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The Remains of a Manila Galleon Compass: 16th-Century Nautical Material Culture

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Abstract: This article reveals the recovery of a compass balance from a Manila galleon that was wrecked in the 16th century off the coast of Baja California, Mexico, and discusses the possibility that it was made in Spain. Based on an analysis of navigation treaties, written in the context of the training of pilots by the Casa de Contratación (House of Trade), it is revealed in detail how nautical compasses were manufactured in Spain during that period. As a result of the review of the nautical literature of that century, it is concluded that the compass was the most important nautical instrument on board and that its simple design allowed any malfunction to be resolved during the journey. In addition, the authors affirm that the design of this compass was very similar to those suggested in the European navigation traditions of the 16th century, and thus, it seems quite possible that the compass rocker found in Baja California was made in the Hispanic world.

Keywords: House of Trade; pilots; Spanish nautical treaties; Spanish navigation instruments

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1. Introduction

A shipwreck represents a great diversity of material remains for archaeological investigation. In the 16th century, ships, as the only way of interoceanic communication, were used mainly for commercial, military, and exploration purposes. The ship served as a container for merchandise in the case of commercial voyages, as a defensive and offensive tool for protection against enemies during the journeys, and as a means of geographical reconnaissance for the identification of new territories. The ship itself was a sophisticated machine adapted to take advantage of the force of the wind and sea currents. The multiplicity of a ship's functions entails complex mechanical systems, and thus, a variety of materials can be found in a shipwreck.

The cargo and the structure of the ship represent the highest percentage of elements present in a historical shipwreck, while the purely nautical elements are reduced. Therefore, the possibility of locating the remains of nautical instruments are limited both by the fragility of their materials and by the low number of instruments being shipped [1] (pp. 118–120, 157–159).

In Hispanic navigation, the construction and sale of nautical instruments was supervised by a group of experts who worked at the Casa de Contratación (House of Trade) in Seville. As will be detailed later, the Spanish crown considered both geographical information on the routes to the New World (charts, maps, and directions) and navigation instruments to be objects of great value in the context of the competition with other maritime powers for control of the oceans. This precaution generated a strict regulation on the manufacture, sale, and use of these objects [2] (pp. 675–686). The instruments necessary for navigation were the responsibility of the pilot. He shipped them among his belongings, and from the nautical treaties published by the Casa de Contratación, it is possible to infer that he must have also had the knowledge and ability to build or repair them. In the 16th century, the list of the pilot's instruments was small; it included charts, handheld dividers, two compasses, an astrolabe, a forestaff, a quadrant, two clocks, and an hourglass [3]. The charts were used to understand the geographical environment through which one was navigating and to trace the sailing route; the compasses were used to locate north and set the ship's course; the astrolabe, the forestaff, and the quadrant were necessary to obtain positioning data for the ship on the high seas; and the hourglass was used to obtain the time data to make the necessary calculations for the route and other maneuvers. All of these instruments were necessary; however, we can state that the most elementary and indispensable instrument was the compass.

Regarding this instrument, various authors agree that the magnetic needle was a Chinese invention, documented at least since the 11th century, and introduced to Europe by the Arabs [4] (pp. 188–196). Once European navigators understood the virtue of magnetite to orient itself to the north, they modified the container of the magnetized needle until they obtained the design that is familiar to us from the name compass or magnetic compass; this consists of a nautical rose with the 32 directions and the magnetized needle supported by a pivot, all of which is contained in a mortar inside a wooden box, as will be seen in detail later [5] (pp. 87–90). The instrument's materials were glass, paper, metal, and wood, all of which are susceptible to degradation in an underwater archaeological context [6] (pp. 150–151).

Due to these circumstances, the discovery of a compass in an archaeological context is an opportunity to deepen our understanding of its materiality and design, in addition to comparing the material remains with historical descriptions of compasses, specifically those in navigation treatises that describe their construction.

In 1999, the Manila Galleon Project began in Guerrero Negro, Baja California, Mexico, under the coordination of the INAH Sub-Directorate of Underwater Archeology and maritime historian Edward Von der Porten. After 11 years of exploration and archaeological campaigns, compass gimbals were located under the sand among the remains of a 16th-century Manila galleon.

This finding adds to just a few archaeological discoveries of vestiges of 16th-century nautical compasses in the world, and the second in the American continent.

This article presents information on the archaeological finding of the compass gimbals. Through the analysis of several navigation treaties and nautical instructions from the 16th century, the materials and manufacturing of the magnetic compass are detailed to propose that it is of Hispanic origin, built under the regulations of the Casa de Contratación in Seville.

2. Manila Galleon Project

The Manila galleon trade route was organized out of a desire to trade with the spice islands from the territory of the American continent in the 16th century. It lasted for 250 years, from 1565 to 1815, and contributed to a rich cultural interaction between New Spain (Mexico) and Asia, and to globalization [7]. Crafted in the Philippines, the ships built for this route were among the sturdiest vessels of their time, crossing heroic distances with voyages from Manila to Acapulco, with more than six months at sea. Mexican silver arrived in Manila to buy various products from China, Japan, India, and Southeast Asia. These commodities were sold in the rich territories of New Spain, South America, and eventually, Europe, via the Atlantic fleets. This trade route is a fruitful area of study for various disciplines such as shipbuilding, nautical science, and material culture, among others [8–10].

The archaeological research of the Manila galleon at Baja California began in 1999, led by the maritime historian Edward Von der Porten, who had learned of the site from the publication by George Kuwayama, *Chinese Ceramics in Colonial Mexico* (1997), where a few shards of Ming Chinese porcelain appeared published under the legend "from an unknown site of the Baja California coast". Kuwayama had learned about it from an archaeologist and a group of beachcombers. The archaeologist Jack Hunter was also a leader of the team and helped identify the site from other testimonies. Thus, came about the first expedition and the location of the site. The Instituto Nacional de Antropología e Historia (National

Institute of Anthropology and History) (INAH) is the governing body for all archaeological work in Mexico. As such, it oversaw the first seasons and would later officially create the archaeological Manila Galleon Project, Baja California, by the Subdirección de Arqueología Subacuática (Sub-Directorate of Underwater Archaeology) (SAS) that has financed part of the yearly campaigns, conserved the remains, and continues to study the site and the materials. For Mexico, Manila galleons are a chapter of great historical importance. During the field seasons from 2000 to 2019, methodologies were developed to locate the remains of the ship and the scattered materials. Magnetometry on land and sea identified magnetic anomalies in the water, but the team had no success reaching them through underwater excavation. On the other hand, surveys at the beach and dunes revealed the locations of several remains, which were mostly ceramics. Surveys with metal detectors have also yielded finds by locating points to be excavated [11].

The site is on the southern Pacific coast of the state of Baja California, Mexico, along an 11 km coast with low dunes, where the materials from the shipwreck have washed ashore and dispersed widely. In total, 3787 artifacts have been recorded, of which the vast majority are Chinese porcelain from the Wan Li reign (1572–1620) of the Ming dynasty (1368–1644), manufactured in the second half of the 16th century. The collection is extraordinary as it comprises the cargo of one of the early Manila galleons [12]. A collection of Asiatic stoneware was documented, representing at least five different types from southern China and Southeast Asia [13]. Furthermore, a few pieces of Spanish olive jars, fragments of cloisonné-type plates, silver coins, a Chinese coin, a small lead object possibly used for fishing, several pieces of beeswax, lead from the sheathing or repairs to the hull, lead shot, metal furniture fittings, a bronze incense burner lid in the shape of a Fo dog, and the compass gimbals were also discovered [14] (p. 104).

Compass Gimbals

During the 2009 field season, the compass gimbals of the Manila galleon in Baja California were found using a metal detector. They were buried in the sand at a depth of less than 50 cm. At the INAH Electron Microscopy Laboratory, archaeologist Emiliano Melgar and chemical engineer Mario Monroy did a preliminary analysis of X-ray Energy Dispersion Spectroscopy (EDS) to obtain semi-quantitative information on the elemental composition of the piece through X-ray backscattered electrons (BEs) detectors with an acquisition time of 90 s. In the gimbal, six points were selected to allow for the comparison of corrosion-free areas. The spectrograms obtained show a majority presence of Copper (Cu) followed by Zinc (Zn) as the combination of the alloy, as well as some elements in smaller proportions, such as Carbon (C), Oxygen (O), Sulfur (S) and Aluminum (Al). The alloy of the gimbal is Copper–Zinc, brass, in several cases, between 69% and 75% of the total sample analyzed. At the points where Copper decays and Zinc is very low or absent, it is related to the increase in Carbon and Oxygen, which is the result of corrosion and oxidation [15] (Figure 1).

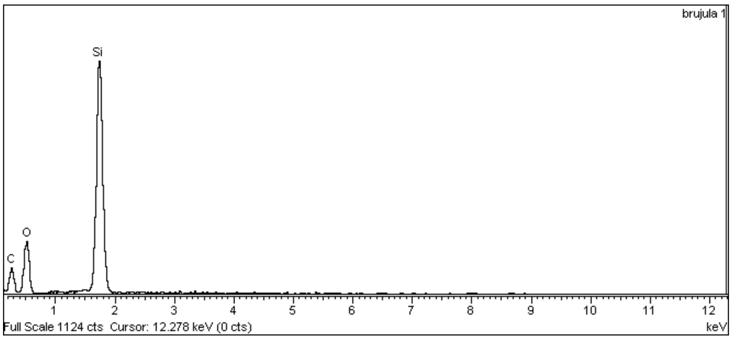

Figure 1. *Cont.*

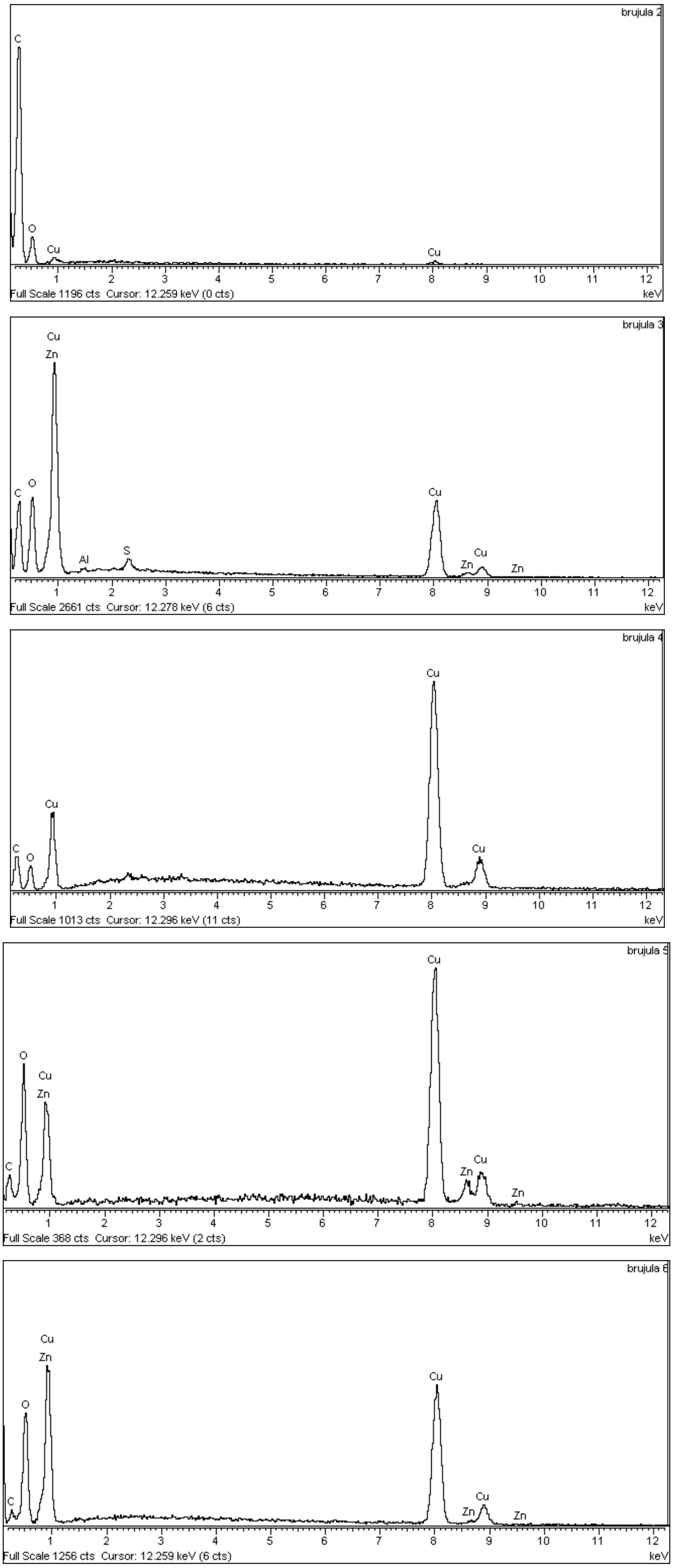

Figure 1. Spectrograms obtained with EDS yielded a composition of Copper (Cu) and Zinc (Zn) for the gimbals.

The gimbals were taken for conservation to the Escuela Nacional de Conservación, Restauración y Museografía (National School of Conservation, Restoration and Museography) (ENCRYM) of INAH. The inner rim was twisted with greenish concretion and sand, but overall, in a good state. Pilar Tapia, head of the ENCRYM Metal Restoration Workshop, mechanically cleaned and stabilized the nautical element with still water [16]. The apparatus weighs 42.90 gr. The outer rim measures 14.3 cm in diameter by 1 cm in width, with a thickness of 1 mm. The inner ring measures 12.7 cm in diameter by 8 mm in width, with a thickness of 1 mm. Both rings are attached by pivot pins 2 cm long by a 3 mm cross-section. The outer rim has 1 flathead nail, 2 cm long with a 3 mm cross-section, that would be connected to the wooden case, permitting movement of the mechanism. The mechanism functions to this day (Figures 2–4).

Figure 2. The compass gimbals after cleaning and stabilization. Photograph by Patricia Carrillo.

Figure 3. Detail of the mechanism articulating the gimbals. Photograph by Patricia Carrillo.

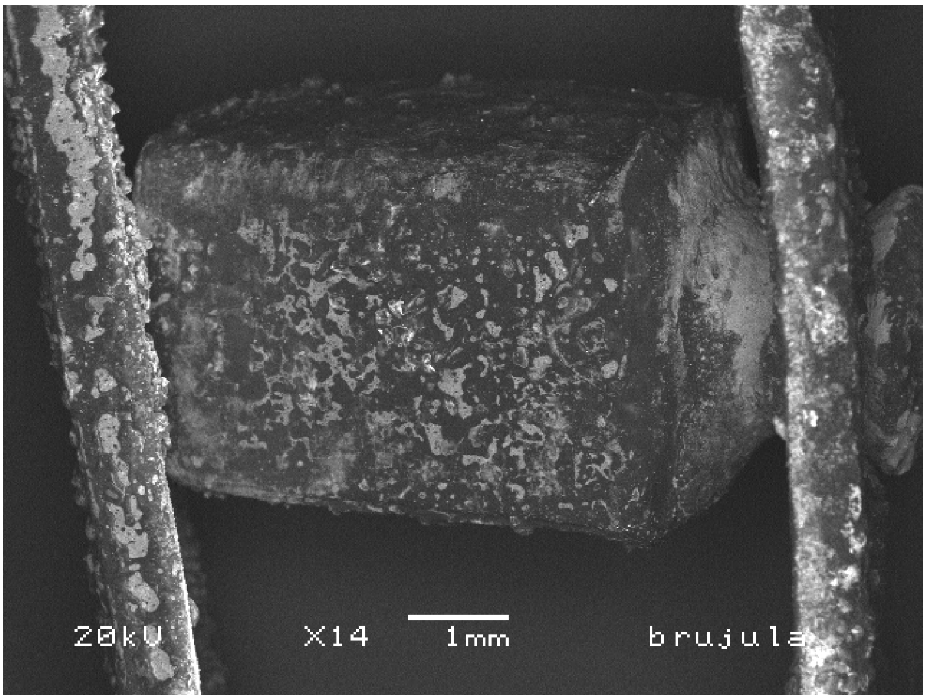

Figure 4. Image of the pivot pin between rings taken from the electronic microscope. Image by Mario Monroy.

3. Archaeological Evidence Regarding 16th-Century Compasses

As Edward Von der Porten reports in his book, there are six surviving compass gimbals known to us from the 16th century [11]. The Manilla galleon from Baja California is the second to be found in the Americas, together with the one from the Basque whaler ship *San Juan*, which sunk in 1565 at Red Bay, Canada [6] (pp. 150–151). The gimbles, together with other parts of the compass, and the protective wooden case, were typically placed near the helm of the ship and are well-documented [6]. Three compasses were found in the *Mary Rose*, Henry VIII's vice-admiral flagship, which sunk in 1545 off the Isle of Wight, England [17] (pp. 277–279). Lastly, another compass from the Willem Barents expedition of 1596 was found off Nova Zembla in the Eastern Arctic [18] (pp. 161–163). Von der Porten argues that because of the similarities in size and construction, the six compass gimbals may have a common origin, perhaps in Antwerp or Amsterdam. However, verifying the geographical origin of a nautical instrument for Western navigation in the 16th century is complex; therefore, aspects that are associated with the origin of a ship must be considered. Furthermore, the commercial networks of raw materials and the monopoly of the construction and sale of nautical instruments are factors. For example, the doctoral research thesis by Swanick shows that the Portuguese used Genoese, Catalan, and Flemish compasses, with no historical evidence of instrument workshops in Portugal [19] (p. 91).

In the case of Hispanic navigation, the Casa de Contratación, the institution responsible for transoceanic navigation, paid great care to the knowledge and nautical instruments necessary for navigation. In this context, important navigational treatises were written, almost all of which include detailed information on the construction of the main navigational instruments. In addition to creating specific texts for the teaching of pilots and masters, the Casa created three positions to both guarantee safe navigation and to protect the monopoly on the routes to which the Casa de Contratación was entitled by papal decree. The highest position was the Chief Pilot, who had three responsibilities, which were to test and graduate the pilots, to approve the charts and navigational instruments, and to supervise the instrument-making cosmographer. The Senior Cosmographer taught courses on cosmography to aspiring pilots and teachers, where one of the chapters addressed the manufacture and use of nautical instruments. The second cosmographer was the Instrument-Maker Cosmographer, and as his title indicates, he was in charge of making the instruments that would be used by the pilots approved by the Casa de Contratación. This position was one of the oldest, having first been held by Diego Ribeiro in 1524. In order to avoid bad practices in the manufacture and sale of instruments, the Chief Pilot, the Senior Cosmographer, and the second cosmographer had to concur in approving the charts and instruments. The pilots could acquire their instruments either in the Casa de Contratación or outside of it. In the case of instruments made by the pilots, they could not be used or sold if they were not supervised and authorized by the Senior Pilot and the two cosmographers. The marks that were placed on the certified instruments were kept in the Casa in a chest with two keys, each held by a different person. Regarding the compass, a document dated October 21, 1564, ordered the cosmographer of the Casa de Contratación to visit the institution with a lodestone on a specific day of the week to magnetize the needles [20] (L.2, c .11, n. 10, 15, 17, 19). A Royal Decree dated February 17, 1540, located in the General Archive of the Indies, corroborates this practice. It indicates that anyone who wants to buy charts and instruments can do so from the pilots and cosmographers residing in Seville, who have been examined and have a license to manufacture them [AGI, Indiferente, 1963, L.7, f.84v].

4. Making a 16th-Century Sailing Needle

The compass, known in the 16th century as sailing needle, was composed of three parts that allowed for its correct orientation at sea, as well as the safe transportation of the instrument (Table 1). Its main purpose—which was to indicate the direction of the vessel—was performed through the magnetic property of a steel needle. The information about the direction was obtained by observing the position of the needle on a graduated circle called a compass rose. This was inserted into a mechanism that helped maintain a horizontal position despite the rolling and pitching of the ship. Finally, the set was placed in a wooden case that protected the instrument during the journey and while in use [5] (p. 87) (Figure 5).

According to Spanish navigation treatises of the 16th and early 17th century, making a compass was a simple task, based on everyday materials [3,21–23]. Thus, if the instrument suffered any damage, the pilot could repair it on board or make a new one, as it is clear from the following list of items:

1 steel needle.

Pasteboard.
1 round wooden box.
1 round or square wooden compass box.
1 iron, steel, or brass pivot.
1 brass needle socket.
2 brass rings.
Brass bolts.
Glass.
Wax, tar, and thin sheets of lead.

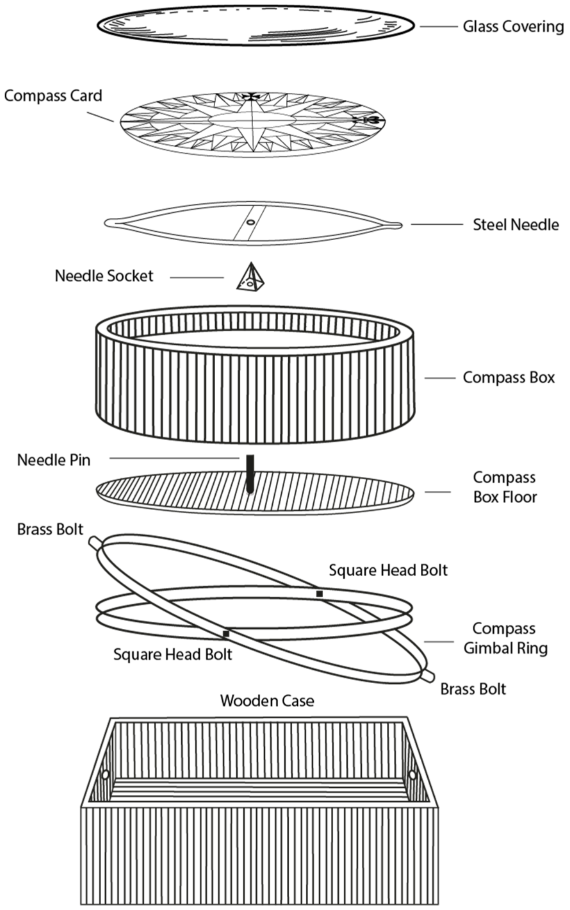

Figure 5. The different parts of a Spanish nautical compass of the 16th century. Drawing by Fatima Troncoso Espinosa.

Table 1. Different parts and materials of the compass (Sources: [21] (pp. 231–232), [22] (pp. 53–58), [24] (pp. 74–75), [25] (pp. 34–35).

Function	Parts of the Compass	Material
Direction	Compass card Direction indicator Magnetic property	Pasteboard Steel needle Magnet
Horizontality	Cardan suspension	Iron, steel, or brass pivot Brass needle socket 2 brass rings and bolts
Protection	Compass case	1 round wooden box (compass box) 1 round/squared wooden box Glass
Supplies	Repairing, modifying, or sealing	Wax, tar, lead sheets

4.1. Creation of the Graduated Card (Compass Rose)

Over a piece of thick paper, similar to that used for playing cards, a circle was traced with a compass. The diameter of the circle varied depending on the maker; however, it was recommended that the size match the palm of an open hand. The next step involved dividing the circle into 32 equal sections, which indicated the 32 winds recorded on the compass rose. Winds were classified into three types, including main, half-, and quarter-winds. Main or whole winds corresponded to the eight principal winds, north, south, east, west, northeast, northwest, southeast and southwest; half-winds represented the main eight winds plus eight intermediate winds; and finally, quarter-winds were created by dividing the half-winds into sixteen more winds. These were named after the principal wind that lies next to them, adding the term "one quarter wind to..." and the name of the closest wind on the other side (Figure 6) [24] (p. 134), [25] (pp. 7–8). The north was identified with a fleur-de-lys, and the east or Levante with a cross.

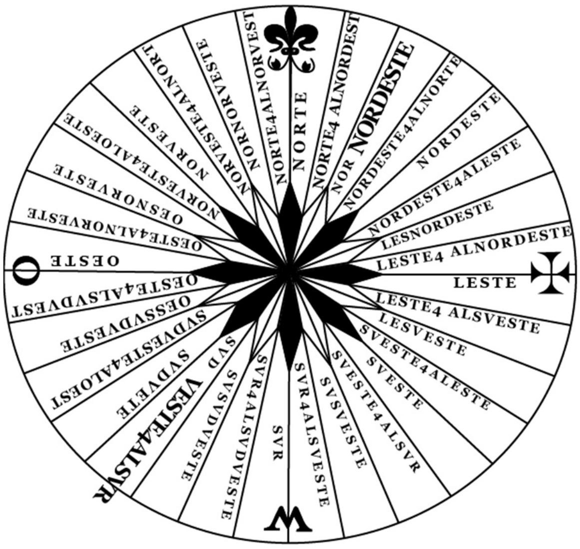

Figure 6. Compass rose in the nautical book of Martín Cortés, 1551 [21] (p. 213).

The eight main winds or their initial letters were highlighted with colors. Blue was used for north–south and east–west, whereas red characterized northeast–southeast and northwest–southwest [22] (p. 57), [25] (p. 34). Finally, on the back of the card, a line was traced with a ruler to follow the north–south direction of the rose and indicate the exact place for the magnetic iron or steel pieces [21] (p. 230).

4.2. Steel or Iron Needle

The iron or steel needle was magnetized in order to indicate the direction. Its size had to exceed the circumference of the compass rose so that the tip, in the form of an arrow point or a beak, protruded and marked the course in which the ship had to be steered [21] (p. 231), [24] (p. 84), [25] (p. 35).

The Spanish cosmographers and authors of navigation manuals, Martín Cortés (1551) [21] and Rodrigo Zamorano (1581) [25], suggested the use of an iron or steel wire, the size of a thick pin, from which the needle was modeled into an oval shape. In a later text, the Valencian cosmographer, Pedro de Syria (1602) [22], recommended having the needle made by a silversmith or a blacksmith in the shape of a "bleeding lancet", that is, a thin blade with a pointed tip. In the middle of the needle, a hole was made where a brass finial would later be welded to connect it with a pivot, as will be explained later. The next step consisted in fixing the needle on the back of the compass rose, following the north–south line previously drawn. The needle was later glued to a thin piece of paper with some paste, so that the steel remained fixed on the north–south direction, being careful to leave the ends of the needle uncovered [21] (p. 231) (Figure 7).

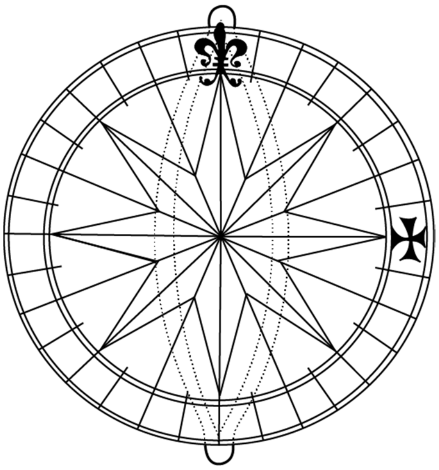

Figure 7. Representation of iron compass needle from the nautical treatise of Martín Cortés, [21] (p. 233). Drawing by Fatima Troncoso Espinosa.

Pedro de Syria suggested attaching the needle to the paper circle using wax [22] (p. 58). Subsequently, the magnetic property was transferred to each point with a lodestone, a process known as "remagnetizing" the needle. In order to achieve this, the end that marked the north had to be previously identified with ink on the stone; by the same logic, it could then be possible to know which part of the lodestone would indicate the south [22] (p. 56). The end of the stone that indicated the north was then hammered, and the northern tip of the needle rubbed against this part. As an extra precaution, the opposite end of the needle could be rubbed with the southern tip of the loadstone, to leave both ends magnetized [21] (p. 231), [25] (p. 34). According to Pedro de Syria's treatise, another way to obtain this result was to heat up the needle with fire, hammer the tip of the lodestone, and rub the hot ends of the needle with the north and south sides of the lodestone (Figure 8) [22] (p. 56).

Figure 8. Image of a blacksmith hammering the tip of the lodestone, which will then be rubbed against the needle [26] (p. 137).

4.3. System to Maintain a Straight Position of the Needle

The needle, along with the graduated compass card, was kept in a round wooden box. At the same time, this box was placed into a suspension mechanism so that the instrument remained horizontal despite the movements of the ship. According to the various treatises consulted for this research [21–23], the construction steps for the instrument were as follows: The graduated card was suspended from its center on a pyramid-shaped brass spike with a hole at its base, which the mariners called the "needle socket". The steel needle rested on the opposite side, fixed to the north–south line drawn on the cardboard. The tips protruded from the diameter of the compass rose, allowing the mariners to see the direction indicated by the needle. The next step was to make a round wooden box, which served as container for the needle. The bottom of the box was removable; this made it possible to open the box and remagnetize the needle in case it lost its magnetic property. The dimensions of the box depended on the size of the steel needle. Its diameter had to be slightly bigger than the length of the needle, so that its ends never touched the sides of the box, whereas its height corresponded to half the length of the needle.

A brass punch was placed on the bottom of the box, as a pivot, and fixed on the needle socket. The box was then covered with glass and sealed with wax to prevent air from entering and destabilizing the compass needle [21] (p. 232–233) (Figure 5). The last step involved placing the box on the compass gimbal. This was made by two crimped brass rings, one larger than the other, joined by the same material. The compass box was then fitted on the smaller ring with pivot pins placed at two ends of the circle. Two holes were made in the outer ring to fix, with brass nails, the rocker arm to a second wooden box that could be round or square. The pivot pins of both rings had to be joined at two opposite points so that they could rotate freely (Figure 9). The aim was for the needle to maintain a horizontal position despite the movement produced by the waves [24] (p. 75), [25] (p. 35).

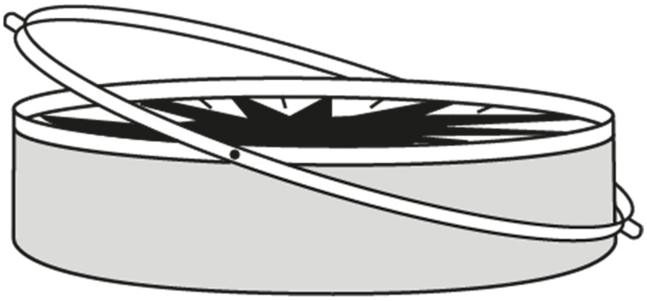

Figure 9. Compass gimbal ring. Drawing by Fatima Troncoso Espinosa.

4.4. The Setting of the Instrument and Required Supplies

To complete the construction, once the needle was placed into the compass gimbal, the instrument had to be stored in another wooden box, which could be round or square. The instrument was attached to this box through a nail placed in each of the opposite axes of the outer ring of the Cardan suspension, which consisted of a framework of concentric rings that rotated on mutually perpendicular axes. This mechanism helped keep the compass stable and horizontal [27] (p. 507). In this way, the compass was attached to the box that protected the whole instrument [21] (p. 233), [24] (p. 75). The pilot had to know how to make these instruments, and also had to carry two pairs of sailing needles during the journey [20] (L.II c. XI n. 15), [25] (p. 314). Furthermore, he needed to bring with him the supplies necessary to repair any damage caused to the instrument. For example, if the glass covering the needle came off, it had to be resealed with wax. Likewise, wax, pitch—a heat-processed pine resin—and thin lead flakes were used to make small corrections to the steel needle, in case the compass rose was tilted toward one end [25] (p. 35), [23] (pp. LXXX–LXXXI). Some pilots, as a practical solution to the problem of magnetic declination, manually corrected the needle. They calculated how many degrees the needle could deviate from the true north and attached a bit of wax to the needle, on the "corrected course" [22] (p. 58). Although this solution was not recommended since it could cause errors during the journey, it was, nonetheless, a common practice among pilots.

4.5. Some Problems with the Functioning of the Needle

Pedro Medina, in his treatise *Arte de Navegar* (1545) [23], pointed out that the sailing needle is a delicate instrument. For this reason, during its use, some problems may arise that affect its performance. Medina presented six main issues that could occur and offered their solutions, which we summarize in the following table (Table 2):

Table 2. Problems in the correct functioning of the compass. Source: [24] (p. 35), [23] (pp. LXXX–LXXXI), [25] (p. 35).

Purpose	Problem	Solution
Magnetic properties	1. The steel tips of the needle are not magnetized.	1. The pilot must bring a lodestone to magnetize the points of the needle. He must verify that the correct end of the needle is magnetized with the correct side of the stone.
Horizontality	2. The needle socket is tilted and prevents the compass rose from maintaining a horizontal position.	2. Verify with a compass where the inclination is.
	3. The pivot tip is worn and prevents the compass rose from moving.	3. Sharpen the pivot tip.
	4. The compass rose is tilted toward one side.	4. Correct the inclination by putting wax, pitch, or lead flakes on the bottom of the compass rose until the tilt is eliminated.
	5. The box in which the compass is stored is open and air passes through.	5. Close the hole with wax or pitch.
	6. The bolts of the compass gimbal are damaged, preventing the instrument from remaining horizontal when the ship is moving.	6. Make sure that this does not happen to avoid errors in the calculation of the ship course.

5. Conclusions

Through the analysis of the remains of a nautical compass located among materials from a 16th-century Manila galleon, it is possible to contribute to research on nautical material culture. To date, there is a very small number of remains of 16th-century nautical compasses from shipwrecks. The materials that compose it, including wood, glass, metal, and paper, are unlikely to withstand the passage of time in both a submerged and terrestrial context. In contrast to the scarcity of material remains of this important instrument, there is abundant historical information about its design and construction. The compass, an essential device for orienting oneself on the high seas and directing the course of the ship, despite its apparent simplicity, was the most important instrument on board. Possibly, for this reason, most of the Spanish nautical treatises of the 16th century devote a chapter to explaining their construction. Unlike the astrolabe, the nautical needle did not require a high level of specialization for its manufacture. The Spanish crown, which was in competition with other maritime powers, faced the need to maintain a monopoly over maritime routes, secure new routes, and control nautical technology. In Seville, navigational instruments could be bought either at the Casa de Contratación or outside of it. The instruments manufactured by the pilots had to have the certification of the Senior Pilot and the two cosmographers. The regulations of the Casa do not mention the option to purchase instruments outside of these two options. Precisely, these data allow us to propose that

Spain provided its pilots and sailors with this instrument, rather than importing them. Furthermore, the design that was current in the sixteenth century continued without any major modification until the eighteenth century. This shows that it was the most suitable design for the space and conditions on board.

The gimbal of the compass presented in this article was a crucial element of the navigation equipment on board the galleon through the journey from the Pacific Ocean to Acapulco. Its study allows us to advance our understanding of Hispanic nautical material culture.

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