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The Shipmaster at Sea: Navigation and Meteorology

Having found sufficient cargo, negotiated freight rates, signed the charter-party with, if relevant, the shipowner's authorisation, recruited a crew, fitted-out and victualled the ship, obtained up-to-date information about the risks of piracy and made his passage plan, the shipmaster was ready to put to sea. How he found his way to his destination is the subject of this chapter.

Direct navigation

'L'art & science tressubtillez & quasi divine du noble mestier de la mer' has been described as the 'haven-finding art'; it might also be described as the 'land-avoiding art' since any undesired contact with land could be fatal. Until navigational instruments became generally available, shipmasters followed the classical advice 'littus ama; altum alii teneant' ('love the shore; let others go to the deep') – holding a safe distance off, but always within sight of land, except for short off-shore passages preferably sailed in daylight. Shipmasters in the fourteenth century, in the absence of instrumentation, had only direct observational methods to know the time, their position and course, and the distance and direction to their next destination. Late fourteenth-century improvements in ship design made longer and safer voyages possible but there was no certainty of a safe return, nor of repeat visits, until the introduction of magnetic compasses in the second half of the century. Although astronomers ashore had long been able to take accurate astral sights and calculate both latitude and longtiude, the former was not used ar sea until the second half of the fifteenth century, and the latter not until three centuries later. A certain complacency amongst northern seamen, habitually navigating without measuring latitude, may have contributed to the delay but the cost and reliability of salt-resistant astral height measuring instruments usable on a moving platform, were a major problem. Measurement of longitude at sea was delayed until reliable time-keeping pieces were manufactured. Meteorology, similarly *faute de mieux*, relied on direct observational methods and folklore.

Direct navigation depends on the recognition of landmarks, visual assessment of the distance off the coast, and estimating bearings extrapolated from the positions of astral bodies. The fourteenth-century shipmaster had a lead-line to determine the depth and to bring up samples from the sea bed, both of which, with previously acquired knowledge, could be used to confirm the ship's position. He may also have had a sand-glass to measure regular periods of time and, perhaps, a primitive, ungimballed compass. For the rest, he observed the behaviour of animals, the direction, strength, humidity and temperature of the wind, the cloud formations over hills and even the smell coming off an invisible shore. With those natural aids, an experienced shipmaster could lay and hold a roughly correct course and estimate the ship's speed and distance run. He also observed the lunar cycle and carried a mental picture of the tidal flow on his route and in his havens. The skills attributed by Chaucer to his Shipman confirm the abilities of late fourteenth-century seamen:

> But of his craft to rekene wel his tydes,
> His stremes, and his daungers hym bisides,
> His herberwe [harbours], and his moone, his lodemenage [pilotage]
> ...
> He knew alle the havenes, as they were,
> Fro Gootland to the cape of Fynistere,
> And every cryke in Britaigne and in Spayne.

That he knew all the havens from the Baltic to Spain is extremely unlikely, but since Chaucer's work required frequent visits to the London docks, and he also undertook several missions abroad, his Shipman was certainly a representative, if caricatured, member of the seagoing fraternity.[1]

Sailing directions, or rutters, for northern waters, became available as handwritten copies at the end of the fourteenth or the beginning of the fifteenth century. Information from the oldest surviving directions, the mid-fifteenth-century manuscript copies of the English rutter and of the Hanseatic Middle Low German *Seebuch*, have been used in this chapter to assess the skills of a contemporary shipmaster, assuming, not unreasonably, that the navigational techniques of English and German seamen were identical. Although few mariners would have had their own copies of those directions, there was a lively exchange of information between shipmasters in havens and on port towns' quays, as described in the *c.*1400 alliterative poem *Morte Arthure* and quoted on p. 85. In addition to the latest news of piracy and current freight rates, information would have been exchanged about good anchorages and hidden rocks – items which were entered by the literate in their notebooks and later evolved into sailing directions. The eventual dissemination of these directions gave shipmasters access to the empirical

1 Chaucer, *Complete Works*, 'General Prologue', lines 401–3 and 406–9.

information accumulated by others over many years, collated in the user-friendly format discussed below.

Land- and seamarks

Landmarks were indispensable to medieval seamen; the *Seebuch* lists over two dozen monasteries, churches, chapels and houses, and many hills, cliffs and promontories. For the entry to Yarmouth on the east coast of England, for example, the marks include a 'house where the sick live' – the local historian has confirmed that this was a leper colony – and a 'house with four oriel windows'. Even ephemera such as a large tree north of Harwich and a high wood to the west of Dartmouth are mentioned. Figures 3 and 7, which are from the Hastings MS copy of the English rutter, show a variety of landmarks, man-made and topographical, useful for in-shore navigation. Such marks were used alone for location identification, and with a second mark to give a leading line past a hazard or into an anchorage. Members of the crew with local knowledge helped to identify the marks, and canny shipmasters made mental notes of useful features along their routes.[2]

References to man-made seamarks on the English coast go back to the earliest surviving documents, many of them confirmed by archaeological evidence. The Romans built beacons at Dover and elsewhere as navigational aids, and the Vikings heaped stones into cairns on headlands for the same purpose. Excavation of a mound at Tywn Llewelyn, Glamorgan, revealed a cairn built on top of a rocky extrusion apparently marking the high water channel up the River Thaw. The eighth-century Old English poem *Beowulf* describes the construction of such a sea mark: 'The Wedra people had made a shelter on the headland, so high and so wide that it was seen by the seafarers from afar, and they built in ten days a beacon for the battle-brave.'[3]

The rutter lists churches and other large buildings as leading marks into Dartmouth, Harwich and Broadstairs and in both the rutter and the *Seebuch* there are buildings apparently sited specifically as navigational aids. Although no mention has been found in any sailing directions of the medieval church at Bosham (from where Harold sailed in 1064), it is built on the line of the channel up Bosham Creek, a site surely not chosen by chance. The *Seebuch* uses a church and a visible rock in describing the entrance to Dartmouth:

[2] Extracts from the Hamburger Commerzbibliothek, *Altes Seebuch*, saeculi, ut videtur, XIV, MSS A and B have been taken from the transcription and translation of both manuscripts into German and English by Albrecht Sauer and Robin Ward, see http://www.dsm.museum /*seebuch* /html. Extracts from the Pierpont Morgan Library, New York, Hastings MS 775 have been taken from the transcription in Ward, 'The Earliest Known Sailing Directions' (cited hereafter as Hastings). *Seebuch*, MS B, fo. 36r, item 1.

[3] Naish, *Seamarks*, pp. 15–24. Hutchinson, *Medieval Ships*, p. 170: citing D.M. Wilson and J.G. Hurst, *Medieval Archaeology*, 27, p. 170. 'Geworhton ða Wedra leode / hleo on hoe se wæs heah ond brad, / weg-liðendum wide gesyne, / ond betimbredon on tyn dagum / beadu-rofes becn': *Beowulf*, ed. C.L. Wren, rev. W.F. Bolton (London, 1973), p. 211, lines 3156–60.

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3 Ships in a busy haven. Folio 130v of Hastings MS 775, reproduced with the kind permission of the Pierpont Morgan Library, New York.

> whoever would sail into Dartmouth should sail by St Petroc's church which stands on the W side of the haven, and should sail in by the large rock [Mew Stone] which lies by the east shore because of the dangerous shallows that lie off the sandy bay.

Depths were often included in the instructions for entering havens, sometimes to delineate a route by isobathic (following a depth contour) navigation:

> and hold the Helsingor church and the beacon-house so that you are able to see between them so that you will not sail the wrong course past Lappesand on the seven fathom line, and also so that you will not steer too close.

More sombrely, the best anchorage in Dieppe, according to the *Seebuch*, is when the gallows and the church are in transit, in seven fathoms at low water and in ten fathoms at high water.[4]

Navigational difficulties at estuary and harbour entrances led, from the end of the thirteenth century, to the construction of seamarks. Between 1299 and 1316, the merchants of Hamburg invested in a tower built on a sand island close to the Scharnoon reef, and towers were built at Nieuwpoort, at Hiddensee (Stralsund) and at Travemünde (although 'ubi signum eiusdem portus habetur' indicates that there may have been a beacon of some sort there much earlier). Lights were necessary on land and sea marks for ships arriving at night: Barbour tells of Robert the Bruce using a fire as a leading line in 1306 on his passage from Kintyre to Carrick (in modernised form): 'until night came upon them … so that they did not know where they were … steering all the time on a fire they saw burning light and bright, until they arrived at the fire and landed without more delay.' In 1314 a laden wine ship was wrecked on St Catherine's Point on the Isle of Wight and pillaged by local people. After litigation and an appeal to Rome, Walter de Godeton was ordered, as a penance and on threat of excommunication, to build an oratory and light-tower dedicated to St Catherine, the remains of which still stand. The Black Prince had a lighthouse built on what is now the islet of Cordouan in the Gironde estuary as a guide for the wine ships; during re-building, the ground subsided to make this the first light at sea. The importance of the man-made marks to sea-borne trade was recognised by the local and church authorities, who accepted responsibility for the construction and maintenance of marks and their top-hampers of baskets, barrels, fires or lamps, for which they levied a charge on passing ships. In 1261, the town of Winchelsea levied 2d. for the maintenance of fires from all ships entering the roads; Yarmouth similarly taxed visitors for two towers with fires on top; and in 1427 John Fitling organised a levy on shipping on the Humber to pay for a beacon at Spurn Head. Some marks were of

[4] *Seebuch*, MS B, fo. 8v, item 4. Sauer, *Seebuch*; *Seebuch*, MS A, fo. 66r, lines 1–3; MS B, fo. 16r, item 2.

national importance: in 1398 all ships sailing from England to Calais had to carry stones as *lastage* (ballast) at 2d. per ton for the repair of the beacon and sea wall which were much decayed. It was as late as 1585, however, that Trinity House of Kingston-upon-Hull laid what appear to have been the first buoys marking the channel in the River Humber – again to be paid for by a levy on passing ships. The disappearance of natural and man-made marks was a serious matter and their removal was forbidden; the preamble to an Elizabethan Statute, referring to marks 'of ancient time', makes their importance clear.[5]

Initially, buoys were probably barrels – off Warnemüde as early as 1288 they were recorded as 'signum quod tunna dicitur' – but the nature of a buoy placed to seaward of the Scharnoon reef, at some time in the fifteenth century, to mark the approach to Hamburg, is not known. The earliest surviving chart recording of buoys is of those marking two channels in the River Swin, near Sluys; there is no differentiation on the chart between port and starboard marks, but the buoys may have been coloured or shaped to show on which hand they were to be held. Buoys would have been difficult to moor and maintain on station, but had the advantage of being easily removed in times of danger from enemy or pirate ships and it is probable that they were lifted in the winter to avoid the worst of the weather. There are no direct records of medieval English buoyage, but it is likely that the entrances to at least Lynn and Boston were marked, either by floating marks or by posts driven into the sand, following advice from Hansa ships sailing in from the well-marked northern German, Flemish and Danish ports where shifting sand was also a problem. There is indirect, later evidence of old navigational aids of some sort at Boston; the 1572 Charter to the burghers refers to marks 'nowe almost utterly decayed'. An example of the use of posts to mark shoals and to give a transit line occurs in the English rutter:

> And [if] ye goo oute of orwell waynis to the nase, ye must goo southe west fro the nase to the markis of the spetis [on a Thames sandbank]. Youre cours is weste southe west. Brynge yowre markis togedir that the parisshe stepill be ought be est the abbey of seynt hosies [St Osyth] than goo yowre cours ouir the spetis southe.[6]

5 Sauer, *Seebuch*, pp. 155–6, citing *Hansisches Urkundenbuch*, I, no. 205. *Barbour's Bruce*, ed. Matthew P. McDiarmid and James A.C. Stevenson, The Scottish Text Society, 3 vols (Edinburgh, 1985), 3, Book V, pp. 104–6, lines 15–21, 29–30. Naish, *Seamarks*, pp. 26–7, 82. Sir Nicholas Harris Nicolas, *A History of the Royal Navy from the Earliest Times to the Wars of the French Revolution*, 2 vols (London, 1847), I, p. 237. Sauer, *Seebuch*, p. 155 citing Roger Degryse, 'De oudste vuurbakens van de Vlaamse kust en nabijgelegn Noordseeoevers' (1983). *Statutes*, 21 Richard II, c. 17, 8 Elizabeth c. 13: 'For as much as by the taking away of certain steeples, woods and other marks standing upon the main shores … being as beacons and marks of ancient time accustomed for seafaring men … divers ships … have by the lack of such marks of late years been miscarried, perished and lost in the sea.'

6 Sauer, *Seebuch*, p. 156. Naish, *Seamarks*, pp. 27–8, 51–2. A.W. Lang, *Geschichte des Seezeichenwesens* (Bonn, 1965). Hastings MS, fo. 131v.

The absence of early records of any marks in the Thames is curious. East of Herne Bay, Reculver church is known to have been used as a seamark, and it is possible that there was a very early fire beacon further to the east on the Isle of Thanet, but other references are few. It is possible that the channels were not marked, either because of the risk of attack, or because the local pilots wanted to keep their secrets to themselves. Ironically, in 1561, the Master of Trinity House himself said that 'in his tyme [he] hathe knowen meny shipps to have perisshid vnder pilottes of this Ryver', and as late as 1597 an Armada pilot reported that 'from the cape at North Foreland to the river at Rochester … and then on to London, it is necessary to take on pilots … since the shoals are shifting'. As in the Thames estuary, around the North Sea the topography made sea-marks very necessary, but the construction close to the water of cairns and beacons, some with lights, often obviated the need for marks below high water.[7]

Distance

Recognition of a landmark establishes a directional line from the shore, but to use that information to avoid hidden dangers it is necessary also to know the distance off. Shipmasters in the fourteenth and fifteenth centuries used the apparent sizes of trees, houses, humans and animals to judge distances and, further out to sea, the first appearance of hills or the line of the shore. They learned empirically the range of their vision, the theoretical limit of which, in clear conditions, is a function of the sum of the square roots of the heights above sea level of the observer's eye and of the object viewed. From a ship's deck and from her mast-head the distance at which objects become visible are:

height of on-shore object viewed	10m high	20m high	30m high
height of eye 3½m (on deck)	10 nM distant	12.5 nM distant	14.5 nM distant
height of eye 15m (at mast head)	15 nM distant	17.5 nM distant	19.5 nM distant

where m = metres and nM = nautical miles

Thus, very roughly, the top of a 100-foot hill becomes visible to a lookout atop a 50-foot mast when the ship is something short of 20 miles off-shore, a distance which became, perhaps not by chance, the *kenning* in Middle English, and the *veüe* in Middle French, the unit of measurement of long distances at sea.[8]

7 Reculver church, built in 669, had towers added in *c.*1170. Naish, *Seamarks*, p. 34 citing W. Camden in 1620: 'the steeples whereof shooting up their lofty spires stand the mariner in good stead as markers whereby they avoid certain sands and shelves in the mouth of the Thames.' *The Concise Oxford Dictionary of English Place Names*, ed. Eilert Ekwall (Oxford, 1981): 'Thanet may have meant bright island or fire island suggesting a fire beacon'. G.G. Harris, *The Trinity House of Deptford, 1514–1660* (London, 1969), p. 102. A.J. Loomie, 'An Armada Pilot's Survey of the English Coastline', *MM* 49, 4 (1963), p. 299.

8 Distance in nM = 2.072 x ($\sqrt{h_e} + \sqrt{h_h}$) where h_e and h_m are the heights in metres of eye and object.

That it was about 20 miles is confirmed by William de Worcestre's survey of the Bristol Channel in 1480: 'From the island of Holm to the island of Lunday, two kennings, that is two sights [where] each kenning [is] 20 miles [totalling] 40 miles', and by another reference in the same passage: 'in English, *vue* [is a] sight [a] kenning [of] 21 miles'. William, interestingly, sometimes translated the distance as an estimated sailing time: 'and the said Isle of Man is a distance of four kennings [80 miles] from Ireland, that is a day and night sailing [i.e. at 3.3 knots].' Flat Holm is actually 60nM from Lundy Island, and from Dublin to the south end of the Isle of Man is indeed *c*.80nM. In the Middle Low German *Seebuch*, multiples of the *myle* of three or four miles and also, on occasions, the kenning, were used: 'and watch out for the dangerous ground in the sea that lies 5 miles, or a good short kenning, to the NNE of the Schilt.'[9]

Shorter distances in the sailing directions were measured as long jumps (? 3–4m), bow-shots (? 100m), boat lengths (? 4m), and ship lengths (? 30m). The unit of length used for depths and for cordage was arm-spans, known in Germanic languages by cognates of Old English *fæðm*, the current English 'fathom' (*c*.1.85m) and in Latin languages by cognates of *bras* from the Latin *brachium*, 'arm'. A foot-length was sometimes used to indicate shallow water. While those measures were generally known and recognised, there was the usual medieval variation in unit size, although that perhaps was irrelevant in the overall inaccuracy of measurements assessed by the human eye. Distances that may be checked on a modern chart indicate that a 'sea mile' was between 5,000 and 6,000 feet, the present nautical mile being 6,080 feet. The length of the armspan and the foot also varied, which could be dangerous in the measurement of shallow depths but, so long as the shipmaster was using information related to his own or his peers' experience, or checked the depth in the sailing directions against his own measurement to establish the necessary correction, confusion could be avoided.

Direction

Recognition of a landmark, and an estimate of the ship's distance off-shore, gives one vector of a ship's position; the other, and more difficult, vector for the shipmaster to establish, is the direction being sailed by the ship, a vital component of his calculation when a course to the next destination is to be set and steered. Without a compass, the cardinal points had to be ascertained by direct observation of any indicators available to the shipmaster. The rise and set of the sun are accurate pointers to east and west at equinox but require a daily correction at other times of the year, an estimation which the medieval mariner could probably apply instinctively with variable accuracy. Similarly, the sun's direction when

9 'De jnsulis Holmys vsque jnsulam Londay [.40. miliria deleted] duo kennyngs jd est twey syghts continet quelibet kennyng.20. miliaria, .40. miliaria': *William Worcestre, Itineraries*, ed. John H. Harvey (Oxford, 1969), pp. 302–3. *Seebuch*, MS B, fo. 34v, item 4.

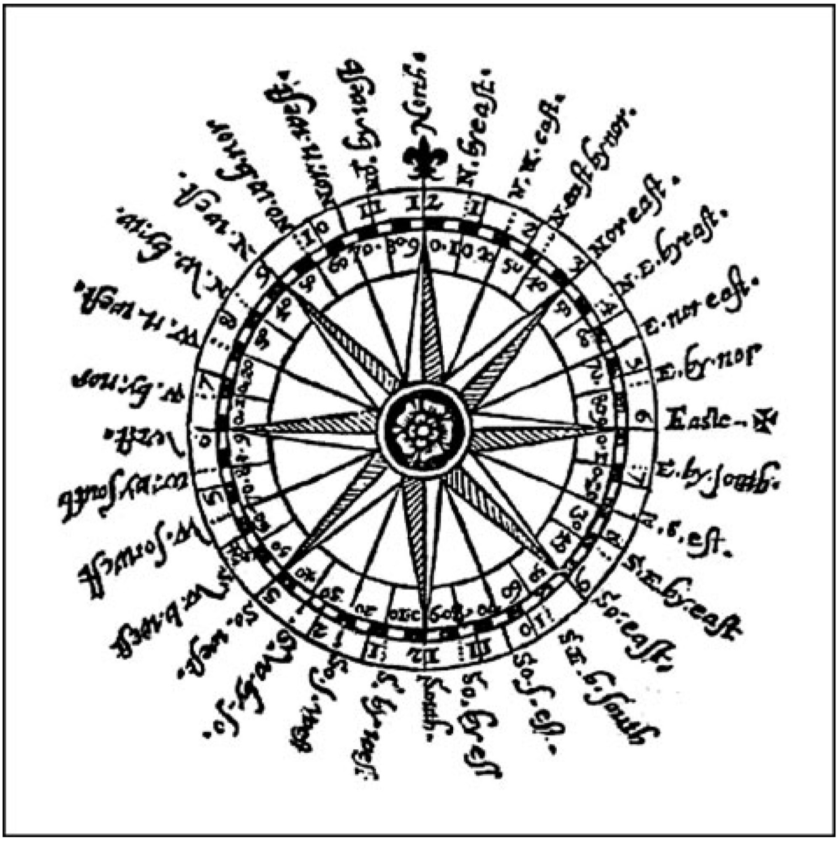
it appears to be at its zenith, indicates south. A sun compass depends on the changing length of shadow measured through the day. In its most primitive form, a trace is made of the diurnal track of the tip of the shadow of a vertical gnomon on a horizontal disc on which north has previously been marked with a notch. At sea, the disc is turned until the tip of the shadow fits exactly on the trace, before or after noon, the notch then again points towards north. Any significant change in latitude or longitude, or delay between zeroing and use, reduces the accuracy of the device, so that for long voyages it was of little value. If, as has been suggested, the sun compass was used by the Norsemen, it might be expected to have been used by medieval shipmasters, but there is no indisputable evidence that such an instrument was carried. Behind cloud cover the sun is difficult to locate but sun-stones, translucent trigonal crystals of calcium carbonate (occurring naturally as Iceland spar) polarise light and may have been used by Vikings and later, possibly, by some medieval seamen to locate the sun; there is, however, no reliable evidence that any early mariners used such stones.[10]

On a clear night the Pole Star (*Polaris* or α *Ursa Minor*), identified by the 'pointers' *Dubhe* and *Marak* in the constellation of *Ursa Major* (the 'Plough', 'Great Bear' or 'Big Dipper'); or the 'guards' β and γ of the constellation *Ursa Minor* (the 'Little Bear'), can be used to locate north. Although the former constellation is the more obvious and easier to use in northern latitudes, the latter appears to have been the constellation of choice for medieval mariners in northern waters, perhaps following the tradition of their Mediterranean predecessors: 'the North star is well enough known by all navigators and is the first of the seven stars of the Little Bear.' *Ursa Minor* was used not only to find north but also as an astral analogue clock with the outline of an imaginary human figure, a method described below, p. 142. When the pointers and the guides of the *Ursae* are hidden by cloud, *Polaris* may be identified, although not with the same accuracy, by extrapolation from other constellations such as *Orion* or *Cassiopeia*. *Polaris* is now circling the pole within a radius of about one degree of arc, in the late Middle Ages it was as much as four degrees off the pole, a drift due to the precession of the earth. This divergence was known to astronomers but unnoticeable to an observer without a compass and was, together with the difficulty of taking bearings and steering an honest course, yet another component in the overall inaccuracy inherent in non-instrumental navigation.[11]

Having established a cardinal point, by whatever method, a shipmaster without

10 Bruce E. Gelsinger, 'Lodestone and Sunstone in Medieval Iceland', *MM* 56, 2 (1970), 219–26. Pliny described the *solis gemma* in his *Natural History* (first century AD); there are several references, possibly to sun-stones, in the Sagas; *MM* 78, 1 (1992), pp. 89–90.

11 *L'Art de navigver de Maistre Pierre de Medine, Traduit de Castillan en Françoys par Nicolas Nicolai du Dauphiné, Geographe du tres-Chrestien Roy Henri II de ce nom* (Lyon, 1554, facsimile edn, Milan, 1988), p. 84. In classical times, β *Ursa Minor* was the 'pole star' which may explain the constellation's original significance.



4 An early 32-point compass with 'lunar times'.

a compass had to extrapolate to left or right to find an approximate course bearing by holding his hand at arm's length. With the arm extended, the width of the fist with thumb alongside subtends at the eye *c*.10° (cf. 11.15° for one point of a 32-point compass rose) and with the thumb and fingers abducted, slightly less than 20°. It is doubtful if even an experienced seaman could consistently estimate bearings within ± 2 points of a 32-point rose, especially when estimating a wide angle on a rolling ship. Further, it is unlikely that even a conscientious helmsman, without a consistent wind or a visible landmark, could hold a ship to within two points of the required course because of the movement of the ship and the force of water against the unbalanced rudder. The resultant course made good, therefore, could have been up to four points either way away from that intended, in other words, somewhere within an arc of 45°. Because something more than two points is the best accuracy that can be expected of a naked eye, any reference to courses and bearings of two points or less, indicates the use of a graduated magnetic aid. In his *A Treatise on the Astrolabe*, Chaucer wrote 'Now is thin orisonte departed in 24 parties by thin azymutes in significacioun of 24 parties of the world; al be it so that shipmen rekene thilke parties in 32.' From that it is clear that sometime before 1391, when the *Treatise* was written, not only were there compasses on at least some ships, but also that some were capable of indicating a direction to within 11.25°. A 32-point 'rose' or 'card' is shown in Figure 4. There are many instances of reliance on astral navigation on medieval ships even after the introduction of compasses. For example, in 1465, Leo of Rozmital set off from Poole for Brittany only to be carried by pirates and unfavourable winds to Guernsey. After an 11-day wait the pirates gave the shipmaster a course to steer by the stars; in the event, a gale blew him to St Malo where he nearly foundered.[12]

With no other indicators, the shipmaster could, as a last resort, obtain a rough idea of direction from a number of natural phenomena. The feel of the surrounding air usually offers not only a clue to the in-coming weather, discussed below, but also an indication of the direction from which the wind is blowing using the rule of thumb that, in northern and western European waters, warm wet winds blow from somewhere between south and west and cold dry winds from somewhere between north and east. Although the accuracy of orientation by the wind is poor in northern waters, in the Mediterranean, where winds are more consistent, they were used for orientation, and the points on a compass card were called 'winds', or *vents*, a practice which continued well into the sixteenth century.[13]

The behaviour of birds may also be used as crude pointers; in season, skeins of geese migrating between British estuaries and Iceland indicate approximately north and south. Less dramatic than the release of birds by Noah and by the Vikings, the evening return of gulls and other non-pelagic birds indicates the direction of land when that is obscured by mist or rain. Positions, rather than directions, can be determined by shipmasters who know certain waters well, for example, by observing concentrations of sea birds feeding on fish attracted by plankton carried by the North Atlantic Drift and brought to the surface by deeper, colder water or by the slope of the continental shelf. The accuracy and reliability of direction-finding by wind or by animal behaviour is uncertain and certainly poorer than by using the sun or the stars however hazily seen. Out of sight of land

[12] Chaucer, *Complete Works*, 'A Treatise on the Astrolabe', 2, 36, lines 6–9. *Rozmital*, pp. 162–4.

[13] The Greek *rosa ventorum* carved in the Athenian Temple of the Winds demonstrates the eight-point (45°) rose:

Tramontano
Maestro Greco
Ponente * Levante
Africo Scirocco
Ostro

Taylor, *Haven-finding Art*, pp. 7, 53–5, discusses 10- and 12-point Mediterranean roses. Barbara Obrist, 'Wind Diagrams and Medieval Cosmology', *Speculum*, 72 (1997), pp. 33–84: 'Ces quatre parties [of the world] se meuuent & sont congneues par quatre vens principaux, qui sont, Leuant, Ponant, Septentrion, & Midy'. Nicolai, *L'Art de navigver*, pp. 25–6.

and with no opportunity to see a heavenly body, a shipmaster had no alternative but to sail his ship on a course which he felt was safe even if it was not taking him to his destination.

Depth and seabed

The seabed is usually the nearest land to a ship and to know its distance and nature are indispensible components of coastal navigation. To measure shallow depths, a pole marked by coloured bands was used from the bows of boats and smaller ships; the Bayeux tapestry shows Harold's ships feeling their way into the French coast in 1064. Medieval ships intending to dry-out on a beach at low water would have felt their way in with such a pole, probably from the ship's boat rowing ahead. In depths of more than a fathom (2m) a lead-line – a weight attached to a length of cord – was indispensable; it could give an approximate position, warn of approaching underwater hazards, guide a ship into a haven, and confirm that the depth and bottom in the haven were suitable for anchoring. No documentary or archaeological evidence of the size and shape of medieval lead weights has been found except for the illustration in the Hastings MS of a ship sounding with a conical or elongated bell shaped weight suspended from a line carried in the leadsman's hand (Figure 7). References in early sailing directions to the nature of the seabed make it clear that the leads were 'armed' with tallow or pitch, pressed into a hollow in the bottom of the lead, to bring up samples. Archaeological finds of seventeenth-century leads (the earliest found) are similar in shape to that illustrated in the Hastings MS and weigh about 7lbs (*c*.3.2kg) and 14lbs (*c*.6.4kg), the latter probably for deep sea work, both with recesses at the lower end to take the tallow. The line to which the lead was attached had pieces of fabric or leather threaded through its strands as depth markers and, for coastal work, did not need to be over 50 fathoms (*c*.30m) and for deep-sea use, up to 150 fathoms (*c*.90m).

There is no reason to suppose that sounding in the Middle Ages was in any way different from today's practice. The lead is thrown as far forward as possible from the bows of the ship by a crew member who allows the line to pay out freely through his hands as the lead sinks. In deep water more men are required, standing along the side of the ship paying out the line as the ship moves forward and the weight sinks. When the line slackens the weight has reached the bottom; the run is then arrested and the line hauled back inboard, one man calling out the depth shown by the markers. Admiralty trials in the nineteenth century found that it takes about 45 seconds for a deep-sea lead to reach 100 fathoms (55m), in which time a ship travelling at five knots will have sailed over 130 yards (120m); ships therefore have to moderate their speed by heaving-to or by easing sheets if they are sailing, before deep soundings can be made. To avoid the ship drifting down-wind over the line, heaving should be from the windward side of a sailing vessel which also offers the leadsmen a better working platform on the higher side.

In the Hastings picture, the men are handling the line on the lee side and, apart from the brailed mizzen sail, the ship's speed appears not to have been moderated; artistic licence has prevailed over accuracy. There is an accurate description of sounding in *Morte Arthure*: '[the man] launchez lede apone lufe lacchene ther depez', and then, 'ffrekes mone the forestayne fakene theire coblez' that is, the sounding lead is thrown over the windward side to measure the depth and afterwards men on the foredeck coil the rope. 'Fakeing' is still the nautical term used for coiling cables on deck or in boxes, ready to run out freely again.[14]

The dramatic change of depth from the continental shelf down to the abyssal depths of the ocean was, and is, used by mariners as they come into, or go out of, 'soundings', as an indication of their distance from land. A unique example occurs in the English rutter, describing a passage from north-west Spain into the Western Approaches: 'And ye bee at capfenister [Cape Finisterre] go your cours north northest … till ye come into Sowding [soundings], And yif ye have an C. fadome depe or else iiijxx.x than ye shall go north.'[15]

Closer in-shore, depths were used to warn of dangers ahead; from the rutter, when crossing the Channel from the South Downs: 'And yif ye turn [tack] in the Downes come not nere Godwyn than ix. fadome ne not nere the brakis [the Brake sandbank] than v. fadome.' Sailors making night passages, or caught in fog, have traditionally followed a suitable depth contour (isobathic navigation) until sure of their position. An example from the rutter reads:

> And yif ye goo fro the shelde [Cromer] to the Holmes [sandbank], and it be in the nyght ye shall go but xviij fadome fro the coste till the gesse [you estimate] that ye be past Limber and Urry [sandbanks], and to the estermare cours [hold an easterly course] till ye come to xiiij fadome … but the moost wisedome is to abide till it be day.

Knowledge of the depth was not always sufficient however to avoid the hazards ahead: heaving-to with plenty of searoom off the coast overnight was not uncommon and ships could be seen in the Channel 'lyeing howlyng in the trowghe of the sea taryeng for the night'.[16]

Samples of the seabed brought up by the tallow on the lead gave the navigator, from his experience or from the information in sailing directions, an idea of his position. In the Western Approaches, for example, pale coloured stones found on the bottom indicate that the ship is standing closer to the dangerous French side of the Channel than to the safer English side where dark stones occur. Sailing in

14 J.E. Davis, *Notes on Deep-Sea Sounding* (London, 1867), pp. 2–8.

15 Hastings MS, fo, 138r, lines 11 ff.

16 Hastings MS, fo. 132r, lines 20 ff. and fo. 131v, line 3 ff. G.V. Scammell, 'European Seamanship in the Great Age of Discovery', *MM* 68, 4 (1982), p. 359: PRO HCA 1/33 fo. 262.

the neighbourhead of Ushant before entering the Western Approaches, the seabed is usefully described in the *Seebuch* thus:

> Also, anyone sounding near Ushant who finds fine white sand and small shells which are white, and small white long things, will know that Ushant lies NW of him; and if he finds small long things like needles, then Ushant lies E of him.

The nature of the seabed decides the holding power of an anchor; thick seaweed has to be avoided as anchors cannot get a grip and rocks of a certain size and shape can imprison an anchor. Anchoring requires a cable of at least four times the depth to ensure a low pulling angle between the cable and the seabed as the ship is blown astern, but such a length may allow the ship to swing with tide or wind into danger. Before anchoring therefore, a shipmaster has to establish that the bottom offers good holding and that within the scope of the cable, i.e. within the radius of the circle around the ship, there are no hazards. After anchoring, the master has to keep an eye on marks ashore to ensure that the anchor is holding fast. He might also assess the state and range of the tide by measuring the variation in depth with time – necessary information if it is proposed to beach the ship to handle cargo, or to proceed further up an estuary.

Tidal times and range

The medieval shipmaster had to know the tidal characteristics of the havens and channels he used, and the off-shore tidal currents in his passages between waypoints. The importance of this information is reflected in the surviving contemporary sailing directions, about one third of which are devoted to tidal information. Although harmonic tidal prediction is an extremely complex mathematical exercise quite unknown to medieval seamen, three lunar phenomena enabled him to obtain sufficiently accurate tidal information to meet his needs. The first phenomenon is the syzygies: when the moon and sun are in line on the same side of the earth, that is, in 'conjunction', the face of the moon is unlit and invisible and said to be 'new'. When they are in line but on opposite sides of the earth, that is, in 'opposition', the face of the moon is fully illuminated and it is 'full'. The second phenomenon is that two 'heaps' of water on opposite sides of the earth are dragged by the gravitational attraction of the moon around the world from east to west in something less than 24 hours. There are therefore usually two high and two low tides in every 24-hour period, occurring at times related to the meridional passage of the moon. Approximately every 15 days, the increased gravitational attraction of the sun and moon, whether in conjunction or opposition, causes a greater range between high water and low water, a phenomenon known as 'Spring tides'. When the sun and moon are at right angles to each other, the range is reduced to give 'Neap tides'. This phenomenon was known, but probably neither understood nor quantified, from the earliest times; a newcomer to tidal phenomena, William of

Worcester, wrote an account of the tidal range at Bristol, sometime before 1480, which, translated reads:

> The height of the sea [the tidal range] in the Avon at the new flood of the sea on the first day of the moon's change [new moon], as I have seen and heard, in the lunation next before the sun's entry into Libra [the equinox] is 7 or 8 arm-breadths, in English 'fathom', and a fathom contains 6 feet, at the beacon.

William's estimate of the Spring range at Bristol, one of the largest in the world, is close to the current Admiralty figure of 12.3m at Avonmouth.[17]

High water springs might be expected to coincide with the meridional transit of the full or new moon, but because of global hydrodynamic friction, inertia, irregularities in depths and the shapes of coastlines, the tidal 'heaps' of water are impeded in their circumterrestial passage and lag behind the moon. The time between the full moon's meridional transit and the next high water springs is the 'lunitidal interval' at each location, known in the past as, variously, the 'tide-hour', 'High Water, Full and Change' (HWF&C), and the 'Establishment' of that place. This interval, assumed for general navigation work to be a constant, was formerly defined by a lunar bearing, using the moon as an analogue clock (explained below); it is now stated as a time relative to high water springs at a standard port, for example Dover, or to a secondary port.[18]

The third lunar characteristic relates to the daily retardation of high water. The earth appears to rotate around the sun faster than the moon circles the earth by between 38 and 66 minutes per day, averaging 48 minutes or 12° in a 360° rotation. Because 180°÷ 12° = 15, the moon takes about 15 solar days to move from conjunction to opposition; and the interval between consecutive Spring tides (and between Neap tides), is therefore approximately 15 days. The 'age' of the moon on any day, counted from 'new', can be used to calculate the delay of the time of high water (HW) relative to the time of high water springs, so that [(the age of the moon in days) x 48 minutes] = the delay of HW (or LW) on that day. As a working approximation, the mediaeval shipmaster rounded down the 48 minutes to 45. Using the moon as an analogue clock, with midnight at north and midday at south (and 06.00hrs and18.00hrs at east and west), any time can be defined by a lunar bearing, as may be seen in Figure 4 and Table 2. The approximate 45-minute daily retardation of the moon, is represented by one point on this analogue clock, and has to be subtracted for each day of the age of the moon. It was therefore

[17] *William Worcestre, Itineraries*, pp. 262–3. In practice, the largest tidal range is typically one or two days after the corresponding syzygy but this 'age of the tide' may be zero or negative in certain locations.

[18] 'Establishment', French *Etablissement*, was described by Admiral W.H. Smyth in his *Sailor's Word-Book* (London, 1867), as 'an awkard phrase lately lugged in to denote the tide-hour of a port'; it is, however, still in use colloquially rather than 'lunar tidal interval'.

Table 2 The moon as an analogue clock

The table gives the time corresponding to a lunar bearing when the moon is full or new, and at seven days into the lunar cycle, i.e. when the moon's 'age' is seven days. For example: in the English rutter: 'All the haunenes be full at a west southe west mone betwene the start and lisart' means that between Start Point and The Lizard, high water will be at 4.30 or 16.30 when the moon is full or new (a Spring tide), and in a week's time it will be at approximately 10.00 or 22.00. By today's assessment, high water Springs at that location is more accurately 5.00 or 17.00 – an error of 30 minutes. A compass rose, with lunar bearings, is shown in Figure 4, p. 131.

Lunar bearing on 32-point compass rose	Lunar bearing in degrees	Time of moon at 'Full and change'	Time of moon at 7 days of age
N	0°/360°	00.00/12.00	05.36/17.36
N by E	11.25°	00.45/12.45	06.21/18.21
NNE	22.5°	01.30/13.30	07.06/19.06
NE by N	33.75°	02.15/14.15	07.51/19.51
NE	45°	03.00/15.00	08.36/20.36
NE by E	56.25°	03.45/15.45	09.21/21.21
ENE	67.50°	04.30/16.30	10.06/22.06
E by N	78.75°	05.15/17.15	10.51/22.51
E	90°	06.00/18.00	11.36/23.36
E by S	101.25°	06.45/18.45	12.21/00.21
ESE	112.5°	07.30/19.30	13.06/01.06
SE by E	123.75°	08.15/20.15	13.51/01.51
SE	135°	09.00/21.00	14.36/02.36
SE by S	146.25°	09.45/21.45	15.21/03.21
SSE	157.5°	10.30/22.30	16.06/04.06
S by E	168.75°	11.15/23.15	16.51/04.51
S	180°	12.00/24.00	17.36/05.36
S by W	191.25°	12.45/00.45	18.21/06.21
SSW	202.5°	13.30/01.30	19.06/07.06
SW by S	213.75°	14.15/02.15	19.51/07.51
SW	225°	15.00/03.00	20.36/08.36
SW by W	236.25°	15.45/03.45	21.21/09.21
WSW	247.5°	16.30/04.30	22.06/10.06
W by S	258.75°	17.15/05.15	22.51/10.51
W	270°	18.00/06.00	23.36/11.36
W by N	281.25°	18.45/06.45	00.21/12.36
WNW	292.5°	19.30/07.30	01.06/13.06
NW by W	303.75°	20.15/08.15	01.51/13.51
NW	315°	21.00/09.00	02.36/14.36
NW by N	326.25°	21.45/09.45	03.21/15.21
NNW	337.5°	22.30/10.30	04.06/16.06
N by W	348.75°	23.15/11.15	04.51/16.51
N	360°	24.00/00.00	05.36/17.36

possible for a shipmaster in possession of a compass, to forecast, but only very roughly, the time of high water on any day in the lunar cycle, at any location where he knew the lunitidal interval. As an example: if high water springs occurs at a certain location at 06.00 (the lunitidal interval of that location), then four days later high water will occur at the time represented by a lunar bearing four points N of E, which is NE, or 03.00 hrs. Aware that the tidal range was greatest at Springs and least at Neaps, the shipmaster would also have been able to forecast, from the age of the moon, the approximate range and therefore the depth of water throughout the lunar cycle.

The lunitidal intervals of many havens are given in the sailing directions, always as lunar bearings: the time of high water springs at the location in the above example would have been defined in the rutter as an 'est mone maketh hiest water' and in the *Seebuch* as 'maket vulsee eyn osten mane'. Information about the direction of tidal streams and of their times of reversal is given in slightly different formulae, which are discussed below.[19]

As an alternative to the sailing directions as sources of tidal information, early coastal maps (they cannot be described as sea charts) illustrated the time of high water springs on a compass rose, at specific locations. The earliest known example of a such a diagram, in the Catalan Atlas manuscript of 1375, consists of 14 concentric circles, each for a different port in Brittany, France and England.[20]

The shipmaster's tidal calculations could incorporate an error possibly greater than an hour, and further deviation from the theoretical might be caused by a persistent wind or by high or low barometric pressure. In short, the medieval mariner with a compass was able to calculate an approximate theoretical time for high water and low water (provided he could see the moon and had kept count of its age), but his rough assessments, local factors and meteorological conditions inevitably reduced the accuracy of his forecast. It is therefore probable that when the tide was of vital importance, a fail-safe factor of an hour or more was incorporated into the shipmaster's calculations. It is possible to calculate tidal times more accurately by observation of the moon with an astrolabe, as Chaucer demonstrated in his *A Treatise on the Astrolabe*, but it could not be used on the wind-blown deck of a violently moving ship. The instrument was available ashore long before the fourteenth century but apparently seamen were not interested, presumably because of its expense and limited use – 'Ffor as moche as yche man may not have þe astrolabe'.[21]

19 In relation to the stars, the sun appears to move about 1° E and the moon about 13° E each day, hence the apparent 12° 'lag'. There are several definitions of the lunar cycle; the synodic (relative to the sun) is 29.53059 days, the sidereal (relative to the stars) is 27.32166 days, the tropical (relative to the equinox) is 27.32156, and others.

20 Derek Howse, 'Some Early Tidal Diagrams', *MM* 79, 1 (1993), pp. 27–43.

21 Chaucer, *Complete Works*, pp. 544–63, although the authorship of these *Supplementary Propositions* is uncertain.

Illiterate shipmasters without sailing directions had to remember the tidal times for the havens they used, possibly with mnemonics to assist them of the type: 'High water London Bridge, / Half ebb in the Swin; / Low water Yarmouth Roads, / Half flood at Lynn.' The earliest tide tables known in Europe, 'of fflod at london brigge', were produced by the monks of St Albans, early in the thirteenth century. It is interesting that, as those tables show a constant 48 minutes daily correction, they appear to have been constructed from theoretical calculations rather than by empirical observation. Considerably earlier, the Chinese are known to have constructed tide tables for the bore on the river Chien-Thang, near Hangchcow, some time before the eleventh century, demonstrating their understanding of the regularity of Spring tides and the lunar influence on tides.[22]

Knowledge of the depths at the entrances to and within harbours and anchorages was valuable information for enemies and pirates and not to be shared lightly with ships from other ports. Perhaps for that reason, the early rutters are stronger on tidal streams directions, tide-hours and off-shore depths than they are about the depth of water in havens. The few harbour depths that are included in the sailing directions are usually simple statements of the minimum depth, and only rarely is any indication of the depth at several points in the tidal range given. For example, in the rutter there is a very generalised (and not entirely accurate) reference to high water times in the harbours on the south-west coast of England but with no depths. The *Seebuch*, however, is more forthcoming on the depth of water in the havens along the same stretch of coast, perhaps because for the Hansa seamen these were not home waters and there was no need for security: 'Between Falmouth and the Lizard there lies a tidal haven called Helford and whoever wants to sail in must have a quarter flood tide [i.e. 1½ hours after low water] for a ship which draws two fathoms [5.4m] and it is a good haven.' The Helford estuary is indeed a good haven, sheltered from all but easterlies with a Springs tidal range of 4.7m. Entering strange havens without information from sailing directions, the canny navigator had always to include a fail-safe margin in his calculations, or lie off for a tide to observe the time and range, unless he had hired the services of a local pilot.[23]

Tidal streams off-shore do not necessarily change direction at the times of high water and low water on the adjacent land, but the necessary information about current directions and reversal times was given in the sailing directions. No speeds of the currents could be given, however, as the measurement of the speed of a tidal

[22] *MM* 3 (1913), p. 319, 'Answers 81 (S.G.)'. Commander W.E. May and Captain L. Holder, *History of Marine Navigation* (Henley on Thames, 1973): British Library Add. MS 30221 (Codex Cotton, Julius DXVII, page 45b). Joseph Needham (with Wang Ling), *Science and Civilisation in China*, 3, 21, pp. 483–94 (Cambridge, 1959).

[23] Hastings MS, fo. 133r. *Admiralty Tidal Stream Atlases*, Hydrographic Office, NP 250 (English Channel), NP 251 (North Sea, Southern Part), NP 265 (France, West Coast). *Seebuch*, MS B, fo. 7v, item 1.

stream was not possible. In the *Seebuch*, the actual stream reversal times are given in terms of lunar bearings, sometimes at different distances off-shore, and in the English and French rutters they are defined as the duration of the flood or ebb after high water or low water ashore, at an unspecified distance from the coast. The time lag between high water ashore and the tidal stream change is generally described in the rutter as one tide running under the other – 'under rothir' – and was measured in quarter or half tides, i.e. 1½ hours or 3 hours. An example from the rutter reads:

> And at the schelde it floweth on the londe west north west and half strem vndir rothir be the londe till ye come to wyntirbornesse and fro wyntirbornesse til ye come to kyrkle rode it floweth on the londe northe west and quarter tide and half quarter vnder rothir.

This may be paraphrased 'And off Cromer as far as Winterbourness it flows WNW for 3 hours after high water ashore. And from Winterbourness to the Kirkley roadstead it flows NW for 2¼ hours after high water ashore'.[24]

Although not quantified, warnings of severe tidal dangers, especially around Ushant and amongst the Channel Islands, are sometimes given in the sailing directions. For its dramatic value, a somewhat later example from the 1540 French edition of the Scottish rutter of Alexander Lyndsay describing the Corrievreckan, is worth repeating:

> There is another great danger … caused by four or five contrary tides with a great swirling of water causing a deep and noisy whirlpool. The middle is very dangerous for all ships, large and small … and there is no other refuge but to die.

Enough, surely, to deter any mariner.[25]

The rutter and the *Seebuch* make use of every possible non-instrumental aid to navigation and often include several 'notes to mariners'; a good example from the *Seebuch* describes the approach to Hunstanton thus:

> when you arrive at the Wash with a heavy ship and want to go further in, then take a big quarter flood tide, but if you have an outward flowing stream and a westerly wind, then anchor until the stream sets inwards; when the wind blows with the sea [i.e. on the flood tide], then run in with a small sail for as long as the stream sets inwards; and if you arrive by day, anchor over-night in

24 Hastings MS, fo. 131r.

25 R.M. Ward, 'Sailing Directions for James V of Scotland', *History Scotland*, 4, 2 (March / April 2004), pp. 25–32. Spring tides race through the Corrievreckan at up to eight knots. It is navigable under sail at slack water with a favourable wind.

> 10 fathoms and wait for the [next] flood tide. And there is there a dangerous high stony sandbank and it is on the port side as one sails in; then you see a headland [Gore Point] and a steep cliff close by the water and you will see the two pointed high towers [possibly the Church of St Mary the Virgin] to the west of the chapel [St Edmund's chapel on St Edmund's Head]'.

With knowledge of the local lunar-tidal interval to calculate the time of the flood, a shipmaster had all the information he needed to approach the town. When sailing out, the shipmaster is advised to bring the two spires, which are described as 'runners' (presumably because of the parallax effect as the ship moves), a good bow-shot to the west of the chapel. Silting and erosion have radically altered the shape of this coast line so that the accuracy of the directions cannot be assessed today.[26]

Time, speed and distance made good

An accurate estimate of the time of day was of greater importance to the medieval shipmaster than to his peers ashore, most of whom lived by an elastic liturgical *horarium* marked by bells. The shipmaster was also interested in elapsed time, for example, how long his ship had been on one tack or how long a piece of wood took to float along the length of the ship. Sometime towards the end of the thirteenth century, sand-glasses, probably of a half-hour duration, began to be used on board ships for the measurement of fixed periods of time (their appearance in ships' inventories is discussed below). There still remained the problem of the estimation of variable periods of elapsed time. Guesses at the passage of time are subjective, the accuracy of the guess decreasing with the length of time estimated. Long periods of elapsed time may be measured by the difference between the time of day at the beginning and end of an event. Ashore, that was easily measured with a sundial or an astrolabe; as early as 1024 an academic in Cologne invited a friend to see his astrolabe with which he could calculate, *inter alia*, the time of day, and therefore elapsed time, and latitude. But sundials and astrolabes require a stable base for operation, a condition not available on the deck of a rolling the ship, and instruments were expensive; in daylight at sea, therefore, only midday could be judged by the sun's meridional passage (provided that a compass was available), from which rough estimates of the time of day could be extrapolated, albeit with limited accuracy.[27]

Telling the time on a clear night is an altogether easier and more accurate process. Apart from the use of the moon for tidal time calculations, medieval

[26] *Seebuch*, MS B, fo. 34r, item 1.

[27] Psalms, 119, 64: 'seven times a day I praise Thee for thy righteous ordinances': matins, prime, tierce, sext, none, vespers and compline (also lauds at dawn). Taylor, *Haven-finding Art*, p. 90: Ragimbold, *magister* of the schools of Cologne, invited Radolf of Liège to see his new astrolabe.

seamen used the circular movement around the Pole Star, *Polaris,* of 'the guards' of *Ursa Minor,* now known as stars β and γ of that constellation, which can be read as if they were the hands of an analogue clock. The clock, however, marks sidereal time, a 'day' of which is 3 minutes 56 seconds shorter than the mean solar day of 24 hours. The classical Mediterranean method of reading solar time from sidereal information was to imagine a 'man in the sky' over the observer's head; he was thought of as face downwards, head towards north, hands stretched out laterally east and west. To know the time, the position of the guards relative to the figure was noted, and mnemonic jingles were recited to convert that to the time, for example: 'Mid-July, midnight in the right arm. End of July, an hour before the right arm.' There is no mention in either the German or the English sailing directions of such methods of telling the time, all tidal times being related to lunar bearings. However, an experienced seaman would have had no need for the 'man in the sky' nor for the mnemonics; by mentally relating the guards as they appeared at sunset to his estimate of the time, he could follow the astral rotation through the night and instinctively 'read the time'. Such a reading of the time probably had an accuracy of no better than ± 1 hour, and then only if the reference time had been correct. The time of dawn could also be deduced from the position of the guards at any season of the year or, alternatively, Pierre de Medine's *L'Art de Navigver* suggests dividing by two the day length in hours (if that information is known), then subtracting the quotient from 12 (i.e. midnight). Interestingly, the day length examples given in the table in *L'Art de Navigver* are valid for latitude 46° 40′ N (just south of the île de Yeu in the Bay of Biscay) and the dates are in the Gregorian calendar.[28]

Short periods of time may be measured by recitation or counting. To measure in seconds, rhythmic counting was (and is still) used: 'one-and-two-and-three-and …' and for longer periods, prayers were recited. Surviving examples from the fifteenth century include: 'And in a minute, a man may resonably say a *pater noster* and an *ave*'; a *miserere* took the length of time required to boil an egg (hard or soft is not specified, but perhaps four minutes!); and one hour is 'as longe tyme as thou may say two nocturnes of the psalter'. No doubt there were other traditional mnemonics for counting the passage of seconds, minutes and hours. To estimate a ship's speed, a floating marker could be timed down the length of her hull; the time in seconds, related to the water-line length, giving a measure of the speed through the water. A marker passing down the side of a 23-m ship would take the following approximated times:

[28] *L'Art de navigver*, pp. 114–15.

At a speed of 1 knot	44 seconds	e.g. a cog sailing in a light breeze (Beaufort scale 1–2)
At a speed of 3 knots	15 seconds	sailing in a gentle breeze (Beaufort scale 3)
At a speed of 5 knots	9 seconds	sailing in a fresh breeze (Beaufort scale 5)
At a speed of 6 knots	7 seconds	sailing in a strong breeze (Beaufort scale 6).

All these times are within the range of accuracy of rhythmic counting.[29]

Although some idea of the ship's progress could be obtained by multiplying the estimated average speed by the number of hours sailed, a ship's speed through the water is not necessarily the same as her speed over the ground. The precise distance covered was uncertain so long as the shipmaster was unable to measure the ship's leeway and the speed and direction of any current. Sailing at night, a shipmaster would have had to 'fail-safe' by deliberately overestimating the ship's speed and, if necessary, heave-to, to avoid reaching land before dawn, as in the example given earlier of the entrance to Hunstanton.

In the unusual event of a long passage out of sight of land, the shipmaster could measure his progress only as the number of days sailed, just as his predecessors had done hundreds of years before: Ohthere's eighth-century account of his North Cape voyage illustrates this: 'Then he travelled north close to the land: he left that west land always to starboard, and then the open sea on the port side for three days.' William of Worcester, as discussed above, did the same in the mid-fifteenth century: 'Et dicte insula Man distat per 4 kennyngs de Irlanda [and the said Isle of Man is a distance of four kennings from Ireland] id est a day and a nyght saylyng.' Given the substantial doubt that a shipmaster must have entertained about his position after a day out of sight of land, it is not surprising that he preferred to keep the coast in sight whenever possible.[30]

The introduction of instrumental aids, however primitive, allowed the first steps towards 'indirect' navigation. The aids have now evolved into a suite of instruments dependent on gyroscopes, radio waves, high-frequency sounds and geo-positioning satellites, all requiring the minimum of human intervention (or indeed, skill) to operate.

[29] Laurel Means, 'Popular Middle English Variations on the Compotus', Speculum 67 (1992), pp. 595–623 at p. 621: Cambridge, Trinity College, MS o.10.21, fols. 36v–37r. Don Lepan, The Cognitive Revolution in Western Culture (London, 1989), p. 91. Albrecht Sauer, 'Segeln mit einem Rahsegel', in Die Kogge, ed. Gabriele Hoffmann and Uwe Schnall (Bremerhaven, 2003): for sailing performance of cog, see 'Sailing', chapter 7.

[30] 'Þa for he norþryhte be þaem lande: let him ealne weg þaet weste land on ðaet steorbord, ond þa widsae on ðaet baecbord þrie dagas', British Library, Add MS. 47967, 'The Voyages of Ohthere and Wulfstan', in *Sweet's Anglo-Saxon Reader in Prose and Verse*, ed. Dorothy Whitelock (Oxford, 1983), p. 17, lines 9–11). *William Worcestre, Itineraries*, pp. 302–3.

Indirect, or instrumental navigation

Magnetic compasses

North-seeking magnetic devices have been known in Europe since the twelfth century and perhaps earlier, but exactly when they began to be used at sea is not known. The earliest direction indicators were 'lodestones', pieces of a naturally magnetic mineral, magnetite (Fe_3O_4), which, suspended by a thread, would point north. The discovery that iron could be magnetised by stroking or touching with magnetite, led to the substitution of the stones by needles which, because they were of 'soft' iron, had to be frequently remagnetised. The use of such needles for direction finding was the subject of a lecture in Paris in 1180 by an English monk, Alexander Neckam. In his *De Naturis Rerum* he wrote:

> hidden by the gloom of nocturnal shadows as the world revolves, and not knowing towards which point the bow is heading, they place a needle above a magnet, which turns around continuously until, its movement ceasing, its point may indicate the north region.

It has been generally accepted that Neckam meant by this that contemporary sailors were already familiar with magnetic aids to navigation but the use of the subjunctive of 'indicate' should suggest some caution.[31]

More convincing evidence of the early use of a magnetic needle at sea may be found in the poetry of Guyot of Provins from around 1205, in which he describes sailors magnetising a needle by touching it with lodestone and then floating it, stuck through a straw, on water'. Such a compass would, however, swill about with the movement of a moving ship and was probably usable only in the calmest of seas. It is interesting that although the current Italian for a compass is *bussola* there survives the older term *calamita*, 'a frog', which might possibly be a reference to the floating needle. That remagnetisable devices were well known a century later may be adduced, by default, from *Barbour's Bruce*: 'in addition, there was no needle nor stone' in the ship in 1306 for Bruce's passage to Carrick. The need to remagnetise the compass needle is apparent over more than a century; there are several references to a needle and stone in English alliterative poetry written around 1400, the former never without the latter. Examples include a line in *Morte Arthure*: 'with the nedylle and the stone one the nyghte tydez'; and a line in *The Libelle of Englyshe Polycye* written in 1435–36: 'Men have practised by nedle and by

[31] The extract in full reads: 'cum caligine nocturnarum tenebrarum mundus obvolvitur, et ignorant in quem mundi cardinem proara tendat, acum super magnetem ponunt, quae circulariter circumvolvitur usque dum, ejus motu cessante, cuspis ipsius septentrionalem plagam respiciat': Taylor, *Haven Finding Art*, pp. 9 and 95–6. *Respiciat* here is the third person present subjunctive of *respicere*. Taylor cites Alexander of Neckam, *De Naturis Rerum*, ed. T. Wright, pp. xxxv–xxxix and 183.

ston.' As late as 1485, the Celys bought a piece of magnetite in order to remagnetise two compasses on their ship.[32]

Flavio Gioia of Amalfi has been credited with the invention of the graduated compass card to which a magnetised needle was attached, as early as 1302. Although a dubious claim, it is said by Amalfians to be substantiated by the motto on the city's arms, 'prima dedit nautis usum magnetis Amalfis'. As this is a line from a poem by Antonio Beccadelli who died in 1471, the provenance of the motto, and the claim, have to be regarded with some circumspection. The problem of the oscillations of a needle on a ship at sea appears to have been partially overcome sometime in the fourteenth century by pivoting it on a pin, and it is perhaps this that was the invention of Flavio. With the next step of mounting a magnetised needle under a marked card (the 'rose') pivoted on a pin, the compass evolved to become an instrument with which bearings could be read to an accuracy of one point of a 24-point rose, i.e. 15°. Further improvements in the mounting of the card allowed an accuracy of one point of a 32-point rose, or 11.25°, even at sea. This development was confirmed by Chaucer in 1391 and has been discussed above, p. 132.[33]

The manufacture of magnetic compasses, probably for use on land, flourished in Flanders from the fourteenth century but by 1394 the Hansa employed its own compass makers, no doubt for marine use. The earliest known references to magnetic direction-finding aids in English naval ships are in the 1410–12 inventory of the *Plenty*, which had on board '1 sailing piece', and the *George*, for which '12 stones, called adamants, called sailstones' were bought for 6s. in Flanders. Although it is probable that the adamants were to be used to 'stroke' the soft iron compass needles, their purpose is not known with any certainty.

The date of the introduction of magnetic devices to English merchant ships is not known. Although the *OED* gives the earliest reference to the word 'compass', in an indubitably magnetic sense, as late as 1515, the Yarmouth customs accounts show a dozen 'compas' brought in by a Netherlands ship in 1400 for unknown customers and purposes, and the naval inventories of 1422 show one 'compass' on each of the *Rodcogge* and the *Katerine Britton* (but none on the two dozen other ships of the fleet). If those 'compas' were magnetic and not geometrical instruments, which is possible, then there were remarkably few in the English fleet. Indeed, a nineteenth-century naval historian remarked that 'every vessel might not have been supplied with them, only the Admiral or leading ship of a squadron or fleet'. It is possible, however, that naval shipmasters, like mercantile mariners, had

[32] *Barbour's Bruce*, 3, Book V, pp. 105, l. 18. *Morte Arthure*, l. 753. *Libelle of Englyshe Policy*, chapter 10, l. 801, p. 41. Hanham, *Celys' World*, pp. 362–3.

[33] António Estácio dos Reis, *Medir Estrelas* (Lisbon, 1997), pp. 30–42. J.A. Bennett, *The Divided Circle* (Oxford, 1987), pp. 27–30. Gimballs to allow the compass bowl to swing freely were first recorded in 1537 by the Portuguese Pedro Nunes. Chaucer, *Complete Works*, pp. 544–63.

their own compasses which were not listed in the ships' inventories, as in the case of John Aborough (see p. 117).[34]

Magnetic variation (the angle subtended between lines pointing to magnetic and to geographic North) had been observed by academics ashore and by the Augsburg sundial manufacturers from early in the fourteenth century. Variation, together with compass deviation (errors due to an inherent fault in the compass or to adjacent pieces of iron), however, was not recognised, or at least not corrected, at sea until much later. Historic variation in the northern hemisphere has been calculated from palaeomagnetic evidence by two groups of researchers who, unfortunately, reached differing conclusions. The variation in the English Channel in 1450, for example, was calculated by one group to have been 2°W and, by the other group, 4°E. Although substantially different, these results suggest that the variation was not gross in either direction and certainly less than one point on a 32-point rose. Given the inaccuracies of the early compasses and the difficulties of reading a bearing on a heaving ship, such a variation would have been unnoticeable. Indeed, since the Pole Star could be used to calibrate compasses to within a degree of true North, the failure of the early navigators to notice any variation reflects the poor accuracy of their instruments.[35]

The eventual general introduction of the marine compass, whatever were the instrument's shortcomings, had a remarkable effect on sea-borne exploration and commerce. With some guarantee of the accuracy of the course, passages out of sight of land became less speculative and the efficiency of the commercial shipmaster was improved dramatically, perhaps by a factor of two. The increasing quantities of goods loaded on ships for transport around, rather than by cart

34 D.W. Waters, *The Art of Navigation in England in Elizabethan and Early Stuart Times* (London, 1958), p. 25. G.V. Scammell, *The World Encompassed: The First European Maritime Empires c.800–1650* (London, 1981), pp. 22, 76: PRO E 122/150/3m. 7d. Rose, *Lancastrian Navy*, pp. 142, 155 and Appendix III, pp. 229–46. Nicolas, *Royal Navy*, II, p. 444. Burwash, *Medieval Shipping*, pp. 33–4: shipmaster John Aborough's 1533 inventory included four compasses.

35 It was thought at one time that lines of equal variation ran north and south and could be used to estimate longitude (isogonal navigation). Columbus, in 1492, recorded the fallacy: 'En este dia, al comienzo de la noche, las agujas noruesteaban, y a la mañan nordesteaban algo tanto' (from his *Diário* in dos Reis, *Medir Estrelas*, p. 35). *Obras Completas de D. João de Castro*, ed. A Cortesão and Luis de Alburquerque (Coimbra, 1969–82): in 1538 João de Castro observed magnetic deviation induced by a cannon close to the compass. L. Hongre, G. Holst, and A. Khokhlov, 'An Analysis of the Geomagnetic Field over the Past 2000 years', *Physics of the Earth and Planetary Interiors*, 106 (1998), pp. 311–35; C.G. Constable, C.L. Johnson and S.P. Lund, 'Global Geomagnetic Field Models for the Past 3000 Years: Transient or Permanent Flux Lines?', *Philosophical Transactions of the Royal Society of London*, 358 (2000), pp. 991–1008. These two archaeomagnetic studies found, for 1450, magnetic variation of: 2°E and 5°E in northwest Spain; 3°E and 3°W at Ouessant and in the Irish Sea; 4°E and 2°W on the east coast of England; and 5°E and 1.5°W on the coast of Brittany, respectively. Magnetic variation is now ± 7°W in the English Channel.

across, Europe, has been attributed to the increasing availability of the compass; ships were at last seen to be reliable alternative carriers.[36]

Measurement of astral heights

Instruments such as the quadrant, rectangulus and cross-staff had been in use on land for measuring astral altitudes before the fourteenth century. Although sufficiently robust, compact and economic, the first two had the practical limitation of reliance on a plumbline, which was impracticable at sea. Cross- and back-staves may have been in use at sea in the fifteenth century but the first record is from 1514 and is Portuguese. The 'astrolabe', mentioned above as an instrument with which to measure azimuths and altitudes and so derive latitude, the time of day, sunrise, sunset and the sun's position in the zodiac, had been known since the eleventh century. It began to appear in commercial quantities in the fourteenth century and its operation was described by Chaucer in *A Treatise on the Astrolabe*. Its use at sea was restricted by its sophistication and cost, however, and, although it was suspended by an integral ring and was weighted in the lower arc to reduce oscillation, it was practicable only on the calmest of days. The earliest known reference to the use of an astrolabe on a ship dates from 1481 and is also Iberian, but the ship may have been in shelter and not sailing.[37]

The importance of knowing the ship's latitude while at sea had become apparent to the Portuguese early in their exploratory voyages. They began colonising the Azores in the 1430s and in repeatedly re-finding the islands, they must have practised some form of latitude estimation, although there is no record of that until a generation later. Further, by 1433 they had doubled Cape Bojador some 700 miles south of Portugal. Returning by the *volta pelo largo*, a wide swing out into the Atlantic to find wind with a southerly component, they somehow knew when to turn east for home. There is some evidence that, before measuring instruments usable at sea were available, they made very rough estimates of latitude from astral heights measured against a vertical lance or perhaps by the length of the shadow cast by the mast. The first recorded measurement of *alturas* (astral heights) at sea was off the African coast in 1455 by Alvise de Cadamosto. By 1460 Diogo Gomes,

[36] *Encyclopaedia Britannica* 99, 'Compass': William Barlowe, *Magnetical Advertisements*, p. 66. As late as 1616 the compass was described as 'the most admirable and useful instrument for the whole world [but] is both amongst ours and other nations for the most part, so bungerly and absurdly contrived, as nothing more': F.C. Lane, 'The Economic Meaning of the Invention of the Compass', *American Historical Review* 68, 3 (1963), pp. 605–17.

[37] Means, 'Variations on the Compotus', p. 599: Cambridge University Library MS Ll. 4.14, fo. 155r, 'The Wise Book of Astronomy and Philosophy'. Bennett, *Divided Circle*, pp. 12–19, 32–6. dos Reis, *Medir Estrelas*, p. 55, 79: the quadrant is mentioned from the thirteenth century in the Portuguese *Libros del Saber Astronomia*. Bennett, *Divided Circle*, pp. 12–19. National Maritime Museum, *The Planispheric Astrolabe* (London, 1989). Alan Stimson, 'The Mariner's Astrolabe', *HES Studies in the History of Cartography and Scientific Instruments*, 4 (Utrecht, 1988), pp. 13–44: citing the West African voyage of Diogo d'Azambjos.

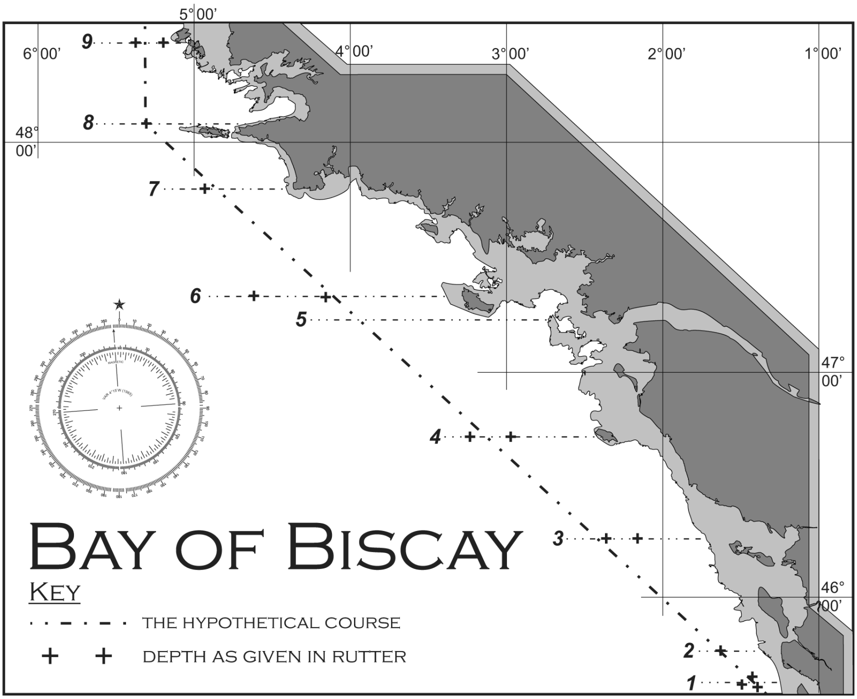
sailing south on the west African coast, could write: 'And I had a quadrant when I was at those countries [places], and I wrote on the scale of the quadrant the height of the arctic pole.' With pre-calibrated instruments it was possible for Portuguese ships, with relatively unschooled navigators, to remain far off-shore for days when sailing north or south before turning east for land.[38]

The introduction of northern seamen to Portuguese methods of determining and using latitude is thought to have been effected in the sixteenth century via Pedro de Medina's *Art de Navegar*, first published in 1545 and later translated into German, French, Italian and English. The determination of latitude was therefore apparently not part of a northern European shipmaster's navigational technique until mid-sixteenth century. The Bordeaux wine ships returning to England, have generally been assumed to have sailed in-shore around the Bay of Biscay, with a victualling stop at St Matthieu. However, a section in the rutter lists depths, descriptions of the seabed, and invisible waypoints on land, with which it is possible to plot a hypothetical off-shore passage on an Admiralty chart, even without distances and course bearings, none of which are given. The information in the rutter is in the form: 'open of Pertuis Maumusson, in 12 fathoms there is stinking mud; open of the Pointe d'Arseaux, in 24 or 26 fathoms there is large gray sand and small black stones with large white shells'; and so on past the Île d'Yeu; the Loire; Belle-Île; until 'open of Ushant, in 50 or 60 fathoms there is red sand and black stones with white shells'. A course drawn through the mean positions of these soundings, with confirmation from the description of the seabed, runs north-west from the Gironde, turning north, probably off Penmarc'h, to lead, west of Ushant, into the Western Approaches. Relevant extracts from the rutter text and the hypothetical course pricked on a chart, may be seen in Figures 5 and 6. This evidence makes it very probable that English shipmasters did take this off-shore route, which would have been quicker, free of pirates and less exposed to the risks of shipwreck.[39]

But there remains the question of how the shipmaster was to know when he was 'open' of the waypoints listed, when they would have been out of sight for most of the passage. Was he to compare mentally the distance along the in-shore arc (which he knew) with the distance he had sailed on the off-shore chord (which he could measure)? Or might this section of the rutter have been the 'borrowed' depth and seabed section of a thematically organized Portuguese *roteiro* which included the *alturas* (astral heights and therefore latitudes) of the waypoints? Astral heights, not yet measurable by Englsh navigators but perhaps vaguely

[38] dos Reis, *Medir Estrelas*, *passim*.

[39] Hastings MS, fo. 137v, lines 6 ff. The counts of Léon controlled the coast from Roscoff to St Mathieu from the thirteenth century; *sceaux*, later *brefs*, were sold to merchants on passing ships as guarantees that in case of shipwreck their goods would be safe (contrary to the Breton *droits de bris*); Guyomarc'h de Léon in 1235 described the coast as 'une pierre plus précieuse qu'aucun joyau': Jean Delameau, ed., *Histoire de la Bretagne* (Toulouse, 1987), pp. 160–2.



No.	'Open of'	*Rutter* **Soundings** (in fathoms)	***Rutter* description of sea-bed**	**Admiralty sea-bed information**	**Notes**
1	The Gironde	12, 14 and 16	Mud and sand	Sand, shingle	Course North West
2	Pertuis Maumusson	12	Stinking mud	Sand, mud	
3	Pointe d'Arseaux	24 or 26	Large grey sand, small black stones, large white shells	Sand, shingle	Out of sight of land
4	Île d'Yeu	50 or 60	Muddy sand	Sand, mud, shingle	
5	The Loire	None given	None given		
6	Belle-Île	60 or 70 (?aberrant)	'Dial sand'	Mud, sand, shingle	'Dial sand': small, round grains (as in sand-glasses)
7	Pointe de Penmarc'h	50	Black mud	Sand	
8	Île de Sein	60	Sandy mud and black 'fishy stones'	Sand, shingle	Course North. Fish-shaped black lenticular biotite (mica)
9	Ushant	50 or 60	Red sand, black stones, white shells	Sand, shingle	

5 Hypothetical passage across the Bay of Biscay. Illustration by Ruairi Prendiville.

understood by them, may have been translated, *faute de mieux*, as 'open of', and taken to mean 'on the same east–west line'. If that hypothesis is correct, 'open of', before translation, was 'on the latitude of' and Portuguese mariners had already estimated and logged the latitudes of port towns on the Bay of Biscay.

Another item in the description of the off-shore Biscay course is of particular (and peculiar) interest: 'Opyn of the saym [the Ile de Sein] in lx fadim ther is sondi wose [mud] and blak fischey stonys amonge.' On the latitude of 48° 6′N, which is approximately the latitude of the Île de Sein, the hypothetical passage crosses a geological fault where 'mica fish', or black lenticular porphyroclasts of biotite distorted to fish shapes by tectonic stresses, might be expected. The depth of 60 fathoms (*c.*110m), the reference to the Île de Sein, and this geological phenomenon thus give a precise latitude fix for that point on the course.[40]

It is not known if it were simply a lack of technique, or a complacent satisfaction with their coastal routes, that explains the fifteenth-century northern seamen's lack of interest in astro-navigation. Even voyages from England to Iceland could be made by compass alone, by sailing up the Irish Sea and the Sea of the Hebrides in sight of land, and thence due north until landfall was made on the Faroes. From the north end of the Faroes the course would have been altered to WNW for Iceland, a leg of about 240 miles, with the 2000m mountains in south-east Iceland being visible as marks in clear conditions from not far past half way. Passages across the North Sea could be made in three or four days by sailing on a compass bearing with no visible waypoints, until making landfall somewhere on the Danish or Norwegian coasts. It was therefore possible for a shipmaster trading in northern waters to go about his business without any knowledge of latitude.[41]

Measurement of time

The sand-glass, the first instrument (after the lead-line, if that may be described as an instrument) to be introduced on board ship, begins to appear in the inventories of English ships from 1295 as a 'dyoll', 'horloge de mer' or 'renning glass'. Primarily used to measure day and night watches, it could also be used to mark a fixed period (that of the particular glass) for navigational purposes; for example, when the ship's course had to be altered after a certain time in order to clear a known hazard, or when a certain fraction of tide was required before attempting to enter a harbour. Both situations may be found in the early sailing directions: 'than ye must goo southe a glass or ij for cause of the rokke' in the rutter; and 'but a large

[40] Admiralty chart no. 20, 'Île d'Ouessant to Pointe de la Coubre'. Dr Gerald Roberts, University of London, kindly identifed the 'fishey stones'. The geological fault runs irregularly slightly north of W through the Île de Sein and out to sea. It may be seen on Google 'MapApp' from which a bathymetric profile showing the fault may be drawn from land to sea.

[41] Distance in nM = 2.072 x $(\sqrt{h_e} + \sqrt{h_h})$ where h_e and h_m are the heights in metres above sea level of eye and object.

ship must have two thirds of the tide and a ship which draws two fathoms must have one third of the tide' in the *Seebuch*.[42]

Medieval sand-glasses were too fragile and degradable to have survived, but the example above of an elapsed time as a measure of distance, confirms that the running time of a sand-glass must have had some degree of standardisation, probably of 30 minutes. Assuming a speed of five knots in the example, such a standard glass would allow the ship to travel 2½ miles. The optional second glass may have been for ships sailing in light winds or otherwise incapable of attaining a reasonable speed. The glasses were not always filled with sand but sometimes with crushed egg-shells or powdered silver or tin; whatever the powder, the neck of the instrument eroded in use, and the time measured consequently decreased. In Columbus's log of his first voyage he wrote '14 glasses each of half an hour or slightly less', illustrating this lack of accuracy due to erosion. False measurements were also obtained when the glass was turned by a cold, tired and impatient watch-keeper before the run was complete. In short, estimates of elapsed time measured by the glass were not entirely reliable, but almost certainly better than by any non-instrumental method.[43]

Assessment of speed and distance run

The methodology of measuring speed (and so calculating the distance run) was inverted by the introduction of the sand-glass. Instead of counting the time required to travel a fixed distance (for example, to time a wood chip floating the length of the hull), it became possible to measure the distance covered in a fixed time. A substantial piece of wood, the 'log', was attached to a length of line and thrown into the sea; at the same moment a short period sand-glass was turned over. The length of line pulled out by the 'log', measured in arm-spans, during the fall of the sand, gave a direct measure of the speed of the ship (assuming that the wood had not been dragged through the water). A half-minute glass represents $^{1}/_{120}$ of an hour and the pro rata fraction of a 5,000-foot mile (as it was then thought to be) is 41 feet 8 inches or about seven arm spans (or seven fathoms); each length of seven fathoms veered in half a minute therefore represents one mile sailed by the ship in an hour. Seven fathom lengths were later marked by knots in the line to give an immediate measure of the ship's speed in 'knots'.[44]

It is not known when the log came into general use; the first known English reference is as late as 1574:

42 Waters, *Art of Navigation*, p. 36. Rose, *Lancastrian Navy*, pp. 169, 173, 177. Hastings MS, fo. 132r, lines 3–4. *Seebuch*, MS B, fo. 10r, item 1.

43 dos Reis, *Medir Estrelas*, pp. 25–8: the log entry is for 17 Jan. 1493.

44 In 1637, a minute of longitude at the equator (= one sea mile), was revised to 6,120 feet, the sand-glass having to be reduced from 30 to 28 seconds, or the distance between knots increased to eight fathoms. The nautical mile is now 6,080 ft (1.852 km).

> And to know the ship's way, some do use this which (as I take it) is very good; they have a piece of wood & a line to vere out overborde, with a small line of great lengthe … In like manner they haue either a minute of an hour glasse, or else a knowne part of an houre by some number of wordes spoken.

This suggests that although the method had been known for some time, it was still not in general use amongst English shipmasters. This mention of counting the passage of time even in the late sixteenth century is interesting, and perhaps reflects a paucity of sand-glasses. However, an earlier reference, sometime in the first half of the fifteenth century, indicates the earlier use of a log in northern waters: Nikolaus von Kues (1401–64), from Mosel, measured the time, possibly by counting, required to cover a fixed distance. It is probable that if logs were in use on north German ships before the middle of the fifteenth century, then English sailors were almost certainly also using them soon after, but that cannot be confirmed.[45]

Sailing directions

By early in the fifteenth century, a literate northern shipmaster could have had access to handwritten copies of sailing directions, as *aides mémoires* to familiar waters or as pilots to new areas. Copies of these directions could be purchased, copied or simply memorised but, unsurprisingly and unfortunately, given the conditions at sea, examples which have been used on board a ship are unknown. The oldest surviving sailing directions compiled for, but not necessarily originated by, northern seamen, are a manuscript volume of two editions of a pilot in Middle Low German (the *Seebuch*), and two manuscript copies of a pilot in Middle English (the rutter). All those surviving manuscripts date from the mid-fifteenth century, but they contain material of mixed provenance attributable to the fourteenth or earlier centuries. The manuscripts of the two editions in Low German survive in Hamburg in good condition and were bound together in one volume entitled *Das Seebuch* sometime after 1474. The manuscripts of the rutter, also in good condition and textually very similar to each other, are each bound into a family library's *Grete Boke*, one now in London and the other in New York. Figure 6 shows the first folio of the Lansdowne MS copy of the rutter. Those directions are described in more detail below. Printed directions, which had a much wider distribution and of which many examples have survived, did not

45 *A Regiment for the Sea and Other Writings on Navigation by William Bourne, a Gunner, 1535–82*, ed. E.G.R. Taylor, Hakluyt Society 2, 121 (London, 1963), p. 237. Sauer, *Seebuch*, p. 140, citing Arthur Breusing, *Die nautischen Instrumente bis zur Erfindung des Spiegelsextanten* (Bremen, 1890), p. 24.

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6 Folio 137v of the Lansdowne MS 285, by kind permission of the Picture Library, British Library, London.

appear until the beginning of the sixteenth century and are therefore outside the period examined in this book.[46]

Both the *Seebuch* and the rutter are compilations of some original work by the editors and a much larger quantity of eclectic borrowings from other, mostly southern European, sources which have not survived. Both cover the same coasts from eastern England to Gibraltar including Ireland, but the Baltic, German Bight and the stretch of southern Spain from Gibraltar to Cartagena are peculiar to the *Seebuch*. The English and German directions show no direct commonality in their descriptions of the various routes, havens and hazards, but they do establish that the navigational techniques practised by all northern seamen were very similar. The *Seebuch* is substantially more comprehensive and thorough than the rutter and is largely organised thematically, that is, for each area there are sections listing tidal stream directions, times of high water, compass bearings and distances between waypoints, havens and anchorages, soundings and dangers. In comparison with the *Seebuch*, the rutter is a poor thing, partly thematic and partly narrative in form, with many incomplete or missing sections. If what has survived represents the whole work, then it could have served as little more than an *aide mémoire* for the compiler or as additional notes to another, unknown collection of sailing directions.

Although the information in the two editions of the *Seebuch* was, without doubt, collated by Hansa seamen, original Hanseatic contributions can be detected only occasionally. It is particularly detailed on the coasts of Normandy and the Iberian peninsula but the areas described do not all correspond primarily to Hanseatic shipping routes, and the main sphere of Hanseatic influence – the North and Baltic Seas and the passage to Bourgneuf Bay, for example – are not dealt with in any detail. The Hamburg manuscripts have been dated by identification of the watermarks to *c.*1470, that is, during the 1469–74 conflict between Hanseatic, English and Dutch merchant ships. During that period, Hansa ships had little choice but to sail off enemy coasts, often without reliable local pilotage, and it is possible that the purpose of the *Seebuch* was to give Hanseatic merchantmen and privateers the highest possible degree of self-sufficiency.

The New York copy of the English rutter is part of the Hastings collection of manuscripts formerly belonging to Sir John Astley (d. 1486). Written on vellum in several good book hands, the *boke* contains, in addition to the rutter, a miscellany of treatises on knighthood, jousting, state ceremonial, classical texts, astrology, weather forecasting and various domestic subjects. The London copy of the rutter is in the Lansdowne collection of manuscripts formerly belonging to Sir John Paston (d. 1479); that *boke* is written in a good secretarial hand on paper, and the contents are similar to those in the Hastings collection; folios of the rutter may

[46] Full references are made to the *Seebuch* manuscripts and the English rutter manuscripts at the beginning of this chapter.

be seen in Figures 3 and 7 (from the Hastings MS) and 6 (from the Lansdowne MS). The two copies of the rutter differ only in scribal errors, omissions and idiosyncrasies and were probably copied from the same original.[47]

On the last folio of the Hastings MS copy of the rutter, shown in black and white in Figure 7, there is a coloured illustration of a ship taking soundings; her structure and rigging suggest that she is no earlier than mid-fifteenth century. If that illustration has always been integral with the main text, as seems probable, then the Hastings copy of the rutter may be dated to the same period. The absence of the Garter on the arms of the Earl of Hastings, reproduced on three pages of the *boke*, suggests that at least part of it was written in or before 1461 when Hastings was appointed to the Order. In the Lansdowne manuscript, the scribe William Ebesham's hand has been identified. An invoice for his work done for Sir John Paston has been found, drawn up, sadly, while he was in *seintwarye* (sanctuary) from creditors. If, as is thought likely, the invoice refers to the rutter, it establishes that the Lansdowne copy was made in or before 1468. The two copies of the English rutter, therefore, may be dated with some confidence to early in the second half of the fifteenth century and are approximately synchronous with the two editions of the *Seebuch*.[48]

The English rutter appears to have been edited by a lone shipmaster based on the east coast of England, for which detailed information is given from Berwick to the Downs, probably from his own experience. For other areas, although the rutter may be seen as a personal record of his own trading voyages, completed or planned, the contents appear to have been 'borrowed' from an assortment of other sailing directions. The rutter includes many waypoints on both sides of the Channel with bearings and distances between them, a circumnavigation of Ireland, information for a passage up the river Gironde and much about the coast of Brittany. Unlike the *Seebuch*, the information for the Iberian coast is meagre. Of particular interest are an off-shore passages from Santiago de Compostela to England which, uniquely for the early sailing directions, goes 'out of soundings', i.e. over the continental shelf; and the off-shore passage across the Bay of Biscay,

[47] G.A. Lester, *Sir John Paston's 'Grete Boke': A Descriptive Catalogue, with an Introduction, of British Library MS Lansdowne 285* (Woodbridge, 1984), pp. 164–6.

[48] Harold Arthur, Viscount Dillon, 'On a Manuscript Collection of Ordinances of Chivalry of the Fifteenth Century Belonging to Lord Hastings', *Archaeologia*, 2nd series, 7 (1900), pp. 29–70. A.H. Moore, 'Some 15th-Century Ship Pictures', *MM* 5 (1919), pp. 15–20; G.F. Howard, 'The Date of the Hastings Manuscript Ships'; *MM*, 63 (1977), 3, pp. 215–18. Howard concludes that the ship in the final folio may be *c.*1470 and those on the first folio, by the gun-ports on the lower deck, perhaps 1510–30; Norman Davis, ed., *The Paston Letters and Papers of the Fifteenth Century* (Oxford, 1976), II, pp. 386–7, 391–2, letters 751 (invoice) and 755 (receipt) dated between July and end of October, 1468. Curt Bühler, in 'Sir John Paston's "Grete Booke", a 15th-century "best seller"', *Modern Language Notes* 56 (1941), pp. 345–51, queries whether Ebesham's invoice was indeed for the Grete Booke or for other manuscripts in the Paston library.

which was discussed above (p. 134), as possible evidence of the early use of latitude by Portuguese navigators.

A version of approximately the first third of the text of the rutter, entitled *A Newe Routter of the Sea for the North Parties* and attributed to Richard Proude, was added to the 1541 and subsequent printed editions of Robert Copland's *The Rutter of the See* which was, in turn, a translation of *Le Routier de la mer*, attributed to Pierre Garcie, and first printed in France in 1502. Copland's translation was the first rutter to be printed in English, in 1528. The remaining two thirds of the rutter, and the two editions of the *Seebuch*, were never printed for the use of contemporary seamen.[49]

Summary of the shipmaster's navigational methods

During the hundred years between 1350 and 1450, navigation evolved from 'direct' methods reliant on the five senses to indirect methods in which instruments were used. Shipmasters relying solely on direct observation were generally restricted to in-shore routes, their off-shore navigation being necessarily of limited reliability. Shipmasters using the new technology, and in particular the magnetic compass, were able to set and steer courses, calculate the distance run, and forecast tidal conditions in channels and havens. Estimation of latitude was not used by northern seamen until the sixteenth century but that appears not to have mattered on the routes which they habitually sailed. The increasing availability of written sailing directions further improved the reliability of ships, as masters became less dependent on their memories, and on information gathered informally in dockside conversations. As a result of this improved efficiency and safety of sea transport, shipping became an increasingly attractive alternative to road transport.

49 D.W. Waters, *The Rutters of the Sea* (New Haven, CT, 1967), includes facsimile copies of Garcie's and Copland's rutters.