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RESEARCH ARTICLE

The plain scale from *Warwick* (1619)

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Abstract

Among the artefacts recovered from *Warwick*, an English ship wrecked in Bermuda at the end of November 1619, was a small wooden navigational device. Discovered during the 2010 archaeological field season, the object was cleaned, analysed, and later conserved. It has been identified as an analogue navigational tool known as a plain scale. A novel instrument at the time, the device showed real-world applications of complex mathematical formulas for charting a course on a map. Its presence on *Warwick* is striking; it is believed to be the earliest known example of a plain scale in use on board an English ship sailing to the colonies. The goal of this paper is to present the artefact, provide its historical and archaeological background, and discuss the current body of research related to its purpose in resolving navigational problems.

1. Historical background

The late 16th and early 17th centuries witnessed many advances in astronomy and mathematics, which collectively had some profound effects on the practice of ocean navigation in England. Knowledge was initially channelled through translations of foreign treatises, primarily Portuguese and Spanish, or through the consolidation and discussion of other European sources. Towards the end of the 16th century, English seamen took advantage of important navigational manuscripts, such as William Bourne's *Regiment for the Sea* published in 1574, John Dee's *General and Rare Memorials Pertayning to the Perfect Arte of Navigation* published in 1577 and Anthony Ashley's translation of *The Mariners Mirrour* published in 1582 (see Bourne, 1574; Dee, 1577; Ashley and Waghenaer, 1588). Leveraging knowledge about ocean exploration and discoveries, and increasingly accessible charts, instructions and guides, Robert Hues published his 1592 book on the use of terrestrial and celestial globes. John Davis, an outstanding navigator and famous explorer of the Northwest Passage, established a system for keeping columnar logbooks and published *The Seaman's Secrets* in 1595, and Edward Wright, a prominent Elizabethan mathematician and cartographer, synthesised a number of contemporary sources to provide an explanation of the Mercator projection in *Certaine Errors in Navigation* in 1599. These are just a few of the examples of seminal English works produced at the time (Waters, 1978, pp. 131–137, 219–220; Grattan-Guinness, 1994, pp. 1128–1129; Rose, 2004, pp. 175–177).

In the sphere of navigational instruments, English sailors made use of Thomas Hood's cross-staff or Jacob's staff, the designs explained in a pamphlet published in 1590 and soon followed by Hood's sector in 1598 (Waters, 1978, pp. 186–189; Mörzer Bruyns, 1994). These instruments provided a practical means of measuring the angle between the horizon and a celestial body, such as the sun or stars. Other navigational aids highly prized by explorers and mariners alike were globes and charts produced by Emery Molyneux (among others) as early as the 1590s. For the English, Molyneux's products were a natural choice, accurately depicting the world in terms of the latest discoveries in the northern waters

(Waters, 1978, p. 190). To facilitate navigational calculations that could be rather challenging for ordinary seamen, John Speidell has been credited with the 1607 development of a simple rule or scale, a form of analogue navigational calculator known as the plain scale (Waters, 1978, p. 445; Grattan-Guinness, 1994, p. 1129). Around the same time, Edmund Gunter developed a sector, a mathematical instrument consisting of two hinged legs along which were matching pairs of lines whose starting point was the centre of rotation of the hinge. The pairs of lines were variously divided into equal parts or into geometrical ratios and other mathematical relationships (Cotter, 1981, pp. 363–367; Sangwin, 2003, pp. 1–2).

The first two decades of the 17th century were an exciting time for English mathematics, and any discussion of Speidell or Gunter should also reference the role played by John Napier and Henri Briggs through their ground-breaking work on logarithms. These men of science were vital to the development of the numerical approach for calculating logarithms and compiling the corresponding tables, as reflected in manuscripts published by Napier in 1614 and Briggs in 1617 (Smith, 1929, pp. 149–155; Van Poelje, 2004, pp. 1–3). Gunter, who befriended Briggs while at Gresham College in London, later expanded on this work by producing logarithmic sailing tables, which in turn led to the invention of a wooden logarithmic scale in 1620. The description of the scale, known later as the Gunter scale, first appeared in a publication in 1624. It quickly gained prominence as a successful navigational aid in England and beyond and was still in use in the late 18th century. Both Speidell's plain scale and Gunter's scale were simple navigation tools that made calculations fast, easy and practical, and served as the impetus for further improvements, such as Richard Delamine's (c. 1630) and William Oughtred's (c. 1632) work on slide rules (Cajori, 1909, pp. 199–203; Waters, 1978, pp. 403–419; Babcock, 1994, pp. 14–15; Grattan-Guinness, 1994, p. 1129; Von Jezierski, 1997, pp. 7–8, 2000, pp. 3–6; Otnes, 1999, p. 6; Van Poelje, 2004, pp. 1–3). In effect, these instruments showcased the real-world applications of complex logarithmic formulas by allowing more accurate plain navigation, later refined as 'plane sailing,' and Mercator-type sailing (Waters, 1978, pp. 416–420). In its most basic form, plain (or plane) sailing relied on the principles that the Earth was an extended plane (or otherwise a flat two-dimensional surface) and the meridians, instead of converging towards the poles, were always parallel to one another. Mercator sailing relied on the mathematical principles and map projection set forth by Gerardus Mercator in 1569 (Taylor, 1956, p. 230; Grattan-Guinness, 1994, pp. 1131–1133).

2. Excavations and initial analysis

On October 20, 1619, the English galleon *Warwick* arrived in Bermuda. On this voyage, the ship was officially designated as a magazine ship for the Virginia Company of London and charged with bringing supplies and cargo to the colonies. *Warwick* was also charged with delivery of Captain Nathaniel Butler, the newly elected Commander and Governor of Bermuda (1619–1622), other government officials and a group of new tenants. On the second leg of the voyage, *Warwick* was supposed to sail from Bermuda to Virginia and then back to London with the yearly crop of tobacco from both colonies (Craven, 1937, pp. 339–40, 1990; Rich and Ives, 1984, p. 135, 140; Bernhard, 1985, p. 60). At the end of November, while the ship was preparing to depart for Virginia, a hurricane struck Bermuda. Although the crew prepared it for the storm, the historical records indicate that all moorings gave way and the ship wrecked near its original anchorage in Castle Harbour (Hollis Hallett, 2007, p. 126) (Figure 1). The site was heavily salvaged in the 1620s, and then rediscovered and salvaged in the 1960s and 1980s. Eventually, the site was surveyed in 2008 and excavated from 2010 to 2012 by a team from Texas A&M University, a project detailed in archaeological reports and popular publications (see Bojakowski and Custer Bojakowski, 2011, 2017).

Based on the results of the initial 2008 survey, the site was subdivided into three roughly equal sections to be excavated during three consecutive field seasons. The first section, corresponding to the stern of the vessel, was excavated in 2010. The second, the midship, was excavated in 2011. The third, corresponding to the bow section, was excavated in 2012 (Figure 2). Taken together, these three sections constituted a 21 m by 6 m section of the starboard side of the ship's hull. It was preserved from the turn

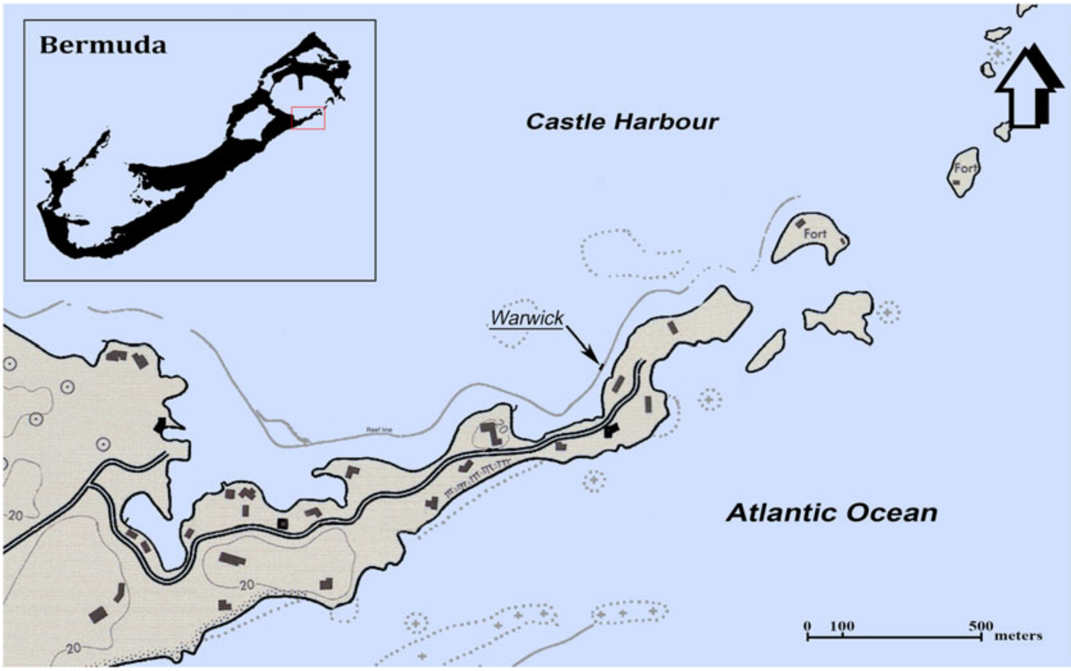

Figure 1. *Location of the site; Castle Harbour, Bermuda. (Modified after nautical chart 26342; Illustration: P. Bojakowski).*

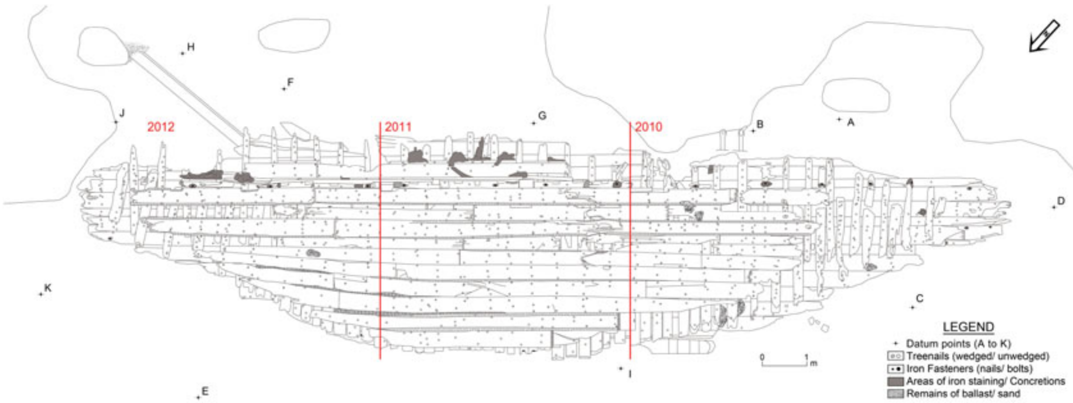

Figure 2. *Site plan as excavated between 2010 and 2012. (Illustration: P. Bojakowski).*

of the bilge (where the hull broke off during wrecking) to just above the first deck, which on *Warick* also functioned as the gun deck (Bojakowski and Custer Bojakowski, 2017, pp. 286–288).

During the 2010 field season, work began by removing the top layer of overburden (consisting of loose silt and sand) and the ship's ballast, and cleaning the final layer of thick dark-grey clay. The latter provided favourable anaerobic conditions for the preservation of the ship timbers and other organic objects. In total, the team excavated 188 individual artefacts, including armament, rigging elements, barrel staves and withies (flexible branches for tying, binding, or basketry) associated with provision casks, lead and wood objects associated with various ship functions, hundreds of ceramic sherds, and numerous other material types and items (see Bojakowski and Custer Bojakowski, 2017, 2023). One of the most intriguing finds was a small piece of wood resembling a common ruler or a scale. Lodged between two stern framing timbers (the first futtock designated as FR3 and the second futtock designated

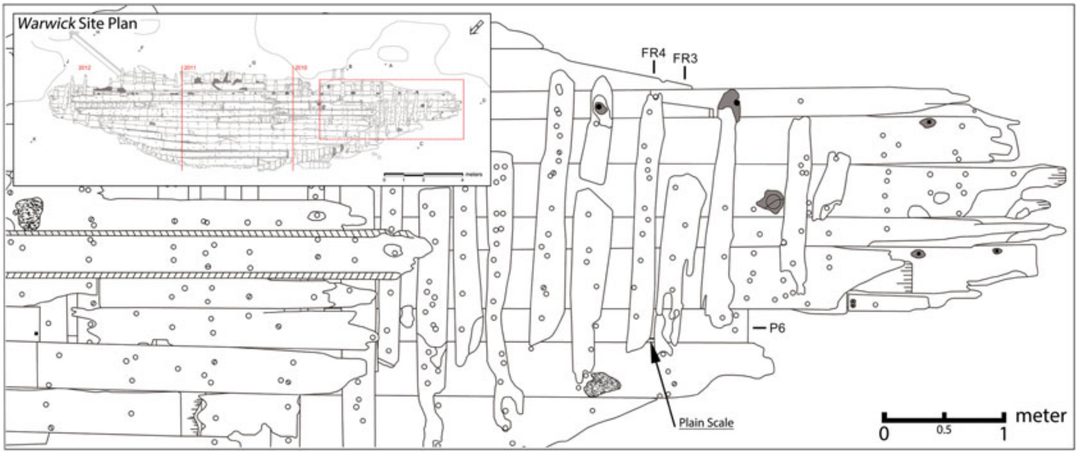

Figure 3. *Detailed site plan showing the location of the recovered plain scale. (Illustration: P. Bojakowski).*

Figure 4. *Photographs of both sides of the plain scale. (Photograph: P. Bojakowski).*

as FR4 in Figure 3) and the inside face of one of the external hull planks (the plank designated as P6), the object was mapped and carefully recovered. It was then transported to the Corange Conservation Laboratory (CCR) at the National Museum of Bermuda (NMB) for cleaning, desalination and initial analysis (Figure 4).

The object was made of wood visually similar to boxwood and measured 206 mm in length, 27 mm in width, and 3·2 mm in maximum thickness. The front (obverse) face was better preserved and showed three graduated parallel lines or scales. The two top lines were 85 mm in length, while the very bottom line was about 130 mm. In other words, each increment of 10 along the bottom line corresponded to about 10 mm, thus resulting in the initial resemblance to a common wooden ruler. Except for the bevelled lower edge, all other edges of the scale appeared to be flat. The back (reverse), which originally adhered to the hull plank, was significantly more deteriorated. It was inscribed with two parallel lines with a set of partly preserved triangular shapes in between. These extant lines and triangles covered an area of approximately 52 mm by 18 mm (Figure 5). Upon field inspection in 2010 and initial analysis at the CCR, the object was tentatively designated in the museum's records as a Gunter scale. After the desalination and cleaning were completed, previously undiscernible surface details in the form of various stamped numerals along the lines became noticeable on both the obverse and reverse of the object. The item was shipped to the Conservation Research Laboratory (CRL) at Texas A&M University for conservation

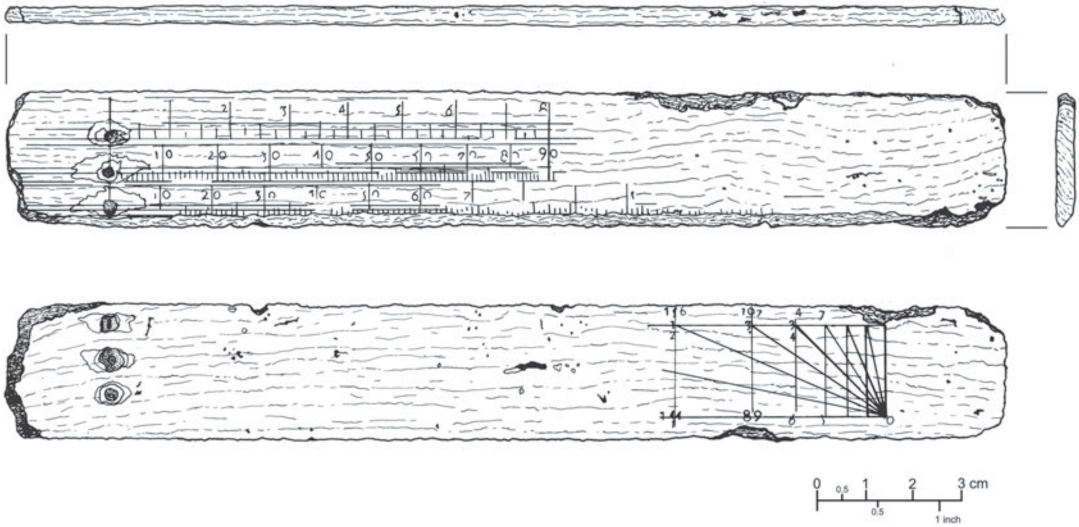

Figure 5. *Archaeological drawings of the plain scale in four views. Surface details after the conservation. (Illustration: M. Clyburn).*

treatment and further research. Conservation was completed in 2013 and the object was returned to the NMB, but the analysis and research at Texas A&M University continued. It was concluded that the small wooden ruler excavated from *Warwick* represented a mathematical and navigational analogue computing instrument identified more specifically as a plain scale.

3. The plain scale

Plain scale was first described and illustrated by John Aspley in his 1624 book *Speculum Nauticum* (Figure 6) (see Aspley, 1624). Although little is known about Apley, he did not present himself to the readers as a scientist but rather as a practitioner of mathematics and the science of navigation. He was a pragmatic individual whose primary objective was to provide direct and tangible assistance to sailors engaged in various forms of maritime ventures and ocean navigation. At the time of his writing, Aspley (1624, p. 8) noted that the plain scale was 'in use with very few, yet [it was] most necessary with Sea men, because of questions in Navigation thereby easily and plainly wrought' (Waters, 1978, pp. 438–439). If the plain scale was, in fact, a novel instrument at the time, its presence on *Warwick*, five years prior to the publication of Aspley's manuscript on its use, is noteworthy. We can only speculate that even fewer people had used or knew about the plain scale during the time of *Warwick's* voyage to Bermuda in 1619.

Aspley did not claim to be the original inventor of the instrument. His fame came from popularising it among sailors and navigators. It is commonly accepted that the plain scale was invented, at least in principle, by John Speidell, a professor in London who became a successful teacher of applied mathematics and the use of scientific instruments. In his 1616 book entitled *Geometricall Extraction*, Speidell mentioned a small mathematical scale, a device he invented in 1607. Speidell explained that the scale was produced according to his instructions by two preeminent London navigational instrument craftsmen, Elias Allen, known for his work in brass, and John Thomson, an expert in wood (Speidell, 1616; Waters, 1978, pp. 445–446; Higton, 1996, pp. 29–39, 58, 285). Because nothing more is known about Speidell's scale or its connection to a type of sector (known for its particular selection of scales) developed around the same time by Gunter, we can only hypothesise what sets of lines must had been inscribed on the obverse and reverse of that early device. Although the object recovered from *Warwick* did not provide any clues as to who manufactured it, the illustration of the plain scale in *Speculum Nauticum* (1624) and extant lines and numerals on the obverse of the artefact are a nearly perfect match

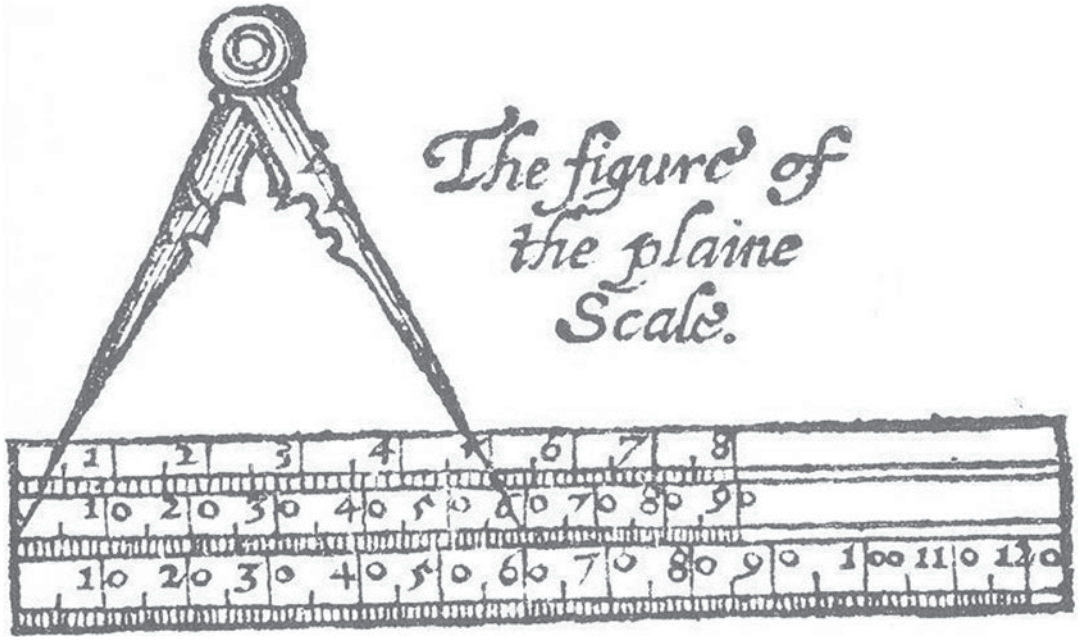

Figure 6. *Plain scale, as illustrated by Aspley. (Modified after Aspley, 1624, p. 9).*

(Aspley, 1624, p. 9). Starting from the upper edge, the obverse shows three parallel lines (or scales). The lines start at the zeroth point, marked with corroded but still preserved metallic plugs inserted at the points of heavy use. Their function was to protect the wood at the point where one of the sharp legs of the navigational dividers would be inserted and then extended out to take a given measurement. Due to the fragile nature of the artefact, no test was performed to verify the type of metal used for the plugs.

3.1. The obverse

The top line is the line of rhumbs numbered 0 through 8, representing the divisions or points of a magnetic compass in a quadrant. The line is divided into eight equal parts or rhumbs (1 rhumb represents 11¼ degrees on a compass), each rhumb being further subdivided into half-rhumbs and quarter-rhumbs. The middle line is the line of chords, divided into 90 equal parts (or degrees). These are numbered 0 through 90 in increments of 10 and represent the length of a chord for a given angle in a quadrant. For example, the number 10 on the line represents the length of a chord for an angle of 10 degrees, number 45 represents the length for an angle of 45 degrees, and number 90 the length for an angle of 90 degrees. Incorporating two different concepts, the lines supplement one another. As postulated by Waters (1978, p. 440), the two lines were likely provided on the plain scale for convenience purposes, as some navigators preferred to use the rhumbs of a compass while others the degrees of a quadrant. The bottom line is the line of equal leagues, in essence a distance line for the plain scale. It is numbered 0 through 130, in increments of 10. Although it is likely that the line extended past 130, poor preservation of the artefact has made identification of its original terminus impossible. The number 60 on the line of chords corresponds with the number 60 on the line of equal leagues. This means that the length of a chord for an angle of 60 degrees is an equivalent to 60 leagues, a distance known as the 'radius of the scale' because it serves as the starting point for drawing all applicable arcs and quadrants in navigational computations (Figure 7) (Waters, 1978, p. 439).

In Chapter VIII of his manuscript, Aspley (1624, pp. 12–14) explained how the three lines on the obverse of the plain scale could be used to graphically solve navigational problems, including how to find a difference in latitude and hence the new position of a ship. For instance, starting at a set latitude of

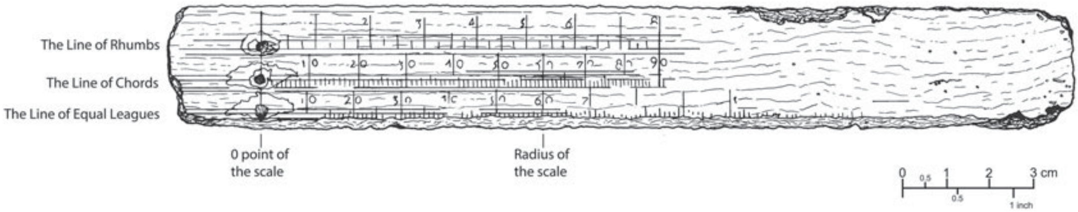

Figure 7. *Description of the obverse of the plain scale. (Illustration: M. Clyburn; Modified by P. Bojakowski).*

56° 05′ N, a ship sails a distance of 100 leagues (or 300 miles) on a southwest-by-south (SWbS) course, a course three points west of south (or a chord of a third rhumb). The starting position of the ship is in point **A**. Using navigational dividers, the first step would be to measure the radius of the plain scale (the chord of 60 or 60 on the line of equal leagues) and transfer it on paper to construct a quadrant **ABK**. In this example, the **AK** line represents the meridian (a line for longitude) and the **AB** line the parallel (a line for latitude). As the course is set to SWbS following the third rhumb west from the meridian, the length of the chord can be measured with the dividers on the plain scale along the line of chords and marked along the arc of the quadrant as point **C**. Then, by drawing a straight line from **A** (from the starting position of the ship) through **C**, the ship's course along the third rhumb is plotted and extended far enough to produce a line **ACD**. Using the dividers, a distance of 100 leagues can then be measured on the plain scale on the line of equal leagues. That distance is transferred on the line **ACD** to indicate the new position of the ship in point **D**. In other words, the ship sails 100 leagues from point **A** to point **D** on a southwest-by-south (SWbS) course.

To calculate a new latitude, a line from **D** can be extended back to the of line representing the meridian, crossing that line at **F**. The line **DF** must be parallel to the original line **BA**. Again, using the dividers, a distance from **A** to **F** is then taken and transferred on the plain scale on the line of equal leagues. This distance would read 83 leagues (83 leagues = 249′ of longitude), which can be converted into 4° 09′ (249' = 4° 09′). Because the original latitude of the ship was 56° 05′ N and it sailed on a southerly course (SWbS), the distance of 4° 09′ must be subtracted from the starting latitude of the ship, indicating a new latitude of 51° 56′ N (Figure 8). Although this example is provided to illustrate the calculation of a change in latitude (sailing along a meridian), theoretically, the plain scale could also be used to solve navigation problems involving changes in longitude (sailing along parallels). As such, the length of line **DF** would be transferred with the dividers to the line of equal leagues, reading 56 leagues (56 leagues = 168′) or a 2° 48′ change in longitude to the west. Unfortunately, early in the 17th century, errors in calculating longitude at sea were difficult to compensate for due to differences in distances between meridians at different latitudes, and particularly when sailing further away from the equator. To correct this, navigators required a knowledge and understanding of tables and the use of high-quality globes (Waters, 1978, pp. 196–197; 224–226; 440–442).

3.2. The reverse

Unlike the obverse, Aspley did not illustrate the reverse of the plain scale in his manuscript. Nonetheless, a general concept presented on that side of the scale was not new at that time. In fact, it was already well understood, having been described and illustrated by John Davis in 1595 and before him by William Bourne in 1574, the latter in an English interpretation of an even earlier Spanish source, *Suma de Geographia* (first published 1519) by Martín Fernández de Enciso (Enciso, 1519; Davis, 1595). Among various regimens and rules included in his early English translation, Bourne provided a circular diagram that in a simple form illustrated the concept of raising or lowering a degree of latitude while at sea. Unlike in Portugal, Spain or even France, where one degree of latitude was considered to be 17 ½ leagues, Bourne postulated that for the English it was 20 leagues or 60 miles (three miles to a league) (Waters,

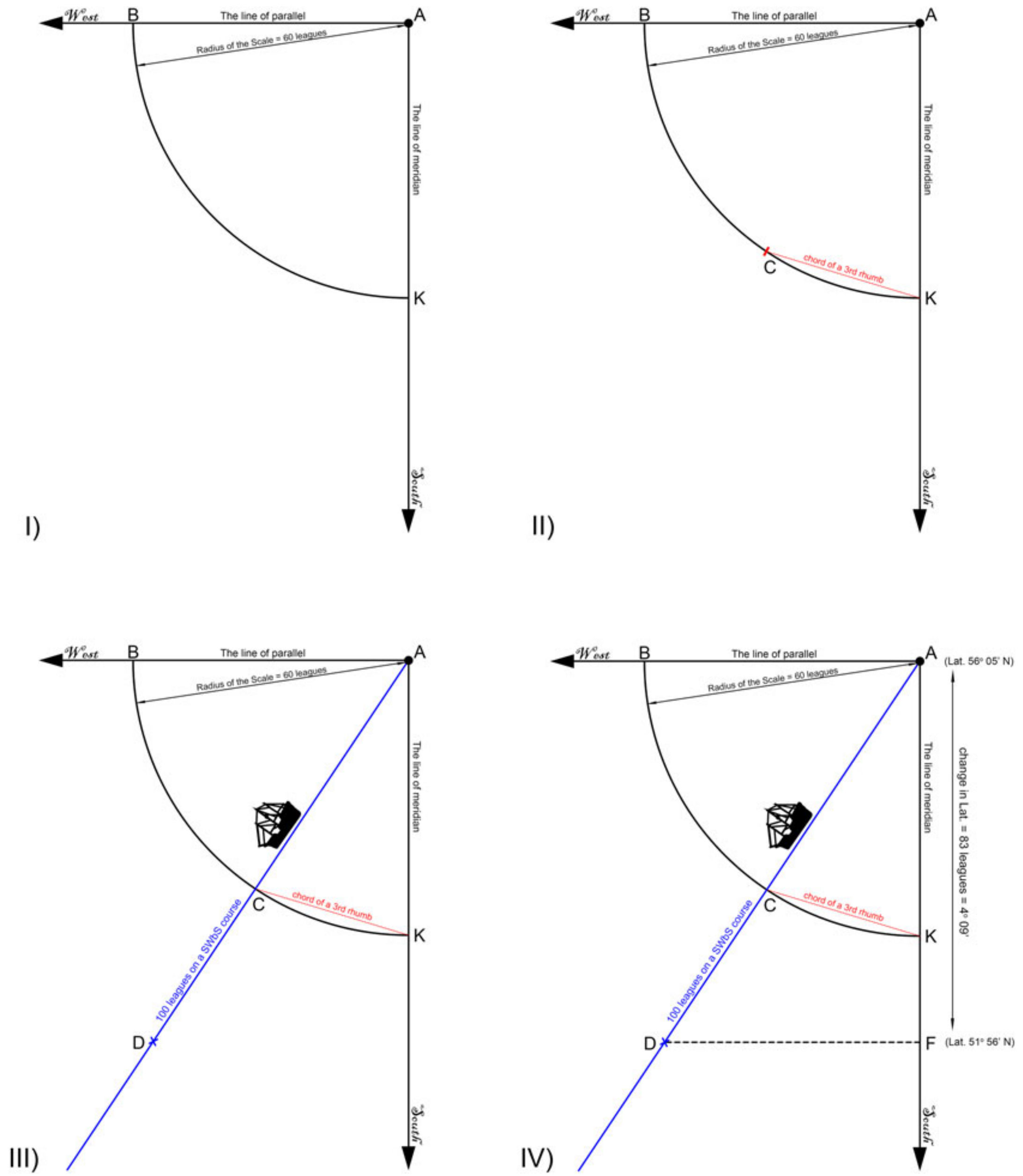

Figure 8. *Hypothetical calculations of ship's change in latitude using the plain scale method. (After Aspley, 1624, p. 12–14).*

1978, pp. 136–137). Because of its English source, the most relevant to the plain scale from *Warwick* is a navigational text by Davis, where he presented a diagram of how to raise or lower a degree of latitude. The diagram was set to a scale of 20 leagues, or one degree of change in latitude (Figure 9). To Davis (1595), degrees carried greater significance in ocean navigation than leagues or miles. Writing nearly 30 years later, Aspley revisited Davis's concept, indicating that the lines on the reverse of a plain scale are 'the first and second lines of longitudes' (Waters, 1978, p. 443). The first line of longitude, showing the number of miles or leagues, represents sailing along a given parallel directly east or west. The second line of longitude, showing the number of miles or leagues, represents one degree of change north or south.

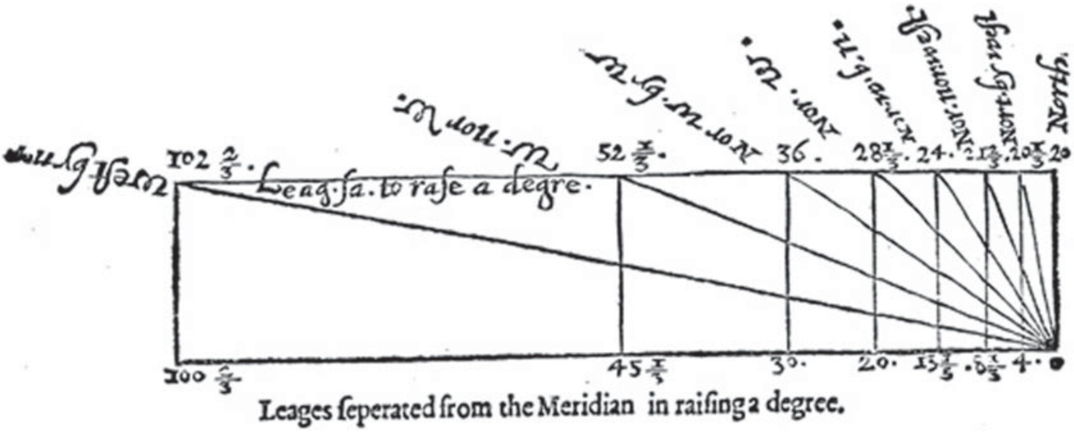

Figure 9. *Reverse of a plain scale as illustrated by Davis. (Modified after Davis, 1595).*

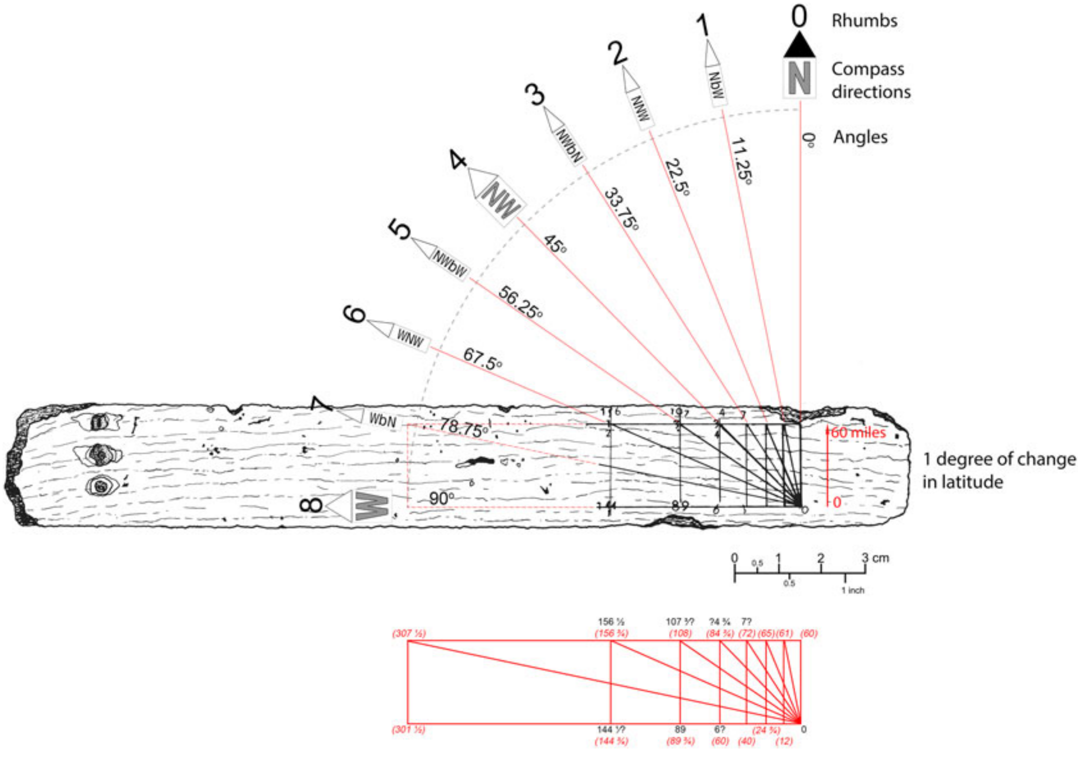

Figure 10. *Description and hypothetical interpretation of the reverse of the plain scale. (Illustration: M. Clyburn; Modified by P. Bojakowski).*

The reverse of the plain scale from *Warwick* is inscribed with a set of lines and triangles along each of the rhumb lines, geometrically projecting how many miles or leagues are needed for a ship to either raise (or lower) its latitude by one degree. Due to the very poor level of preservation, only a few numerals are visible. However, it is clear that the first vertical line represents zero, or the course directly north (or south), while the last line represents the eighth rhumb, or a course directly west (or east). The lines in between are inscribed accordingly in one-rhumb increments, while the angles correspond to the division of a quadrant of 90 degrees into eight equal parts. Based on the angles and the extant numbers on the scale, other numbers could also be deciphered using basic trigonometric functions. The reverse of a plain scale is not graduated in degrees, but rather set to a common scale of 60 miles (60 miles corresponding to one degree of change in latitude). Overall, the numbers presented on *Warwick's* plain scale are quite accurate, all within less than a mile of tolerance (as verified using a modern scientific calculator). The angles are within less than one degree of tolerance (as verified using modern graphics software). As for the application of the lines on the reverse of the plain scale to real-world navigation, it is self-explanatory. Using a simple graphic concept, a navigator would read numerical values for distances along given rhumbs directly from the scale. According to this example, a given ship on a WNW course (or a course of a sixth rhumb) would need to sail 156.5 miles along that course to raise a latitude by a degree (Figure 10).

4. Conclusion

The first two decades of the 17th century positioned a culture of English mathematical scholars whose work ranged from the theoretical and academic to the highly practical, while providing the basis for the development of new navigational instruments. The goal of these new tools was simple: to reduce the need for complicated mathematical calculations that were often beyond the capabilities of ever-increasing body of regular seamen, while at the same time to provide them with the knowledge most essential for long distance sailing (Higton, 1996, pp. 275–278). Although it is not possible to draw a definite conclusion regarding the extent to which such instruments were employed by an average navigator, it is clear that an early version of a plain scale was already present onboard *Warwick* when it sunk in Castle Harbour, Bermuda, in November 1619. For ocean crossings, this device required only a modest knowledge of mathematics, a clear advantage over more advanced instruments. It supplemented the well-known dead reckoning and facilitated the plotting of ship's route on a plane or otherwise flat surface of a chart, allowing the user to devise a change in latitude. As explained by Rose (2004, p. 184), the English practice of navigation at the time was still as much an art as a science, but that balance was rapidly shifting towards the latter.

John Speidell is credited with inventing the plain scale in 1607, but his relationship with Edmund Gunter and the early Gunter sector is unclear. The distinctive device known as the Gunter scale was not invented until 1620 (Babcock, 1994, p. 14). If we accept Speidell as the original inventor, the plain scale recovered from *Warwick* postdates its initial development by 12 years. At the same time, the means of raising or lowering latitude by a degree (presented on the reverse of the artefact) postdates its introduction in English by at least 24 years, if not much longer (as per various other texts and the translations of earlier Iberian sources). As such, it is evident that by the second decade of the 17th century, the mathematical concepts behind the plain scale were not new, but the instrument itself still was. This is supported by Aspley, who in 1624, five years after *Warwick's* sinking, published a text to popularise this device (Aspley, 1624). Nonetheless, a small number of these early scales were likely circulating around even before Aspley or Gunter published and explained how to use them.

The scale excavated from *Warwick* did not bear any maker's mark or date. However, being well provenienced within the structure of the shipwreck, its *terminus ante quem* was the date of the sinking. Unlike a classic Gunter scale, the plain scale did not have any logarithmic lines or values (see Van Poelje, 2004). It combined simplicity of the design with ease of use while avoiding being encumbered by long and laborious calculations by hand. The obverse of the plain scale shows a line of rhumbs and a line of chords that complement one another, as well as a line of equal leagues that provides a relative scale. The reverse is a basic 'cheat sheet' of how to raise (or lower) a ship's latitude by a degree, and the specific distances needed by a navigator can be read directly from the numerals stamped on the instrument.

By comparing the plain scale from *Warwick* with other known Gunter-type scales, it can be seen that the former became particularly prominent in the Netherlands (called by the Dutch a *pleyn-schael* or *pleinschaal*), while the latter (distinguished by their logarithmic lines along with the navigational lines) were favoured in England (see Crone, 1927; Cowan, 1982; Mörzer Bruyns, 1982). A plain scale was discovered and excavated from the Dutch East India Company (VOC) shipwreck *Hollandia* (sunk in

1743), on which, among many other important navigational instruments required on board, the ship's officers likely possessed three or four such devices as part of their standard toolkit (Cowan, 1982, pp. 287–289; Engelsman, 1982). As for *Warwick*, archaeological data have not provided any evidence whether an individual (or individuals) entrusted with navigation on the ship of this size might have carried more than the one plain scale on this transatlantic voyage to Bermuda (see Mörzer Bruyns, 1982, p. 294). However, prior salvage activities at the site in 1979 and 1980 revealed that the ship carried other navigational instruments, including two pairs of brass navigational dividers and a compass rose engraved on a piece of grey slate (Bojakowski and Custer Bojakowski, 2023, p. 341). At present, these objects are housed in a private collection and exhibited at the Bermuda Underwater Exploration Institute (BUEI) in Bermuda. The plain scale is exhibited at the National Museum of Bermuda.

Although the practice of using navigational instruments was well-known within the English seagoing community, the application of early 17th-century complex mathematical theories to the design, manufacturing and distribution of analogue computational devices was still in its infancy (Higton, 1996, pp. 32–33; Bennett, 2011, p. 702). Notorious for their conservatism, practical seamen needed the instruments to be dependable, accurate and user-friendly – and the plain scale offered that. With a few simple manipulations of the dividers, all a navigator had to do was to read the results directly from the scale. Within a larger context, what makes the plain scale from *Warwick* unique is that it survived within its original archaeological context and was excavated from the stern section of the vessel providing an important case study. To date, it is the earliest known example of this type of navigational instrument from a well-dated shipwreck site. It is also a link between known history reflected in printed manuscripts and sources and the extent to which this tool was in fact utilised on a relatively small English ship for the intended purpose of ocean crossing from England to Bermuda (Roche, 1981, p. 3; Mörzer Bruyns, 1987, pp. 281–282, 1994, pp. 15–16; Einarsson and Mörzer Bruyns, 2003, p. 53; Rose, 2004, p. 176).

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Permission statement. The authors excavated the English galleon *Warwick* and collected primary data between 2010 and 2012 under the permit from the Bermuda Wrecks Authority, Bermuda. The National Museum of Bermuda is a designated repository of the original archival copies of the data.

Declaration of interest. The authors have no potential competing interests to report.

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