday or from midnight can be seen to be equal by their shadows']

This clearly shows that Stikford himself thinks that the method is novel and also that he is designing a dial for the latitude of Oxford.

De Umbris Versis et Extensis

A full transcription, translation and interpretation of Stikford's masterwork is currently being produced.[15] Some key features have already emerged and will be discussed here.

The opening page, shown in Fig. 1, begins with the basics, giving the key elements of geometry from Euclid which are required for dialling. Stikford fills twelve folios with text and diagrams showing the geometric constructions needed to construct the various non-linear (trigonometric) scales for projecting the position of a shadow.

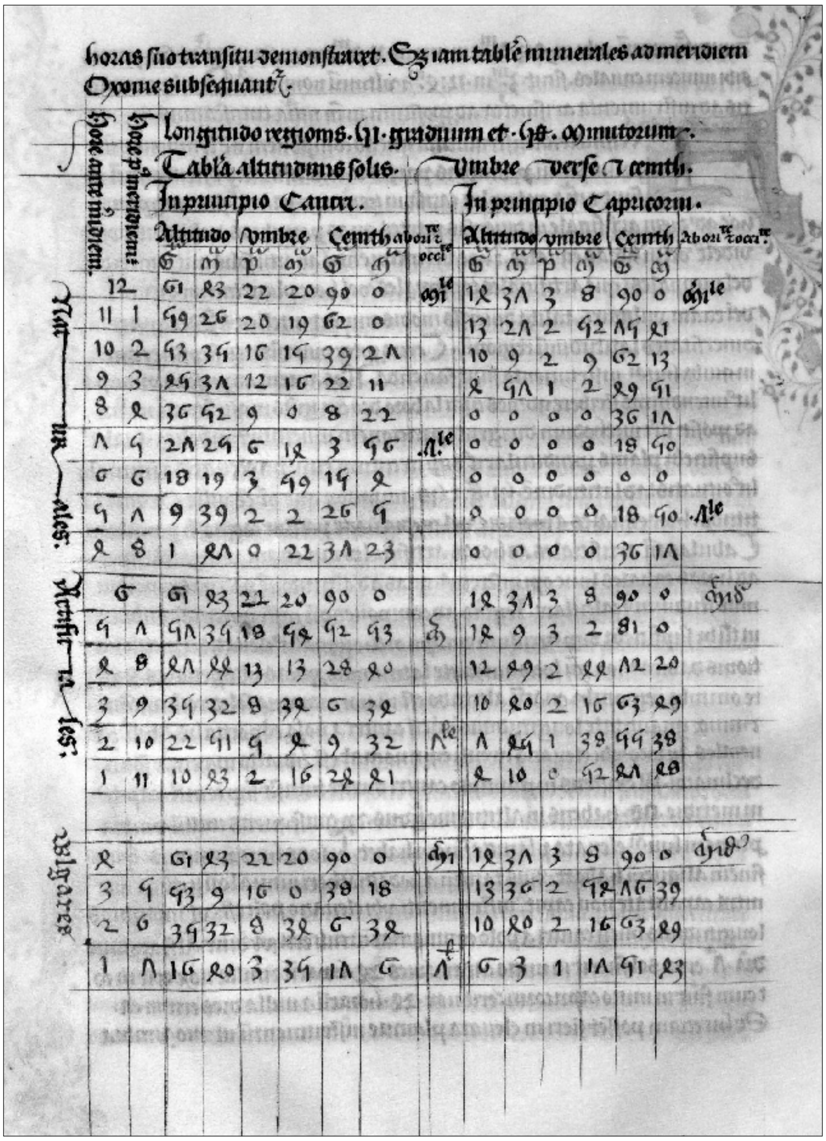


Fig. 2. The table of shadow positions in Ambr. & 201 bis sup, f.86v. © Biblioteca Ambrosiana.

It is interesting that Stikford uses the word '*sciotherum*' (originally from ancient Greek) to mean gnomon, although it becomes clear later that this is a horizontal gnomon in which it is only the tip which casts the time-indicating shadow. As is common to many medieval treatises, the length of the gnomon is reckoned as 12 units.

After the folios of basic geometry, Stikford sets about calculating the directions of the sun and a shadow at various times of the day and for different occasions during the year. The result is a table (Fig. 2), headed *iam tabule numerales ad meridiem Oxonie subsequantur* [A table of solar values for the latitude of Oxford follow]. The table gives values of three parameters:

- *altitudo* : the Sun's altitude in degrees and arcminutes.
- *cenith* : the Sun's azimuth in degrees and minutes but measured from the E or W points. The word 'cenith' (Chaucer uses *cenyth*) might suggest a translation to 'zenith' but it actually derives from the Arabic for 'direction'.
- *umbre* : the vertical position of the shadow cast by the tip of a horizontal gnomon, of length 12 units, in units and 1/60th unit. Whilst the word *umbre* clearly means 'shadow', its use with this specific technical meaning of distance is unusual.

The values are given in two vertical blocks, for the beginning of Cancer (the summer solstice) and for the beginning of Capicorn (the winter solstice). No values are given for the equinoxes. The table is then divided into three horizontal blocks, for different types of hour. The first, labelled on the left for the *hora Naturales*, run 4-12-8 and are clearly the equal or modern hours. The second block is for the *hora Artificiales*, running [0]-6-[12] and which are thus the unequal or temporary hours, counted from sunrise to sunset. Finally, the *hora Vulgares*, (common hours) run [0]-4-[8] are best described as the octaval system normally seen on Saxon dials and some mass dials. Each of these hour systems is well-known to diallists, though not necessarily with these names. The common terms are *æquales* or *æquinoctales* for the equal hours and *horæ inequales* or *temporales* for unequal hours.[16] But the use of the terms 'artificial' and 'vulgar' hours can be found in the calendars of Nicholas of Lynn (*fl.* 1386–1411).[17] What is surprising, though, is that clearly the three systems are coexisting at the end of the 14th century. The general understanding has been that equal hours gradually took over from unequal hours during the 15th century but here we see that the old Saxon system is still hanging on as well, probably used more outside the environs of the monastery and university. It must have been most confusing.

The calculations used for the values in the table can be run backwards to derive the value of the obliquity of the ecliptic that Stikford has used. A value of 23° 33′ is obtained, suggesting that Stikford has consulted a version of the Alfonsine tables as earlier works of Al Battani (Albategni) and Al Farghani (Alfaginus, mid-9th century), both of whom he quotes elsewhere in *De Umbris*, are associated with a value of 23° 35′.[18] The calculations of the sun's altitude to individual minutes parallels the calendars of Nicholas of Lynn who produced values for each equal hour of every day of the year.[19] Whereas Nicholas also calculated the horizontal shadow length (in feet and sixtieths) for a man 6-feet tall, Stikford has the vertical distance of the shadow from a horizontal gnomon. It seems possible, even likely, that there was contact between Nicholas and Stikford given the closeness of their dates and that the former was at Oxford at exactly that time.

One other noteworthy feature of the table is the use of a sexagesimal system for lengths as well as for angles, and of the use of a basic length of 12 units (representing a foot of 12 inches?). This was standard practice for the time and results in a higher level of precision than is strictly necessary for a sundial.

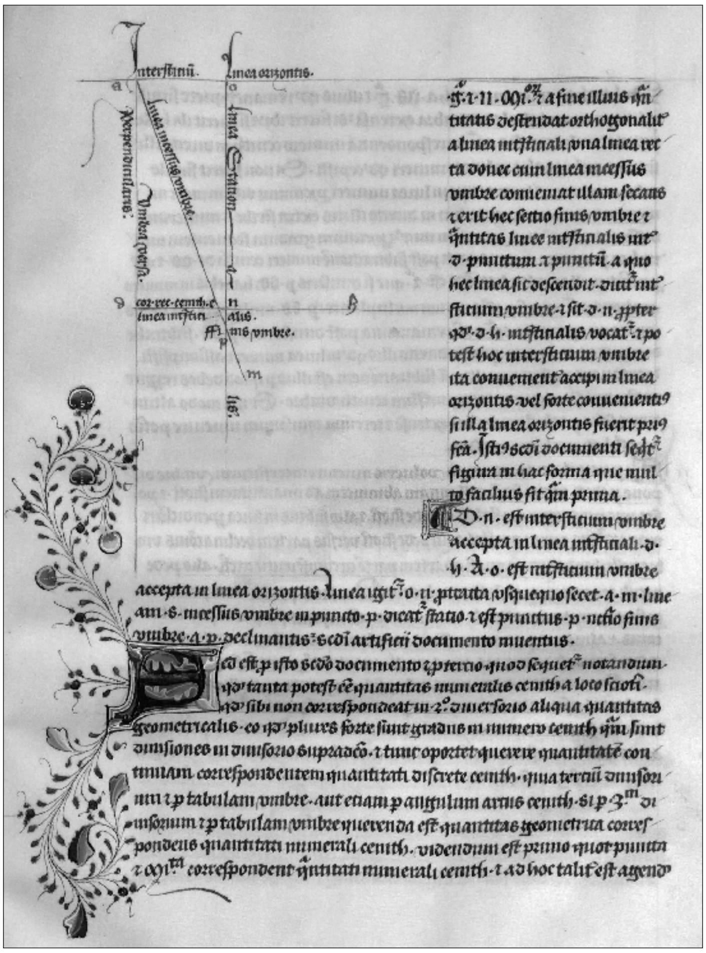


Fig. 3. A typical page of from 'De Umbris...'*, Ambr. & 201 bis sup, f.93r. © Biblioteca Ambrosiana, Milan.*

Stikford then sets about using these solar values to calculate the lines of vertical sundials. A typical folio is shown in Fig. 3. After many folios, his results are displayed by five example designs; direct east and west, together with declining dials and, finally, a direct south dial (Fig. 4). The first drawing is introduced with the text:

> *Iuxta canones predictos sequuntur hic figure exemplares tam ad plagas orizontales rectas quam eciam ad declives seu ab ipsis veris punctis orizontalibus declinantes*

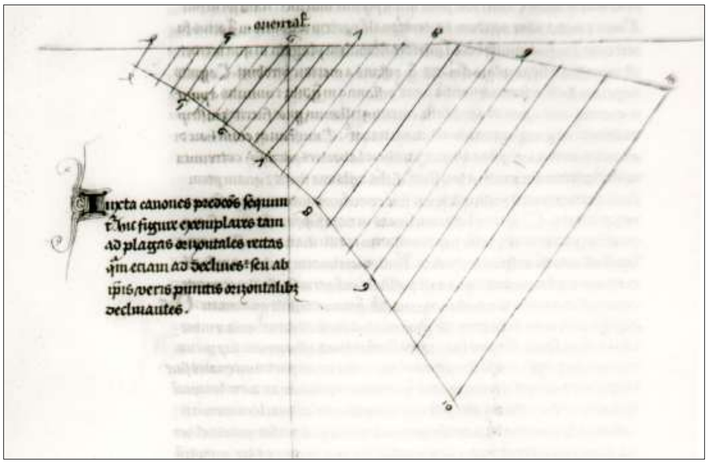
The production quality of these drawings is significantly poorer than the geometric diagrams earlier in the text, probably indicating that they were drawn by another hand – perhaps a mathematician rather than a full-time scribe. Nevertheless, the dials are fascinating as they may well be the earliest scientifically-delineated equal-hour dials in Europe. The two declining dials appear to be for SW and SE walls although this is not specifically stated. What is significant though is that at this very early date in European scientific dials the relatively difficult calculations for a declining dial have been attempted at all: the vast majority of surviving early dials are all direct S.

The method by which the dials have been drawn is clearly discernable. The position of the shadow of the tip of the gnomon has been plotted, for each equal hour, at the summer and winter solstices and these have been joined by straight hour-lines. Declination lines for the two solstices have been drawn, piecewise linear, from the ends of the hour-lines. Each hour has been divided into three parts by intermediate hour-lines, probably by trial-and-error with the dividers. These lines thus represent 20 minute periods, also known as a mile-way in this Chaucerian period.[20] The division of the hour into thirds seems to have been quite common at this time.

The position of the gnomon and its length are surprisingly not shown on the drawings and must be found by the user. It is clear that this is a theoretical study and not an instruction manual for making a real dial. The realization that extending the hourlines backwards to a common origin, and then stretching a string from this point to the tip of the gnomon seems to have been missed, though it was tantalizingly close.

Conclusion

Stikford's treatise strongly indicates that the earliest scientific dials in Europe were not very simple ones with polar-aligned gnomons and on vertical south walls, as would be suggested by the extant mid-fifteenth-century examples found on a few church walls in continental Europe. Instead, rather more sophisticated designs were available in England around half a century earlier. We do not know how far this



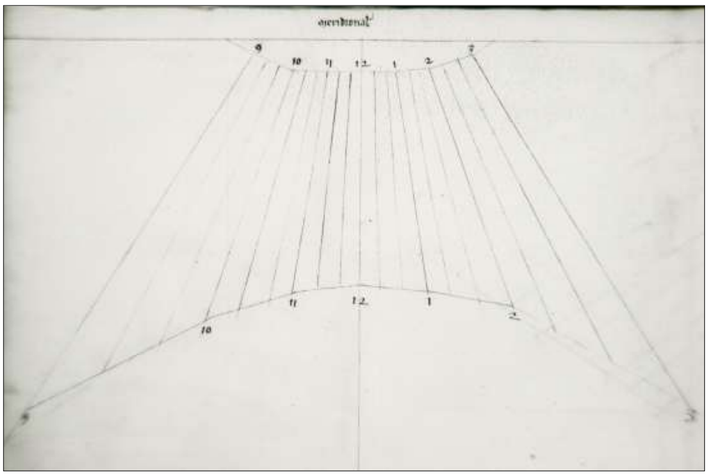


Fig. 4. The final dial designs at the end of De Umbris, (a) a direct E dial at f. 103v and (b) a direct S dial at f.104r. Ambr. & 201 bis sup. © Biblioteca Ambrosiana, Milan.

knowledge spread from St Albans and how many actual dials were made but, given the tightly-connected monastic links of the time, it is likely that the information became known within a few decades. The belief that simple always predates complex in the world of technology is a common fallacy: in the clock world, complicated astronomical clocks were around for some time before the one-handed church clock became common.

The step in Europe from the equal-hour scientific dial with a nodus and declination lines to one with a polar-aligned gnomon passing through the nodus point still eludes us. It might be that, once a Stikford-design was seen in action, the possibility of a polar-pointing rod gnomon became obvious. Certainly, it happened within a few decades, if not more quickly.

The degree to which Stickford's work is novel, and the debt which he owed to earlier Islamic work, is not completely clear. The only two Arab mathematicians that he quotes (Alfaganus and Albategni) lived several centuries before him and, although Alfaganus is believed to have written on sundials, he did so in a period well before the development of the polar-aligned gnomon: although his *Elements of astronomy on the celestial motions* was translated into Latin in the 12th century his work on sundials seems to be lost. Thus it seems that Stikford worked out the theory for himself, perhaps by extending the shadow-length tables of Nicholas of Lynn.

ACKNOWLEDGEMENTS

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14. The actual latitude of Oxford is 51° 45.2′ N. The value of 51° 50′ seems to have been derived by William Rede (d.1385) of Merton College and was common in many medieval MSS.
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19. See North, *op.cit*. (ref 16) pp. 89 & 106 for samples of Nicholas Lynn's tables.
20. See North, *op. cit.* (ref 16) p.47 for a discussion on Chaucer's use of the mileway.

For a CV of the author, see *Bulletin* 23(ii) p.13.