THE CHETWODE QUADRANT
A Medieval Unequal-Hour Instrument

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This article is an extended version of one which was originally written for *The Searcher* (May 2015), a monthly magazine for metal detectorists. It describes a quadrant found near Chetwode, Buckinghamshire, in October 2014 by the amateur metal detectorist Simon Neal of Oxford.

The quadrant (Fig. 1) found by the detectorist Simon Neal might not, at first sight, look particularly exciting as it is small (radius of 51 mm and thickness of about 1 mm) and has only a simple set of lines on it. But it is this very simplicity, added to its rarity and the fact that the numerals are clearly in a late-medieval script, that are the clue to its importance as an early time-keeping instrument.

Fig. 1. The Chetwode quadrant. Photo © Simon Neal.

The device is of a general type known as an horary quadrant and it is delineated to indicate the time in the old 'unequal hour' (or 'seasonal hour') scheme in which the time from sunrise to sunset is divided up into twelve 'hours', which will be longer in the summer than in the winter. Noon, in the middle of the day, will be at the end of the sixth hour. The night-time was also divided up into twelve hours, counting from sunset, but only at the equinoxes were the daytime and night-time hours of equal duration. This scheme seems very strange to us today but it has many practical advantages in a society where work was ruled by the availability of daylight and thus this scheme was the one most commonly used by the general population throughout the late Middle Ages.

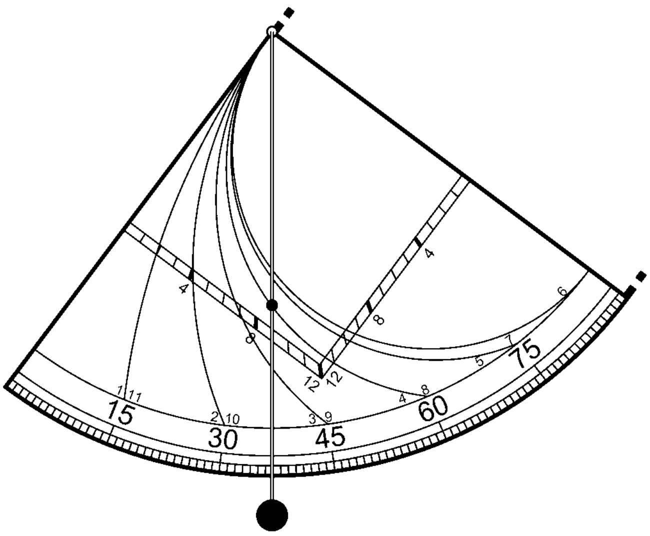

Fig. 2. Schematic drawing of a quadrant similar to the Chetwode one. The sun's altitude is 37° and the bead has been set for a noon altitude of 44°, so that the instrument shows a time of 2 hours before or after noon. Drawing courtesy of Frank King.

On the Chetwode quadrant, it is the engraved semi-circular line that indicates noon. (Fig. 2 shows a schematic of a quadrant to the same basic design in operation.) The other part-circles with increasing radii show the successive hours both before or after noon: the user had to know which part of the day it was as the hours are symmetrical about noon and, in this case, they are not numbered. Note that all the hour-lines pass through the origin of the quadrant. The same basic scheme of hour-lines is also commonly found on the backs of astrolabes. Astrolabes, though, were exceedingly expensive instruments and would have been owned only by the top levels of society. As a result, they were highly prized and several hundred of them have survived and are to be found in museums and other collections. Simple quadrants, more affordable but still expensive, might have been owned by scholars, wealthy merchants or senior churchmen, and were probably relatively common but are today almost unknown as they would not have been valued once they were superseded and the brass would have been recycled. Thus the finding of the Chetwode example is a great benefit to the history of science.

The modern scheme of 24 hours of equal duration throughout the year and counted from noon and midnight had been known and used by astronomers since antiquity but it only started to become the normal form of everyday timekeeping with the coming of mechanical timekeepers from the end of the 13th century. The Zutphen quadrant,[1] found by the detectorist Sicco Siegers of the Netherlands in 2012 and reported in *The Searcher* of June 2014, is a very early example of an instrument delineated to show this form of time. Throughout the 14th century, both equal and unequal hours were used – it must have been most confusing!

The Chetwode quadrant, like most horary quadrants, works by measuring the altitude (height) of the sun. It was used by pointing it at the sun and tipping it so that a pinhole in the foresight cast a spot of light on the backsight. The sun's altitude was then indicated by a plumb-bob hanging from the centre from which the quadrant is drawn. On the Chetwode quadrant the sights and the plumb-bob are, not surprisingly, absent.

Because the sun has a different altitude at a given hour for different days of the year and at different latitudes, some means of incorporating this information has to be used with the quadrant. This was accomplished by placing a sliding bead on the string of the plumb-bob with its position chosen to suit the season and location. The position of the bead amongst the hour-lines then indicated the time. Different types of quadrant used various means of doing this. It is unclear how it was intended to achieve this on the Chetwode quadrant as it does not have a date scale (as the Zutphen quadrant has) and there is no table of solar altitudes on the back, as is found on a group of quadrants made at the end of the 14th century for Richard II.[2]

The very simple design of the Chetwode quadrant is sometimes known by the Latin name *quadrans vetustissimus* ('oldest quadrant') and it can be found in an Islamic manuscript from 9th-century Baghdad.[3] It is unclear when it first came to the Latin West but sometime before the middle of the 13th century seems likely.[4] By the late 13th century, a more sophisticated version of the design using the same set of lines to indicate unequal hours was described by John of Montpellier. This later became known as the *quadrans vetus* (old quadrant) or the 'quadrant with cursor' as it incorporated a large sliding cursor which moved in a curved track around the outside of the basic set of hour-lines and was used to set the position of the bead for the date and at the appropriate latitude.

Fig. 3. The British Museum quadrans vetus*, an unequal-hour quadrant with moving cursor. Courtesy of the Trustees of the British Museum, inv. no. 1972,0104.1.*

Although there are quite a number of manuscripts which describe this scheme, only a very small number of actual instruments still exist: examples can be found in the British Museum (Fig. 3), the Oxford Museum of the History of Science, and in the Museo Galileo in Florence.

The Chetwode quadrant also incorporates a 'shadow square', a simple geometrical arrangement which allows the heights of distant buildings to be measured. Its two scales are divided [0], 4, 8, 12 twice, with the corner meeting the 45° point on the altitude scale. This latter scale is divided to individual degrees (not an insignificant task in an age without protractors) and numbered [0], 15, 30, 45, 60, 75, [90]. The numerals are engraved quite deeply and with some skill – the instrument was made by a craftsman with a proper sharpened steel burin (or graver) rather than a pure amateur using a sharpened point. Their form is clearly characteristic of the medieval period but it is difficult to date accurately – any time from the mid 13th century is possible. The numbering in groups of 15 is quite common on small medieval instruments.

Location and History

It is worth considering the circumstances in which the Chetwode quadrant was found. Whereas the Zutphen instrument was discovered in a beautifully layered context in which the layers could be closely dated by many other finds such as coins and pottery, the Chetwode device was simply found in the topsoil of an agricultural field without any closely-associated finds. A cut farthing from the reign of Henry III (r. 1216–72) was found within a metre of the quadrant but in England that can hardly be considered secure dating evidence, although it is at least a sign of medieval occupation. Other coins, of a slightly later date, have also been found in the general vicinity.

Instrument	Notes	Date	Cu	Zn	Sn	Pb	Other significant components
Chetwode *quadrans vetustissimus*	a	14th C?	75	6	6	8	0.3% Ag; 0.4% Sb. Fe omitted.
Norfolk quadrant	b	14th C?	71	11	8.5	6.0	1.8% Fe; 0.9% As
Norfolk *horologium*	c	15th C?	77	12	7.4	2.4	0.2% Ag; 0.9% Fe
Navicula, NMM AST1146	d	mid 15th C?	82	8.6	5.2	1.2	0.9% Fe; 0.9% Ti
Brit Mus *quadrans vetus* inv. no. 1972,0104.1	e	14th C	83	11	3.6	1.3	0.3% Fe; 0.2% Ni
Canterbury *quadrans novus*	f	1388?	87	5.3	3.4	1.5	0.2% Ag; 0.6% Fe
Zutphen quadrant	g	c. 1300	85	12.5	0.5	0.2	0.3% Ag; 0.7% Fe
Richard II quadrant	h	1396	78	22	nd	tr	
Grafendorf compendium	i	c. 1450	79	12	0.8	2	1.4% Fe

Table 1. Composition of metal alloys in wt% as measured by XRF of the Chetwode quadrant and several other medieval time-telling instruments.

a. Fig. 1. Found near Chetwode; analysed by Dr Brian Gilmour. Results after allowance for ground enhancement/depletion.
b. Fig. A1. Found in Norfolk by Graeme Simmonds; analysed by Dr Brian Gilmour.[5]
c. Metal detectorist's find from Shotesham, Norfolk. Analysed by Dr Brian Gilmour (Oxford).
d. Found at Sibton Abbey, N. Suffolk. Measurements by J. Davis, courtesy of the National Maritime Museum, Greenwich; thanks to Dr Louise Devoy.
e. Fig. 2. Measurements by J. Davis, courtesy of the British Museum; thanks to Oliver Cooke.
f. Found in Canterbury by excavation, now in the British Museum. Analysis by Dr Brian Gilmour and Dr Peter Northover (Oxford).
g. Found in Zutphen, The Netherlands. Measured by Dr Bertil van Os of the RCE (Netherlands Cultural Heritage Agency). Thanks to Bert Fermin.
h. One of four known devices (1396–1400), this is the earliest (unsold by Bonhams in 2012). Results supplied by Christopher Becker (Australia). The two devices in the British Museum have very similar compositions (results from Dr Susan La Niece, BM) as does the one in the Dorset County Museum (measured by J. Davis).
i. Excavated in Grafendorf Castle near Vienna, analysis by Prof. Dipl. Ing Dr Manfred Schreiner (Akademie der Bildenden Künste). Thanks to Dr Ronald Salzer.

In the Table, 'nd' and 'tr' indicate not detected and trace, respectively.

The find site was on a footpath that led to Chetwode Priory, a very small Augustinian outpost founded in 1244 by a certain Sir Ralph de Norwich who is believed to have been Bishop of Norwich for a short spell in 1236 (in 1222 he had been Rector of nearby Oakley). It was dissolved in 1460. The possible association with Norwich is an intriguing one as the county of Norfolk has been a particularly rich area for detectorist finds and a significant percentage of early pocket timekeeping instruments now in museums have been found there. One of the items found by a Norfolk detectorist in 2009 was a fragment of a small quadrant very similar to the Chetwode one.[5] (See the Appendix for a re-assessment of the Norfolk quadrant.) In the Norfolk case, the original unequal-hour-lines had been reworked with a later design of quadrant and the outline of the shadow square had been erased, though the numerals (4, 8, 12, 12) are still visible. Other comparisons are still being made but it is possible to speculate that there could have been a link between Norwich, famed for its very early astronomical clock in the cathedral, and Chetwode.

Another interesting coincidence is that the licence for the foundation of Chetwode Priory was signed by Robert Grosseteste (c. 1175–1253), the Bishop of Lincoln and widely recognised as one of the leading proto-scientists of the era. Grosseteste did not write on the quadrant but copies of his works on astronomy and the sphere are sometimes found in codices which also contain instructions on drawing quadrants and other sundials.[6] Thus, whilst it is not suggested that Grosseteste had any direct connection to the Chetwode quadrant, the general interest by scholarly churchmen in timekeeping and cosmology is illustrated.

Metallurgy

The metallurgy of the quadrant is another possible clue to its origins. The alloy of the Chetwode quadrant was analysed by X-ray fluorescence (XRF) by Dr Brian Gilmour (Research Laboratory for Archaeology and the History of Art, Oxford). The use of XRF is sometimes criticised as a method of examining archaeological finds because it is only semi-quantitative and is sensitive to surface corrosion effects. Nevertheless, it is a fast and non-destructive method of obtaining a very useful initial impression of the alloys involved, as shown by recent assessments.[7,8]

A partially-cleaned area on the back of the quadrant and a nearby uncleaned area were analysed, allowing an approximate allowance to be made for the surface enhancement/depletion of some elements (particularly Zn and Sn) by the effects of contact with the soil. The results are shown in the first line of Table 1, which also shows the analyses of a number other medieval scientific instruments. It is clear that the quadrant is made from a quaternary (Cu-Zn-Sn-Pb) alloy, in modern terminology a leaded gunmetal or, in some circles, 'red brass' but at the time called 'latten'. In this, it is quite similar to the other instruments in the top part of the table, most of them associated with East Anglia. This similarity does not allow a definite link of the quadrant with this area as the alloy type was quite widespread but it does not rule it out. By contrast, the last three instruments of Table 1 are clearly of a quite different alloy, best described as brasses with medium levels of zinc and with virtually no tin which are usually associated with Continental sources in the medieval period.

It is interesting to compare the compositions in Table 1 with those of some of the contemporary artefacts found in the Parisian workshop of the Hôtel de Mongelas, dated to 1325–50, which were classed as coming from 'sheet' material, that is, hammered to a thin sheet, as opposed to cast.[9] A total of 102 finds, mainly small artefacts and cutting waste, were examined and had a wide range of low- to medium-zinc quaternary alloys broadly in line with the instruments in Table 1. One noticeable difference, however, was that the vast majority of the Parisian specimens had a tin concentration of below 5 wt%, significantly less than the quadrants of Table 1. Whether this is related to the fact that England had good supplies of tin but no known indigenous source of zinc ores at that time remains to be explored.

Final Thoughts

An alternative possibility for the source of the Chetwode quadrant is St Albans Abbey, not very far away, home of Richard of Wallingford's astronomical clock and known to have been supplying quadrants to ex-Queen Isabella in the 1350s.[10] But our knowledge of the manufacture of mathematical instruments in the medieval period is still very far from complete.

APPENDIX
Revisiting the Norfolk Quadrant

In an earlier article,[5] I described a fragment of a quadrant found by a detectorist in Norfolk (Fig. A1). It featured medieval numerals and two sets of hour-lines. One set of lines was for unequal hours and the second, with the general appearance of a Gunter's quadrant, was for equal hours. The finding of the Chetwode device, having a very similar size (the radii are within 1 mm), has occasioned a reassessment of the Norfolk one.

Fig. A1. The Norfolk quadrant.[5] Note the alignment of the two '12's.

One puzzling feature of the Norfolk quadrant was that the noon lines of both sets of hour-lines appeared to be labelled with a numeral '12'. This was strange because noon is the sixth unequal hour. A numeral '8' also labelled one pair of equal-hour-lines. Comparison with the Chetwode device has now led to the realization that these numerals actually belong to a shadow square which has since been erased. The lines and divisions of the square are completely absent but the positions, orientation and alignment of the numerals would fit perfectly and, looking closely, the medieval numeral '4' can also be seen, merging into a patch of corrosion near the left-hand edge. Clearly, what we see is another early *quadrans vetustissimus* which has been later modified to show equal hours with a more modern, perhaps experimental, design. How much later remains an open question. The lines of the shadow square would have been relatively easy to erase as they were quite shallow, as were the unequal-hour arcs in the region now occupied by the equal-hour-lines. The numerals, however, were much more deeply engraved – as is also the case for the Chetwode quadrant – and thus are still visible.

The similarities between the (original, unmodified) Norfolk and Chetwode quadrants are so great that there is a reasonable possibility that they were produced in the same workshop, or at least using the same basic design. One feature which remains puzzling is that neither quadrant features a date or declination scale, needed for setting the position of the bead on the plumb-line. Such a scale would make the device specific to a particular latitude so its absence suggests that the maker was keen to keep the device universal, perhaps supplying the sun's noon altitude in a table for different dates and latitudes separately.

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Gilmour (Oxford University) is thanked for his work in conserving the find and for the XRF analysis. Graeme Simmonds (Norwich Detectors Club) kindly allowed me to study the Norfolk quadrant. Frank King kindly provided Fig. 2.

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For a portrait and CV of the author, see *Bulletin* 23(ii), June 2011. He can be contacted at *john.davis@btinternet.com*

NEW DIALS (1)

A Horizontal Stereographic Projection Dial for South Africa

This dial was commissioned by Pierre Holtzhausen, a noted cartographer of Centurion in Pretoria, as a teaching instrument for his children. It was, for budget reasons, reduced to the minimum area required by the stereographic projection.

The dial is made of 316 stainless steel; I finish all my 316 stainless dials with a satin texture, using 80 grit emery, so that the shadow is not reflected away: the dark appearance in the photograph is an optical illusion. I then passivate the surface as my tools and etching baths have also been used to process brass and thus they can sometimes form a thin layer of Monel on the stainless steel which looks like rust though it is not.

The overall diameter of the dial is 300 mm and the diameter of the horizon circle is 277 mm. The azimuth scale was limited to 120° East and West of North since the maximum azimuth in Centurion is about 116°. The centre of the stereographic projection and the vertical edge of the gnomon are in the geometric centre of the plate, with the bottom of the sloping face of the gnomon offset towards the North, at the bottom of the picture. Note that the ecliptic arc for the summer half of the year (September to March) is nearly a straight line on account of the latitude of 25° 54′ 13″ S.

The Afrikaans and the Latin at the top both mean "moved by the sun's light".

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