THE NAVICULA
Made in Medieval East Anglia?

JOHN DAVIS

This article is based on the presentation made at the 2017 BSS Conference in Oxford.

The navicula is an extremely rare and interesting portable altitude dial dating originally from the late Middle Ages: see Fig. 1 for an example. As well as several articles, a whole book has been published dedicated to the subject.[1] There are only five extant medieval examples from that period in the world, all currently in museums, together with reliable written evidence of one further example. There was a revival of interest in the navicula in the 16th century following the publication of a description in a book by Oronce Finé[2] and several examples of his somewhat simplified geometry[3] also exist (sometimes called 'ship-shaped dials' to distinguish them from the medieval originals[4]) in museums – an example is shown in Fig. 2 – though they will not be considered further here.

The existing medieval examples are now in the National Maritime Museum, Greenwich,[5] the Oxford Museum of the History of Science,[6] the Musée d'Histoire des Sciences, Geneva,[7] and the Museo Galileo (previously the Isituto e Museo di Storia della Scienza), Florence.[8] A detailed engraving of a fifth navicula was published in a letter to the *Gentleman's Magazine* in 1786 although the whereabouts of the actual dial are now unknown.[9] During the research for this article, a further medieval navicula was found by a metal detectorist and it currently resides for analysis with the National Museums Scotland so it will be referred to as the 'Edinburgh' navicula, though it was excavated elsewhere. The sizes and basic features of the medieval naviculae are shown in Table 1. Although all of these examples were found in Britain they were originally attributed to Germany by Lewis Evans and Robert Gunther, possibly because the design geometry is similar to that underlying the Regiomontanus dial and to the Organum Ptolomei.[10] The dial now in Florence is of quite a different style from the other five: it was at one time in the Medici

Fig. 1. Photograph of the medieval navicula now in Geneva. Photo courtesy Musée d'Histoire des Sciences, Geneva.

Fig. 2. Photograph (in front of a mirror) of the later 'ship-shaped dial' by Oronce Finé and dated 1524, in Museo Poldi Pezzoli, Milan (inv. no. 4277). This example, unusually, is in ivory. Photograph courtesy of Darek Oczki.

	Mast overall	Mast pivot to 60° latitude line	Sight–sight o'all	12–12	Hour Divisions
Oxford	93.8	42	82.6	52.4	½
Greenwich	110	49	89	51	½
*Gentleman's Magazine**	158	51	128	55	⅓
Geneva	162	73	120	83	⅓
Edinburgh	132	71	107	75	⅓
Florence	171	78	92	80	⅓

* taken from the full-size printed drawing, assumed 1:1.

Table 1. A list of the known medieval naviculae with their key dimensions (mm) and time divisions.

collection.[11] Although it may possibly be English-made, it will be considered separately from the other five which are all stylistically very similar. It is now generally accepted that the navicula is uniquely English, partly because the list of latitudes engraved on some of them are all for English towns and cities and partly because all the manuscript descriptions of their design and use have English roots: no naviculae have been excavated outside England. Until now, no-one has tried to narrow down the location of their origin but I wish to suggest here that they are quite likely to have come from medieval East Anglia, possibly from an as-yet unidentified workshop in Norwich or Bury St Edmunds.

There is almost no information on the actual making of any scientific instruments in the Latin West during the Middle Ages until the emergence of the Parisian workshop of Jean Fusoris at the very end of the fourteenth century and early fifteenth.[12] The existence of a small number of well-made instruments, particularly astrolabes and quadrants, from the previous century shows that some centres of expertise must have existed in England, quite probably located in universities and monasteries. Individual scholars, such as the 'Oxford calculators' at Merton College, seem to have made their own individual (and rather idiosyncratic) instruments in the mid-fourteenth century. At about the same time, there was a centre at St Alban's Abbey which was possibly a spin-off of the workshop that produced Richard of Wallingford's celebrated astronomical clock[13] and which was supplying simple quadrants.[14] But the source(s) of the great Sloane astrolabe[15] and the much smaller one known as 'Caius B',[16] both in the 1320s, are yet to be identified.

Operation and Design of the Navicula

The navicula is a surprisingly sophisticated altitude dial considering its early invention date, thought to be in the late-14th or early-15th century. John Whethamstede (ca. 1400–1465), an Abbott of St Alban's Abbey, credited its invention to a Benedictine monk called Peter of Muchelney.[17] It is 'universal', i.e. for latitudes between the tropic of Cancer and the Arctic circle, and shows equal hours which had become the standard form of timekeeping only relatively recently. Although David King makes much of the fact that the principles it uses were available in 9th-century Baghdad,[18] in its navicula form it does seem to be a uniquely English development and was in use around half a century before the more widely-known Regiomontanus dial in Germany which was based on the same principles but using a strictly practical rectilinear shape.

Making a navicula involves drawing four separate non-linear scales.[19] Firstly, the positions of the parallel hour-lines must be set out. Then, the positions of the slider on the mast from which the plumb-bob is suspended must be calculated for the range of latitudes required. Next, the arc on the 'keel' with the zodiac dates which determines the tilt of the mast is drawn, with the equinoxes in the centre. Finally, a different date scale is required on the side of the hull (invariably the right, or stern side) to allow the correct setting of the time-indicating bead on the plumb-line. To aid conversion of the civil date to the sun's position in the zodiac, a table giving the dates of its entry into each sign is usually provided. Not all the naviculae are correctly delineated and it seems that even Oronce Finé made some 'approximations'.

The Five/Six Naviculae

The only one of the group of similar medieval naviculae with an unequivocally East Anglian origin is the instrument now in the National Maritime Museum (NMM, Greenwich, Fig. 3) which was excavated by a metal detectorist in 1989 at the remains of Sibton Abbey, near Yoxford in the north of Suffolk (Fig. 4). Sibton Abbey was founded ca. 1150 as the only Cistercian abbey in East Anglia, twinned with Warden Abbey in Bedfordshire. It was one of the main houses under the control of the Bishop of Norwich and it grew rich through dealings in the wool trade. There would have been many monks and merchants travelling to Sibton from Norwich and King's Lynn (a Hanseatic port) and beyond so it is not difficult to see one of them losing their portable dial.

The navicula in the Oxford Museum of the History of Science (Fig. 5) was originally part of the museum's founding Lewis Evans collection. Examination of Evans' handwritten inventory card shows the revealing footnote "Given to me by Mr Reve, curator of the Norwich Museum 1898". 'Mr Reve' can be identified as James Reeve who was indeed a long-standing curator and benefactor at the museum.[20] His personal collecting interest was in the

Fig. 3. The navicula found at Sibton Abbey, now in the NMM, Greenwich. Photographs by the author, with thanks to the National Maritime Museum.

Fig. 4. The remains of Sibton Abbey, in an 1827 etching by Henry Davy (above) and photographed in 2014 (below).

painters of the Norwich School (he sold his collection to the British Museum) but he would have been a natural recipient of 'curiosities' brought in by local residents and he had a very wide range of connections at all levels of society. Though there is no guarantee that the navicula was local,

Fig. 5. The Oxford navicula. Courtesy of the Oxford Museum of the History of Science, inv. no. 54358.

the chances are high that it had not travelled far. Its condition suggests that it was probably found by excavation. This navicula was the first one to come to modern attention: David King calls it "crudely-made" and "a crude imitation of better instruments from 14th-century England" but he is wrong – it is just smaller than some of the others and has been buried for a long time.[21]

It was initially less easy to find an East Anglian link for the navicula in the Musée d'Histoire des Sciences, Geneva (called the Geneva navicula in the rest of this paper). It is rather larger than the Oxford and NMM examples (the overall height of its mast is 162 mm) but it is in almost pristine condition and it shares most of their stylistic features. The Geneva museum purchased it in 1993 from the dealers Trevor Philip & Sons who had recently bought it at a Sotheby's auction for £36,000.[22] There, it had been consigned by the descendants of a John Wilson who had owned it in the 18th century. John Wilson (1719–83) lived at Broomfield Hall near Sheffield and he was a prolific collector of early manuscripts and books, particularly on the history of the region around the Hall, as well as of other 'curiosities'.[23] Sheffield is a long way from East Anglia so it was difficult to see how the dial could have got there as there were no national sales of antique scientific instruments, or indeed other curiosities, at that time. Of course, it could have been lost or given away by a traveller but it initially seemed just as likely that it had local origins. However, looking deeper into Wilson's development as a minor collector produced a very significant fact: his mother's brother was the Rev. Cox Macro, DD, a well-known antiquarian and important collector of manuscripts and many other antiquities and very likely the role-model for Wilson. Cox Macro (1683–1767) lived at Little Haugh Hall in the parish of Norton, seven miles east of Bury St Edmunds in Suffolk (Fig. 6). He was educated at Christ's College, Cambridge, was a chaplain to the King and a J.P.[24] Wilson actually catalogued Cox Macro's collection shortly before his death in 1767[25] but unfortunately the navicula is not listed amongst the items, which range from paintings through manuscripts to items such as a "bull pizle" and an Indian tomahawk! It is, though, quite possible that Macro had already passed the navicula to Wilson who clearly kept it separate from his own collection, as evidenced by the fact that it remained in the family after his death even though most of his collection was auctioned off. Evidence of Munro's interest in scientific items is shown by the fact that he once owned a codex originally from the abbey of Bury St Edmunds in the 14th century. It is now in the Cambridge University Library[26] and amongst its separate manuscripts are a copy of the

Fig. 6. Little Haugh Hall in Suffolk, painted by the Dutch painter Peter Tillemans (1686–1734), the home of the Rev. Dr Cox Macro, who was a possible 17th-century owner of the Geneva navicula. Courtesy of the Norwich Castle and Museum (Patterson Collection).

pseudo-Massahala treatise on the astrolabe and several astronomical tracts by Robert Grosseteste.

The navicula illustrated in the *Gentleman's Magazine* (Fig. 7) was drawn by the correspondent "W.B." from Colchester, in Essex just south of the Suffolk border. All efforts to identify W.B. have so far failed. In his letter, he says that the engravings are accurate enough to allow a replica to be made though they carry no scale. There are no clues to how this navicula was obtained: the drawings show no imperfections or damage which may indicate that it has not been found by excavation though the artist may have decided to show a 'perfect' representation. Although the engravings show it to have a style extremely similar to the extant examples, some small features have slight variations and thus indicate that they are of a different example which is now lost – there remains a possibility that it will one day re-appear.

The Edinburgh navicula (Fig. 8) is still undergoing conservation but it can be seen to follow the style and layout of the Geneva instrument quite closely.

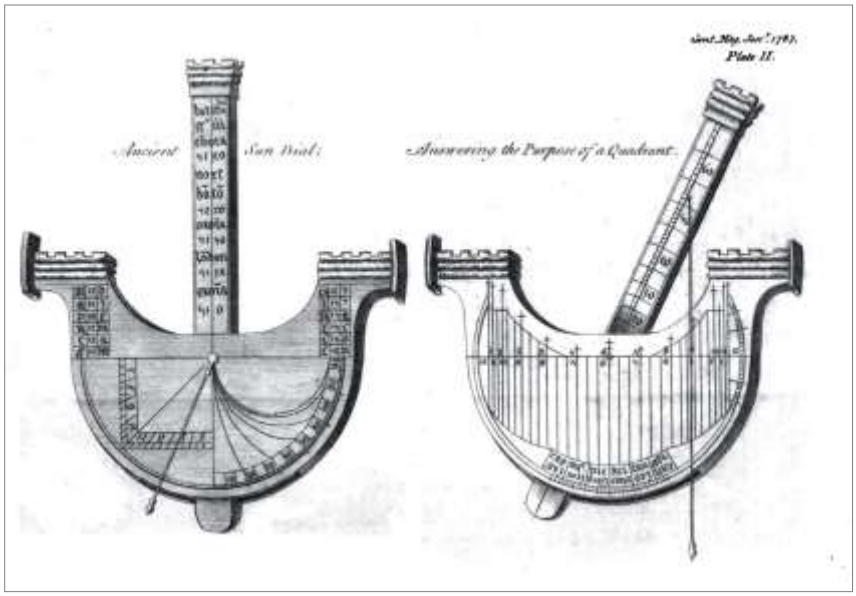

Fig. 7. The Gentleman's Magazine navicula drawing.

Fig. 8. The Edinburgh navicula. Photos courtesy of Tacye Phillipson, National Museums Scotland.

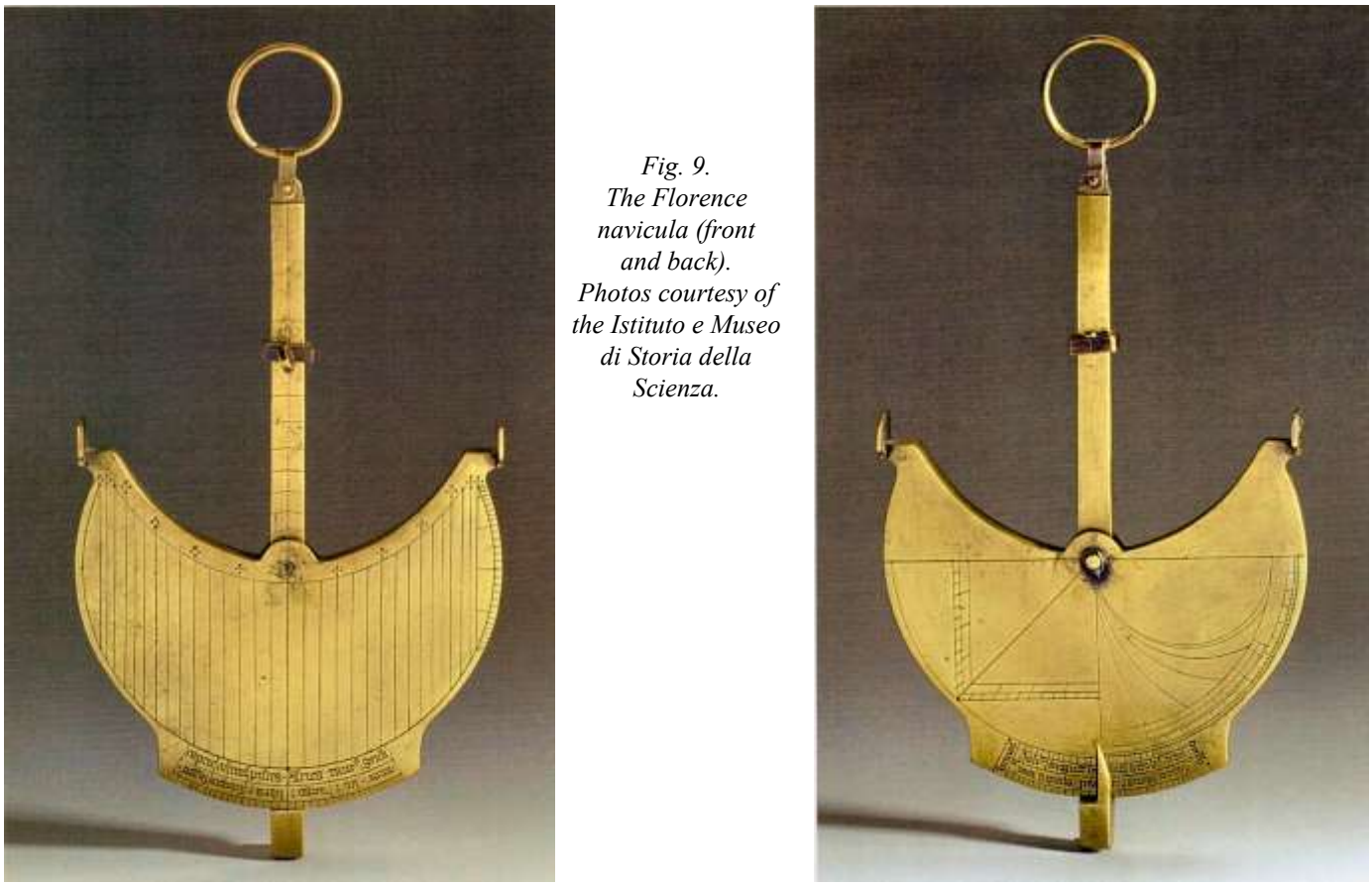

Fig. 9. The Florence navicula (front and back). Photos courtesy of the Istituto e Museo di Storia della Scienza.

The Florence navicula (Fig. 9) can be seen to have a completely different style from the others although the general principles, form and construction are the same. It is of high quality but it is unfinished in that the scales are unnumbered. The engraving is very neatly done, in the Gothic style and suggesting, perhaps, that it was a high-value gift from an Englishman to an Italian merchant. Its design is less obviously ship-shaped, being a more formal and practical layout.

Style, Construction and Metallurgy

The construction of these quite small instruments is rather more sophisticated than might be appreciated at first sight. The engraved cheeks which make up the 'hull' are cut from hammered copper-alloy sheet of just over 1 mm thickness (rather variable). They are held in alignment with a pair of slightly thicker spacers by several flush alloy rivets, leaving a gap within which the 'mast' can swing. This riveting has, in all cases, been performed with considerable skill and the

'heads' of the rivets are not always easy to see, only an occasional difference in colour giving their positions away. The engraving is continuous over the rivets and hence was performed after assembly. The use of rivets was standard practice in the Middle Ages and short lengths of copper-alloy wire suitable for use as rivets have been recovered in archaeological excavations of London workshops of the 14th century.[27]

The mast is made from a strip of the same alloy as the hull with two small trapezoidal pieces attached at the bottom, again by a rivet, to form the 'keel' which carries the fiducial marker for the declination scale. The top of the mast is capped on the complete examples (the NMM one is an exception) with a castellated piece formed from the same three-stripe shape which is also used for the 'fore-castle' and 'stern-castle'. This strip is likely to have been made as a single casting and cut and folded to shape afterwards. In modern mass-production, a piece like this would be formed by extrusion or continuous casting but in the medieval period it was probably made in a relatively short clay mould. The castellation may have been included in the pattern but it is more likely to have been made by filing at a later stage. Some of the naviculae also use the same three-stripe strip to make the slider on the mast as well, although some sliders are either missing (*Gentleman's Magazine*) or a replacement (Geneva).

The pieces for the stern-castle and fore-castle are also riveted onto the hull with the heads of the rivets being carefully spaced and filed to match the strips in the surface. The actual sights – a pair of small holes in each sight, spaced to avoid the obstruction of the mast – are small pieces of alloy plate with a slight curvature. This curve seems to be intentional rather than damage and is presumed to be for aesthetic/architectural reasons rather than practical ones.

The size of the rivets varies with the overall size of the navicula, being 3.4 mm diameter (average) for the Geneva instrument and 2.6 mm for the NMM one. Thus, there was clearly no standard off-the-shelf rivet available to the maker. Indeed, it is likely that the (spade?) bit used to drill the holes for the rivets had a short life and needed to be re-sharpened regularly.

The use of rivets to hold parts of a scientific instrument together looks to be a particularly English trait at this period and can be compared to the construction of contemporary astrolabes. Here, the limb may be either integral with the mater (i.e., cast in a single piece) or soldered on, or riveted. Some English astrolabes, particularly of the 'Chaucerian' design with Y-shaped rete details, favour the integral construction as do most contemporary Continental and Islamic instruments. 'Gothic' English astrolabes with quatrefoil retes, on the other hand, are mainly of riveted construction. The ability to fit these rivets points to a workshop or workshops where this skill could be learned and it is particularly appropriate for a small-scale enterprise lacking the large foundry and machining facilities needed to cast and turn an integral limb/mater design. The skills of making riveted constructions could readily be applied to naviculae, and also quadrants etc., as well as astrolabes.

The small size of the numerals and lettering on the navicula would require another set of skills. The basic lines of the design could be scratch-engraved with a sharp point, needing abilities mainly in geometry for their laying-out. The wielding of a burin for the lettering may have required a separate artisan – accounting, perhaps, for the fact that the Florence navicula is generally unfinished, lacking the labelling. The form of the numerals and letters, though clearly medieval, shows some variation in form between the instruments, leading Eagleton[28] to declare that they cannot have been made in the same workshop. This is not necessarily the case, though.

The metallurgy of three of the medieval naviculae has been investigated by X-ray fluorescence; the Oxford and Greenwich examples by the author using a portable analyser and the example in Geneva in 1995 by an SEM-based system with the results kindly conveyed by Stéphane Fischer.[29] (An analysis of the Edinburgh navicula is planned for the future.) A summary of the results is shown in Table 2, which also includes for comparison the components of a roughly contemporary compendium found on the Thames foreshore and now in the British Museum (Fig. 10). It should be borne in mind that the surface-sensitive measurements had to be made through the surface patination and thus will not be an accurate representation of the bulk alloy: in particular, 'dezincification' will mean that the reported zinc concentrations of the Oxford and Greenwich examples are likely to be several percent too low.

Although the compositions of the majority of the instruments is best described as 'latten' (a quaternary alloy of copper, zinc, tin and lead) there is significant variation in the amounts of the alloying elements and it cannot be stated that all were made from the same basic stock, as might be hoped for if they were made at the same time in the same workshop. The main sheet components (mast and hull) are the most important to consider and here it can be seen that the Oxford navicula has a composition which could be classed as a brass – it has a composition which is very close to the four slightly earlier Richard II quadrants which have been analysed previously.[30] This rather high-quality material has sometimes been thought of as being Continental (owing to the absence of tin) and might initially suggest that this instrument was made at a different location to the others. The case of the British Museum compendium (Fig. 10; found in the river Thames at Isleworth) proves that this is not necessarily the case as this one instrument has two of its major components (compass and equatorial dial) made of latten but its third, the nocturnal which serves as a lid, is made of brass. Clearly,

Navicula	Part	Cu	Zn	Sn	Pb	Ag	Ni	Fe	As	Others/Comments
Greenwich	Hull	82.0	8.5	5.9	1.9			1.1		
	Mast	78.7	8.3	4.9	6.5		0.1	0.8		
	Castles	72.2	7.5	7.0	11.7			1.1		
Oxford	Hull	76.8	21.1	0.07	0.3	0.37	0.18	1.1	0.6	Sb 0.03
	Mast	79.7	19.4	0.08	0.4	0.12	0.55	0.5		Sb 0.03
	Castles	78.4	16.2	3.0	0.6	0.10	0.10	1.0	0.2	
Geneva	Hull	80.4	13.2	4.8	1.6	tr.				Sb (tr.)
	Mast	82.7	12.0	4.3	1.0	tr.				
	Castles	86.3	8.2	4.5	1.0	tr.				
	Spacer	70.5	11.0	9.5	9.0					
Whipple #0731 (1620)	Hull (front)	65.6	33.3	0.1	0.3	0.09	0.05	0.31	0.13	
	Hull (back)	72.2	24.7	1.8	1.1		0.27	0.26		different from front
	Mast	71.5	24.7	2.0	1.2		0.38	0.26	0.07	same as hull back
	Castles	not measured								
Brit Museum Compendium 1853,0618.1	Compass base	84.9	9.2	3.9	0.4			0.2		
	Equatorial dial	86.2	8.7	3.9	0.3			0.2		
	Nocturnal/lid	77.8	21.0		0.1		0.1	0.7		

Table 2. Alloy compositions of three of the medieval naviculae and one later 'ship-shaped dial', together with a contemporary compendium, as measured by XRF. Values in wt%, rounded to one decimal place. The Greenwich and BM instruments were measured by the author using an InnovX portable analyser; the Whipple and Oxford naviculae were measured with a Niton analyser with higher sensitivity and the Geneva instrument was measured by its owners in an SEM EDAX system with a smaller spot size but lower sensitivity. Note that the measurements were obtained on unprepared surfaces and hence are subject to an unknown amount of patination. tr. = trace. Blank cells = not detected.

both materials were available in a single workshop. Perhaps the brass (Cu:Zn) was chosen for the lid on account of its preferred golden colour.

The castellated castles are generally more heavily leaded than the other components and this suggests that they were castings, probably made in continuous strips with the 'three-stripe' shape which could then be filed to form the castellations or folded and silver-soldered to make the mast fittings. Similarly, the shaped spacers which separate the two sides of the hull and create the space for the mast to pivot also appear to be specially cast.

Fig. 10. The British Museum compendium (1853,0618.1), contemporary with the naviculae. Photo by the author, with thanks to the Trustees of the British Museum.

Origins of the Ship-Shape

Part of the charm of the navicula is exactly that it is shaped like a ship: the Regiomontanus dial, which uses very similar geometric and gnomonic principles, is a much more utilitarian rectangular shape. This was clearly a conscious design choice as the name is original, appearing in early manuscripts, and not just as a modern description. It is the Latin diminutive of the term *navis*.[31] The shape is based on the 'cog', a single-masted trading vessel which was common around English shores in the 14th and 15th centuries. There were also river-going cogs, distinguished by their lack of a crow's nest. An example of a sea-going cog is seen in Fig. 11 from the Luttrell Psalter, and representations can be found on coins of the period, such as that shown in Fig. 12. Perhaps more significantly, the shape also appears as graffiti on the walls of medieval churches, particularly those in Norfolk.[32]

Fig. 11. A drawing of a 'cog' (Wikimedia Commons) and a representation found in the Luttrell Psalter (British Library Additional MS 42130, f. 161v, first quarter 15th century). Note the anchor emanating from amidships – not good nautical practice but a nice representation of the plumb-bob on a navicula!

One of the examples of ship graffiti in Fig. 13 has been selected for its location on the walls of St Nicholas' church at Blakeney, on the north Norfolk coast. The greater part of the church dates from the 15th century, when Blakeney was a seaport of some importance (it features on the contemporary Gough map). It could well be merely coincidence, but it is worth pointing out that the oldest signed and dated European scientific instrument is an astrolabe in the British Museum which carries the inscription "Blakene me fecit Anno do[i] 1342", suggesting that its maker came from Blakeney.[33]

Other images of 'cogs' from the medieval period abound, including one which features on the seal of the great port of Dunwich, on the north Suffolk coast, which still features as the sign of the local Ship Inn.

The concentration of naviculae in East Anglia does not, of course, prove that they were invented or made there. However, it does add to the circumstantial evidence that suggests that it could be so.

Fig. 12. A gold noble from the reign of Edward III featuring a ship.

ACKNOWLEDGEMENTS

Tim Pestell (Norwich Museums), Tacye Phillipson (National Museums Scotland), Anthony Turner (Paris), Lucy Blaxland and Silke Ackermann (Oxford Museum of the History of Science), Louise Devoy (National Maritime Museum), Stéphane Fischer (Musée d'Histoire des Sciences, Geneva), Giorgio Strano and Anna Giatti (Istituto e Museo di Storia della Scienza), Josh Nall (Whipple Museum, Cambridge), Darek Oczki (Poland), Matthew Champion (Norfolk Medieval Graffiti Survey) and Oliver Cooke (British Museum) are all thanked for their help.

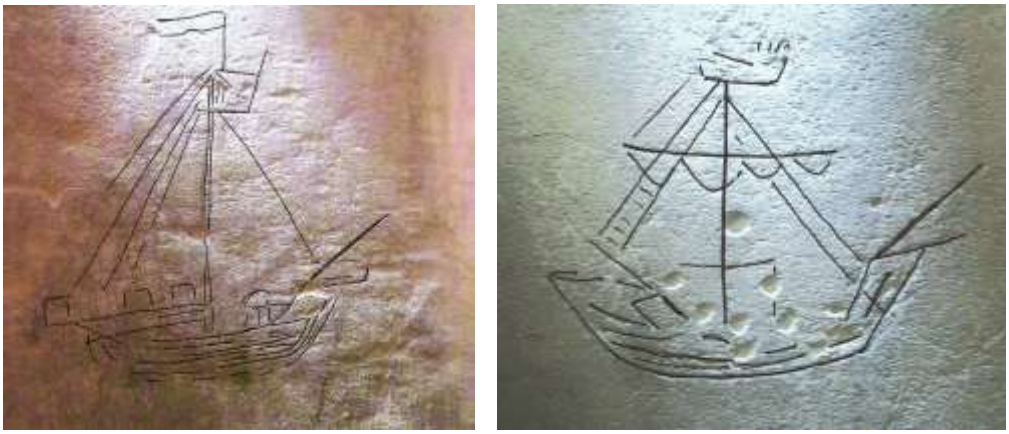

Fig. 13. Ship graffiti on the inside of Norfolk churches. Left: Cley next the Sea. Right: Blakeney. Photos courtesy of Matthew Champion.

REFERENCES and NOTES

1. C. Eagleton: *Monks, Manuscripts and Sundials: the navicula in medieval England*, Brill Academic Publishers (2010). A follow-up article appeared as K. Eagleton: 'Medieval Sundials and Manuscript Sources: the transmission of information about the navicula and the *Organum ptolomei* in fifteenth-century Europe', pp. 41–72 in Sachiko Kusukawa, Ian Maclean (eds.), *Transmitting Knowledge: Words, Images, and Instruments in Early Modern Europe*, Oxford University Press (2006). See also notes 3 and 19.
2. Oronce Finé: *Protomathesis*, Paris (1532). It also appeared in his 1560 *De Solaribus Horologis*, Paris (1560).
3. A good article on the connections of the various naviculae (identifying the geometry problems) by Yvon Masse: 'Les particularités de la navicula de Genève. Histoire d'une invention ingénieuse et mal comprise' is at *http://yvon.masse.perso.sfr.fr/divers/la_navicula_de_geneve.pdf*. See also J. Kragten & F.J. de Vries: *The Little Ship of Venice – Navicula de Venetiis, a time measurement device with surprising construction*, De Zonnewijzerkring, Eindhoven (1989, revised 1997).
4. Examples of 'ship-shaped dials' from the 16th/17th centuries can be found, for example, in the Whipple Museum, Cambridge, inv. no. 0731 as well as modern replicas, e.g. Whipple inv. no. 5902.
5. National Maritime Museum, Greenwich (NMM), inv. no. AST1146. An outline description of the acquisition is given in Kristen Lippincott: 'The Navicula Sundial', *SIS Bull.*, 35, 22, (1992).
6. Oxford Museum of the History of Science inv. no. 54358.
7. Musée d'Histoire des Sciences, Geneva, inv. 2139. See also Margarida Archinard: 'Navicula de Venetiis, une acquisition prestigieuse du Musée d'histoire des sciences,' *Musée de Genève,* 334 (April 1995), pp. 2–8, plus illustration.
8. Museo Galileo, inv. no. 3163.
9. *Gentleman's Magazine*, Letter from W.B., Colchester, 7 December 1786 (published on p. 49 and Plate II, January 1787).
10. Robert T. Gunther: *Early Science in Oxford*, vol. 2, p. 41, OUP (1922).
11. Anthony J. Turner: *Catalogue of Sun-dials, Nocturnals and Related Instruments*, Istituto e Museo di Storia della Scienza (2007). The navicula (no. 22) is described on pp. 60–63.
12. The standard source for Fusoris is Emmanuel Poulle: *Un constructeur d'instruments astronomiques au XV^e siècle Jean Fusoris*, Librairie Champion, Paris (1963). See also G. Aubry: 'Cadrans de Jean Fusoris' *Cadrans Info*, 18, 4–12 (October 2008).
13. J. North: *God's Clockmaker – Richard of Wallingford and the invention of time*, Hambledon & London (2005).
14. See J. Davis: 'The Chetwode Quadrant – a medieval unequal-hour instrument' *BSS Bull*., 27(ii), 2–6 (June 2015), note 10.
15. J. Davis: 'Fit For A King: Decoding the Great Sloane Astrolabe and other English astrolabes with 'quatrefoil' retes'. *Medieval Encounters,* forthcoming.
16. J. Davis and M. Lowne: 'An Early English Astrolabe at Gonville & Caius College, Cambridge, and Walter of Elveden's *Kalendarium*'. *J. History Astronomy,* 46(3), 257–290 (August 2015). DOI: 10.1177/0021828615590336.
17. C. Eagleton: 'John Whethampstede, Abbot of St Albans, on the discovery of the liberal arts and their tools: or, why were astronomical instruments in late-medieval libraries?', *Mediaevalia*, **29.1**, 110–36, (2008). Whethamstede's proto-encyclopaedia *The Granarium* was written 1420–40 so the navicula must have been in existence then, even if it was not invented by the otherwise-unknown Peter of Muchelney.
18. D.A. King: '14th-century England or 9th-century Baghdad? New insights on the elusive astronomical instrument called *Navicula de Venitiis*', *Centaurus*, 45, 204–26 (2003).
19. See Eagleton, note 1 for details.
20. I am grateful to Dr Tim Pestell, current curator at Norwich Museum, for this information. For an extended biography of James Reeve (1833–1920), see the Norwich Museum website at *http://www.museums.norfolk.gov.uk/Visit_Us/Norwich_Castle/Past_Exhibitions/2005/Cotman_in_the_British_Museum/Online_Exhibition_Catalogue/James_Reeve/NCC081534*
21. David A. King: 'On Universal Horary Dials', Part XIIb in *In Synchrony with the Heavens – Studies in Astronomical Timekeeping and Instrumentation in Medieval Islamic Civilisation. Vol. 2: Instruments of Mass Calculation* (Leiden, Brill; 2005), especially p. 271.
22. Sotheby's (London) 25 February 1993, lot 386. See also Trevor Waterman: *A measure of time – 25th anniversary of Trevor Philip & Sons*, Self-published, undated.
23. John Nichols: *Literary Anecdotes of the Eighteenth Century; Comprizing Biographical Memoirs of William Bowyer ... an Incidental View of the Progress and Advancement of Literature in this Kingdom During The last Century; and Biographical Anecdotes of a Considerable Number of Eminent Writers and Ingenious Artist; with a Very Copious Index*. Volume IX, pp. 359–65 (London, Printed for the author; 1815).
24. For details of Cox Macro's many achievements and antiquarian collections, see his entry in the Oxford Dictionary of National Biography.
25. The archive of Wilson's papers at Leeds University Library contains a reference on p. 11, under entry 120, Book 3 to 'A Catalogue of the Curiosities, Medals, Coins, Paintings, Drawings, Busts, Original Letters & Autographs; with a Description of the House & Garden: Belonging Dr Macro of Norton, Suffolk, 1766'. This document, in the Special Collections of Leeds University Library, runs to 55 closely handwritten pages. I am grateful to Stephen Clatworthy for providing a photocopy.
26. Cambridge University Library MS Additional 6860.
27. G. Egan: 'Some archaeological evidence for metalworking in London c.1050 AD – c.1700 AD', *Historical Metallurgy,* 30, no. 2, 83–94 (1996). See especially figure 4B.
28. Eagleton, note 1.
29. Stéphane Fischer is a curator at the Musée d'Histoire des Sciences, Genève.
30. J. Davis: 'The Chetwode Quadrant – a medieval unequal-hour instrument' *BSS Bull*., 27(ii), 2–6 (June 2015).
31. The dial was called the *navicula de Venitii* (little ship of Venice) by Derek de Solla Price in his article 'The Little Ship of Venice – a Middle English Instrument Tract', *J. History of Medicine*, 400–7 (October 1960) as it is called that in the manuscript version he was editing and that name has since gained wide acceptance. However, in the vast majority (13 out of 16) of manuscripts it is simply called the *navicula* (or *navis*), suggesting that an English origin of the boat is just as likely, so that name is used in this article.
32. Matthew Champion: 'Medieval Ship Graffiti in English Churches: Interpretation and Function', *The Mariner's Mirror*, 101:3, 343–50 (2015) DOI: 10.1080/00253359.2015.1054691.
33. The 'Blakene astrolabe' is British Museum 1853, 1104.1 and can be seen at *www.britishmuseum.org/research/collection_online/collection_object_details.aspx?objectId=54861&partId=1*

john.davis@btinternet.com