Elizabethan Navigation

Jim Bennett

Foreword

Prior to his untimely death, former president of the Hakluyt Society Professor Jim Bennett had started on a major work dealing with the subject of Elizabethan navigation. The following draft, which is the only part of the text to have approached completion, comprises the introduction to the projected work.

Introduction

This book revisits a topic where the solid work of historians in the mid-twentieth century, such as E. G. R. Taylor and D. W. Waters, supported by several editors for the Hakluyt Society, has stood the test of time. Other scholars have added valuable studies without superseding these pioneers and the present work also is not one of fundamental revision but, it is hoped, of enrichment. With the passing of some three-quarters of a century, we might look afresh at an important phase in the history of practical mathematics. We begin with several notable characteristics. One is that mathematicians were not excluded from lives of action and adventure. Another is that mathematics could be a notable element in the policy ambitions of national statesmen. Historians of mathematics, and to some extent of science more broadly, have come to regard the practical and societal relevance of mathematics in greater earnest, which is just as protagonists had advocated at the time. Navigation was one of the most important areas where mathematics became relevant to practice in the sixteenth century, a relevance recognized and adopted in the period. How this came about and how the conviction of practical value took hold deserves further study, not least because, along with astronomy, the practice of mathematical navigation became a model for developments elsewhere.

Navigators of the Atlantic

Long-distance sailing in the Atlantic Ocean did not originate with ships from Portugal and Spain in the fifteenth century and the familiar exploits of those who manned them. Earlier sailors without renown included Norse raiders and traders, English fishermen and Irish monks. All must have relied not only on their general skills in seamanship but also some knowledge of the art of navigation. Of this we have only some scattered references, combined with what we surmise they cannot have failed to notice when looking at the sky we share with them.

As written and printed records, together with material remains, especially from the sixteenth century onwards, offer more definite information and systematic knowledge, we understand more securely what it meant to be a ship's pilot. Specialized techniques came to mark a maritime role with characteristic responsibilities and expertise, alongside the captain, helmsman, surgeon and cook, one involving aspects of mathematics, instrumentation and astronomy. Some of this expertise had previously taken shape in the Mediterranean, through the use of the magnetic compass and the sea chart. There compass and chart worked together, having complementary parts to play in navigation by 'bearing and distance'. The chart

indicated the direction or directions to follow for an intended voyage, so far as winds would cooperate, and the distance this would entail. Under sail the compass was needed to maintain the course, though if clouds would permit, the sky could be useful also.

The pilot could manage reasonably well by bearing and distance in the enclosed space of the Mediterranean — large but not when compared to the intimidating vastness of the Atlantic. Here the techniques he already knew would be needed but would not be sufficient. The first principal area of innovation would be the more systematic use of the sky, drawing and adapting techniques and instruments from relatively elementary aspects of contemporary astronomy.

Early printed references in the English literature to developments in navigation, with the activities they enabled in exploration and trade, often cited the Portuguese and the Spanish, in a mixture of admiration, envy and resentment. By whatever *ad hoc* procedures earlier sailors might have consulted the heavens, the Iberians had systematized such techniques, which the English realized they must learn and adopt. Further, it seemed that the geographical situations of Spain and Portugal had given their seamen more straightforward access to the Americas through temperate climes, where they now occupied an established priority. The English were left with less congenial northerly sailing in hazardous seas to an uncertain reception in lands of unknown endowment.

One response was to ignore papal bulls, disregard the claims of foreign rulers, and establish trade and occupation where opportunities arose. Another was to turn to privateering or to outright piracy. Alternatively, the circumstance could be turned to a moral advantage; might travail and endurance build fresh legitimacy? George Best, adventurer, navigator and author, who accompanied Martin Frobisher on two of his voyages, invoked the aphorism '*Difficiliora pulchriora*, that is, the adventure the more hard the more honorable'. He elaborated as follows:

> … neyther Spaniard nor Portugale, nor anye other besides the English, have bin found by so great daungers of Ise, so neare the Pole, to adventure any discoverie, wherby the obscure and unknowen partes of the world (which otherwise had laine hid) have bin made knowen unto us.[1]

Book learning from Spain

Spanish cosmographer Pedro de Medina published what was intended to be a practical textbook, *Arte de navegar*, in 1545, dedicated to the future Phillip II. It was translated into French, Italian and Dutch, and an English *Arte of navigation*, translated by the merchant John Frampton, appeared in London in 1581.[2] The basis of the technique described required a record of the compass bearings followed by the pilot for one or more watches timed by a sandglass, coupled with the distances covered, which could be gathered from estimates or measurements of speed. Position-finding, determined daily, was then based on the cumulative bearings and distances of the course or courses sailed from a previous determination, a technique known as 'dead reckoning'. A crucial elaboration of the 'bearing and distance' procedure, however, was a direct measure of latitude, taken when desirable and possible

[1] George Best, *A True Discourse of the Late Voyages of Discoverie, for the Finding of a Passage to Cathaya, by the North-west*. (London, 1578), sig. aiiijv. For George Best, see *ODNB*.

[2] Pedro de Medina, trans. John Frampton, *The arte of navigation wherein is contained all the rules, declarations, secretes, & advises, which for good navigation are necessarie & ought to be knowen and practised* (London, 1581).

(weather permitting) as a check on the daily determination of position. This gave what was called the 'height' of the new position, equivalent as we shall see to the measurement of latitude by the sun or the Pole Star.

The chart and the compass worked in tandem, a relationship emphasised by shared features, the chart having a set of 'wind roses', presenting the 32 points of the compass in decorative radial patterns, with the bearings or 'rhumb lines' continued beyond the roses and across the chart. These lines presented the courses that would be sailed on the relevant bearings. The compass in its turn carried a similar pattern on the upper, visible surface of a card, with a magnet balanced underneath on a vertical pin. Medina first offered a graphical method of finding the new meridian after sailing. For this he provided a series of tables for finding the distances east or west according to bearings sailed for recorded durations. This was the counterpart of earlier tables relating distance north or south to changes of latitude, also arranged by bearings, referred to as 'raising a degree'. Unfortunately, this was not subject to a measurement independent of the various uncertainties in the record of bearings sailed and speeds estimated or measured.

When it came to position finding, however, Medina could do better than this. He described a procedure for accommodating the possibility of a latitude measurement. This would be derived from a measurement of the altitude of the sun or of the pole star (Polaris) using, in Medina's case as was typical of Spanish pilots, a mariner's astrolabe. This was essentially a ring suspended manually, with a degree scale and a centrally pivoted rule with two sights, known as an alidade. A measurement of the altitude of the pole star (the angle it made with the horizon) gave the pilot his latitude and could be corrected for any small displacement of the star from the actual pole. Alternatively, in the daytime, the solar altitude could be measured as the sun crossed the meridian, when it would be at its highest altitude for that day. Since the sun moves annually in a circle (known as the ecliptic) about the earth, this maximum altitude at any location varies throughout the year, so a correction had to be made for the date but the pilot was supplied with a set of 'declination' tables giving the annual cycle of deviation from the equator ('the regiment of the sun'). The latitude then follows from the sun's measured altitude, incorporating an adjustment for the solar declination.

A graphical procedure for resolving the final position relied on the simultaneous use of two pairs of compasses (dividers), one opened between the estimated position and the rhumb line sailed, the other opened against the latitude scale of the chart between the initial and measured values.[3] Moving the free point of both the dividers to where they came into coincidence gave the pilot a final position, although allowances may have been required for wind and current: 'of all these the Pilot must keepe a good reckoning in his navigation as much as in him lieth'.[4] The new position on the sea chart or 'carde' was marked by a 'prick', usually an indentation rather than a hole, and was not recorded as a numerical longitude.

> One of the thinges that the Pilot ought to know perfectlie, is to pricke his carde very precisely, for it is verye necessarye for good navigation.[5]

Medina does not so much as mention 'longitude' in connection with position finding (though it does occur in connection with cosmography) and it should not be introduced as a numerical parameter in characterising his understanding of navigational practice.

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[3] Medina, *The arte of navigation*, ff. 26r-v; Waters, *The Art of Navigation in England in Elizabethan and early Stuart times*, pp. 65–6 (account by Cortés).

[4] Medina, *The arte of navigation*, f. 26v.

[5] Ibid., f. 26r.

A second Spanish *Arte of navigation* was originally published six years after Medina's work, in 1551, but appeared in English in 1561, all of 20 years before the translation of Medina. The author was the cosmographer Martin Cortés and the translator Richard Eden, whose publications in translation were generally aimed at encouraging English voyaging in emulation of the Spanish. The relative speed of translation and publication reflects a more intentional project in this case. The distinguished navigator Stephen Borough acquired a copy in Seville and the translation and publication were sponsored by the newly formed Muscovy Company.[6] As with Medina, Cortés principally mentions 'longitude' in the contexts of astronomy, cosmography and cartography, as well as being used in a general sense simply to indicate length.

On shipboard the pilot 'muste knowe two thynges, whiche the Carde shal shew hym': the direction to steer and the distance to cover. Other concerns, such as winds, tides and currents, 'and all suche thynges as may be with hym, or against hym', are managed instead though experience and seamanship. Drawing all together in his 'estimation or computation', the result cannot be exact, especially on a long voyage, but the pilot can 'rectifie or amende' his inference by a celestial measurement of the altitude of Polaris or of the sun in the meridian.[7]

A third early handbook of navigation to be published in English reached its fully formed state in 1574 as *A Regiment for the Sea* by William Bourne of Gravesend. It is appropriate that this work, considered to be 'the first purely English navigation manual published',[8] had strong Spanish links through Eden's translation of Cortés's *Arte of Navigation*. Although 'unlearned' in the sense of the period, Bourne was a man of some property and commercial interest. Serving a term as port-reeve in Gravesend, the equivalent of a mayor, he was a prominent citizen and, while he had practical experience as a gunner and records a meridian altitude of the sun he took at Gravesend in April 1566 with a mariner's astrolabe,[9] there is no record of his going to sea. His first venture into authorship was his *Almanacke and Prognostication for three yeares*, first published in 1567 and followed by a new edition in 1571, where the title-page presents him as 'student of the Mathematicall science'.[10] The calendar section was compromised by mistakes and misunderstandings, while the prognostications were brief and inadequate,[11] presumably because Bourne did not accept the validity of astrology, but conceded that advice on matters such as favourable times for medical procedures and arable labour were expected in such a publication. However the main content of this curious compilation constituted an elementary handbook of navigation, Bourne's 'Rules of Navigation', of which there were sixteen, each being an account of a topic in navigational practice extending over several pages.[12] These rules were later revised and extended to become *A Regiment for the Sea* of 1574, a successful work that went through a number of editions until 1631.[13] Its bibliographical roots are evident through the inclusion of a 'Kalender', which prefaces the 'Regiment'.

[6] Waters, *The Art of Navigation in England*, pp. 103–4.

[7] Cortés, *The arte of navigation*, f. 67r.

[8] Waters, *The Art of Navigation in England*, p. 132.

[9] Taylor, ed., *A Regiment for the Sea and other Writings on Navigation by William Bourne*, pp. 84–5.

[10] For an account of Bourne's publications in navigation, see Waters, *The Art of Navigation in England*, pp. 127–43, and especially Taylor, op. cit.

[11] Taylor, ed., *A Regiment for the Sea and other Writings on Navigation by William Bourne*, pp. 9–10.

[12] Taylor, ed., *A Regiment for the Sea and other Writings on Navigation by William Bourne*, pp. 1, 55–110.

[13] Ibid., p. 456.

Bourne's goal was a simplified account of the navigational methods described by Cortés, better suited to the current needs of English seamen, while at the same time he would add material he found absent from Cortés's work. Already in the 'Rules', the shared content led to a dispute between the printer of Eden's translation (Richard Jugge) and of Bourne's *Almanacke* (Thomas Purfoot), obliging Bourne to omit material and advise readers to 'repayre to the booke of Navigation, made by Martine Curtis a Spaniarde, imprinted by master Jugge printer to the Queenes majestie'.[14]

In both the *Rules* and the *Regiment*, as well as the traditional knowledge of tides, compass, distance and sounding, Bourne covers the recent introduction of latitude finding by the altitude of the 'north starre' (Polaris) and by the altitude of the sun on the meridian, including the use of the relevant instruments, the cross-staff and the mariner's astrolabe. He deals with the application of solar declination to the meridian altitude of the sun and with the displacement of Polaris from the celestial pole, and he adapts his advice 'to them that doe occupie to the north partes'.[15] These must be his compatriots. He would have liked to say more about the use of the cross-staff (the 'Balestela') but is constrained by the Cortés text printed by Jugge: 'for I must meddle with nothing contained in that booke.'[16]

Bourne's discussion of the longitude fits more readily into an account of cosmography, albeit an elementary one, than navigation. It is a parameter to be found by a globe, a map or a chart, but not, as he puts it, 'with instruments'.[17] Why then mention longitude at all? Bourne's justification is that, while he is dealing with latitude, it is appropriate to mention the complementary co-ordinate of longitude — a sensitivity characteristic at the time of cosmography, a discipline we shall deal with shortly — while variations in local time are important 'for all travaylers by Sea or by Lande.'[18] However Bourne is blunt — this has no practical relevance to navigation:

> Therefore I thought it neadefull to bee spoken of. For as countries have Latitude from the poles, so in like manner they have appointed longitude. But nowe you may get the Latitude with instruments, but the Longitude you must bring from an other place, whiche you can not doe but with a Globe, or els a Mappe or Carde.[19]

There follows a section on the longitudes and latitudes of notable towns in England, and on the differences in the longest summer day 'from Southampton to the nethermost place in Scotland'.[20] These are characteristic concerns of the cosmographer. As for the navigator:

> Therfore lette no Sea men trouble them selfe with this rule, but according to their accustomed manner, lette them kepe a perfect accoumpt and reckening of the way of his shipe, whether the ship goeth to lewardes or maketh her way good, cōsidering what thinges be against him or with him: as tydes, corrantes, wyndes, or suche like.[21]

The troublesome and controversial topic of magnetic variation — the variable declination of the compass needle from true north — was taken up briefly by all three authors, Bourne in

[14] Ibid., pp. 8–9.
[15] Ibid., p. 89.
[16] Ibid., p. 89.
[17] Ibid., p. 93.
[18] Ibid., p. 93.
[19] Ibid., p. 93.
[20] Ibid., pp. 96–9.
[21] Ibid., pp. 94–5.

particular.[22] It would become a subject of great importance for English seamen, not least because the effect was notable, even spectacular, in northerly latitudes.

Iberia comes to England

The channels through which English seamen would learn Iberian navigation were not only textual; an unlikely proposition in any case for so practical an art. Personal connections and initiatives were at the forefront of this development, while an intersection of political, technical and commercial ambitions created its opportunity. We can locate stimuli for new ventures and aspirations in overlapping objectives of statesmen and seamen, merchants and mathematicians. To take a few prominent examples, two seamen of influence in the very early days of English distant voyages, who had significant experience of Continental practice, were Sebastian Cabot and Stephen Borough. Two statesmen who supported their cause effectively were William Cecil, Lord Burghley, and Sir Francis Walsingham. Two merchants willing to invest in their ventures were William Sanderson and Michael Lok. Two mathematicians who contributed the technical repertoire essential for such activity were John Dee and Robert Recorde. This somewhat arbitrary selection will readily accumulate more individuals and institutions.

The transferable skills of early-modern navigators created the potential for fluidity in employment, while their lifestyles might present them with ready opportunities for varieties of employment. John Cabot was of Italian birth, combined the roles of merchant and navigator, had seen maritime service in Spain and promoted his ventures in Seville and Lisbon before settling in Bristol in c.1495, where there was known interest in transatlantic exploration.[23] By authority of letters patent from Henry VII he and his sons were permitted to sail in search of land unknown to Christians with the exception of Spanish claims to the south. Already familiar with latitude finding by stars and sun, in May 1497 he commenced an influential voyage to Newfoundland in a modest vessel with a small crew, which probably included his son Sebastian, then a boy of about 12 years of age. John was presumed lost at sea on a later voyage from Bristol, undertaken in 1498 with four ships, again scarcely adequate for the task ahead.

Sebastian was probably of Venetian parentage, while his family moved at times between Spain and England.[24] Like his father, he was both a merchant and a navigator and gave cartographic service to both Henry VIII of England and Ferdinand I of Spain. Exploratory voyages in the north Atlantic in the early sixteenth century were based in Bristol, but he entered Ferdinand's service and was appointed to teach navigation and examine pilots at the Casa de Contratación in Seville. Soon after he was again in England before being appointed Pilot Major of Spain in 1519. Whatever the sometimes deliberate confusion over Cabot's movement and residence in subsequent years, it is clear that he was a valuable conduit of knowledge and expertise between the two maritime powers. Eventually he settled in England and promoted ventures to reach China by a northeast route beyond the Russian Arctic coastline, though he did not sail on the initial, ill-fated voyage of 1553–4, or any later ventures of what would become the Muscovy Company. By now Ferdinand had died and Cabot's whereabouts were confusing and frustrating Emperor Charles V. He had become a thoroughly international authority on navigation and cartography.

[22] Ibid., pp. 83, 86–7, 132; Waters, *The Art of Navigation in England*, p. 71 *et passim*.

[23] See entry by Quinn in *ODNB*; Williamson, *The Cabot voyages and Bristol discovery under Henry VII*, pp. 45–144.

[24] See entry by Loades in *ODNB*; Williamson, *The Cabot voyages*, pp. 145–72.

Another influential maritime family with Continental connections descended from Stephen Borough (c.1474–1548), with John Borough being the eldest of Stephen's four sons. John had seagoing experience in Devon and Cornwall from the early decades of the sixteenth century, notably involving the use of a cross-staff and a quadrant, which evinced his familiarity with Iberian navigation. His nephews, the younger Stephen Borough (1525–84) and William Borough (1536–98) would have notable successes in their seagoing careers. Stephen followed the ambition of Sebastian Cabot in respect of the northeast passage to China, bringing him into the technical difficulties of high latitude navigation and the elemental challenges to be encountered there.

The younger Stephen Borough developed particularly strong connections and reputation in Spain. While he mastered novel navigational practice, he benefited also from a facility in Spanish, gained, it is understood, from studying the Bible and sailing directions in Castilian, augmented by other exercises in Portuguese. He went to Seville in 1558 with a view of exchanging his knowledge of Arctic sailing for a greater familiarity with the training of Spanish pilots. His honourable reception was marked by the presentation of a valuable pair of perfumed gloves, a symbol of his qualification as pilot. It was Borough who brought home the book of Cortés and arranged for its translation into English.

William Borough, a brother of the younger Stephen, was familiar with the use of the cross-staff and the mariner's astrolabe, became adept in chart making and made an extensive study of magnetic variation. He too was influenced by Spanish practice.[25] He was also one of the earliest English chart-makers of that time for the Muscovy Company and for various expeditions including that for Martin Frobisher to the North West Passage 1577–80. [26]

Experience in high latitudes encouraged the understanding that passages to either the east or the west would, though arduous, be relatively short, since the parallels of latitude would be short as meridians converged. This was an insight confirmed by cosmography, in particular with reference to a terrestrial globe.

As early as his *Regiment* of 1574, Bourne uses his account of the measurement of the meridian altitude of the sun at midnight in northerly latitudes to introduce his confidence that 'them that would attempt any viages of discovery unto the Northwards' will find a navigable passage to either the east or the west. They need not fear the frozen seas, thanks to the effect of the continuous sunshine of an Arctic summer, while the passage will be comparatively short, since 'he that were in the Latitude of .80. degrees shoulde have but a short paralele'.[27]

The terrestrial globe was the iconic instrument of cosmography, having the advantage of laying out all known lands and seas on the earth, set in the grid of latitude and longitude. It was valuable to cosmographers before its appearance as a commercial item in the print culture of mathematical instrumentation at the beginning of the sixteenth century. John Cabot, for example, had a globe (presumably in manuscript), which he may have used for demonstration and persuasion. Without one, the geometrical characteristics of polar latitudes were difficult to grasp. However, it was also the case that by the mid sixteenth century globes were used on board as Martin Cortés recommended and as Mercator had produced. [28] A close second in the

[25] *ODNB* entries for John, Stephen and William Borough.

[26] Waters, *The Art of Navigation in* England, pp. 145–6, Sarah Tyacke,' Chart-making in England and Its Context, 1500 –1660' in David Woodward *History of Cartography* Volume 2 (Chicago, 2007), pp. 1722–55.

[27] Taylor, ed., *A Regiment for the Sea and other Writings on Navigation by William Bourne*, p. 225; Waters, *The Art of Navigation in* England, pp. 134–5.

[28] Waters, *The Art of Navigation in England*, p. 73.

instruments that identified the cosmographer was the armillary sphere — a skeletal globe comprised of rings, standing for the principal circles used by astronomers — equator, tropics, arctic and Antarctic circles, ecliptic and horizon, with an adjustment for latitude (by altering the angle between the pole and the horizon) and the ability to rotate around the poles, as the heavens do themselves. These would be joined by the celestial globe: a solid globe, able to depict the constellations and often made and sold as a companion to a terrestrial. We have now stumbled across the discipline of cosmography several times and it is necessary to address its character and role.

Navigation and Cosmography

When the seaman, privateer and sometime ship's master John Alday wrote to the influential merchant Michael Lok in c.1576, seeking service in Martin Frobisher's voyage of that year, he complained that he was being maligned by ill-wishers in London for his seagoing record, even though they acknowledged his worth as 'a man of knowledge in the Arte of Navigation and Cosmographie'.[29] The coupling of navigation and cosmography in the literature of the period was a familiar one and Lok himself had a strong engagement with cosmography. This was a mathematical science, as navigation sought to be, comprising the geometrical relationship between the heavens and the earth and thus the astronomical aspects of navigation. It treated the whole earth, sharing with the heavens such fundamental features as the equator and tropics, and the daily and annual cycles of the sun, while being bound together by the coordinate system of latitude and longitude. Cosmography did not venture into planetary motion, which was the domain of the mathematical astronomers, but the work of Claudius Ptolemy lay at the basis of both disciplines, his *Almagest* for planetary astronomy and for cosmography his *Geographia* or *Cosmographia*. Since geography was closely aligned with cosmography, in laying out the countries, territories, seas and oceans of the world, not least through its use of mathematical cartography, it was a keen interest among many adventurous merchants. Alday probably gained his appreciation of cosmography from his association with Sebastian Cabot, under whom he had served.

The Papal Legate in Spain, Galeacius Butrigarius, reporting on Sebastian Cabot, described him as 'well practised in all things pertaining to navigations, and the science of Cosmographie' [30], while the scholar, geographer and compiler of travel narratives, Giovanni Battista Ramusio's formula was 'very rare in the art of Navigation, and the knowledge of Cosmographie'[31]. In the *Discourse of Western Planting*, Richard Hakluyt was able to cite the reputation of Cabot, descending through no less than Gerard Mercator, 'so skilful in the arte of navigacion and Cosmographie, that he hath not his like in Spaine at this day'. [32]

The coupling of navigation and cosmography appears occasionally in other formulations. Frobisher was said to be 'thorowly furnished of the knowledge of the sphere and all other skilles appertaining to the arte of Navigation'.[33] 'The sphere' could refer to either the armillary sphere or the branch of astronomy it exemplified. When George Best prepared for service in the Frobisher voyages, he applied himself 'wholy to the science of cosmographie,

[29] Richard Hakluyt, *The Principal Navigations* (all references hereafter are to the Hakluyt Society edition unless indicated otherwise) Vol. 6, pp. 136–7; McDermott, *Martin Frobisher*, p. 440, n. 9; Waters, *The art of navigation in England*, pp. 88–90.

[30] Hakluyt, *The Principal Navigations* Vol. 7, 147.

[31] Hakluyt, *The Principal Navigations* Vol. 7, 149; Quinn, ed., *Discourse of Western Planting*.

[32] Quinn, ed., *Discourse of Western Planting* notes, p. 92.

[33] Hakluyt, *The Principal Navigations* Vol. 7, p. 277.

and the secrets of navigation'.[34] His diagnosis of the cause of English tardiness in adventurous voyaging was a reluctance to invest on the part of the nobility and 'want of skill in the cosmographie, and the arte of navigation' [35] Writing in 1578, he could claim that both failings had been remedied, even asserting that all the nobility had 'perfect knowledge in Cosmographie'. [36] While this was scarcely credible, the inclusion of this social location of such knowledge was significant.

The two communities of expertise, as well as the disciplines themselves, were seen as closely related. When Humphrey Gilbert objected that the Queen was reluctant to allow him to command his second voyage in person, in 1580, he challenged the notion of his lack of skill: 'I will offer my selfe to bee opposed, by all the best navigatoures and Cosmographeres within this realme'.[37] That the perceived connection was not limited to those directly involved is seen in the judgment of the historian John Hooker, in 1586, that Gilbert 'had a great delight in the studie of cosmographie, and especiallie in navigations'.[38]

Cosmographer was one of the many personae of John Dee. His succinct characterisation of the discipline in his famous 'Mathematical Preface' to Henry Billingsley's *Elements* of Euclid, published in 1570, was:

> the whole and perfect description of the heavenly, and also elementall parte of the world, and their homologall application, and mutuall collation necessarie.[39]

It is significant that he almost immediately describes a globe as the embodiment of the subject, specifically the 'cosmographical globe' which combines the terrestrial and celestial in the manner of such cosmographers and globemakers as Johann Schoener, Gemma Frisius and Gerard Mercator. Here celestial features (which Dee lists as 'Æquinoctiall Circle, an Ecliptike line, Colures, Poles, Sterres in their true Longitudes, Latitudes, Declinations, and Verticalitie') are superimposed on to the terrestrial cartography:

> This matcheth Heaven, and the Earth, in one frame, and aptly applieth parts Correspõdent: So, as, the Heavenly Globe, may (in practise) be duely described upon the Geographicall, and Hydrographicall Globe.

The 'frame' here is the physical globe and to 'describe' means to draw. It is worth noting in relation to the importance of instrumentation, that just as the armillary sphere could exemplify a discipline, an aspect of astronomy, this globe could stand for the discipline of cosmography. The rotation of the globe on its polar axis facilitates a great many calculations typical of cosmography:

> … revolution of the earthly Globe (as the Heaven, is, by the Primovant, caried about in 24. æquall Houres) to learne the Risinges and Settinges of Sterres … By the Revolution, also, or moving of the Globe Cosmographicall, the Rising and Setting of the Sonne: the Lengthes, of dayes and nightes: the Houres and times (both night and day) are knowne: with very many other pleasant and necessary uses.

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[34] Collinson, ed., *The Three Voyages of Martin Frobisher*, p. 17.

[35] Ibid, p. 22.

[36] Ibid.

[37] Quinn, *The Voyages of Sir Humphrey Gilbert*, p. 341, f.65v.

[38] Ibid. Vol. 2, p. 434, f. 66.

[39] Euclid. *The elements of geometrie* (London, 1570), sig. biijr. The whole of the section on cosmography appears on this page.

Here Dee makes short work of what might be seen as a curiosity of the globe, whether cosmographical or simply terrestrial: rotation on an axis is a feature of the heavens, not the earth, unless we adopt a Copernican view, yet terrestrial globes with this feature were made throughout the sixteenth century. This relates to a fundamental characteristic of cosmography, namely that it is a mathematical science, according to the terminology and distinctions of the period; it does not belong in natural philosophy. Thus, mathematical instruments, such as the cosmographical globe, were intended for the solution of problems, not for revealing causal explanations of natural phenomena. If solutions to the mathematical problems enumerated by Dee were facilitated by rotation, this feature was designed into the working of the instrument; no one imagined that this related in any way to an actual rotation of the real globe of the earth.

If we are inclined to regard this point as a recondite philosophical distinction, far removed from the concerns of merchants and navigators, it is not. It is simply a shared and understood assumption. The Italian historian living in Spain, Peter Martyr, a personal friend of Sebastian Cabot, cited the latter's experience in North Atlantic waters in his *De Orbe Novo Decades* (1516).[40] In introducing arguments from the motions of the seas to support the case for a strait between North and South America, he begins, 'Here we must philosophize somewhat … and digress from cosmography to the causes of Nature's secrets'.[41]

Cosmography in England

In Portugal, Spain and France there was formal recognition of cosmography among the offices of state. In England, by contrast, interest in the discipline grew apace in the sixteenth century, but there was no office of Royal Cosmographer. Instead, it was pursued informally by merchants, adventurers, mathematicians, statesmen and navigators. This gave the subject a distinctive character – more flexible and perhaps less rigid in application.

If we look for early English texts informed by cosmography, they are not found in large, published volumes but in more casual and irregular formats. A significant example is a memorandum written from Seville by the merchant Robert Thorne in 1527, addressed to Dr Edward Lee, then Henry VIII's ambassador to the court of Emperor Charles V of Spain.[42] This treatise became widely cited and known on account of the assertion that Thorne's merchant father (also Robert) in collaboration with another merchant of Bristol, named Hugh Eliot (or Elyot) had discovered Newfoundland on a voyage in the 1490s (perhaps in 1494).[43] For our purpose, however, it is valuable as an instance of the general familiarity of cosmographical concepts, particularly among the merchant community.

Thorne's lengthy memorandum was written in response to the ambassador's enquiry as to the nature of a dispute between the rulers of Spain and Portugal.[44] Thorne responds with an account of the Portuguese and Spanish trades in spices from the east, the competition between these two maritime powers and the possibility of the English becoming involved on their own behalf. He reports in particular that to gather intelligence he had arranged for two Englishmen to take ship on an expedition to South America from Seville, where he had a house and was engaged in the wine trade. His friends were 'somewhat learned in Cosmographie … and to

[40] Williamson, ed. *The Cabot Voyages*, pp. 100, 147–9, 159.

[41] Ibid, p. 266.

[42] Jones, ed., *Divers voyages*, reproduces the Robert Thorne text p.33–52.

[43] Williamson, ed. *The Cabot Voyages*, pp. 26–9.

[44] Ibid. p. 41.

bee experte in the Navigation of those seas'.[45] Though not named in Thorne's report, they were the merchant Roger Barlow and the lesser-known Henry Latimer, and the fleet of four ships was commanded by Sebastian Cabot.[46] The details of this unfortunate adventure are not our main concern, but the memorandum is written with cosmographical learning.

Thorne notes the relative proximity of the spice islands to the Newfoundland discovered (he asserts) by the English. To help Dr Lee follow his argument, he includes a sketch map of the world, drawn by himself, which though small and crude ('I am in this science little expert') outlines seas and countries, and he explains the system of latitude and longitude he will use to direct and locate his narrative:

> … your Lordship knoweth that the Cosmographers have devided the earth by 360 degrees in latitude, and as many in longitude, under the which is comprehended al the roundnesse of the earth

It is worth noting in passing that longitude belongs to the science of the cosmographers. Thorne explains in detail how to use the latitude and longitude scales on his map, applying a pair of compasses, and clearly expects his recipient to engage with this cosmographical practice.[47]

Thorne runs through the coastlines of the world, following his map, till be comes to the Moluccas, 'which be Ilandes of the spiceries of the Emperour. Upon which the Portingales and he be at variaunce.' Engaged in this 'variance' cosmographers and pilots from different nations choose different locations, the Spanish placing the islands further to the east and the Portuguese to the west: they 'by their Industrie doe set them falsely euery one to fauour his prince', and no one can be sure of their true positions.[48]

Dr Lee had encouraged Thorne to write at length, 'your Lordship commanded me to be large', and we cannot follow his account in every detail, but he reported that the protagonists agreed a division of the discoveries whereby 180 degrees of longitude east of the Cape Verde Islands would fall to Portugal and the other half of the world to Spain. In the complex history of threats, negotiations and treaties, brokered so far as possible by papal authority, a key event was the discovery of the Moluccas or Spice Islands by the Portuguese in 1512. This was roughly in the region of the anti-meridian to Cape Verde and raised the question of which hemisphere they occupied. For our purposes it is sufficient to say that Thorne sees this as an issue for the cosmographers and that it raises the difficulty over finding the longitude

> Nowe, for that these Ilands of spicerie fall neere the terme and lymites betweene these Princes (for as by the sayde carde [Thorne's map] you maye see they beginne from one hundred and sixtie degrees of Longitude, and ende in 215, it seemeth all that falleth from 160 to 180 degrees shoulde bee of Portingall: and all the rest of Spayne. And for that their Cosmographers and Pilots could not agree in the situation of the said Ilands (for the Portingals set them al within their 180 degrees, and the Spaniards set them all without: and for that in measuring, all the Cosmographers of both partes, or what other that ever have beene, canot give certaine order to measure ye longitude of the world as they do of ye latitude: for yt there is no starre fixed from East to West as are ye starrs of

[45] Jones, ed., *Divers Voyages*, p. 35.

[46] *ODNB.*

[47] Jones, ed., *Divers Voyages*, pp. 36–9.

[48] Ibid. p. 41.

> the poles from North to South, but all mooveth with the moving divine): no manner can be found how certainely it may be measured, but by coniectures, as the Navigantes have esteemed the way they have gone.[49]

In other words, any such conjectures depend on dead reckoning.

It would seem that Dr Lee had also raised the question of what he regarded as the English discoveries in North America ('the Newe founde lande that wee discouered') in relation to Spain's source of gold in more southerly latitudes. Again, Thorne's response is informed by cosmography. He first, with reference to his map, says that the coast 'is all a mayne lande' of more than 5,000 leagues but then turns attention again to the Spice Islands. Beginning with the critical point, 'if from the sayde newe founde landes the Sea bee Navigable', Thorne proposes a course northwards past the pole, then south to the equator: 'wee shall hitte these Ilandes, and it shoulde bee much more shorter way then eyther the Spaniardes or the Portingales have.'

> For wee bee distaunt from the pole but 39 degrees, and from the pole to the Equinoctiall bee 90, the which added together be 129 degrees, leagues 2480, and myles 7440. Where wee shoulde finde these Ilandes.[50]

The Spanish, he tells Lee, would go by the Magellan Strait and the Portuguese by the Cape of Good Hope, either route being considerably longer than his polar proposal.

Thorne is not suggesting that the English should become entangled with the existing disputes, but he sees other profitable possibilities:

> wee shoulde by the way, and comming once to the line Equinoctiall, finde landes no lesse riche of Golde and spicerie as all other landes are under the saide line Equinoctiall: and also shoulde, if wee may passe under the North, enjoye the Navigation of all Tartarie.

Thorne anticipated an objection from traditional cosmography — 'a generall opinion of all Cosmographers' — that in the polar region 'the sea is all ice, the colde so much that none can suffer it.' However, since cosmographers were formerly just as unanimous that the equatorial region was uninhabitable, Thorne was sufficiently bold to assert that no land was uninhabitable and no sea unnavigable. With equal boldness he asserted that if the advice of the pilots had been followed in the voyage of Robert Thorne the elder and Hugh Eliot, 'the lands of the west Indies, from whence all the gold commeth, had been ours. For all is one coaste, as by the carde appreareth'.[51]

Finally, Thorne acknowledges the inadequacies of his world map — not simply those of size and simplicity, but more fundamental challenges in contemporary cartography. The length of degrees of longitude should differ in different latitudes and, in general, 'to set the forme Spherical of the worlde in *Plano* after the true rule of Cosmographie, it would have been made otherwise then this is'.[52] Such challenges were as yet beyond all cosmographers, so even appreciating their importance was a significant step for an English merchant.

[49] Ibid. pp. 41, 43–5.

[50] Ibid. pp. 48–9.

[51] Ibid. pp. 49–51.

[52] Ibid. p. 52.

A good number of merchants had cosmographical interests but for the present we can take another example of a substantial essay — substantial in the context of its relatively informal setting, namely a published tract in 1578, describing the three voyages to the northwest by Martin Frobisher. This was written by George Best as *A true discourse of the late voyages of discoverie, for the finding of a passage to Cathaya, by the Northwest, under the conduct of Martin Frobisher Generall* (London, 1578). Best was not a merchant but his father had a position as interpreter for the Muscovy Company. Best acted in Frobisher's service on the second and third voyages and his *True discourse* also included the first. In the dedication to his patron, Sir Christopher Hatton, he styled himself as a military man, referring to 'my rude order of writing … which proceedeth from the barren brayne of a souldiour and one professing armes.' Best explains how this 'barren brayne' became engaged with cosmography and navigation through study as a preparation for practice. Addressing Hatton first, among his various offices, as 'Capitaine of the Queenes Maiesties Garde', he says that

> … when I first entended the voyage of Discoverie wyth Mr. Frobisher, for the finding of the passage to Cataya … I applyed my selfe wholy to the sciēce of Cosmographie, & secrets of Navigation, to the ende, I mighte enable my selfe the better for the service of my Countrie, not onely to understande what I read and hearde others speake, but also to execute in effect, and practise with my owne hands, the dutie and office appertayning to a Marriner: and so thereby be better able to make a true reporte of all occurrents in the same voyage.

We might note that he refers to cosmography as a science, a matter of learning, but to navigation as a 'secret' practice acquired through experience.

Best's stratagem seems to have worked, in that he moved between soldier and navigator. He was listed as Frobisher's 'Lieutenant' for the second voyage,[53] to Captain of one of the ships on the third.[54] His accounts are a valuable record of navigational practice. For example, he writes of the second voyage:

> In this voyage commonly wee tooke the latitude of the place by the height of the sunne, because the long day taketh away the light not onely of the Polar, but also of all other fixed Starres. And here the North Starre is so much elevated above the Horizon, that with the staffe it is hardly to bee well observed, and the degrees in the Astrolabe are too small to observe minutes. Therefore wee alwaies used the Staffe and the sunne as fittest instruments for this use.[55]

Further, he was a working example of fluidity between cosmography and navigation. In addition to his accounts of the three voyages, *A true discourse* contains Best's treatise on the habitability of all parts of the globe, a doctrine he shares with Thorne. His title, 'Experiences and reasons of the Sphere …', places the work firmly in the science of cosmography.

Best's argument that the equatorial regions are inhabitable relies first simply on experience but then deploys his command of the annual motion of the sun in relation to both its duration above the horizon in different latitudes and the changing angle its rays make with the earth, appealing to 'him that hath onely tasted the principles of the Sphere'. He is clearly at ease with concepts such as longitude, latitude, the tropics, the zodiac, the meridian, the poles, the

[53] Hakluyt, *The Principal Navigations* Vol. 7, p. 285.

[54] Ibid., pp. 316–7.

[55] Ibid., p. 319.

annual variation of day length in different latitudes (except for the equator) and so on, and at one point even invokes 'an Isoscheles Triangle' whose vertex is in the sun and its base along the meridian of Paris, at a specified time and day (noon on 12 June). Authorities he cites include Johannes de Sacrobosco and Gemma Frisius.[56]

Best deploys a similar set of arguments to the effect that the polar regions are also inhabitable. Here he opines that the low elevation of the sun is compensated for by a day of six months in duration:

> Those lands and regions lying under the pole, and having the pole for their Zenith, must needs have the Equinoctial circle for their Horizon.

He says that having the sun at its maximum altitude of almost 24 degrees is equivalent to noon in London 'about the 29 of October, being in the 15 degree of Scorpio, and likewise the 21 of January being in the 15 of Aquarius' and 'we need no longer to doubt of the temperate and commodious habitation under the poles during the time of Summer'. Admittedly he has a tougher argument to make for the polar winter. Throughout we find him deploying a cosmographical mantra, 'by reason of the sphere'.[57]

A better-known encounter with cosmography was that of Richard Hakluyt. To the merchant and the soldier, we add a scholar. In the dedication, addressed to Sir Francis Walsingham, of the first edition of *Principal Navigations* (1589), Hakluyt recalls a schoolboy visit to the rooms in the Middle Temple of his cousin and guardian, also called Richard Hakluyt.

> I found lying open upon his boord certeine bookes of Cosmographie, with an universall Mappe.[58]

The elder Hakluyt, who was interested in overseas trading ventures, gave his young cousin an impromptu introduction to the discipline, inspiring a passion he cultivated through later lecturing in Oxford and would pursue for the rest of his life. This life mission was the collection, editing and publication of first-hand accounts of overseas travel and associated literature. Was this cosmography? Hakluyt certainly thought it fell within the subject's broad remit. When he came to write a dedication of volume one of the second edition of *Principal Navigations* (1598) to Charles Howard, Baron of Effingham, he considered he had 'waded on still farther and farther in the sweet studie of the historie of Cosmographie'.[59] In the dedication of volume III to Sir Robert Cecil, he refers to 'these studies of Cosmographie and forren histories'.[60] A historical, and in Hakluyt's case archival, approach was not inappropriate: he regarded Herodotus as 'most skilfull and judicial in Cosmographie'.[61] While the clergyman Hakluyt inclined to the humble tag of 'Preacher', his associates could be more effusive: Robert Parke, whom Hakluyt encouraged to translate González de Mendoza's *History of China*, cited his 'manifolde learning and languages, of singular and deepe insight in all histories of discoverie and partes of cosmographie'.[62]

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[56] Ibid. pp. 258, 263, 268.

[57] Ibid. pp. 272–4.

[58] Taylor, ed., *The Original Writings & Correspondence of the Two Richard Hakluyts*, p. 396.

[59] Ibid, p. 426.

[60] See Maclehose edition, 1903 p. lxxix, also Taylor, ed., *The Original Writings & Correspondence of the Two Richard Hakluyts*, p. 474,

[61] Ibid. p. 434.

[62] Jones, ed., *Divers Voyages*, Intro, p. xxix.

Cosmography and navigation; merchants and gentlemen

The relatively informal cultivation of cosmography in England and the absence of an institutional framework fostered flexibility, openness and movement across permeable disciplinary boundaries. We have seen that the merchant community, for example, could readily engage with cosmography to whatever degree they found of interest and value for their activity. Further, since merchants themselves, or their agents, supercargoes or factors, might travel on voyages to take care of their own or their master's interests, we find them, in these circumstances, moving beyond the science of cosmography and becoming engaged with the art of navigation. The close relationship between the two facilitated such movement, especially in the context of shipboard life.

The category of 'gentleman' on board a ship did not quite coincide with that on land. Officers were listed as gentlemen, as were military men of equivalent rank, but so too were a variety of agents often engaged in supervising cargoes or other similar tasks. Roger Barlow, for example, was an adventurous merchant who spent several years trading from Seville, and took part in Sebastian Cabot's voyage to South America of 1526–30. He subsequently returned to England, where he established a long-lasting landowning family at Slebech, Pembrokeshire. Some, whose roles were not specified, were simply 'gentlemen'. Best is a good example of a soldier who became thoroughly engaged with the practice of navigation. Merchants or their agents were valued recorders of voyages, where it was thought that a literate and informed account might be valuable at a later date. Some understanding of navigational practice was an important qualification for such work and we have seen that Best trained himself specifically for this purpose. When Sebastian Cabot, as governor of the Company of Merchant Adventurers, prepared a set of instructions for an intended voyage to China in 1553 by a northeast passage, he clearly expected a good level of competence in the record kept by merchants:

> … the marchants, and other skilful persons in writing, shal daily write, describe, and put in memorie the Navigation of every day and night, with the points, and observation of the lands, tides, elements, altitude of the sunne, course of the moon and stares … [63]

Cabot's world map of 1544, as engraved by Clement Adams (1549), was according to Hakluyt, 'in many marchantes houses in London'.[64]

John Sarracoll would be an example of a merchant who undertook latitude measurements by the sun on his own behalf and included them in his account of the Earl of Cumberland's voyage of 1586, intended for the South Sea.[65] Francis Pretie, described as a 'gentleman' on Cavendish's circumnavigation of 1586–88, took an active interest in the navigation and recorded latitudes, soundings and distances, but unlike Sarracoll does not cite them as his own measurements. He is, however, able to make relevant comments, for example, 'The 24 day [September 1587] wee arrived in the roade of Massatlan [Mazatlan]. which standeth in 23 degrees ½, just under the Tropicke of Cancer'.[66]

Thomas Stevens, a merchant's son who converted to Catholicism and became a Jesuit missionary, sailed from Lisbon to Goa in 1579 and described the voyage in a letter to his

[63] Hakluyt, *The Principal Navigations* Vol. 2, p. 197.

[64] Quinn (eds) *Discourse of Western Planting, c*ommentary to para. 2278–84 on p. 182.

[65] Hakluyt, *The Principal Navigations* (Maclehose edition,1903) Vol. XI, pp. 202–226.

[66] Hakluyt, *The Principal Navigations* Vol. 6, p. 379, and Maclehose edition, pp. 290–347.

father. He explained the technique of latitude sailing as practiced on the voyage, where the crew sailed south and then east only on reaching the latitude of the Cape. He also introduced the longitude problem, 'You know that it is hard to saile from East to West, or contrary, because there is no fixed point in all the skie, whereby they may direct their course …'.[67] This was managed in part by careful observation of birds, the weather and the sea, but more particularly by the known changes in magnetic variation in respect of the African coast.[68] It would require a diligent master or crew member to grasp this technique, noting the difference between the direction given on the magnetic compass and true geographical north. Not all the gentlemen active in navigation were merchants. A good example is Richard Maddox, a clergyman, who was onboard Edward Fenton's unsuccessful voyage of 1582. [69]

Prominent merchants, such as Michael Lok and William Sanderson have their own celebrated roles in the history of the period and need not be treated in the present summary, but we might note the testimony of state papers generated in the aftermath of the Frobisher voyages, where Lok's commitment is cited as: 'XXV yeres studye and travaylle to satisfye his knowledge thereof. M' poundes spent for thinges necessarie for his satisfaction of knowledge therof in bookes, maps, cartes, instrumentes, and gyftes to men for conference therof'.[70] Other evidence points to Lok's substantial collection in the material culture of cosmography. Sanderson was a major financial supporter of both Frobisher and John Davis, each pursuing three voyages to the northwest, but his principal and extraordinary cosmographical project was to promote and finance the earliest printed English globes, the magnificent Emery Molyneux globes of 1592.

The arrangements in both Portugal and Spain were very different from those in England. They had established institutions in the early sixteenth century which had responsibilities for technical maritime matters. In Lisbon, the Armazém da Guiné e Indias (Guinea and Indies Warehouse) was in charge of instruments, cartography, and the training of pilots, and needed staff with relevant expertise. Separately, a position of Cosmographer (Chief Royal Cosmographer by 1547) was given to the mathematician Pedro Nunes (1502–78), who pursued a career between these responsibilities and appointments at different universities, while publishing in algebra, cosmography, and navigation, and improving instrument design. In Spain, the Casa de Contratación (House of Trade) was established in Seville in 1503 and among its responsibilities were the training of pilots and the preparation and updating of maps and charts. Here, the pilot-major in the mid-sixteenth century was Pedro de Medina (1493–1567), whose textbook *Arte de navegar* (Art of Navigation) has been discussed above. In the mid-century, England was beginning to form ambitions for overseas activities in emulation of Portugal and Spain and some appreciated the need for a similar cultivation of practical mathematics.

The Muscovy Company was an early trading enterprise, chartered in London in 1555 for trade with Russia, and the mathematician Robert Recorde (c.1512–58) became an adviser on technical matters such as navigation. He dedicated his algebra text, *The Whetstone of Witte* (1557), to the Company. Dee took up this role and advised the Company on navigation and cartography.

The (English) East India Company (EIC), incorporated in 1600, had similar technical needs. These stimulated publication and private teaching in navigation and chart making, and the

[67] Hakluyt, *The Principal Navigations* Vol. 6, p. 379, and Maclehose edition, p. 379.

[68] Ibid., p. 380.

[69] Donno, ed., *The Diary of Richard Madox*.

[70] Collinson, ed., *The Three Voyages of Martin Frobisher*, p. 166.

overseas chart-making which had been pioneered in England. However, the establishment of the Dutch East India Company, whose marine cartography was more advanced and organized centrally, led to English dependency on their products from the early seventeenth century. The first governor of the EIC, Sir Thomas Smythe (c.1558–1625), had been central to a group of London merchants founding a mathematical lectureship, occupied by Thomas Hood (1556–1620), [71] and the Company later paid Edward Wright (1561–1615) a salary for lecturing on navigation.

Postscript

The Hakluyt Society is deeply grateful to Professor Jim Bennett's widow, Sylvia Sumira, for offering this text to the Society for publication. Jim Bennett's friend and fellow scholar, Stephen Johnston, has reviewed the text, as, we feel sure, Jim would have asked had the book been completed. Gloria Clifton, Katherine Parker, Sylvia Sumira, Sarah Tyacke, Michael Barritt, and Ray Howgego, editor of the online *Journal of the Hakluyt Society*, have all assisted to prepare the final text. This editorial work has been confined to some small corrections, cosmetic improvements and the expansion of references with fuller bibliographic details.

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[71] ODNB.

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