INSTRUCCIÓN NÁUTICA (1587)
BY DIEGO GARCÍA DE PALACIO:
AN EARLY NAUTICAL HANDBOOK FROM MEXICO

A Thesis

by

ERIKA ELIZABETH LAANELA

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

August 2008

Major Subject: Anthropology

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Approved by:

Chair of Committee,	Luís Filipe Vieira de Castro
Committee Members,	James C. Bradford
	Kevin J. Crisman
Head of Department,	Donny L. Hamilton

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ABSTRACT

Instrucción náutica (1587) by Diego García de Palacio:

An Early Nautical Handbook from Mexico. (August 2008)

Erika Elizabeth Laanela, B.A., Simon Fraser University

Chair of Advisory Committee: Dr. Luís Filipe Vieira de Castro

In 1587, an ambitious colonial bureaucrat in Mexico City published a handbook titled *Instrucción náutica*. Although navigational books were common throughout the 16th century, the *Instrucción náutica* was the first printed volume that included an extensive discussion of ship construction and design, and its publication was thus a significant event in the history of early modern nautical technology. While the work is frequently cited in discussions of 16th-century Spanish ship construction and seafaring, little in-depth analysis of the text has been undertaken to verify its accuracy. In order to understand the significance of the book, a critical evaluation was undertaken of its context and content and of the motivations and background of its author.

Analysis of documents written by, about, and to Diego García de Palacio reveals that he held positions of academic, religious, and political power in New Spain, that his motives for publishing the book were complex, and that he consulted a range of disparate sources. Significantly, archival correspondence suggests that García de Palacio was an observer and administrator of navigation and ship construction, rather than an expert practitioner.

Nonetheless, comparison of the technical content of the book with other sources of information for 16th-century ships and seafaring, including contemporary treatises, iconography, and archaeological materials confirms the overall accuracy of the text. The navigational materials included in the *Instrucción náutica* reflect information adapted from existing texts, providing a solid overview of the most common techniques of navigation in use at the time. While useful, García de Palacio's discussion of ship design was clearly intended for a non-specialist audience. Perhaps the most original technical contributions are his descriptions of the rigging of Spanish ships. The brief discussion of naval strategy is historically significant due to its juxtaposition between the last of the great naval battles fought primarily with boarding tactics, and the movement toward increasing reliance on the broadside.

By comparing García de Palacio's text to other sources of information, this study has confirmed the reputation of the *Instrucción náutica* as one of the most comprehensive and accurate written descriptions of 16th-century Spanish seafaring practices.

In loving memory of Hugo Laanela

Explorer, scholar, and raconteur

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Throughout my academic career, I have benefited from the advice and encouragement of many teachers and friends. Once upon a time, Phil Hobler and Cathy D'Andrea of Simon Fraser University provided the inspiration to pursue a career in archaeology, and Charles Moore opened my eyes to the field of nautical archaeology. During my time in the Nautical Archaeology Program at Texas A&M University, Filipe Castro, Kevin Crisman, Donny Hamilton, Cemal Pulak, Wayne Smith, and Shelley Wachsmann challenged and supported me while instilling the value of thorough research. Although he had a less direct role in my education, Dick Steffy provided a model of rigorous scholarship combined with humility and kindness.

I am indebted to Kevin Crisman and James Bradford for agreeing to serve as members of my thesis committee. I especially thank Filipe and Siaska Castro for their resolute support, from the first night that I slept on their couch in Lisbon through to the completion of this thesis many years later. Filipe has been a true mentor, and this thesis would not have been completed without him. Muitíssimo obrigada, Filipe.

The talented and dedicated volunteers of the Underwater Archaeological Society of British Columbia gave me my first practical exposure to nautical archaeology. Marc-André Bernier, Robert Grenier, and the underwater archaeologists at Parks Canada, and Éric Rieth, Francisco Alves, and the staff of the Centro Nacional de Arqueologia Náutica e Subaquática in Portugal have made valuable contributions to my professional development. I am grateful to Peter Amaral for his material support of research in Iberian maritime history.

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INTRODUCTION

By the time that Philip II succeeded to the throne in 1556, Spain had established a vast empire in the Americas that encompassed the viceroyalties of Nueva España (New Spain) and Peru. The colonies were linked to Spain by the merchant vessels and royal ships that sailed the Carrera de Indias, or Indies Route, on a regular basis. Trade routes extended down the Pacific coast of South America to Peru and beyond, and an extensive local maritime commerce quickly developed to serve the colonial settlements. Rather than acting as barriers to communication and trade, the Atlantic and Pacific oceans served as the maritime highways of the Spanish empire in the New World.

The Spanish recognized the need for a convoy system to counteract frequent attacks on their ships by English, French, and Dutch raiders. The *averia*, a tax levied on goods shipped by sea, was used to pay for warships to escort merchant vessels across the Atlantic, and by 1526 the king decreed that all ships were to travel across the Atlantic in convoy.[1] By the 1560s, the system was regularized into two annual fleets.[2] Loaded with Spanish consumer products for sale in the colonies, the convoys left Seville in spring or summer. Upon arrival in the Caribbean, they split into two fleets to collect consignments of royal gold and silver and to engage in trade with colonial merchants (fig. 1.1). The Tierra Firme fleet stopped at Cartagena before calling at Nombre de Dios

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This thesis follows the style of the *American Journal of Archaeology*.

[1] Konstam and Bryan 2004, 17-8.

[2] Parry 1981, 180.

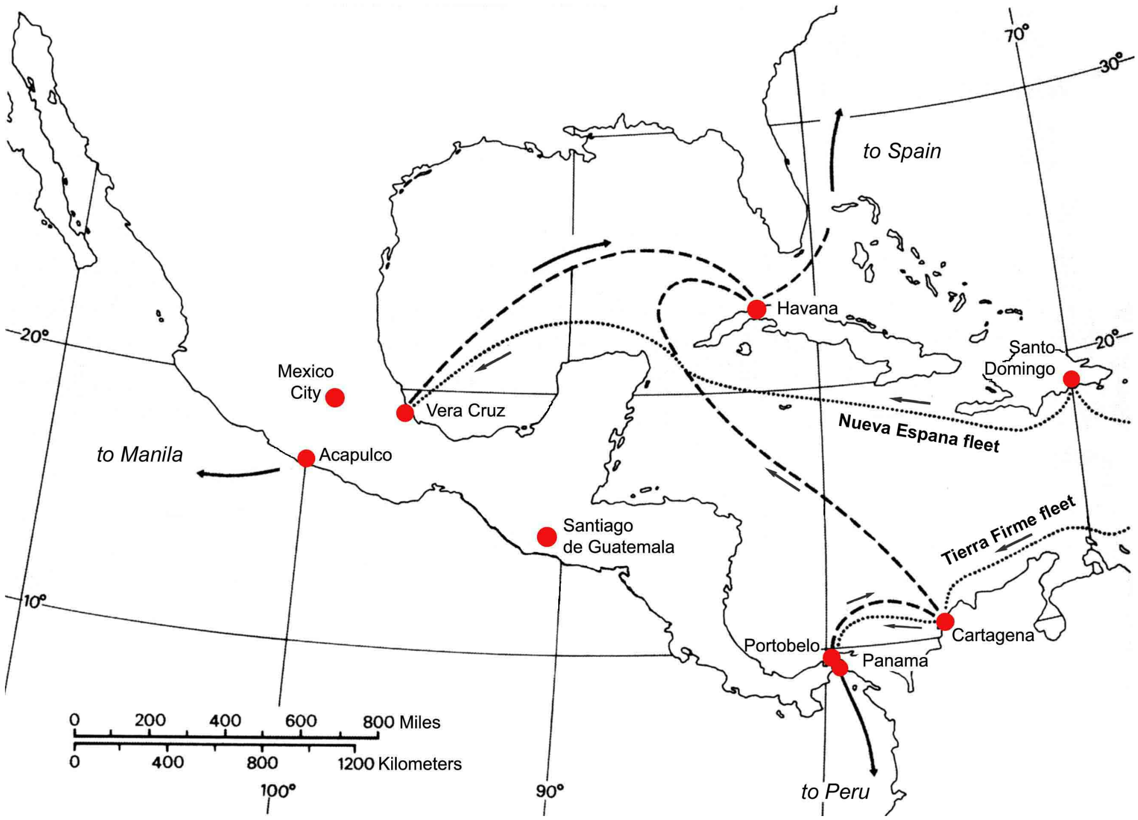

Fig. 1.1. Routes of 16th-century Spanish fleets in the New World. (After Wolf 1997, 138)

or Portobelo to load silver and gold from South America that had been packed overland across the Isthmus of Panama. Colonial products such as cochineal, cacao, indigo, and hides, as well as specie from the royal mint in Mexico City, were loaded into the ships of the Nueva España fleet in the harbor of San Juan de Ulúa near Vera Cruz. Whenever possible, the two fleets met in Havana for the return voyage to Spain. The bulk of the precious metals were carried in large, heavily armed royal warships, while smaller, privately-owned vessels carried other mercantile goods.

Following the discovery of a return route across the Pacific in 1565, a small annual fleet also set off from Acapulco in Mexico to Manila in the Philippines, where silver from American mines was exchanged for fine porcelains, silks, and other oriental products.[3] Upon return to Acapulco, some of this cargo was traded directly to Central and South America, while the remainder was transported overland to Vera Cruz for transshipment to Spain. In addition to these trans-oceanic trading ventures, a significant coastal network serviced the smaller Spanish colonial settlements and transported merchandise, sometimes clandestinely, between Mexico and Peru.

The diversity of these routes required a range of vessel types, ranging from small *fregatas* and brigantines used for coasting, to the galleons and massive *naos* used on the trans-Atlantic routes. By the end of the 16th century, the Spanish colonial administration had established shipyards in Cuba, Mexico, Nicaragua, Panama, and Peru to meet the growing demand for shipping.

Within this context, in 1587, an ambitious colonial bureaucrat in Mexico City published a small handbook titled *Instrucción náutica* (Nautical Instruction).[4] Although navigational books were published throughout the 16th century, the *Instrucción náutica* was unique in that it was the first printed volume that included an extensive discussion of the design, construction, and rigging of ships. While the work is frequently cited in discussions of 16th-century Spanish ship construction and seafaring, little in-depth analysis of the text has been undertaken. The book's author, Diego García de Palacio, held positions of academic, religious, and political power in New Spain. His motives for publishing the work were complex and he appears to have drawn on a range of disparate sources of information while preparing the text. In order to properly understand the

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[3] See Spate 1979.
[4] García de Palacio 1944a.

significance of the book for interpreting 16th-century nautical practice, its context and content must be critically evaluated.

In the following chapters, the *Instrucción náutica* will be analyzed in terms of its historical background and contributions to the understanding of 16th-century Iberian seafaring and ship construction. In order to provide insight into the experiences and ambitions that motivated Diego García de Palacio to write a nautical textbook, chapter II presents a biographical sketch discussing his life, his career, and his other written works. A brief overview of the format and organization of the *Instrucción náutica* is provided in chapter III. The information regarding navigational techniques and nautical astronomy presented in the *Instrucción náutica* is discussed in chapter IV. Chapter V discusses the methods of ship design and construction embodied in the text and the accompanying illustrations, while García de Palacio's extensive explanation of ship's rigging is examined in chapter VI. In chapter VII, attention is given to the officers, petty officers, and crew who manned Spanish ships, and late 16th-century Spanish naval tactics are analyzed in chapter VIII. Chapter IX provides concluding comments on the significance of the *Instrucción náutica*.

CHAPTER II

THE LIFE OF DIEGO GARCÍA DE PALACIO

A wealth of archival documentation has survived to illuminate the life story of Diego García de Palacio. His biography, interwoven through a historical tapestry that encompasses many significant events in late 16th-century New Spain, reveals a complex personality combining seemingly incongruous traits. The portrait that emerges is of an intelligent and inquisitive observer and a conscientious and competent bureaucrat, but also of an artful manipulator who was eventually ruined by the many opportunities for venality available to the colonial elite.

Much of what is known of García de Palacio's life is presented in a monograph first published by Othón Arróniz in 1980 and reprinted posthumously in 1994 by the University of Veracruz.[1] Arróniz's engaging study includes a perceptive biographical essay as well as transcriptions of 20 contemporary documents pertaining to García de Palacio discovered in Seville at the Archivo General de Indias (AGI) and in Mexico City at the Archivo General de la Nación (AGN) and other repositories. The esteemed Mexican historian Edmundo O'Gorman also published transcriptions of several important records concerning García de Palacio held in the AGN.[2]

The Spanish government has recently launched online access to its archival collections, which include numerous original documents that were written by, about, or

[1] Arróniz 1994.
[2] O'Gorman 1940; O'Gorman 1946.

to García de Palacio. Originally launched as Archivos Españoles en Red (AER), a similar service is now provided via the Portal de Archivos Españoles (PARES).[3]

The following discussion provides a synthesis of these accounts, as well as various other primary and secondary sources relating to García de Palacio's life. Key geographic locations in Spain, Mexico, and Central America are shown in figures 2.1 and 2.2. Appendix A provides a chronological list summarizing the events discussed in this chapter.

Family and Education

> And thus the pen has not been an obstacle
> to the temperament of this clever author in any way:
> He who has a strong heart, and skilful hand,
> The legacy of noble ancestors;
> Palacios, and Arzes who gave him their embrace
> and who have bred distinguished men:
> fine soldiers, wise captains,
> against Turks, Frenchmen, and Germans.[4]

Diego's father, Pero García de Palacio, was a native of the tiny village of Ambrosero,[5] located in a river valley about 20 km east of the port of Santander in the province of Cantabria. Pero studied at the University of Salamanca and was ordained into the clergy after benefiting from various family connections.[6] He returned home in

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[3] Facsimiles of many original documents relating to the life of Diego García de Palacio were obtained by the author from the now-defunct Archivos Españoles en Red website (http://www.aer.es) on 17 December 2006. Many of these documents could not be found on the successor website, Portal de Archivos Españoles (http://pares.mcu.es). Copies are retained in the collection of the author.
[4] Prologue to the *Diálogos militares* written by Eugenio de Salazar, translated from Palacio 1944b, 6. Unless indicated, all English translations are by this author.
[5] Deposición de Joan de Ribas en la información sobre la limpieza de sangre del doctor Diego García de Palacio, 22 November 1581, AGN, Inquisición, Vol. 189, Exp. 15, transcribed in Arróniz 1994, 143.
[6] Diego García de Palacio a la Inquisición de México, sobre la probanza de su limpieza de sangre, [1581], AGN, Inquisición, Vol. 189, Exp. 15, transcribed in Arróniz 1994, 141.

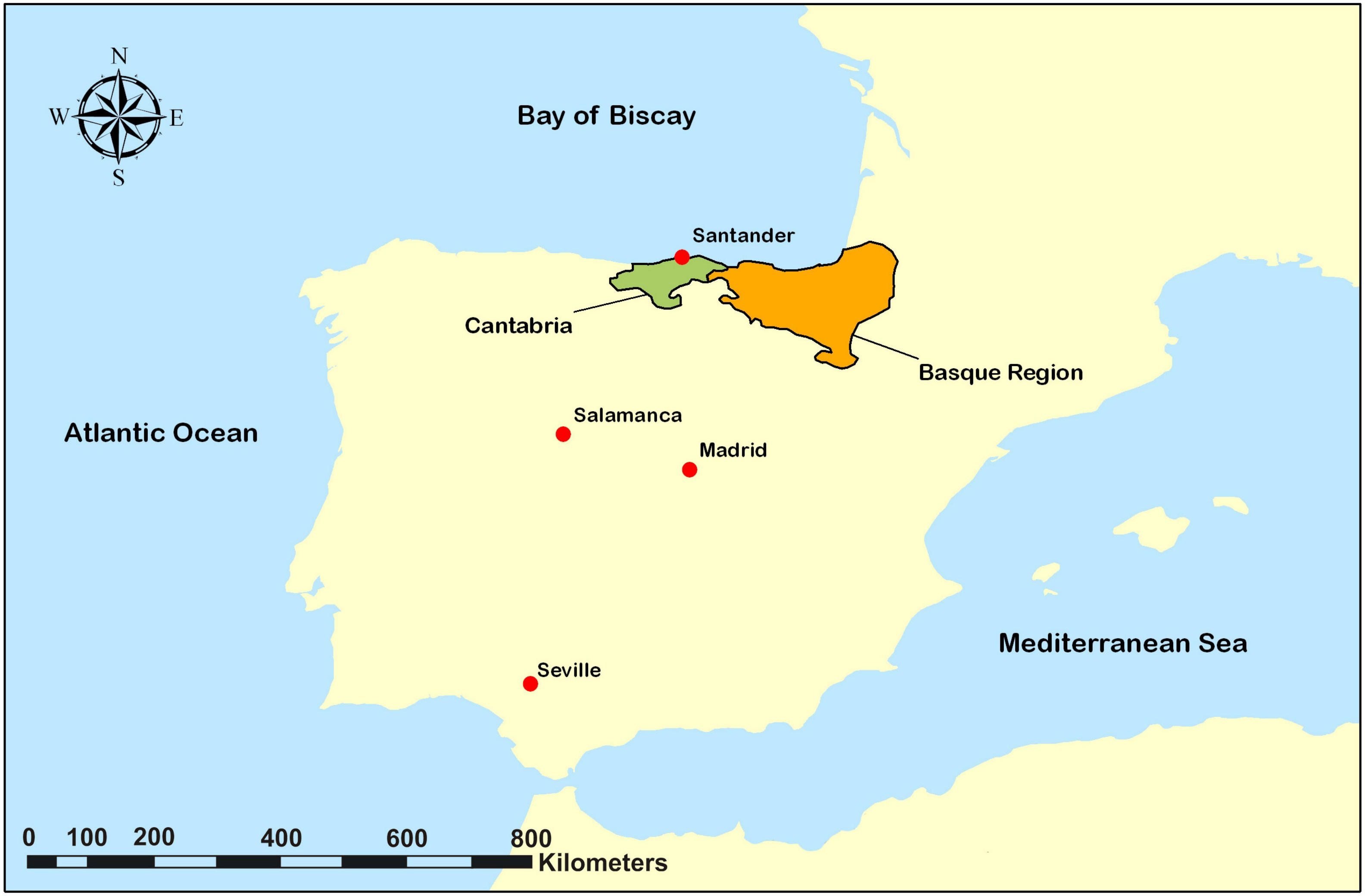

Fig. 2.1. Map of Spain. (T. Nowak and E. Laanela)

Fig. 2.2. Map of Mexico and Central America. (T. Nowak and E. Laanela)

1540 to marry María Sanz de Arce, from the nearby community of Beranga, but encountered fierce opposition from her family. The marriage especially enraged her grandfather, known locally by the sobriquet *el descaperuzado* ("the disheveled one"): "…my grandfather took up arms and with his relatives and associates came at my father with many spears and threats; in this milieu it seems I was born…."[7] The acrimony was so enduring that, some seven years later, Pero was forced to retreat to a fortified tower in the face of continued threats on his life. He eventually escaped by accepting an appointment as prior in Valpuesta, about 100 km away, while María Sanz de Arce remained in Beranga.

Pero de Palacio appears to have been a much-esteemed man: "…the said prior Palacio is known as an honest man and an old Christian, a *hidalgo* [member of the lower nobility] with no Jewish or Moorish blood…."[8] However, doubts about the legitimacy of the marriage between Diego's parents were raised in 1581 when a witness before the Inquisition questioned whether the marriage had occurred before or after Pero joined the clergy. The right of priests to marry was a contentious matter in the 16th century, and the issue was not definitively resolved until the 24th session of the Council of Trent in 1563, which decreed that ordained priests could not marry.[9] The line between priestly marriage and concubinage had long been ambiguous. However, local custom often tolerated such unions. The doubts raised about the legitimacy of the marriage do not

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[7] Diego García de Palacio a la Inquisición de México…, transcribed in Arróniz 1994, 142.

[8] Deposición de Joan Zorrilla de la Concha sobre la limpieza de sangre del doctor Diego García de Palacio, 24 October 1581, AGN, Inquisición, Vol. 189, Exp. 15, transcribed in Arróniz 1994, 145.

[9] Lea 1907, 337.

seem to have hindered Diego's advancement, as he was appointed *consultor* (judge) of the Santo Oficio de la Inquisición (Holy Office of the Inquisition) the following year.[10]

In a letter to Philip II, Diego explained that he was the oldest of five brothers who had all served the king in naval and military affairs.[11] Three brothers were killed in battle: Juan de Palacio was killed during a campaign in Malta (presumably the siege of 1565); Pedro de Palacio met his end while serving in John of Austria's forces against the Ottoman fleet at Lepanto in 1571; and Phelippe de Palacio died in Naples as an *alférez* (lieutenant) in the aftermath of the Italian Wars. The youngest brother, Lope de Palacio, survived the vagaries of war, attained the rank of *capitán* (captain), and emigrated to New Spain in 1582,[12] where he profited from a close relationship with his eldest brother.

The year of García de Palacio's birth was recorded as 1524 in a statement he made before the Inquisition.[13] Although this date cannot be definitively refuted, there is ample reason to suspect that it reflects a copying error. Historian María del Carmen León Cázares has proposed that the correct date is 1542,[14] and circumstantial evidence supports this possibility. García de Palacio's testimony proceeds chronologically, with his birth first mentioned between his father's return to Ambrosero in 1540 and the birth of his first brother in 1544. An error of transcription is somewhat difficult to explain given that the dates in the document are written longhand, but it is possible that the

[10] The appointment as *consultor* was made on 21 February 1582 (Arróniz 1994, 90).

[11] Carta al Rey del licenciado Palacio sobre cosas del gobierno y conquista de las Islas del Poniente, 8 March 1578, AGI, Guatemala, L. 24, R. 44, transcribed in Arróniz 1994, 151.

[12] Real Cédula a los oficiales de la Casa de la Contratación para que dejen pasar a Nueva España al capitán Lope de Palacio, hermano del Dr. Palacio, 5 February 1582, AGI, Indiferente 1952, L.2, f. 6v. (http://www.aer.es [17 December 2006]). The Casa de Contratación (House of Trade) required that all passengers traveling to the New World be licensed to prevent non-Christians from emigrating to the Spanish colonies.

[13] Diego García de Palacio a la Inquisición de México…, transcribed in Arróniz 1994, 142.

[14] León Cázares 1983, 14, n. 29.

scribe worked from notes in which the date was recorded using transposed numerals. As discussed below, García de Palacio received his first bureaucratic appointment around 1567. If the birth date of 1542 is correct, he would have been 25 years old, precisely the minimum age for appointment to government office.[15] The date is further reinforced by testimony given in 1581 by a servant who had known García de Palacio for 20 years, in which his age is estimated to be 42 years,[16] a reasonable approximation if his actual age at the time was 39 years.

It has been suggested by some scholars that Diego was initially educated for a naval career,[17] but this author could find no clear evidence to support this assertion. Whatever the case, his father paid for his studies in Salamanca and Valladolid,[18] and he eventually earned a *licenciatura* (advanced degree) in law. Although literacy was still a luxury in the 16th century, the demand for colonial bureaucrats in the Spanish empire warranted the economic investment of a university education. In Spain, economic priority was given to the eldest son, as reflected in the strong tradition of primogeniture. As such, Diego carried the ambitions and aspirations of his entire family, and his career would have been carefully planned to enhance the family's fortunes. A *licenciado* was virtually guaranteed a secure and often influential position in the colonial bureaucracy: "law was *the* road to wealth, influence, and social prestige."[19] The *letrados* (lawyers) that formed the Spanish bureaucracy were typically impoverished *hidalgos*, and the

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[15] The minimum requirements to be appointed to the civil service were to have reached the age of majority (25 years) and to have studied law (Kagan 1974, 88).
[16] Deposición de Joan de Ribas…, transcribed in Arróniz 1994, 143.
[17] E.g., Fernández de Navarrete 1968, 334; García Icazbalceta 1954, 393.
[18] Deposición de Joan de Ribas…, transcribed in Arróniz 1994, 143-4.
[19] Kagan 1974, xxii. Emphasis in the original.

bureaucracy offered an attractive opportunity for social mobility: a post in the civil service was literally referred to as a *premio*, or prize.[20] *Plazas de asiento* (high level posts) provided lifetime tenure and retirement at half-pay after 20 years. The University of Salamanca was the leading producer of *letrados*, and alumni maintained an "old boy network" in which bureaucrats selected graduates from their own universities for new appointments in the civil service.[21] His father's educational investment was worthwhile: by about 1567, García de Palacio was serving the king in a legal capacity in Spain.[22]

An advantageous marriage may have given García de Palacio some additional priority in obtaining coveted appointments. His wife, Isabel de Hoyo Solórzano, was the niece of the secretary to Charles V,[23] at a time when royal secretaries played a direct role in determining who was appointed to important positions.[24] The couple had a son named Diego while still in Spain, and at least three children were baptized in Mexico City: Alonso in 1583, Isabel in 1585, and Lope in 1586.[25]

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[20] Kagan 1974, 77.
[21] Kagan 1974, 98.
[22] Carta al Rey del licenciado Palacio sobre… las Islas del Poniente, transcribed in Arróniz 1994, 153.
[23] Deposición de Toribio de la Portilla sobre la limpieza de sangre de doña Isabel de Hoyo, mujer del doctor Palacio, 1581, AGN, Inquisición, Vol. 189, Exp. 15, transcribed in Arróniz 1994, 147.
[24] Kagan 1974, 90.
[25] Expediente de concesión de licencia para pasar a México a favor de Diego García de Palacios hijo del doctor Palacios, 1590, AGI, Indiferente, 2065, N. 61 (http://www.aer.es [17 December 2006]); Arróniz 1994, 165, 167, 169.

Audiencia de Guatemala

In April 1572, García de Palacio was appointed to the post of *fiscal* (crown attorney) in the Audiencia de Guatemala.[26] An *audiencia* was the highest court of appeals in a colonial jurisdiction, hearing both civil and criminal cases, and its members also served as an advisory council to the viceroy. The young officer holder was promoted to *oidor* (civil court judge) within a few months, despite the fact that he had not yet departed on his voyage to New Spain. The Crown provided him with 400 *ducados* to defray the cost of the trip, and gave him permission to transport weapons for personal protection and three enslaved Africans.[27] Figure 2.3 shows a Spanish *hidalgo* disembarking in New Spain, accompanied by an African, providing a possible approximation of García de Palacio's personal appearance.

As an *oidor*, García de Palacio enjoyed the prerogative of corresponding directly with Philip II. In March 1574, he wrote to the king from Santiago de Guatemala (now Antigua Guatemala) to explain that, although he had begun his journey to the New World in September 1572, he had been detained in Hispaniola for some time as there were no ships traveling to Guatemala.[28]

García de Palacio's responsibilities as an *oidor* included submitting reports to the king regarding circumstances in the colony, issuing *ordenanzas* (ordinances), making recommendations to improve the administration of the *audiencia*, and various other duties as required. For instance, on 15 February 1575, he composed a document in his

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[26] Nombramiento del licenciado Palacios como fiscal de la Audiencia de Guatemala, 30 April 1572, AGI, Contratación 5788, L.1, ff. 66r-67 (http://www.aer.es [17 December 2006]).
[27] Arróniz 1994, 66.
[28] Carta de Diego García de Palacios, oidor de la Audiencia de Guatemala, 6 March 1574, AGI, Guatemala, 10, R. 1, N. 4 (http://www.aer.es [17 December 2006]).

Fig. 2.3. A Spanish *hidalgo* in the New World. (After Wood 1979, 22)

role as *juez de bienes de difuntos* (probate judge).[29] The Casa de Contratación (House of Trade) served as the trustee for the disposition of the property of those who died in the New World with heirs in Spain, and the office was filled on a rotational basis by the *oidores*.

In 1573, while García de Palacio was en route to the New World, the Consejo de Indias (Council of the Indies) sent out letters outlining 135 questions about the

[29] Carta de Diego García de Palacios, oidor de la Audiencia de Guatemala, 15 February 1575, AGI, Guatemala, 10, R. 2, N. 14, N. 15 (http://www.aer.es [17 December 2006]).

geography, resources, population, and native cultures of each *audiencia*.[30] In response to the questionnaire, García de Palacio undertook a *visita* (inspection) of various provinces along the Pacific coast of the Audiencia de Guatemala. The result was a detailed *relación* (report) to the king, dated 8 March 1576, recording native life in a manner that far exceeded the official requirements, including details of religion, social and political organization, and material culture.[31] This is one of several accounts of *visitas* produced by García de Palacio that are counted among the first systematic studies of the geography, culture, and history of Mexico and Central America.[32] He also produced several sets of *ordenanzas* for regions of Guatemala and Mexico that were intended to provide guidance to other colonial officials regarding the appropriate management of the indigenous population.[33]

García de Palacio's personal interest in recording native cultures led him to seek information from a range of sources that included personal observation, the collection and study of native manuscripts, reports produced by other colonial officials, and consultation with credible informants such as indigenous elders and local priests.[34] Ethnographers and historians consider his descriptions of native cultures to be exceptionally reliable:

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[30] Fowler 1985, 49.
[31] This noteworthy document has been published in a number of editions, including a Spanish transcription by Léon Cázares (1983) and an English translation by Squier (1985).
[32] Rodríguez-Sala 1994, 186.
[33] García Bernal 1985.
[34] Fowler 1985, 50.

> …nothing could be more exact than his accounts of the physical features and natural productions of the districts of country which he visited, and his truthfulness, in these respects, inspires complete confidence in those portions of his narrative which we are no longer able to verify.[35]

The *relación* of 1576 has served as a primary source for ethnohistorical analysis of the Nahua-Pipil Indians of present-day El Salvador.[36] García de Palacio was also the first European to describe the Classic Mayan ruins of Copán, and his letter remained the most comprehensive account of the site until archaeological investigations were initiated 250 years later. In addition, the report reveals García de Palacio's growing interest in ships and maritime trade: he evaluated the suitability of the ports of Iztapa and Acajutla to serve as the Pacific terminus of the trade route across Central America, deeming both to be inadequate for regular trade due to a lack of shelter and deep water.[37]

Under the authority of a *cédula real* (royal decree), García de Palacio's name appears on a contract dated 4 December 1576 with Diego López, a *vecino* (citizen) of Trujillo in Honduras, for the conquest and colonization of the province of Tegucigalpa between Cape Camarón and the San Juan River, a section of the Atlantic known as the Mosquito Coast.[38] In exchange for his services, López received an assurance that he would be appointed governor and *capitán general* (fleet commander) of the province.

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[35] Squier 1985, 1.
[36] Fowler 1985.
[37] Squier 1985, 20, 23; León Cázares 1983, 73, 75.
[38] Fernández de Navarrete 1968, 331-2.

Port of El Realejo

In May 1577, García de Palacio arrived in the port of El Realejo on the Pacific coast of Nicaragua to oversee the construction of two Manila galleons.[39] El Realejo was an entrepôt for trade with Peru and had an established shipyard assembling vessels for local and trans-Pacific routes. In 1560, the town was reported as having a population of 30 *vecinos* (property-owning residents), which included a few Spaniards, but primarily consisted of Genoese attracted by the thriving coastal trade.[40] The Genoese were renowned shipbuilders, and it can be safely assumed that they also played an active role in the shipyards. Its location afforded relatively easy access to lumber (particularly excellent pine and cedar), pitch, and resin, and García de Palacio ordered the planting of cotton for canvas and the harvesting of *agave* (maguey) to produce fiber for rigging. Bartolomé de Las Casas reported that the use of native laborers in transporting lumber for shipbuilding was a major cause of death and misery in Nicaragua, and much of the local indigenous population soon fled to escape the exploitative conditions in the shipyards.[41] Africans were imported to fill the labor gap: in the early 17th century, it was reported that the shipbuilders in El Realejo included enslaved and free Africans and mulattoes.[42]

In a letter to Philip II dated 8 March 1578, García de Palacio offered to conquer the Philippines at personal expense in exchange for the governorship of the islands and a monopoly over the Pacific trade route, a proposal that suggests he had considerable

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[39] Carta de Diego García de Palacios, oidor de la Audiencia de Guatemala, 2 June 1578, AGI, Guatemala, 10, R. 5, N. 49 (http://www.aer.es [17 December 2006]).
[40] Salvatierra 1939, 302.
[41] Radell and Parsons 1971, 302.
[42] Radell and Parsons 1971, 303.

financial resources at his disposal.[43] Spain had taken control of the Philippines seven years earlier, and the colony was administered by the government of New Spain until 1584. Although it took some time, García de Palacio's ambitions regarding the trans-Pacific trade would eventually be fulfilled, as discussed below. García de Palacio also petitioned for the trade route across the isthmus of Central America to be moved from Panama to Honduras, where it would run from Puerto Caballos (now Puerto Cortés) to the Gulf of Fonseca.

García de Palacio was nominated by the Council of the Indies to the position of *alcalde del crimen* (criminal court judge) in Mexico City in April 1578.[44] He did not assume the post until almost three years later, instead receiving permission from viceroy Martín Enríquez de Almanza to continue his work in El Realejo.

In April 1579, García de Palacio wrote to the king from El Realejo describing attacks that had been made along the coast of Peru by 80 men led by the English adventurer Francis Drake.[45] Drake had managed to sail through the Strait of Magellan in the *Golden Hind* and had captured a pilot who knew the route to China, causing considerable anxiety to the colonial administration. García de Palacio was appointed by the viceroy to act as *capitán general* (fleet commander) of an expedition to confront Drake. However, despite his ambitious pursuit of such appointments, García de Palacio wavered in executing his command. Diego García de Valverde, the president of the Audiencia de Guatemala, described his inaction thus "…once *licenciado* Palacio had

[43] Carta al Rey del licenciado Palacio sobre… las Islas del Poniente, transcribed in Arróniz 1994, 151-4.
[44] Consulta del Consejo de Indias propone personas para vacantes de algunas Audiencias, 11 April 1578, AGI, Indiferente, 739, N. 63 (http://www.aer.es [17 December 2006]).
[45] Carta de Diego García de Palacio al Rey sobre la presencia de Drake en Centroamérica, 30 April 1579, AGI, Patronato, L. 266, R. 18, transcribed in Arróniz 1994, 155-9.

received the orders regarding what needed to be done… he became fearful of the difficulty and the danger, and therefore he wrote me some letters giving me frivolous excuses and others that were false and untrue….”[46] Frustrated by the lack of action, Valverde ordered García de Palacio to bring the fleet to Iztapa. In response, García de Palacio sent a letter stating that he had fallen seriously ill with a paralyzed arm and leg and was unable to lead the expedition.[47] Valverde later reported to the king that witnesses had informed him

> …that *licenciado* Palacios had not suffered any illness whatsoever… to some it had appeared that he was ill… but his recovery occurred the second day… I tell Your Majesty this because *licenciado* Palacio has written a military book which they say he has sent to Your Majesty and he teaches the arts of warfare at sea and on land… to discuss something and to do it are not the same thing, and it seems to me that I have an obligation to advise you of this….[48]

García de Palacio was not discomfited by his failure: Arróniz describes how the half-hearted naval expedition nevertheless provided an ample opportunity for a meticulously executed pillaging of the royal coffers by García de Palacio and his cronies.[49]

The galleons begun in 1577 were originally scheduled to be finished in December 1579. Christened *Santa Ana* and *San Martín*, they were not completed until 1582, long after García de Palacio had left for Mexico City.[50] Final construction expenses were considerably higher than originally estimated: the ships cost 46,000 pesos

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[46] León Cázares 1983, 15.
[47] Rubio Sánchez 1977, 33-4.
[48] Rubio Sánchez 1977, 34.
[49] Arróniz 1994, 82-8.
[50] Rodríguez-Sala 1994, 190.

each, at a time when similar ships could be built for 6,000 pesos in Manila.[51] While expenses may have been legitimately higher in Nicaragua, the excessive expenditures did not escape official scrutiny and were doubtless a contributing factor to subsequent charges of corruption brought against García de Palacio.

Audiencia de México

García de Palacio finally appeared in Mexico City to present the *cédula* appointing him to his new post on 22 December 1580.[52] In January 1581, he received a doctorate of canon law conferred by the Real y Pontificia Universidad de México, now the Universidad Nacional Autónoma de México.[53] The conferral of this degree did not require that he study in Mexico City, but rather recognized work previously undertaken in Spain.[54] He was appointed rector of the university for a term of one year beginning 10 November 1581, although he only served until 31 July 1582.[55]

In early 1583, García de Palacio published his first book, the *Diálogos militares*. Apparently a draft had been completed before March 1578, when he wrote to the king soliciting the right to conquer the Philippines: "…in order to emend the deficiency that is commonly presumed to exist among the *letrados* regarding military affairs… I have

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[51] Arróniz 1994, 77.
[52] The copy of the *cédula real* confirming his appointment that he presented to the Audiencia de México is preserved in the AGN (Título de alcalde del crimen de la Audiencia de México para el licenciado Palacio, 13 May 1578, AGN, Duplicados de reales cédulas, Vol. 2, Exp. 173, ff. 96-97, transcribed in Arróniz 1994, 149-50).
[53] Título de doctor en la Facultad de Cánones de la Universidad de México al licenciado Palacio, 24 January 1581, AGN, Universidad, Vol. 5, ff. 123v-124v, transcribed in Arróniz 1994, 161.
[54] Rodríguez-Sala 1994, 184.
[55] Nombramiento de rector de la real Universidad de México al doctor Diego García de Palacio, 10 November 1581, AGN, Universidad, Vol. 6, ff. 5-5v, transcribed in Arróniz 1994, 163; Rodríguez-Sala 1994, 184.

composed some military dialogues…."[56] Notably, the publication of the book in 1583 coincided with Philip II's initiation of a program to train members of the nobility in practical military strategy in order to enhance their effectiveness on the battlefield.[57] This was part of a major shift in the Crown's approach to education, away from a focus on humanist philosophy towards a practical curriculum that emphasized technical knowledge of architecture, artillery, combat, cosmography, and navigation.

The *Diálogos militares* comprise four books presenting a discourse between a *vizcaíno* (Biscayan) and a *montañés* (native of Santander). The *vizcaíno* is considering emigrating to the Indies, and seeks advice from the *montañés*, who has just returned thence. Boasting of the military experience he acquired in the Italian Wars, the *vizcaíno* expresses doubt about the abilities of captains and soldiers in the New World, given the absence of adequate training opportunities. Somewhat affronted, the *montañés* assures him that the captains and soldiers in New Spain are men of intelligence, experience, and courage, who all received proper training in Italy prior to learning the specific tactics used in the Americas. The *montañés* invites the *vizcaíno* to question him thoroughly in order to verify the soundness of his knowledge, and the resulting answers serve as a course in the military arts. The dialogue clearly reflects military tactics developed in Italy, and makes little reference to the conditions in the New World. For example, frequent references are made to the Turks as a prototypical enemy, but there is no discussion of the Spanish campaigns against the native populations of the Americas.[58]

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[56] Carta al Rey del licenciado Palacio sobre… las Islas del Poniente, transcribed in Arróniz 1994, 153-4.
[57] Kagan 1974, 39.
[58] Espino López 2000, 311.

Because there is no reason to believe that García de Palacio ever personally served in the Mediterranean, it can be assumed that the book reflects knowledge garnered from sources other than the author's own practical experience.

Eugenio de Salazar Alarcón, a noted poet and a fellow *oidor* in Mexico City, provided an extended poetic prologue to the work. Based on the distinctive styles of different sections, Arróniz has speculated that Salazar Alarcón may have been the uncredited author of the first and fourth books, which are written in Italian verse forms typical of his other work, while the more straightforward technical discussions of the second and third books may have been composed by García de Palacio.[59]

The First Book begins by examining the circumstances under which war is justified and the moral obligations of the soldier. The qualities and responsibilities of good officers and solders are enumerated, and the section concludes with a list of the arms and exercises in which soldiers must be trained. The Second Book explains the preparations to be made prior to battle, how to maintain troop morale, how to proceed in cases of victory or defeat, and how to pacify the conquered. The Third Book deals with practical aspects of artillery, beginning with recipes for gunpowder. The appropriate weights, lengths, sizes of shot, and powder charge are provided for various firearms in use at the time, including arquebuses, falcons, sakers, and lombards. Of particular interest is his attempt to devise a rudimentary form of multiple-fire artillery by loading an arquebus with multiple balls separated with layers of powder, which he proposes would fire sequentially when lit through the muzzle. Finally, the Fourth Book outlines

[59] Arróniz 1994, 46-8.

the proper formation of squadrons for marching and battle, and specifies rules for fighting under different circumstances.

A *cédula* dated 7 February 1583 appointed García de Palacio to undertake a *visita* of Yucatán, Cozumel, and Tabasco at the request of Francisco Palomino, *protector de los indios* (protector of the Indians).[60] Even though it was not his turn to fill the position, he received the appointment as *juez visitador* (royal inspector) due to the great personal satisfaction he took from such work and the high esteem with which he was regarded. The *visita* began on 9 July 1583,[61] and García de Palacio produced detailed tax censuses of Mayan populations throughout the region.[62] His census of the town of Pencuyut was sufficiently detailed to allow ethnographers to reconstruct the early post-contact residential patterns of the Maya.[63] Years later, his excursion was remembered in a Chontal Maya account from Acalan written in 1612: "Dr. Palacios came to visit the land, and we, the people of Tixchel, gave him canoes and paddles. We opened the roads so that the minister might go to visit these *cahob* [villages]…"[64] The *visita* was cut short in December 1583, when García de Palacio was forced to return prematurely to Mexico City due to the deaths of viceroy Suárez de Mendoza, Conde de la Coruña, and of one of

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[60] García Bernal 1985, 3. The *cédula* is cited by Diego López de Cogolludo, who wrote a history of the Yucatán in 1688 (López de Cogolludo 1971, 62-3).
[61] García Bernal 1985, 3.
[62] Visita y cuenta de los pueblos, 1583, AGN, Ramo Civil, Vol. 661, Exp. 2, transcribed in O'Gorman 1940.
[63] Cuenta y visita del pueblo de Pencuyut, 1584, AGN, Tierras, Vol. 28, Exp. 20, translated in Roys et al. 1959.
[64] Title of Acalan-Tixchel, 1612, translated in Restall 1998, 74.

the *oidores*. Upon his return, he prepared a set of *ordenanzas* to provide guidance regarding the resolution of issues in the pueblos that he had not been able to visit.[65]

García de Palacio's actions during the *visita* reflect the tensions inherent in Spanish colonial policies, which embodied the competing objectives of protecting the personal and property rights of the newly-Christianized indigenous population, while at the same time attempting to fulfill the demands of colonists to use native labor to ensure the profitability of their enterprises. A native petition of 1605 protesting colonial abuses of Indian labor recalled that "Doctor Palacio" had abolished forced labor rotations imposed on Maya communities in Acalan "because of the misery we experience here."[66] At the same time, there is evidence that García de Palacio took advantage of his position to illegally acquire Indian lands in the area of Coatzacoalcos and to exploit indigenous labor in the construction of houses and corrals and in the transportation of cattle he had obtained in Chiapas and Tabasco.[67]

Such transgressions of official policy brought García de Palacio to the attention of archbishop Pedro Moya de Contreras soon after he was appointed to undertake a *visita* investigating bureaucratic corruption in New Spain in late 1583.[68] Moya de Contreras was disturbed by the conditions in the Audiencia de México, and was particularly concerned about the involvement of the *oidores* in land speculation and conflicts of interest involving trials in which they owed the defendants money.[69]

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[65] García Bernal 1985, 4. The *ordenanzas* are dated 8 January 1584.
[66] Petition by the *cah* of Tahnab, 1605, translated in Restall 1998, 174.
[67] O'Gorman 1946.
[68] Visita de la Audiencia de México y demás tribunals por Pedro de Moya y Contreras, arzobispo de México, May 1584, AGI, Escribanía 271a (http://www.aer.es [17 December 2006]). See also Poole 1981.
[69] Poole 1981, 164.

To exacerbate the situation, García de Palacio and his brother were involved in a scheme with the new viceroy Álvaro Manrique de Zúñiga, marqués de Villamanrique. Villamanrique had arranged to auction off the two galleons built under the supervision of García de Palacio, under the rationale that it would be more economical for private merchants to assume the costs of commerce with the Philippines (and presumably much of the profits). Lope de Palacio purchased the *San Martín* from the Crown for about 16,000 pesos, a fraction of its original construction cost of 46,000 pesos.[70] The García de Palacio brothers thus effectively gained monopolistic control of the Manila-Acapulco trade route, which had been largely established with monies from the royal coffers, while the viceroy enjoyed a financial interest in the venture. As discussed below, the *Santa Ana* was captured off Baja California in late 1587 as it returned from the Philippines, while the *San Martín* sank off Macao in 1591.[71]

On 18 January 1586, Moya de Contreras brought charges against several *oidores*, who were given 40 days to prepare a defense.[72] As a result of the proceedings, three *oidores* were suspended, including García de Palacio. This ostensible punishment seems to have had little practical effect on García de Palacio due to his close relationship with the new viceroy. Villamanrique resented the investigation undertaken by the archbishop and disputed the results of the *visita*. As a result, García de Palacio continued to serve the *audiencia* in an official capacity for several more years.

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[70] Arróniz 1994, 127.
[71] Arróniz 1994, 132.
[72] Poole 1981, 165.

The following year, García de Palacio wrote to the king informing him that he had completed a volume on nautical instruction specially written for use in the latitude of Mexico.[73] The publication seems to have had an immediate effect in reinforcing García de Palacio's reputation. A commission of 10 September 1587 records that García de Palacio was appointed by Villamanrique to serve once again as *capitán general* of a fleet dispatched to pursue English raiders in the Pacific, following a series of raids in Peru by Thomas Cavendish.[74] The viceroy justified his choice of García de Palacio for the role due to his qualifications as one "very well-versed and skilled in matters of warfare at sea and on land."[75]

However, García de Palacio once again failed to successfully execute his orders, eagerly accepting premature reports that Cavendish had left the coast. In fact, Cavendish was awaiting the return of the Manila galleons off Baja California. On 4 November 1587, the *Santa Ana* finally appeared, unarmed due to the perceived lack of naval threats in the Pacific Ocean, sometimes called the "Spanish Lake." After a chase of three or four hours, Cavendish captured the ship, which was carrying 122,000 pesos of gold in addition to silks and other merchandise.[76] After removing all the treasure they could carry, the English burned the *Santa Ana* and left the passengers on shore. Cavendish then sailed west to the Philippines guided by captured Spanish pilots. The survivors

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[73] Fernández de Navarrete 1968, 333. Detailed discussions of the content and significance of the *Instrucción náutica* are provided in chapters III to IX.
[74] Instrucción del virrey de Nueva España al doctor don Diego García de Palacio, sobre el seguimiento que debía hacer al corsario inglés, 1587, AGI, Patronato 265, R.49 (http://www.aer.es [17 December 2006]). Note that the *corsario* who appeared in the Pacific in 1587 has sometimes been erroneously identified as Drake (*el Draque*).
[75] Carta del Marqués de Villamanrique al Rey sobre Thomas Cavendish, 28 October 1587, AGI, México, 21, transcribed in Arróniz 1994, 179.
[76] Hakluyt 1972, 287.

were able to use the burnt hull to reach safety and notify the viceroy.[77] Villamanrique ordered García de Palacio to set sail in pursuit, which he eventually did, but by that time Cavendish was already on his way across the Pacific.

Final Years

The reprieve from legal justice that García de Palacio had brazenly enjoyed since his initial conviction by Moya de Contreras in 1586 did not last indefinitely. On 22 February 1589, the Consejo de Indias convicted García de Palacio on 72 separate charges of corruption and abuse of office.[78] As a result, he was suspended for nine years from his post as *oidor* and ordered to pay fines and restitution. The charges included nepotism, acceptance of bribes, use of threats, exploiting his office for financial gain, displacing native communities, and forcing Indians to work without pay. The fortunes of family members were interconnected, and García de Palacio had evidently used his position to improve not only his own wealth and status, but also to enhance those of his relatives. The charges cited Diego's brother Lope and his uncle Felipe as the beneficiaries of questionable acquisitions of land, slaves, cattle, and water rights for a sugar mill.[79]

García de Palacio's actions were far from unusual: land speculation was an established practice among *letrados*, involving the consolidation of titles to illegally acquired properties into ranches under the names of close relatives.[80] The network of

[77] Arróniz 1994, 121.
[78] O'Gorman 1946, 6-7.
[79] O'Gorman 1946, 25-8.
[80] Poole 1981, 156.

social relationships between *letrados*, as well as the relative independence of colonial authorities, allowed local bureaucrats to pursue financial and social advancement through judicial favoritism, influence peddling, and bribery.[81] To some extent, they believed their actions were justified: officials in the Indies complained that their salaries, although higher than those of their peninsular counterparts, were insufficient to compensate for the higher cost of living in the New World.[82] Indeed, in the first book of the *Diálogos militares,* García de Palacio groused openly that "things in the Indies… are so meager that if one does not hold an office in the service of His Majesty or trade in merchandise, one can no longer afford the comforts that seem reasonable for a respectable person."[83]

García de Palacio did not live long enough to reclaim his post. He died sometime before 15 November 1595, when his funeral oration was read in the church of the Santísima Trinidad in Mexico City.[84] The following year, Isabel de Hoyo and her son petitioned Philip II for financial relief, citing ruin caused by the penalties imposed by the *visita*.[85] The family seems to have retained control of substantial assets despite their asserted hardships: in 1599, his widow sought permission to remove four or five thousand head of cattle from the family's estate in the region of Coatzacoalcos.[86] The request suggests that the land was being seized, as in addition to being fined and

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[81] Poole 1981, 150.
[82] Poole 1981, 156.
[83] García de Palacio 1944b, 7v.
[84] Bankston 1986, v.
[85] Consulta del Consejo de Indias sobre hacer alguna merced a la viuda e hijo del doctor Palacio, 1596, AGI, Mexico 1, N.40a (http://www.aer.es [17 December 2006]).
[86] Doña Isabel de Hoyo, viuda del Dr. Palacio, solicita permiso para sacar cuatro o cinco mil cabezas de ganado de su hacienda que esta en terminus de Coatzacoalcos, jurisdicción del Espíritu Santo, 1599, AGN, Ramo Civil, Vol. 2227, Exp. 1, cited by Arnold n.d.

suspended, those convicted by Moya de Contreras were required to give up all the property that they and their family members had acquired illegally.[87]

The rich archival records concerning Diego García de Palacio's career and personal life provide a window into the social and political circumstances of his time. The men who formed the bureaucracy of the Spanish colonies of the 16th century have been described as the spiritual descendants of the conquistadors: they were ambitious men with aggressive personalities who did not hesitate to manipulate the law in order to seize opportunities for personal gain and to secure positions of respect in an emerging society.[88] García de Palacio went to the New World in pursuit of wealth, power, and adventure, all of which he found there in abundance. He actively used his relationships with the most powerful men of New Spain to solicit favors and concessions, and he had no qualms when presented with illicit opportunities to appropriate land, cattle, and other assets. At the same time, like many other *letrados*, he seems to have been genuinely interested in establishing an efficient colonial administration and often undertook his bureaucratic responsibilities with great diligence. His writings demonstrate careful observation and deep comprehension not only of military and nautical affairs, but also of native cultures. While García de Palacio's ingenuity and intellect are indisputable, his failures as a naval commander suggest that he was unable to execute practically the rules of navigation and warfare that he wrote about with such apparent acumen.

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[87] Poole 1981, 168.
[88] Poole 1981, 150.

CHAPTER III

OVERVIEW OF THE *INSTRUCCIÓN NÁUTICA*

Both of García de Palacio's books, the *Diálogos militares* and the *Instrucción náutica*, were printed in Mexico City by Pedro Ocharte, a native of Normandy who relocated to New Spain in 1548.[1] Ocharte married the daughter of Juan Pablos, an Italian printer who had established the first commercial press in the New World, and he operated his father-in-law's business from 1563 to 1592. While most of the early books published in New Spain were religious texts or studies of native languages, a more diverse range of books was published in Mexico City by printers such as Ocharte, including texts on technical subjects such as medicine, law, and music.[2] An intriguing character in his own right, Ocharte was an active promoter of free scientific inquiry, and his religious hereticism brought him under the scrutiny of the Inquisition.[3] After his release from several years of imprisonment and torture, he resumed his publishing career without further recorded incident.

The *Instrucción náutica* was published as a small quarto: each of the printed sheets was folded twice to form four leaves or eight pages, producing a total of 312 pages. Only the recto, or front right-hand side, of each leaf is numbered.[4] The book is set in roman typeface, a style preferred by Renaissance humanists for its efficient spacing. It was typical for 16th-century Spanish books to include an ornate display at

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[1] Rodríguez-Buckingham 1984, 67.
[2] Rodríguez-Buckingham 1984.
[3] Arróniz 1994, 17-20.
[4] In this study, verso pages are indicated with a letter *v*.

the beginning, with little ornament or rubrication in the text.[5] Indeed, aside from the elaborate *escudo* (coat of arms) printed on the title page (fig. 3.1), the *Instrucción náutica* is relatively plain. Some of the chapters begin with decorative initials, but even these are extremely simple. While characteristically lacking in embellishment, the *Instrucción náutica* is illustrated with 24 remarkable woodcuts that serve not as decoration but rather as a practical means of conveying complex technical information discussed in the text. Compared to later methods of engraving, the technique of wood block printing produces relatively crude images. Some of the illustrations in the *Instrucción náutica* are slightly distorted, possibly as a result of wear on the softwood blocks as they were reused.

The contents are divided into standard sections that are familiar to a modern reader: a title page; a license for publication; a dedication; a table of contents; an introduction; four "books" or sections each comprising many shorter chapters; and a glossary.

The title page bears the *escudo* of viceroy Álvaro Manrique de Zúñiga, marqués de Villamanrique (fig. 3.1). The left portion of the shield depicts the emblem of the Zúñiga, a noble family from Navarre, consisting of a silver field with a sable band and a border formed from a chain of eight gold links. The emblem of the Manrique family, on the right side, features four cauldrons, each with six serpents emerging from them, alternating with a checkered lion and castle motif representing the unified kingdoms of León and Castile. Notably, the title page refers to García de Palacio as an *oidor* of

[5] Bliss 1964, 89.

INSTRVCION.
NAVTHICA, PARA EL BVEN
Vſo, y regimiento de las Naos, ſu traça, y
y gouierno conforme à la altura de Mexico.
Cõpueſta por el Doctor Diego garcia de
Palacio, del Cõſejo de ſu Mageſtad,
y ſu Oydor enla Real audiẽ-
cia de la dicha Ciudad.
Dirigido, al Excellẽtiſsimo Señor Don Aluaro Manrrique, de
çuñiga, Marques de Villa manrrique, Virrey, Gouer-
nador, y Capitan general deſtos Reynos.

Con licencia. En Mexico, En caſa de Pedro
Ocharte. Año de 1587.

Fig. 3.1. Title page of the *Instrucción náutica*.
(After García de Palacio 1944a)

Mexico City, despite the attempt by Pedro Moya de Contreras to suspend him from this position in 1586 (see Chapter II).

The license to publish the *Instrucción náutica* was approved on 7 February 1587 by viceroy Villamanrique, to whom García de Palacio addressed the two-page dedication. As part of the approval process, the manuscript was reviewed by Francisco de Noboa, *capitán general*, and Diego de la Madriz, *piloto mayor*, of the Nueva España fleet harbored in San Juan de Ulúa, who both considered its printing to be beneficial to seafarers and shipbuilders. The license served as a copyright, stating that García de Palacio had the exclusive right to print the text for the next 20 years, with a penalty of 500 gold pesos for any violations.

Using a popular literary convention of the Renaissance, the text of the four books forms a lengthy conversation between a *vizcaíno* (Biscayan) and a *montañés* (a native of Santander), comprising a series of questions and responses. Renaissance humanists frequently imitated the dialogue form used by classical writers such as Plato,[6] and the style was in fashion at the University of Salamanca in the 16th century.[7] It is important to remember that the act of reading in the Renaissance was different than it is today. Books were often read aloud to an audience, and a dialogue provided a means of presenting complex issues in a more engaging manner, even if the discussion proved to be didactic and one-sided. In the case of the *Instrucción náutica,* the *vizcaíno* serves as a foil, asking questions that set up the explanations made by the expert *montañés*, representing García de Palacio himself. By requesting examples, clarifications, and

[6] Kristeller 1983, 6.
[7] Rodríguez-Sala 1994, 194.

illustrations the *vizcaíno* ensures the reader's comprehension. He then heartily agrees with the merit of each explanation, emphasizing the authority of the *montañés* to the reader.

The first three books of the *Instrucción náutica* comprise a tutorial on many of the common techniques of navigation and nautical astronomy in use at the time. The First Book (pages 1 to 49) consists of nine chapters. It is devoted to nautical astronomy and describes the divisions of the celestial sphere; the use of navigational instruments, including the astrolabe, cross-staff, quadrant, and compass; and instructions for calculating the time at night based on the positions of the stars. Tables of solar declination are published on pages 15v to 23. The Second Book occupies pages 49v to 65 and comprises nine chapters that include a discussion of nautical astronomy, including methods of predicting the movement of the moon and the tides. The three chapters of the Third Book span pages 65v to 87v, and contain information on navigation, including reading weather signs, the use of sea charts, and a lunar almanac for the years 1586 to 1604. The content of these sections is discussed further in Chapter IV. The Fourth Book of the *Instrucción náutica* is the most original and has attracted the most scholarly attention. It includes discussions of the proper proportions of hulls; masting and rigging; the responsibilities of the ship's personnel; and naval tactics. It also includes a number of woodcuts depicting the overall dimensions of two ships, one of 400 *toneladas,* and the other of 150 *toneladas*, and the forms of sails. The contents of the Fourth Book are analyzed in Chapters V to IX of this thesis.

The final section of the *Instrucción náutica*, running from pages 129 to 156v, consists of a glossary titled "Vocabulary of the terms that seamen use, in all that pertains to their profession, in alphabetical order." It appears to be the earliest published nautical glossary, defining more than 500 terms related to navigation, ship construction, rigging, personnel, and equipment. The inclusion of this lexicon reinforces the inference that the *Instrucción náutica* was intended for a non-specialist audience. García de Palacio's word list seems to have been a primary source used by the author of the anonymous *Vocabulario marítimo* published in Seville in 1722, as well as Timoteo O'Scanlan's *Diccionario marítimo español*, published in 1831.[8]

The *Instrucción náutica* is a very rare book, with about a dozen known surviving copies. Original copies are held in the collections of the Library of Congress, the Smithsonian Institution, the New York Public Library, the John Carter Brown Library, Yale University, the Huntington Library, the British Museum, the University of Salamanca, the Museo Naval, and the Biblioteca Nacional in Madrid. A facsimile edition, with a prologue by noted naval historian Julio Guillén Tato, was published in 1944 by the Instituto de Cultura Hispánica in Madrid.[9] A useful English translation was published in 1986 by J. Bankston.[10] The present study made use of both the 1944 facsimile edition and Bankston's translation, with priority given to the original Spanish text.

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[8] Anonymous 1992; O'Scanlan 1974.
[9] García de Palacio 1944a.
[10] Bankston 1986.

CHAPTER IV

NAVIGATION AND NAUTICAL ASTRONOMY

The first three books of the *Instrucción náutica*, together comprising roughly half of the text, discuss common navigational techniques of the 16th century. Up to the end of the Middle Ages, navigation had been based largely on practical knowledge of winds, weather, currents, and compass bearings for specific established routes.[1] It was not necessary to be literate, but a good pilot required an excellent memory for coastlines and sea bottoms, and skill with simple instruments like the compass and sounding lead. As ships began to travel further into the Atlantic in the late 15th and early 16th centuries, celestial navigation allowed sailors to check their positions by measuring the altitude of the sun or of Polaris, the North Star. Navigation now required more than practical experience, although experience was still crucial. By the 16th century, a skilled navigator was also expected to be trained in theoretical principles of astronomy and cosmography. To meet the demand for these new skills, in 1503 the Casa de la Contratación established a school for training, examining, and licensing pilots for the Carrera de Indias.[2] It was considered a minimum requirement for pilots to be literate and to possess basic mathematical skills, although in practice not all pilots met these standards.

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[1] Parry 1981, 87.
[2] Smith 1993, 137.

According to García de Palacio, a late 16th-century pilot's equipment properly included the following items:[3]

- *carta de marear* (sea chart)
- *compases* (dividers)
- *astrolabio que pese doze libras, y este esperimentado* (an astrolabe weighing 12 pounds, certified by the Casa de Contratación)
- *ballestilla* (cross-staff)
- *quadrante de madera* (wooden quadrant)
- *dos reloxes de los de lisbona* (two sundials of the type from Lisbon)[4]
- *dos pares de agujas de marear* (two pairs of sailing compasses)
- *ampolletas de Venecia* (sand glasses from Venice)
- *candil de cobre* (copper lamp, presumably for the binnacle)
- *algodon para mechas* (cotton for wicks)
- *cien braças de sonda alquitranada* (a hundred yards of tarred sounding line)
- *seys libras de plomada* (a six-pound sounding lead).

Like many of his contemporaries, García de Palacio was gravely concerned about the lack of suitable pilots possessing both practical experience and technical training in astronomy, mathematics, and cosmography, and he hoped that the *Instrucción náutica* might help in correcting the deficiency.[5] Due to the shortage of skilled practitioners, pilots were sometimes given positions on ships before they were fully trained and

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[3] García de Palacio 1944a, 113v.
[4] This is likely a reference to a type of sundial originally made in Nuremberg that incorporated a small magnetic compass, allowing the user to align the instrument with the local meridian (see Taylor 1971, 173; López Piñero 1986, 121).
[5] García de Palacio 1944a, 112v-3.

licensed. Despite its weaknesses, the English, French and Dutch emulated the navigational training system developed in Portugal and Spain, and Iberian pilots and navigational treatises were held in high esteem.[6]

The Portuguese were the first to publish navigational manuals for use at sea, followed by the Spanish and later by the French and English.[7] By the 16th century, navigational treatises were relatively common in Spain due to the increasing need to ensure safe navigation as the empire expanded across the Atlantic and Pacific oceans. Only medicine exceeded navigation in the number of technical treatises written in Spanish in the 16th century.[8] It has been said that "the principal and traditional maritime countries of Europe learned their navigation from Spanish works."[9] Among the most widely read were Pedro de Medina's *Arte de navegar* (1545) and Martín Cortés's *Breve compendio de la sphera y la arte de navegar* (1551), both of which were very widely distributed throughout Europe, with 42 editions in five languages.[10] After 1581, most Iberian pilots began to use the *Compendio del arte de navegar* written by Rodrigo Zamorano, the pilot-major of the Casa de Contratación in Seville.[11] A comprehensive list of Iberian nautical treatises of the 16th and 17th centuries is provided in Appendix B.

The noted historian of navigation Eva Taylor observed that a conventional formula for navigation manuals was established by at least the 16th century.[12] Plagiarism was an established and apparently accepted practice, and the titles of many of

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[6] Phillips 1986, 132; Taylor 1949, 59.
[7] Taylor 1931, 349.
[8] Carriazo Ruiz 2003, 11.
[9] Julio Guillén Tato quoted in Waters 1971, 357.
[10] López Piñero 1986, 24.
[11] Phillips 1986, 131.
[12] Taylor 1931, 346-7.

these books openly reveal their origins as compendia. Existing sources were compiled to form new books, or simply translated in their entirety, although compilers would often add new information to their edition. Typically, the first section presented the celestial sphere, while the second section outlined rules for navigation and for establishing one's position using the altitude of celestial bodies. The final section was a portolan which combined a navigational chart with a rutter of sailing directions.

Unlike some of the other nautical treatises of the 16th century, the *Instrucción náutica* does not include sailing directions for specific locations. By way of comparison, the *Itinerario de navegación*, written in 1575 by Juan Escalante de Mendoza, includes extensive detailed information about the routes used in the Spanish West Indies.[13] Escalante de Mendoza never received permission to publish his work, possibly due to fears on the part of the Crown that foreigners might benefit from the volume. Mariners from rival nations, including men like Drake and Cavendish, actively sought to capture Iberian pilots who were familiar with the routes across the Atlantic and Pacific, and charts and rutters were among the most prized plunder seized from captured Spanish ships.[14] It is likely that García de Palacio's omission of specific geographical references from his work facilitated his ability to obtain a license for its publication.

The Celestial Sphere

Following the standard convention described by Taylor, the *Instrucción náutica* begins with a discussion of the celestial sphere, an enormous imaginary sphere centered

[13] Escalante de Mendoza 1985.
[14] Phillips 1986, 133.

around the earth and rotating on its axes, onto which the observed positions of celestial bodies are projected.[15] The information presented by García de Palacio reflects the work of Johannes Sacrobosco, whose 13th-century treatise on the celestial sphere was one of the most widely reprinted texts of the Renaissance. His *Tractado de la sphera* was a basic textbook used in early modern education, and would have been read by virtually all university students in the late 16th century.[16]

García de Palacio's explanation is accompanied by a relatively crude image of an armillary sphere (fig. 4.1). The equinoctial, or celestial equator, represents the projection of the earth's equator onto the celestial sphere. The zodiac forms a belt running along the ecliptic, or the oblique path of the sun across the sphere. It extends 6º to either side of the ecliptic line, and is divided into twelve equal sections of 30º, each associated with one of the signs of the zodiac. Although this figure shows the zodiac intersecting with the Arctic Circle, it should properly extend only as far north as the Tropic of Cancer. The colures are two circles that intersect the poles: the solstitial colure passes through the solstitial points (the intersections of the ecliptic with the tropics), while the equinoctial colure should properly intersect with the equinoctial points (the intersections of the ecliptic and the equinoctial), although this is not shown correctly due to distortion in the figure. García de Palacio also discusses the other standard features of the sphere, such as the tropics, polar circles, and poles, and explains the concepts of horizon, zenith, and meridian in relation to a hypothetical observer.

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15 García de Palacio 1944a, 9-13.
16 Taylor 1971, 154.

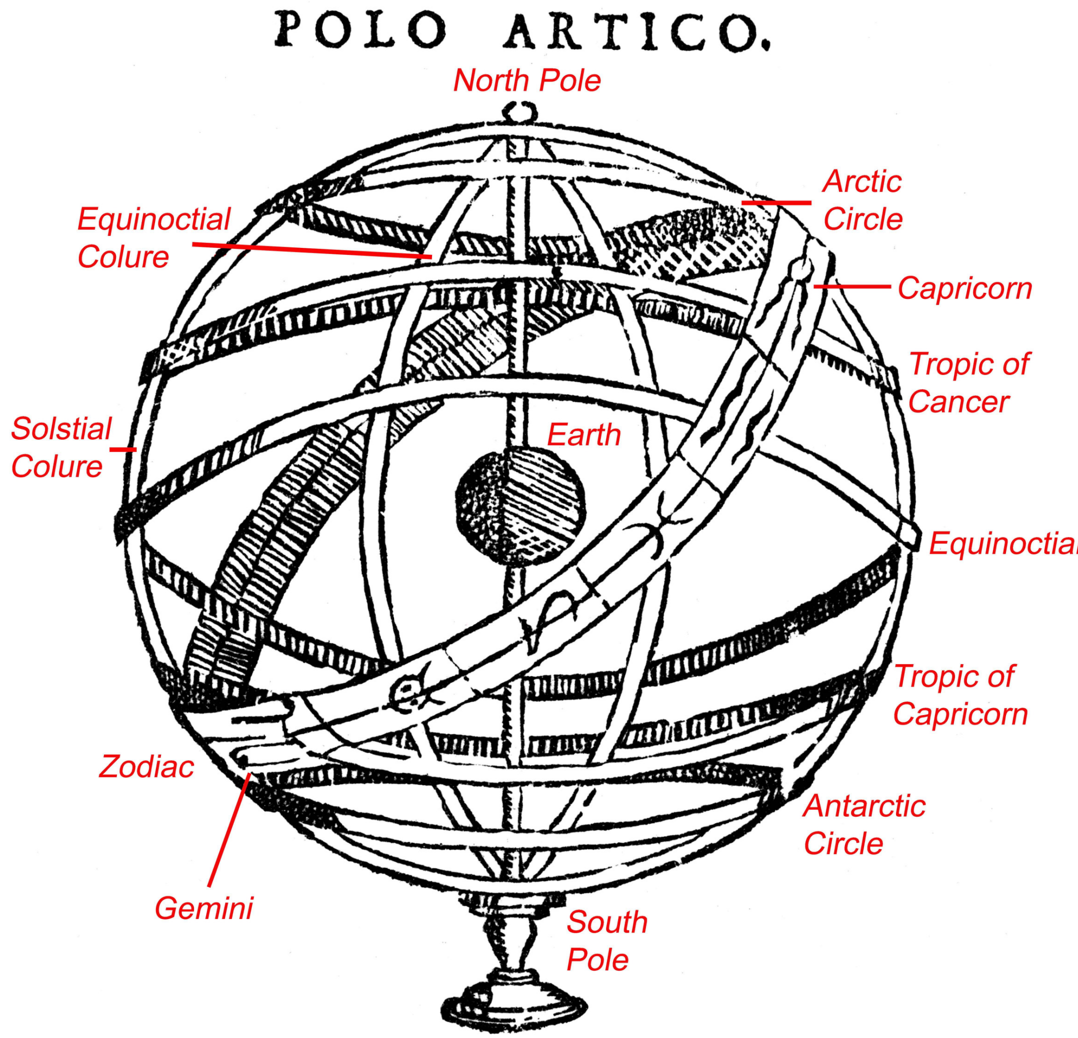

Fig. 4.1. Armillary sphere from the *Instrucción náutica*.
(After García de Palacio 1944a, 13)

Notably, the zodiac signs depicted on the ecliptic of García de Palacio's sphere are inverted. A symbol clearly representing Capricorn as a horned goat is shown in the upper right hand sector of the zodiac, intersecting the Tropic of Cancer, while the twin pillars representing Gemini, the first sign before Cancer, intersect with the Tropic of Capricorn. Based on this error, it appears that the image reproduced in the *Instrucción náutica* was copied from a figure in which the north and south poles were inverted following Classical convention. Figure 4.2 is an illustration from an edition of Sacrobosco that shows the celestial sphere oriented in this manner, with the South Pole at the top. When García de Palacio reversed the poles of his sphere, he failed to make the corresponding correction to the signs of the zodiac. This oversight reinforces the conclusion that García de Palacio borrowed not only the theoretical discussion of the celestial sphere, but also the image of the armillary sphere from another text, a common practice at the time as noted above.

Measuring Latitude

Medieval Arab astronomers were the first to discover how to calculate latitude using the meridian altitude of the sun and its declination from the equinoctial. By 1587, determining latitude at sea had become a fairly straightforward exercise, though one requiring some knowledge, skill, and specialized equipment. First, the meridian altitude of the sun or of Polaris was measured using one of the three instruments illustrated in the *Instrucción náutica*: the quadrant, the astrolabe, or the cross-staff. To obtain a valid

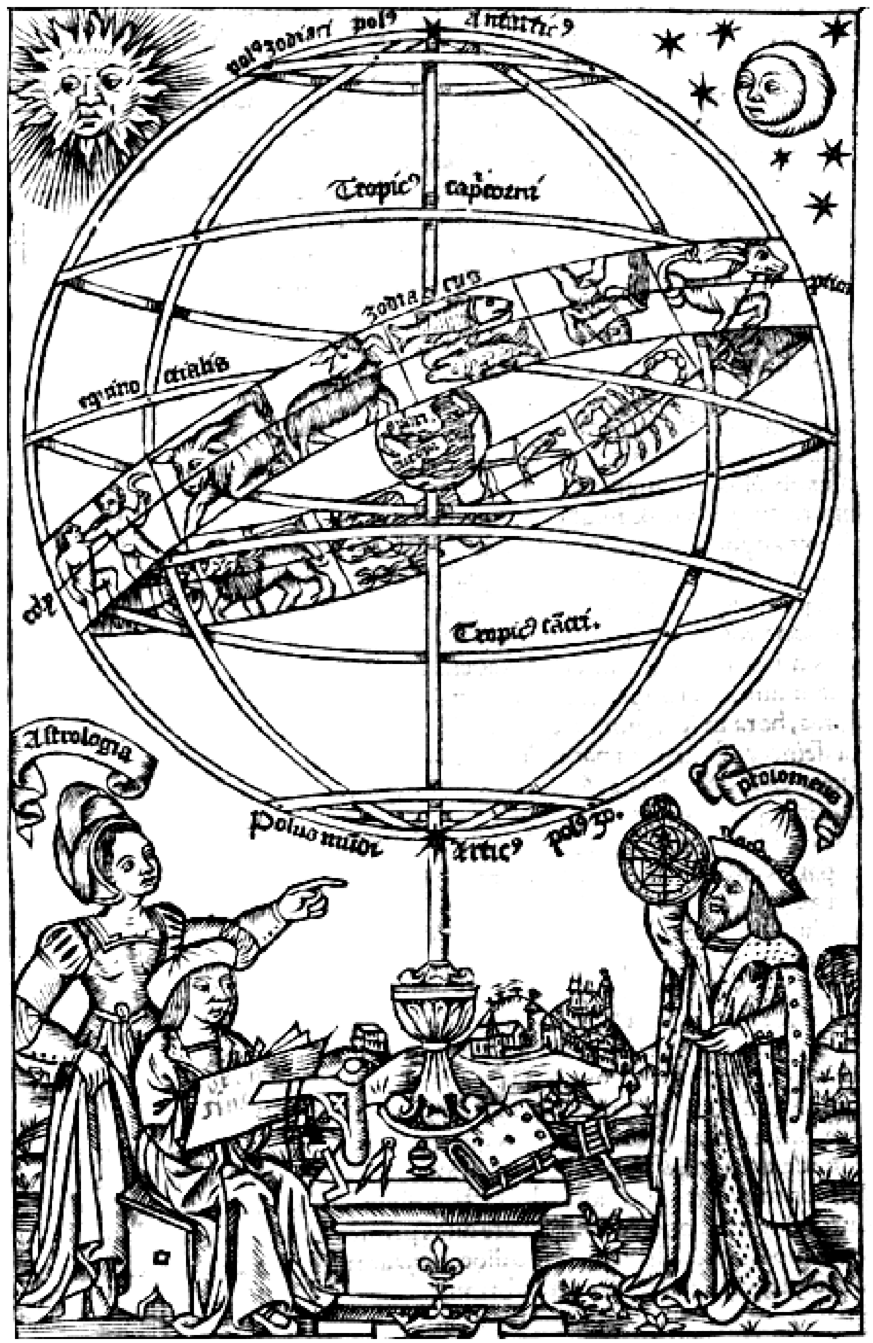

Fig. 4.2. Armillary sphere from 1538 edition of Sacrobosco.
Note inversion of north and south poles. (After Vincent and Chandler 1969, 10).

reading the measurement had to be taken at exactly noon, with the observer standing near the mainmast to minimize the effect of the ship's movement. García de Palacio advised his readers to consult a sundial to ensure that they were ready and waiting at least 15 minutes before noon.[17]

<u>Quadrant</u>

Quadrants were the simplest instruments used for measuring the altitude of a celestial object. As illustrated by García de Palacio, the device consists of a quarter-circle panel of wood or brass with markings painted or inscribed on its surface (fig. 4.3).[18] Until the 15th century, quadrants used for shipboard navigation were not marked in degrees.[19] Instead, the meridian altitude of the sun at the latitude of common destinations was inscribed directly onto the instrument. By García de Palacio's time, quadrants were normally marked in degrees, providing greater flexibility to pilots sailing less established routes. Two pinnules were mounted along one edge of the quadrant to form an alidade for sighting the sun or star, and a weighted line was suspended from the center of the 90º arc. The navigator held the quadrant so that the plane of the panel was vertical, then sighted the object through the alidade. The weighted line hung vertically, indicating the altitude of the object in degrees. Two people were often needed to acquire an accurate measurement, with one person holding the instrument in position while the other took the reading. It is easy to image the difficulty of obtaining an accurate measurement with a swinging plumb bob in windy or rough conditions at sea.

[17] García de Palacio 1944a, 24v.
[18] Parry 1981, 91.
[19] Taylor 1971, 159.

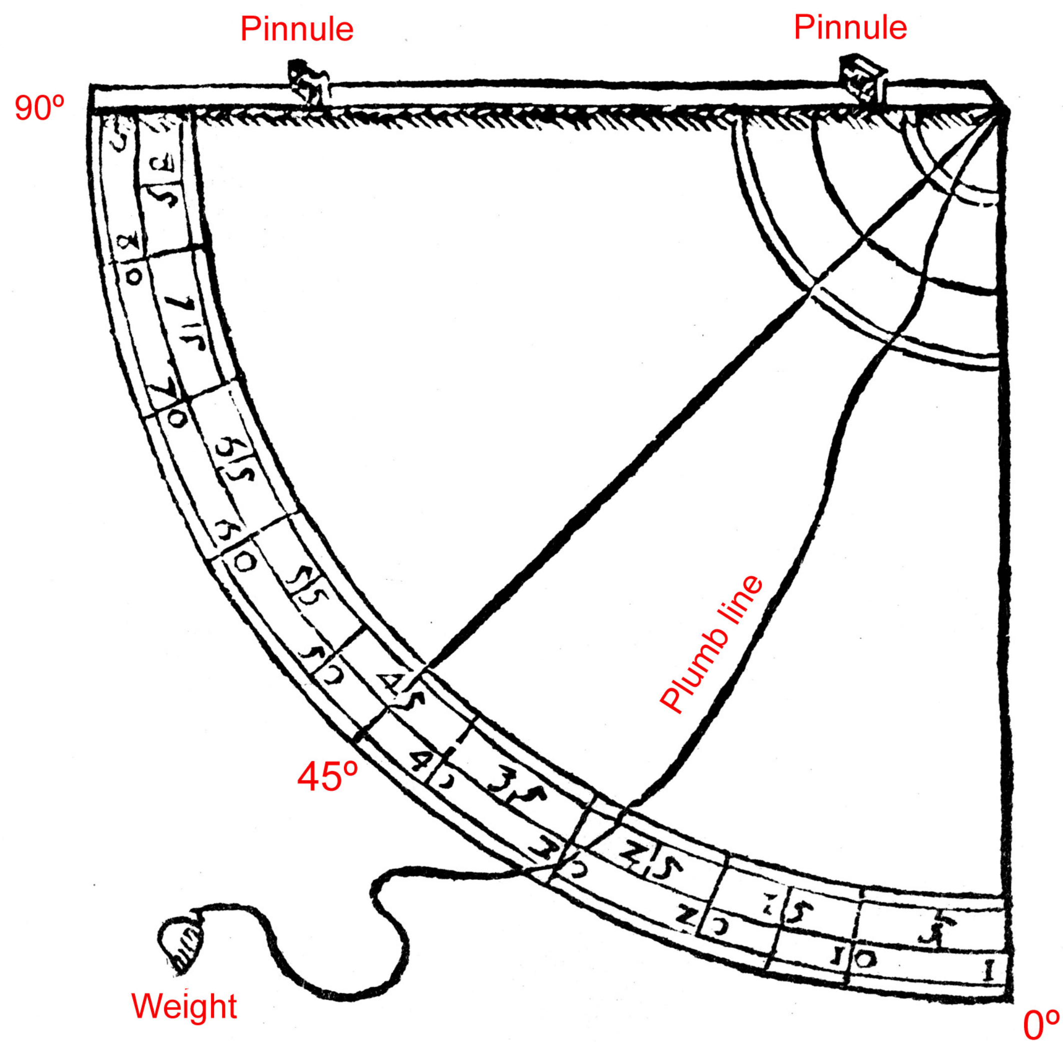

Fig. 4.3. Quadrant from the *Instrucción náutica*.
(After García de Palacio 1944a, 25)

Astrolabe

The next illustration in the *Instrucción náutica* is of a typical mariner's astrolabe of the 16th century (fig. 4.4). Like the quadrant, the astrolabe was equipped with an alidade with two pinnules. The alidade was attached to the body of the instrument with a pin, allowing it to rotate, and a scale was engraved in the outer rim of the disk. The ballast helped the instrument to hang vertically on the shifting deck of a ship, while the four cutouts in the disk reduced windage.

Among well-preserved surviving mariner's astrolabes, the closest parallels to the astrolabe illustrated by García de Palacio are the Palermo astrolabe dated to 1540 (fig. 4.5), and the Arts et Métiers I astrolabe dated to 1563.[20] Both have their scales marked in the 0º - 90º - 0º pattern illustrated by García de Palacio, thus giving a true altitude rather than a zenith reading as with some Portuguese astrolabes. These are classified by Alan Stimson as Type Ia astrolabes, indicating that they are cast wheels with base ballast, and they are most likely of Portuguese and Spanish origin, respectively. The Arts et Métiers I astrolabe bears marks that suggest it was inspected and approved for use by the pilots of the Casa de la Contratación,[21] echoing García de Palacio's advice that pilots should only carry astrolabes that had been certified.[22]

Figure 4.6 shows a 16th-century navigator taking a solar reading while holding the astrolabe by its gimbaled ring at waist level. The alidade was rotated until the sun's rays shone through the small hole in the uppermost pinnule and cast its image onto the

[20] Stimson 1988, 58-9, 100-1.
[21] Stimson 1988, 100,
[22] García de Palacio 1944a, 113v.

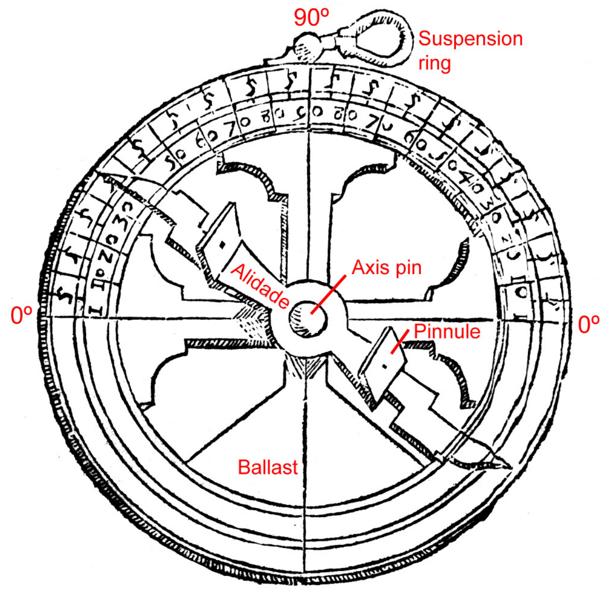

Fig. 4.4. Astrolabe from the *Instrucción náutica.* (After García de Palacio 1944a, 26)

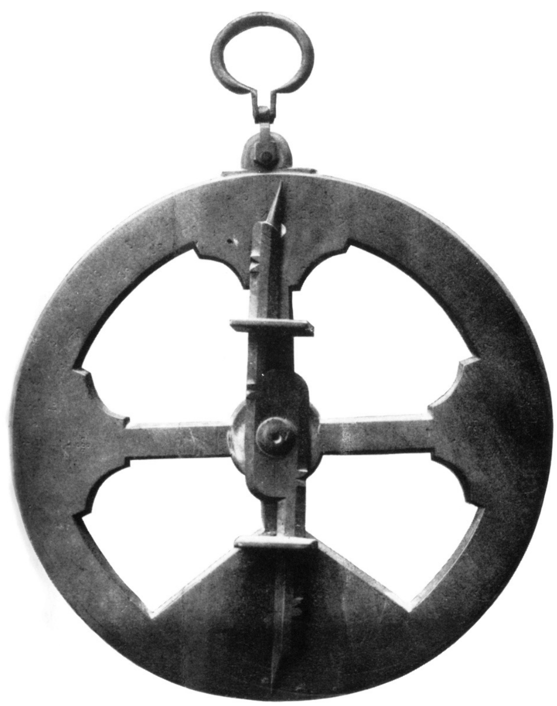

Fig. 4.5. The Palermo astrolabe. (After Stimson 1988, 59)

Fig. 4.6. Proper use of an astrolabe from Medina (1545).
(After Medina 1545)

center of the second pinnule. The altitude of the sun was then read in degrees off the scale.

Cross-staff

The *Instrucción náutica* also includes instructions for the fabrication of a cross-staff, a third instrument used to measure the altitude of a celestial object. A cross-staff consisted of a shaft marked with graduations along its length with a crosspiece called a transom or rattle that slid freely up and down the shaft. Two or three transoms were typically fabricated for each instrument, each used for reading a different range of angles. Unlike an astrolabe, a cross-staff was cheap and easy to make, and a mariner could make one for himself if provided with proper instructions.[23] Although García de Palacio does not provide an illustration of the complete instrument, he does provide a diagram showing the method of graduating the shaft using a graphic method of deriving the required algorithmic scale (fig. 4.7).

When using a cross-staff, the mariner rested the tip of the instrument just below his eye on his cheek (fig. 4.8). The horizon was positioned at the lower end of the transom, which was moved back and forth until the sun or the star was sighted at the upper edge of the transom. The position of the transom on the graduated scale indicated the altitude. The instrument required the user to look directly at the object being measured, which was taxing when taking the height of the sun, eventually leading to the invention of the back-staff in the late 16th century. According to García de Palacio, the astrolabe was typically used during the day, and the cross-staff at night, although he

[23] Parry 1981, 93.

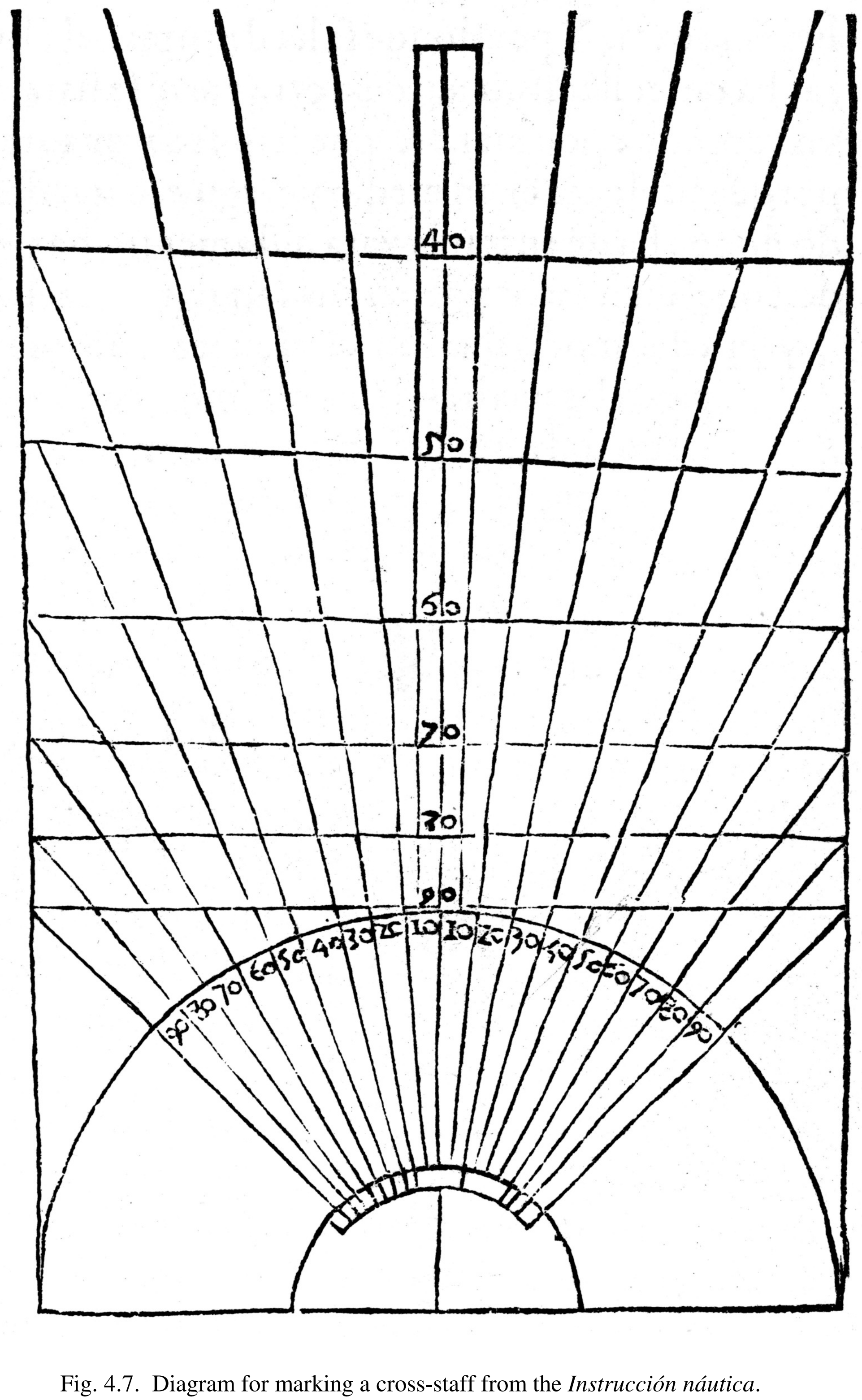

Fig. 4.7. Diagram for marking a cross-staff from the *Instrucción náutica*.
(After García de Palacio 1944a, 36v)

Fig. 4.8. Sighting Polaris with a cross-staff from Medina (1545).
(After Medina 1545)

recommended that readings be taken with both for extra certitude.[24]

Regiment of the Sun

After the altitude of the sun in degrees above the horizon was known from the quadrant, astrolabe, or cross-staff, the pilot consulted a table like that provided in the *Instrucción náutica* to determine the value of the solar declination, or the sun's distance north or south of the equinoctial, for that day.[25] Because the calculation was too complex to be undertaken by pilots on a regular basis, simple solar declination tables for use at sea were developed by Portuguese astronomers in the late 15th century.[26]

[24] García de Palacio 1944a, 34.
[25] García de Palacio 1944a, 15v-23
[26] Parry 1981, 94; Taylor 1949, 59.

Because of the need to accommodate the surplus six hours of each solar year, declination tables were printed for a sequence of four years. While the cycle repeated indefinitely, the pilot needed to know which of the four tables to consult depending where he found himself in the leap-year sequence. For this purpose, García de Palacio presents a rule of thumb for determining the leap year: the last two digits of the year were divided by half; if the quotient was an even number, the navigator could be sure that it was an *año de bisiesto,* or leap year.[27] Once the nearest leap year had been determined, it was a simple matter to determine one's position within the four-year cycle.

After the proper values of the altitude and declination were determined, the mariner needed to know whether the sun was north or south of the equinoctial, as this determined the rule used to calculate the latitude. As noted by García de Palacio, the sun is on the north side of the equinoctial from 21 March to 23 September, and on the south side of the equinoctial from 24 September to 20 March.[28] Once the correct rule was selected, the sun's altitude was either added to or subtracted from the declination for that day, giving the observer the altitude of the celestial equator above his horizon. This value was subtracted from 90º to obtain the ship's latitude.[29] The *Instrucción náutica* provides examples for many different situations to ensure the reader's comprehension of these rules.

[27] García de Palacio 1944a, 14v.
[28] García de Palacio 1944a, 39.
[29] Parry 1981, 95.

Regiment of the North Star

When the weather permitted, navigators could determine their position by observation of the stars at night, an older and simpler method. Polaris, or the North Star, was preferred because it was easy to identify and was close enough to the celestial pole, or true north, to provide a reasonable estimate of latitude without requiring the use of tables of declination. However, the position of Polaris does not correspond precisely with the celestial pole. Instead, Polaris rotates around the pole in a circle, the diameter of which shifts over time. In the 16th century, Polaris was located about 3½º from the celestial pole.[30]

In order to obtain a more accurate reading of latitude, García de Palacio provides a diagram and rules of thumb that were commonly memorized by 16th-century seamen. The method relies on observing the position of Kochab, the lead guard star of Ursa Minor, relative to Polaris (fig. 4.9). The inner circle represents the circle made by Polaris around the pole, while the outer circle follows the route of Kochab. The position of Kochab was described in terms of the eight principal points of the compass rose, a common mnemonic device favored by sailors. Depending on the position, up to 3½º were added or subtracted to correct the altitude reading.

In the example shown in figure 4.9, Kochab is between the northwest and west positions, indicating that Polaris is about 1º higher than the celestial pole. Thus, 1º had to be subtracted from the measured height of Polaris to obtain the corrected altitude. The observer's latitude was obtained by subtracting the corrected altitude from 90º.

[30] Taylor 1949, 59.

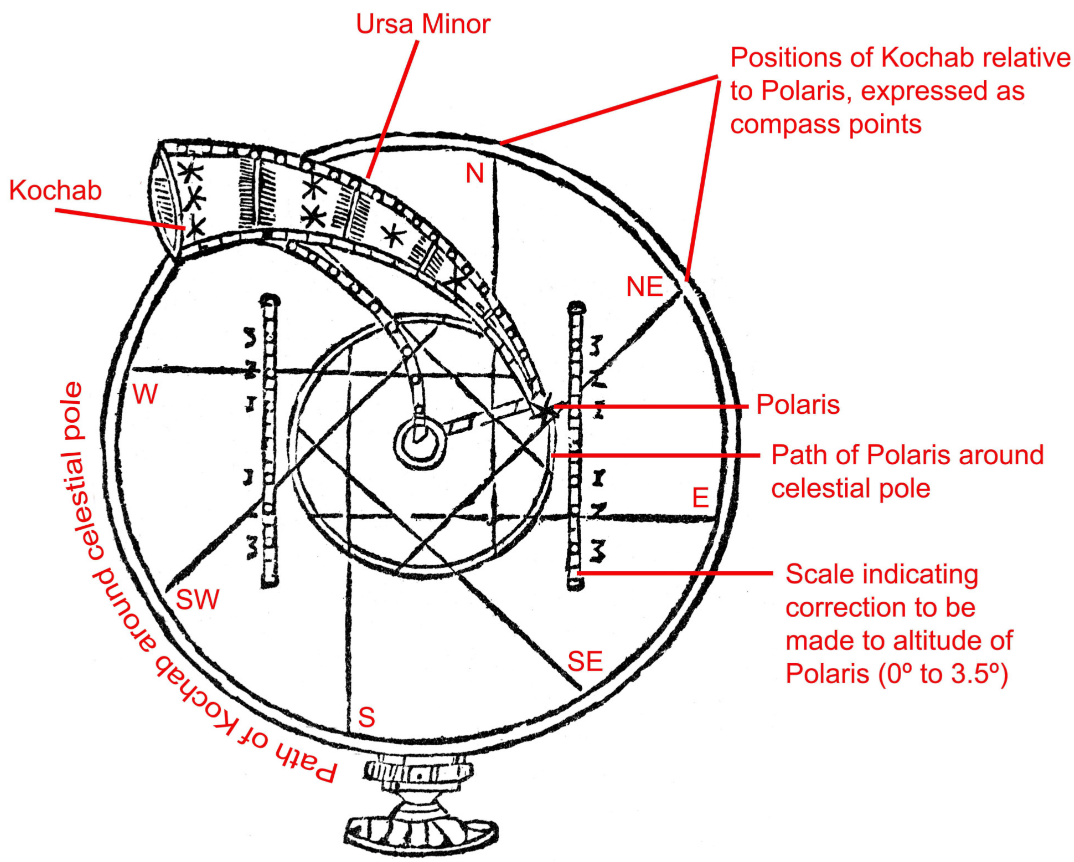

Fig. 4.9. Correcting the altitude of Polaris.
(After García de Palacio 1944a, 39v)

<u>Regiment of the Southern Cross</u>

For navigating below the equator, for example when sailing the Pacific route to Peru, García de Palacio describes a similar method of using the *Cruzero* (Southern Cross) to measure latitude.[31] Just as Polaris rotates around the northern celestial pole, the Southern Cross rotates around the southern celestial pole (fig. 4.10). The distance between Acrux, the brightest star in the Southern Cross, and the celestial pole was about 30º. The pilot was instructed to wait to take the measurement until the constellation was oriented as a cross with Acrux at the foot. Latitude was then calculated by correcting the altitude reading of Acrux by 30º to compensate for its distance from the celestial pole.

<u>The Problem of Longitude</u>

While 16th-century celestial navigation techniques allowed mariners to calculate their latitude north or south of the equator fairly accurately, there was no reliable means for calculating longitude at sea prior to the invention of the marine chronometer in the 18th century. Precise calculation of longitude required an accurate means of keeping time on board a ship, to allow the pilot to calculate the time separating the occurrence of a specific astronomical event at a fixed reference point and at the observer's location.[32] Even the most sophisticated 16th-century pilots were forced to rely on the crude and unreliable practice of dead reckoning, which involved maintaining a continuous record of the ship's course as indicated by the compass and of distance traveled, which was estimated in terms of time measured with a sand glass and of estimated speed. Whenever possible, celestial determinations of latitude were used to adjust the course.

[31] García de Palacio 1944a, 43-3v.
[32] Parry 1981, 98.

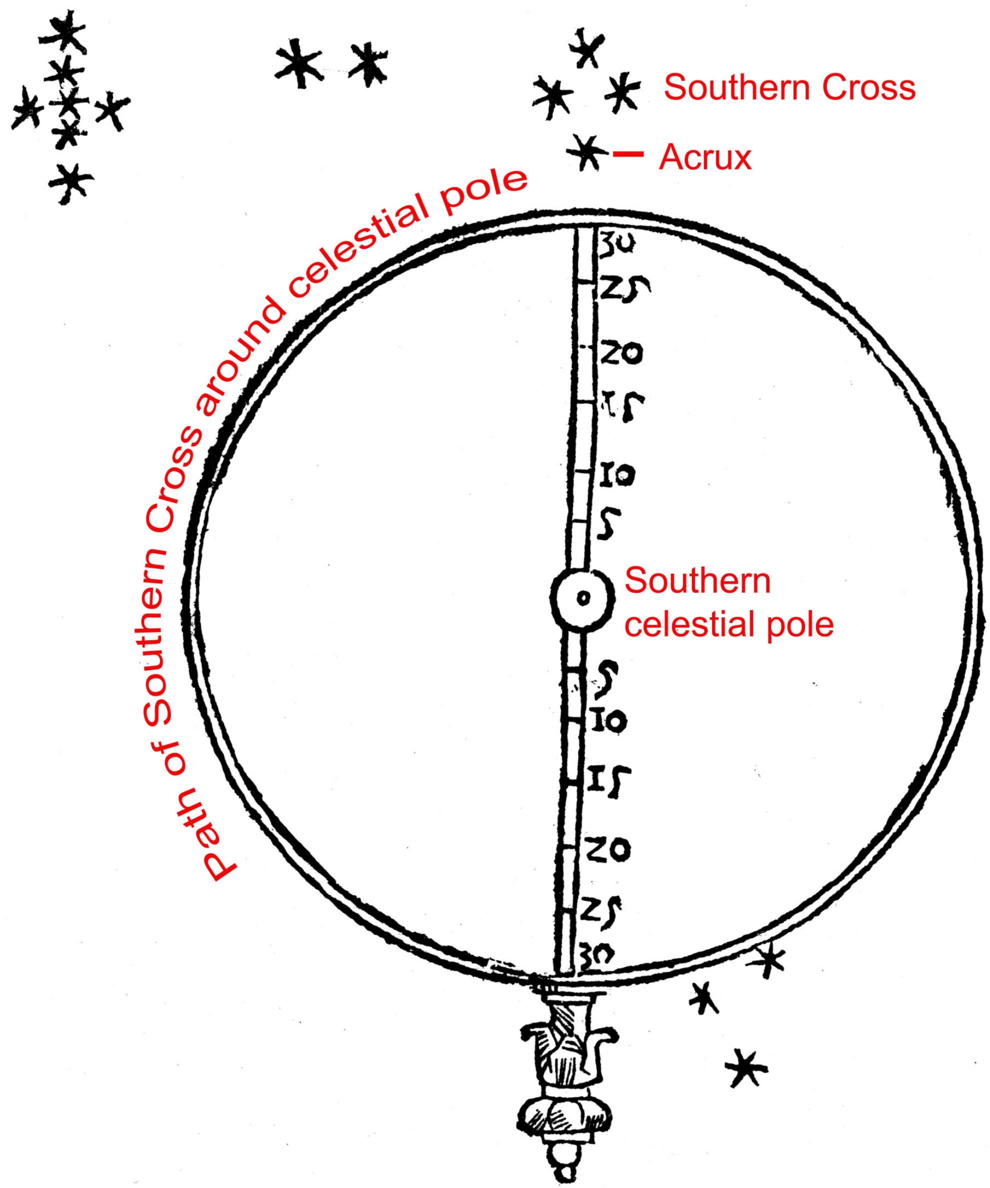

Fig. 4.10. Measuring latitude by the Southern Cross.
(After García de Palacio 1944a, 44)

While the experience and intuition of the pilot could help to reduce errors, inaccuracies could accumulate over the course of a long transoceanic voyage with sometimes disastrous results. One solution to the problem of longitude was latitude sailing. Pilots steered the ship north or south until the desired latitude was reached. The course was then turned due east or the west, and the ship remained at the same latitude until the destination was sighted.

The Star Clock

The *Instrucción náutica* also explains a method of using Ursa Minor as a "star clock" for determining the time at night. The orientation of the guard stars of Ursa Minor, Kochab and Pherkab, at midnight at different times of the year was memorized using the human body as a mnemonic device (fig. 4.11).[33] According to a tradition developed by shepherds in the Middle Ages,[34] a man was imagined in the sky, with Polaris in his chest, and the position of the guard stars was described in terms of this imaginary figure (fig. 4.12). The star clock runs 4 minutes earlier each day relative to the solar clock, or about an hour every two weeks, causing the midnight position of Ursa Minor to shift counterclockwise about 15º every fortnight.[35] The outer ring of the diagram in figure 4.11 is marked in two-week intervals reflecting this annual cycle. The time could be determined by estimating the difference between the observed position of Ursa Minor and its memorized position at midnight for that time of the year. Miguel de

[33] Vincent and Chandler 1969, 375-6.
[34] Vincent and Chandler 1969, 375-6.
[35] Taylor 1949, 59.

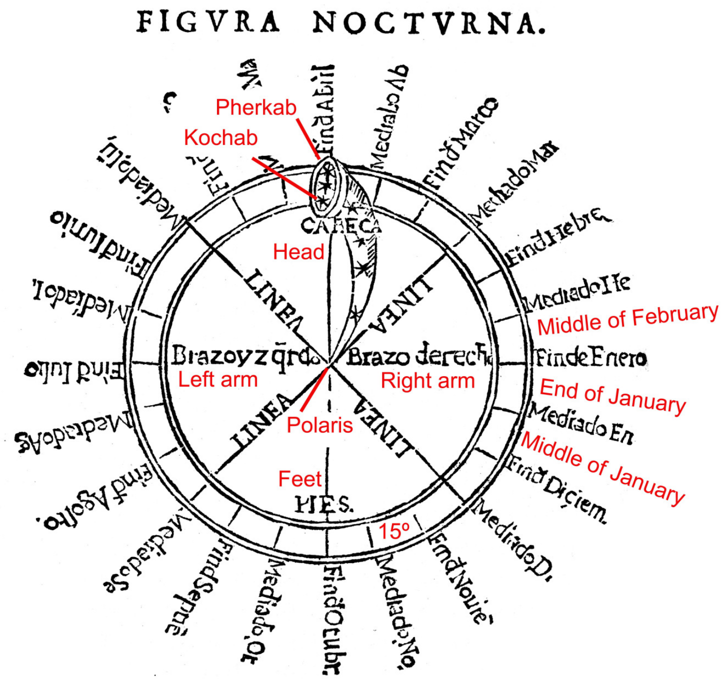

Fig. 4.11. Star clock from the *Instrucción náutica*.
(After García de Palacio 1944a, 42v)

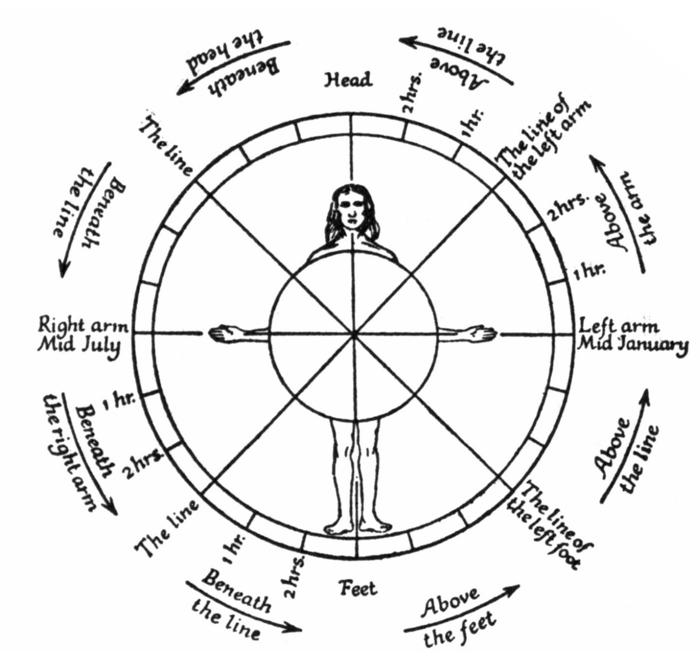

Fig. 4.12. Telling time by the star clock.
(After Taylor 1971, 146)

Cervantes mentions the technique in *Don Quixote*, when Sancho says "for by what the art tells me I learnt when a shepherd, it should not be three hours from now to dawn, for the mouth of the Horn is over the head, and shows midnight in the line of the left paw."[36]

Both figures 4.9 and 4.11 show Ursa Minor as a horn, a common metaphor used for this constellation in the 16th century. The mouth of the horn is formed by the guard stars, while Polaris sits at the tip. The imagery appears in Dante's *Divine Comedy* in the 14th century:

> Imagine, too, the bell-mouth of that Horn
> Whose tip is marked by that bright star which serves
> as axis for the Primum mobile….[37]

Remarkably, a mural recently discovered during the restoration of the 16th-century Convento de San Juan Bautista located in Motul in the Yucatán Peninsula (fig. 2.2) depicts a star-clock that is virtually identical to that illustrated by García de Palacio.[38] The mural is located on the south wall of the upper cloister, allowing the observer to refer to the mural while simultaneously observing the constellation. Construction of the convent was completed in the late 1580s.[39] García de Palacio traveled through this area in 1583 (see Chapter II), producing a census of the nearby community of Pencuyut,[40] indicating a probable connection between the mural and his *visita*.

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[36] Cervantes Saavedra 1899, 140.
[37] Musa 1986, 158.
[38] Rodríguez-Alcalá, n.d., 9-10.
[39] Perry and Perry 2002, 231.
[40] Roys et al. 1959.

The Sailing Compass

The Compass Rose

Figure 4.13 shows the diagram of the *vientos de la aguja* (compass rose, literally "winds of the needle") illustrated in the *Instrucción náutica.* A fleur-de-lys marks north, and the center of the diagram is decorated with a rose. García de Palacio discusses the naming of the compass points, dismissing the division of the compass into 12 points named for the winds used by the ancients (e.g., tramontane for north, levant for east) in favor of the cardinal directions with which we are familiar today. The figure shows the eight whole winds (e.g., north, northeast), the eight half-winds between the whole winds (e.g., north-northeast), and the 16 quarter winds (e.g., north by east) but does not give their names.[41] All sailors were expected to be able to "box the compass," or name the 32 points, in order to properly steer the helm.

The Problem of Magnetic Variation

At the end of the First Book, García de Palacio discusses the problem of the *nordestear y noruestear* (northeasting and northwesting) of the compass.[42] By the 16th century, navigators were aware that magnetic variation, or the variable angle between true and magnetic north, changed depending on the observer's location. In order to set an accurate course, the heading had to be adjusted to counter the error caused by the magnetic needle. At night, a good pilot could correct a compass reading by comparing it to the position of Polaris, which marked the position of true north fairly accurately.[43]

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[41] García de Palacio 1944a, 23v.
[42] García de Palacio 1944a, 44v-9.
[43] Pérez-Mallaína 1998, 233; Taylor 1971, 181.

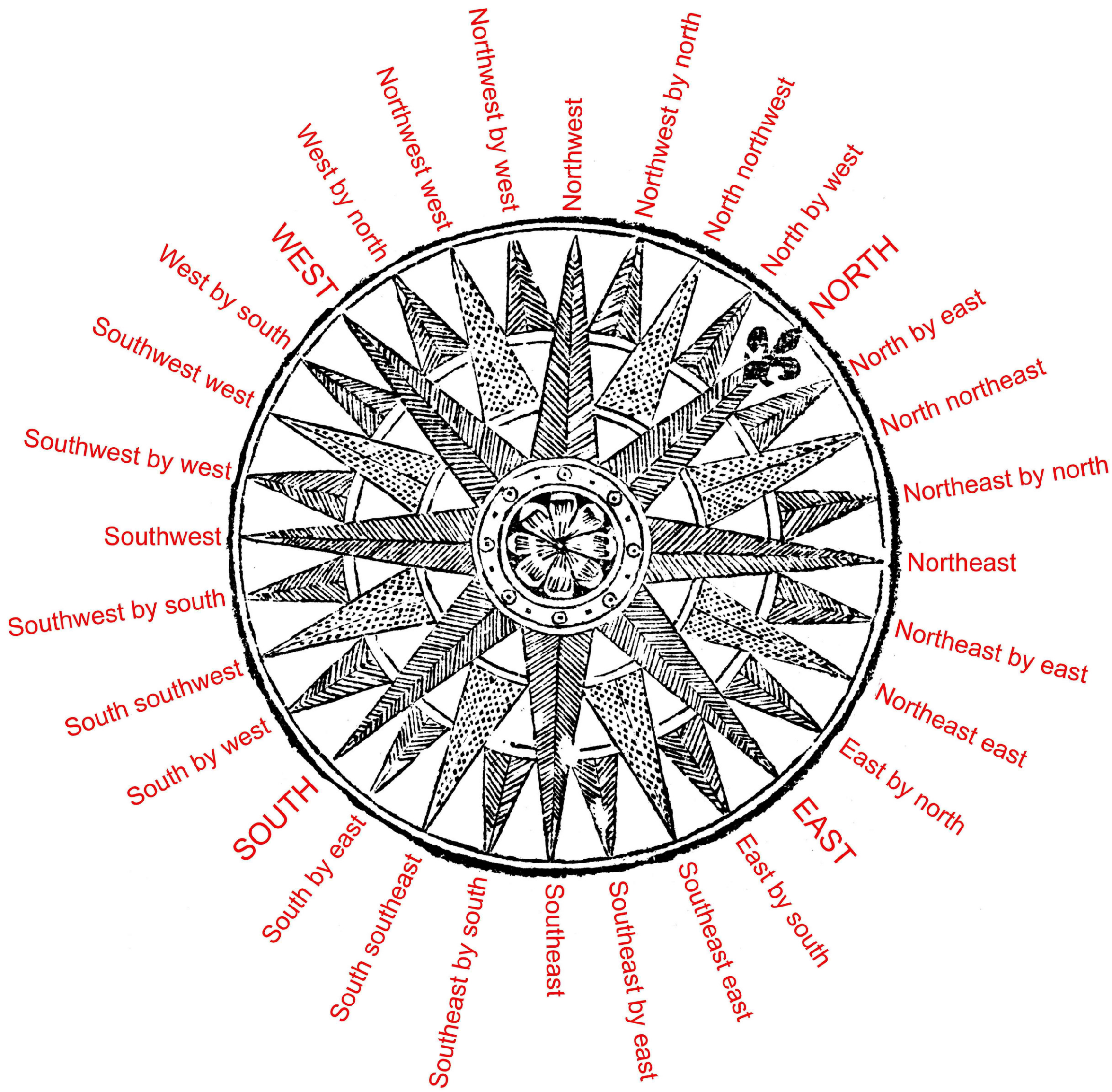


Fig. 4.13. Compass rose from the *Instrucción náutica*.
(After García de Palacio 1944a, 24)

Near the Azores, navigators observed a change from northeasting to northwesting, leading to the belief that there was a permanent meridian of no variation, or agonic line, in this area. Its exact location was disputed: while it was sometimes thought to run through the Canary Islands, García de Palacio considered the agonic line to lie somewhere amid the islands of Santa Maria and Corvo in the Azores.[44] Although not discussed by García de Palacio, there was an erroneous belief among many navigators that magnetic variation increased proportionally with one's distance east or west of this agonic line, leading some to propose that the solution to determining longitude was to find a reliable method of measuring magnetic variation.[45] Unfortunately, magnetic variation does not vary in such a systematic manner and therefore this method could not be used to solve the problem of longitude.

Because the nature of the earth's magnetic field was not understood in the 16th century, the reasons for the phenomenon of variation remained a mystery. García de Palacio examines a number of proposed explanations, but finds none of them satisfactory. These include the idea that variation is caused by indiscriminate shifts in the location of the north pole; the possibility that the error is caused by erratic behavior on the part of the needle depending on one's location; and speculation that the course sailed somehow affected the reading.

The *montañés* warns the *vizcaíno* to avoid at all costs the practice of some compass makers, particularly in the Mediterranean, who attempted to correct the variation by offsetting the needle against the compass card in a manner that was not

[44] García de Palacio 1944a, 44v.
[45] Taylor 1949, 60.

readily visible to the user.[46] While this corrected the variation for the specific local area in which the compass was manufactured, the practice only caused greater confusion and danger when a navigator used the compass on longer voyages.

The Shadow Instrument

García de Palacio discusses an instrument used by navigators to accurately measure the variation of the compass. By the mid-16th century navigators had realized that the problem of magnetic variation could only be addressed by carefully recording systematic observations in different locations.[47] As noted by García de Palacio, navigators needed to accumulate knowledge of variation in different parts of the world so they could apply the appropriate correction to their compass courses. Sailors soon developed the habit of recording their observations of the local value of variation in their log books and rutters for future reference.

In the first half of the 16th century, Portuguese navigators invented a "shadow instrument" that simplified the measurement of variation through comparison of the compass reading in any location to the sun's true azimuth. The device consisted of a vertical style set into a metal plate inscribed with a meridian and a line running east-west, with the quadrants graduated from 0º to 90º.[48] A small magnetic needle was pivoted on the meridian line. The instrument was leveled and set in accordance with the magnetic meridian using the needle. Before noon, the position of the sun's shadow was read off the plate, while another observer simultaneously measured the altitude of the

[46] García de Palacio 1944a, 47-7v.
[47] Parry 1981, 97.
[48] Taylor 1971, 181-2.

sun with an astrolabe. When the sun descended to the same height after noon, the position of the shadow was again noted. If the midpoint between the two positions of the shadow fell on the meridian, there was no variation. If the midpoint was offset to one side of the meridian, then the variation east or west was equal to half of the difference between the two observations.

Cartography

In the Third Book, García de Palacio discusses the use and manufacture of the *carta de marear* (sea chart).[49] Noting that they cannot be used to determine latitude or longitude reliably because of the problems of projecting a curved sphere onto a flat surface, he argues that they are useful only for determining the distance between places and the wind that should be used to sail from one location to another. Due to the convergence of the meridians, the length of a degree of longitude varies according to latitude. Because charts were generally small in scale, the effect of even minor errors was magnified. It was not until the end of the 16th century that a practical means of projection was formulated that allowed the development of a chart based on a grid of parallels and meridians on which compass courses could be plotted as straight lines.[50]

García de Palacio begins his explanation of chartmaking by describing the process of drawing rhumb lines by centering a circle on the midpoint of the chart and dividing it according to the 32 points of the compass. The rhumb lines for the eight principal winds were to be drawn in black ink, the half-winds in green, and the quarter-

[49] García de Palacio 1944a, 71v-6; Bankston 1986, 86-91.
[50] Taylor 1971 207-8.

winds in red.[51] The locations of the geographical features could be drawn either from their known latitudes and longitudes, or from a *padrón* (master chart, literally "pattern") using a system similar to that illustrated by Martín Cortés in 1551 (fig. 4.14). García de Palacio then discusses the method of adding a scale divided into degrees of 17½ leagues, similar to that shown in figure 4.15.

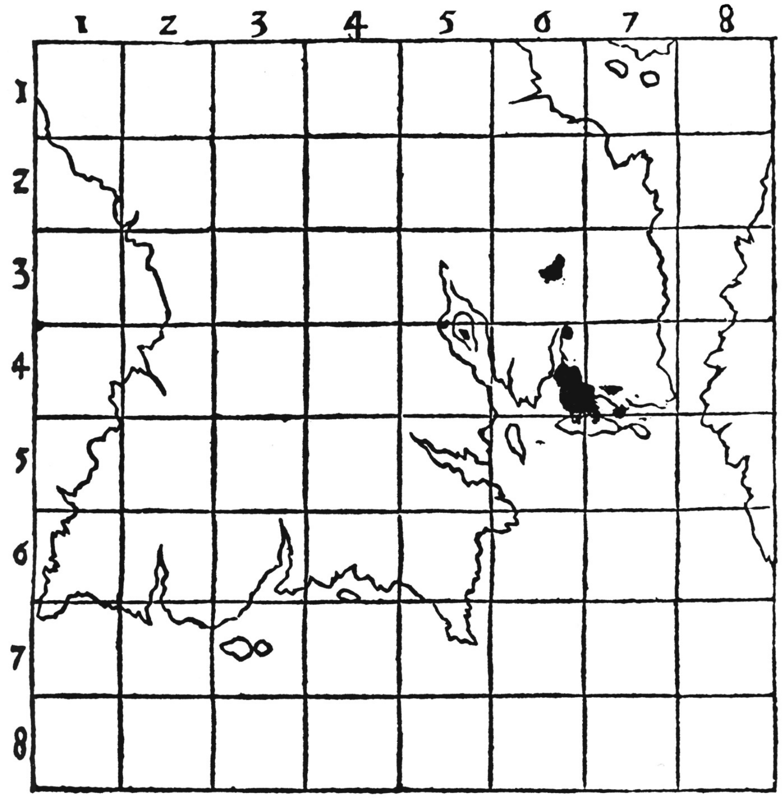
Astronomical Prognostication

The Second Book of the *Instrucción náutica* includes a lengthy discussion of astronomical prognostication, spanning pages 49v to 65. The primary purpose of this section of the text is to aid the pilot in determining the age of the moon and the corresponding changes in the tides. The rise and fall of the tides and changes in direction of tidal flow had to be known when entering ports and to avoid unexpectedly grounding a ship when in shallow water. Pilots needed to calculate the times of high and low water in each port they visited and the direction of flow likely to be encountered in the area.[52]

Golden Number

García de Palacio begins by explaining the method of calculating the *Aureo Numero* (Golden Number). This is a system used to determine the date of Easter by assigning each year a position within the 19-year cycle of the Lillian epact used after 1582 in the Gregorian calendar system. The epact is used to compensate for the fact that the lunar year consists of 12 months of 29.5 days totaling 354 days, or 11 days less than

[51] García de Palacio 1944a, 72v.
[52] Parry 1981, 86.



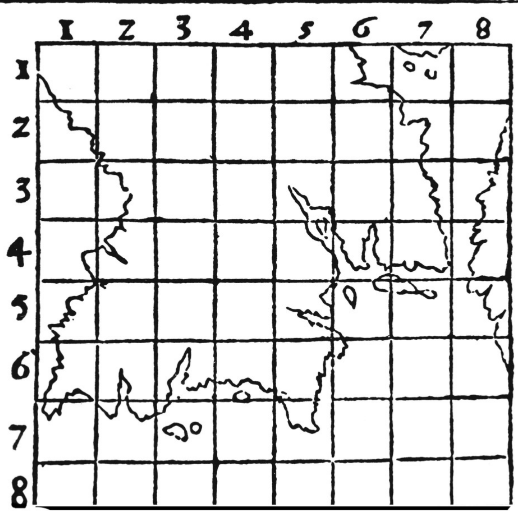


Fig. 4.14. Method of copying a chart from Cortés (1551).
(After López Piñero 1986, 211)

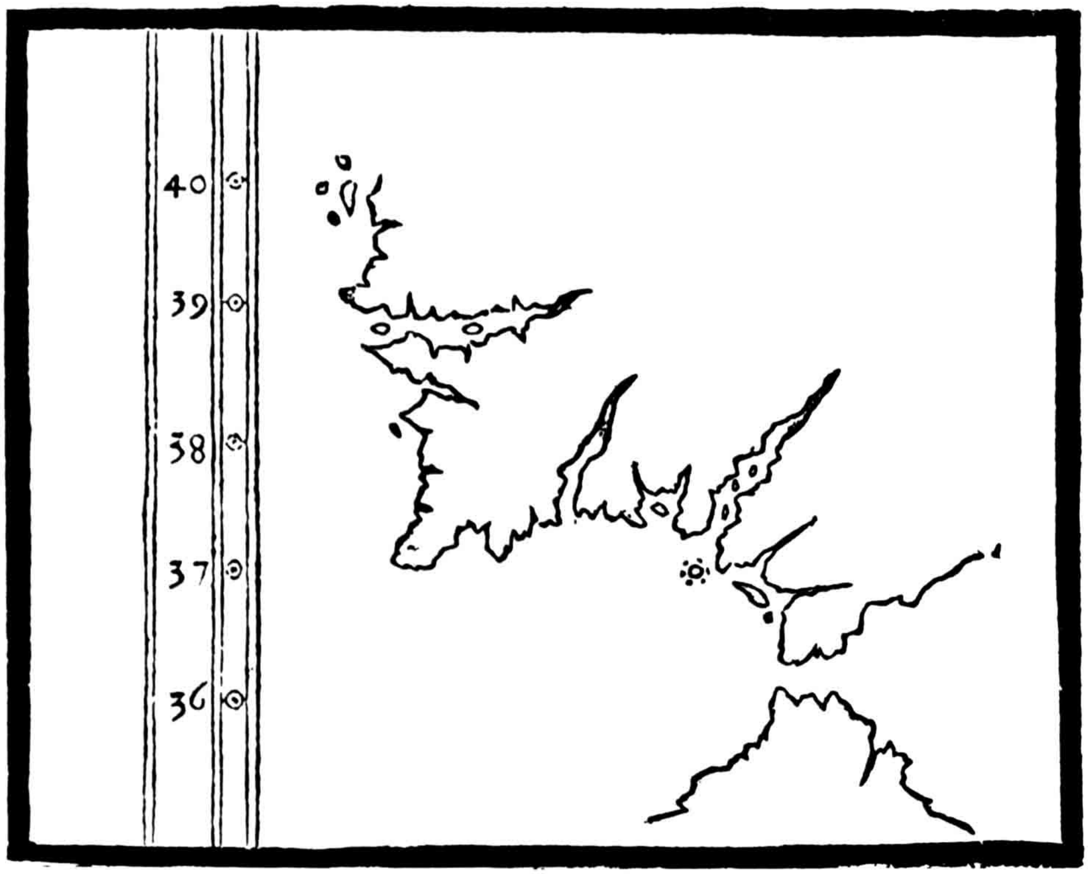


Fig. 4.15. Degrees of latitude on a chart from Cortés (1551).
(After López Piñero 1986, 210)

the solar year of 365 days. Because it indicates the date of the first full moon on or after the spring equinox of March 21, the Golden Number is of great value to mariners in predicting tidal cycles.

The *Instrucción náutica* provides several methods for calculating the Golden Number for any year. The simplest involves dropping the first two digits of the year, dividing the remaining number into even increments of 20, and adding the quotient to the remainder.[53] For example, for the year 1587, the first two digits are dropped to leave 87. Then, 87 is divided by 20, producing a quotient of 4 and a remainder of 7. By adding the quotient and remainder, the Golden Number of 11 is obtained for the year 1587. García de Palacio also includes an illustration of a *rota perpetua* (perpetual wheel) that shows the value of the Golden Number for the years 1586 to 1604 (fig. 4.16).

<u>Tidal Rota</u>

Once the Golden Number and the date of the full moon at Easter were known, a navigator could use this information to predict tidal cycles throughout the year. Figure 4.17 shows a tidal rota from the *Instrucción náutica* that could be used for this purpose. The inner circle has 30 divisions indicating the age of the moon in the 29.5 day lunar cycle. The occurrences of two strong spring tides on the 3rd and 17th days, just after the moon was new or full (marked *pleamar*), and two weak neap tides on the 9th and 24th days, just after the moon was in quadrature (marked *baxamar*), are marked in relation to the age of the moon.[54] This reflects the delay of two days between the age of the moon

[53] García de Palacio 1944a, 50-0v.
[54] Taylor 1971, 171.

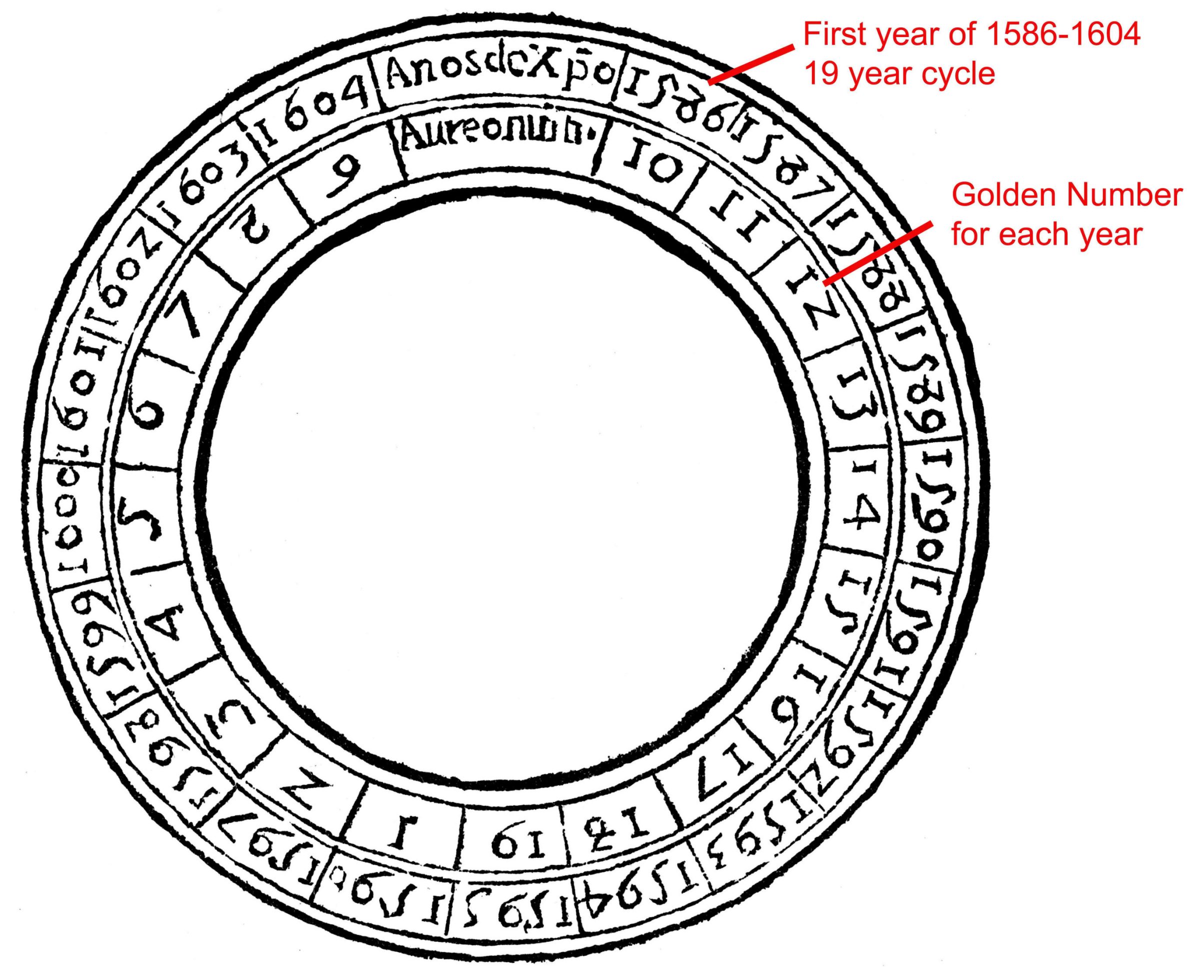


Fig. 4.16. *Rota perpetua* from the *Instrucción náutica*.
(After García de Palacio 1944a, 50v)

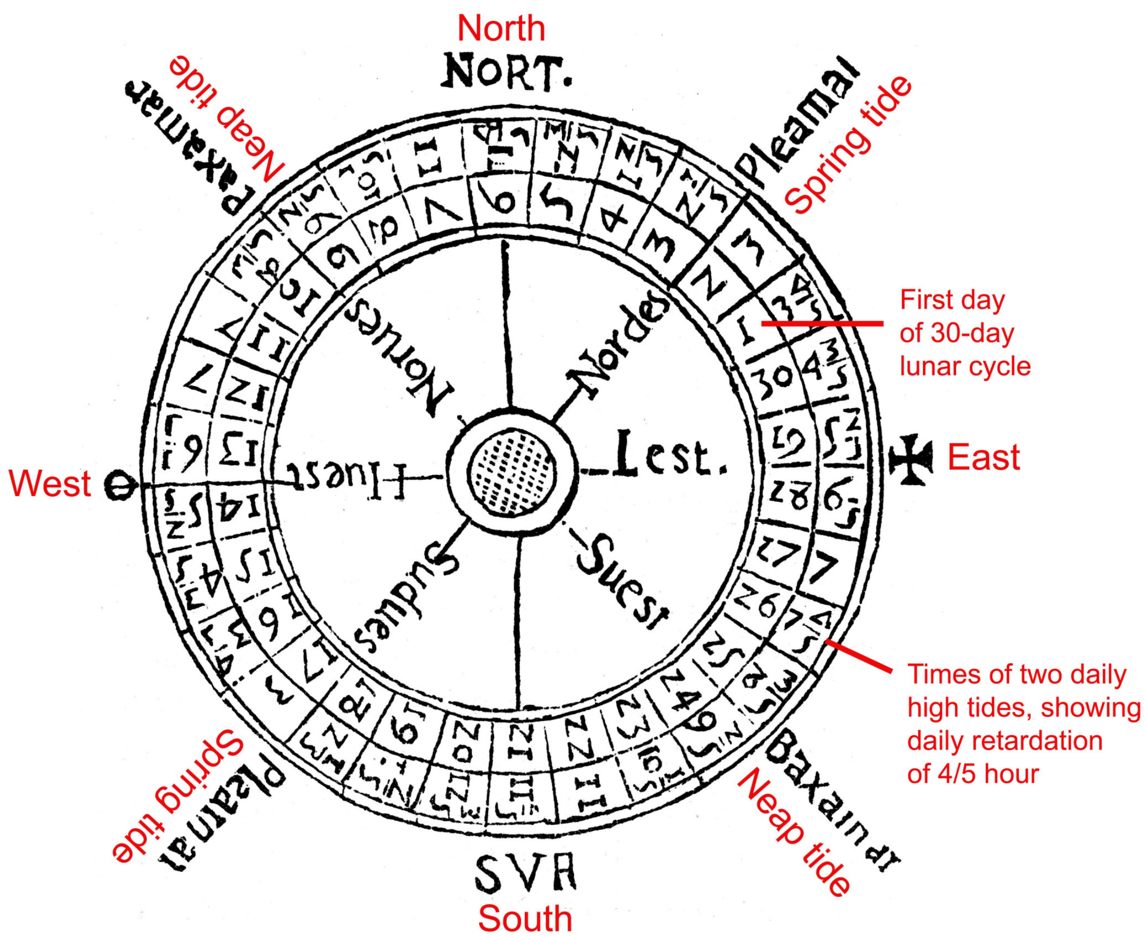


Fig. 4.17. Tidal rota from the *Instrucción náutica*.
(After García de Palacio 1944a, 59v)

and the age of the tides that occurs in most locations. The outer circle divides the 24 hours of a day into 30 sections giving the actual times of the two daily high tides in hours and fifths of an hour, changing by four-fifths of an hour each day to reflect the daily retardation of the tide by 48 minutes.

The inclusion of the cardinal directions on the tidal rota reflects the universal method used by 16th-century mariners to describe the tides of a particular port.[55] The tide was described in terms of the point of the compass on which the new moon appeared at the time of the high tide, and the opposite point on which it was observed at the time of the second high tide 12 hours later. This bearing was known as the "tidal establishment" of the port and was often noted on charts and rutters. The rota in figure 4.17 shows an establishment that might be described as "moon northeast-east and southwest-west, full sea" meaning "high water occurs on days of the new or full moon when the moon is seen northeast-east and southwest-west."[56] Once he knew the establishment of a port, a navigator could then calculate the time of the high tides on any day either by calculating the age of the moon mathematically or consulting a lunar almanac and adding the required daily retardation.[57] Although García de Palacio discusses the tidal rota in the *Instrucción náutica* as though it is of general utility, due to the vast differences in tides depending on location, such rota were only useful for very limited local areas. Unfortunately, there is no indication of the specific location for this tidal establishment anywhere in the text.

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[55] Taylor 1971, 133-4.
[56] Parry 1981, 86.
[57] Parry 1981, 86.

Lunar Almanac

The Third Book ends with a *lunario*, or lunar almanac, for determining the age of the moon.[58] The almanac covers a complete 19-year cycle, with tables provided for the years 1586 to 1604. As García de Palacio points out, the almanac can be used perpetually if the user adds a day to the tables to compensate for the westward precession of the equinoxes each time the 19-year cycle repeats. For each month of the year, the almanac gives the date and time of the new moon (the conjunction of the sun and moon) and of the full moon (the opposition of the sun and the moon). The exact time of the new moon is dependent on the observer's longitude, and this almanac is original in that García de Palacio calculated these tables specifically for the meridian at Mexico City. As a further convenience to the user, the almanac also states the dates of major Catholic religious observances, such as *ceniça de febrero* (Ash Wednesday), *ascension de mayo* (Ascension Day), and *pascua de resurrección* (Easter Sunday).

Weather Signs

The Third Book includes a discussion of *astrología rústica*, or meteorological forecasting using simple weather signs.[59] Pilots had to be able to anticipate changes in the winds in order to set the course properly, and the ability to read signs that indicated approaching storms could be crucial to avoiding disaster. Notwithstanding his references to Aristotle, Pliny, Ptolemy, Virgil, and other Classical sources, for the most part, the advice presented by García de Palacio reflects common folk knowledge that farmers and sailors had accumulated over generations based on empirically observed

[58] García de Palacio 1944a, 76-87.
[59] García de Palacio 1944a, 65v-71v.

patterns. The discussion includes signs based on observation of the color, brightness, and clarity of the sun, moon, stars, seas, and candle flames. Occurrences of rainbows, thunder, lightning, and excessive heat were also interpreted. Even instances when flowers and grasses smelled more intensely were used to prognosticate impending rains, although this particular example may have had little practical value at sea.[60]

Some of this advice will seem familiar even to 21st-century readers. For example, García de Palacio observes that "…when the knuckles and joints in the limbs hurt, or are stiffer, there will be a change within 24 hours; and when the feet sweat, the south winds will normally appear; and when the limbs injured in some accident ache, the weather will similarly change."[61] Pain in arthritic or rheumatic joints due to changes in barometric pressure and humidity remains a commonly accepted weather sign today. García de Palacio's remark that "…when the sounds of the bells can be heard further away than is usual, it will shortly rain,"[62] is similar to the English folk saying "when sounds travel far and wide, a stormy day will betide."[63] The scientific explanation for this phenomenon is that sound travels faster in moist air than in dry.

According to García de Palacio, "…when a star moves… at night, like a rocket, from one place to another, anticipate winds from whence it came before daybreak, more or less; and if [shooting stars] are seen in various places, the winds will also be diverse and variable."[64] This passage may reflect his reading of Pliny, who wrote in his *Natural History*: "stars are seen to move about in various directions, but never without some

[60] García de Palacio 1944a, 71.
[61] García de Palacio 1944a, 70v-1.
[62] García de Palacio 1944a, 71.
[63] Inward 1898. 128.
[64] García de Palacio 1944a, 69-9v; Bankston 1986, 84.

cause, nor without violent winds proceeding from the same quarter."[65] In his *History of the Winds* (1622), Francis Bacon, who also cites Aristotle and Pliny, wrote that "shooting stars, as they are termed, foretel immediate winds from the quarter they shot. But if they shoot from different or contrary quarters, there will be great storms of wind and rain."[66] There are a number of other parallels between García de Palacio and Bacon's works, suggesting a common origin for much of their material.

The navigational information included in the *Instrucción náutica* generally reflects information that was previously published elsewhere, and much of the content appears to have been adapted from existing sources. In particular, close parallels to the navigational information presented in the *Instrucción náutica* are found in Pedro de Medina's *Arte de navegar* (1545), Martín Cortés's *Breve compendio de la sphera y la arte de navegar* (1551), and Rodrigo Zamorano's *Compendio del arte de navegar* (1581), probably the three most widely read Spanish navigational treatises of the 16th century. Despite its apparent lack of originality, it provides a comprehensive grounding in the technical concepts needed for celestial navigation, and would have been useful, for example, to a literate seaman seeking to elevate himself to the position of pilot. Significant innovations made by García de Palacio include the calculation of dates such as the computus using the Gregorian calendar introduced in 1582 and the computation of a lunar almanac specifically for the meridian of Mexico City.

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[65] Pliny 1893, 64.
[66] Bacon 2000, 190.

CHAPTER V

SHIP DESIGN AND CONSTRUCTION

The first chapter of the Fourth Book presents a discussion of ship design and construction comprising 11 pages of text accompanied by five woodcut images depicting the form of two different ships. On the basis of this section, the *Instrucción náutica* is widely recognized as the first published book that includes an extensive discussion of ship design and construction,[1] and for this reason it represents a significant milestone in the history of early modern shipbuilding. García de Palacio himself was conscious of the novelty of this section of the text, advising the reader that "you must listen with attention, because I believe that what I am about to tell you has not been written about until now."[2]

Shipbuilding Treatises

Although treatises on ship construction and technical drawings of ships are now widespread, the practice of describing ships through text and images only developed during the Renaissance. Like architectural texts, shipbuilding treatises seem to appear first in 15th-century Italy, then spread throughout Europe during the 16th century.[3] The scope and quality of these texts varies: some authors were experienced shipbuilders, while others were laymen with no first-hand knowledge of ship design or construction.

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[1] Burlet and Rieth 1988, 466.
[2] García de Palacio 1944a, 87v.
[3] Castro 2005, 36.

Some of these documents were technical works either kept as personal notebooks or written to provide guidance to other practitioners, while others were intended to provide an overview of shipbuilding practices for a non-specialist audience.

In consideration of its novelty, the most surprising aspect of the *Instrucción náutica* is not how early it is, but rather how long such information took to reach the printing press. As a result of the esoteric and guarded nature of methods of ship design and construction, shipbuilding treatises were remarkably slow to appear in print. In the words of historian Elizabeth Eisenstein, "doctrines cultivated by cloistered monks and veiled nuns were less hedged in by secrecy than trades and mysteries known to lay clerks and craftsmen."[4] Until early modern times, shipbuilding knowledge was closely controlled by practitioners, and was transmitted through apprenticeship, oral communication, mnemonic devices, and repeated physical practice, rather than through written texts or printed images. By 1486 the first edition of Vitruvius's treatise on architecture had been published,[5] yet the first book discussing shipbuilding did not appear until almost 150 years after the invention of the printing press.

As printed books became available, information about shipbuilding that had been carefully guarded by specialists became accessible to anyone who was literate. It is significant that the first published work on shipbuilding was printed in the New World rather than in Europe, and that its author was a bureaucrat, not a shipbuilder. The publication of the *Instrucción náutica* in Mexico City not only reflects García de Palacio's geographical location and the importance of seafaring for Spain's colonies, but

[4] Eisenstein 1983, 138.
[5] Hart 1998, 4.

may also indicate that the ability of the guild system to limit the transmission of specialized shipbuilding knowledge was less effective in the New World.

The general form and content of the *Instrucción náutica* are similar to other contemporary Spanish treatises, particularly the manuscript "Itinerario de navegación de los mares y tierras occidentales" written by Juan Escalante de Mendoza around 1575; the *Arte para fabricar y aparejar naos* published by Tomé Cano in 1611; and an anonymous unpublished text written about 1631-2 and tentatively attributed to Pedro López de Soto.[6] Each of these documents was written in dialogue form by a native of northern Spain. Unlike the technical notebooks of Mathew Baker and other early naval architects, these texts were written by captains, navigators, pilots, and bureaucrats who, although intimately familiar with ships and seafaring, did not necessarily have direct experience building or designing ships. They include few illustrations and are concerned with the overall proportions of ships rather than with specific aspects of design or construction. Either the beam or the length of the keel is used as the basic measurement from which all of the other measurements are calculated.

Ship Design

While the value of the *Instrucción náutica* for understanding 16th-century shipbuilding is beyond dispute, it is an overstatement to suggest that "the text is so complete that a twentieth-century shipwright would have little, if any, difficulty in using it as a guide for the construction, rigging, and equipping of any of the vessels described

[6] Escalante de Mendoza 1985; Cano 1964; Vicente Maroto 1998.

therein."[7] Although methods of ship design similar to those used in the Renaissance are still employed in some traditional shipyards,[8] the processes of building wooden ships were much different in the 16th century than those typically used today. The older empirical methods are only beginning to be deciphered by scholars. Arróniz aptly compares the notion that the *Instrucción náutica* contains all of the practical knowledge required to build a ship in 16th-century Mexico to the expectation that a treatise on musical composition might provide a reader with sufficient understanding to write a symphony.[9]

The design and construction of a ship in 16th-century New Spain was a matter of negotiation between the owner, the shipwright, the carpenters, and often the Crown. Within general parameters, ship designs were adapted to suit specific circumstances. Proportions and shape were flexible and could be varied in order to reach an appropriate compromise between factors such as capacity, speed, maneuverability, stability, strength, cost, and availability of materials.

García de Palacio considered the crucial variables of a ship's hull to be steering, the height of the freeboard, and the narrowing of the ends to allow sailing by the bowline.[10] He describes a variety of vessel types used by the Spanish in the New World, including *fregatas* (frigates, or small swift vessels), *barcos de trato* (coastal trading vessels), and *naos*. The sizes and proportions of these vessels were modified to suit the environments and purposes for which they were used. For example, small *fregatas* with

[7] Bankston 1986, v.
[8] See, e.g., Sarsfield 1991 and Rieth 1996, 165-99.
[9] Arróniz 1994, 37.
[10] García de Palacio 1944a, 92.

a capacity of 50 *toneladas* used in the Windward Islands were designed to be sailed close to the wind and therefore had a sharp form, while the 50-*tonelada* vessels used on the Gulf Coast of Mexico were built with a relatively flat bottom and a shallow draft to allow safe entry into the ports of that region.[11]

Despite this inherent flexibility, once a successful design was developed for a specific purpose, efforts were made to reproduce ships on the same model. The ability to construct dependable ships for trade and warfare was essential to the viability of Spain's empire. It is possible that there were relatively fewer shipwrights in the Americas with the training and experience to build consistent ships, and New World shipbuilders may have been more likely to disregard prescribed dimensions than their counterparts in Europe. Juan Escalante de Mendoza referred to this intuitive method of ship design as *troche moche* (haphazard) and complained that, as a result, ships that were intended to be small turned out large, and ships that were intended to be large turned out small.[12] An 18th-century description of the colonial shipyard at Guayaquil illustrates the lack of standardization in at least one isolated location:

> The builder in this shipyard is a *negro* [black]: he is the only one who directs the construction of ships, according to the best idea his experience permits, because even the principal measures received from Europe, which are fundamental to a ship, are not followed: the keel, length, breadth, and depth of the ship is left to his judgment or to that of the owner who is paying for the vessel; once these dimensions are determined, he continues the construction to the end, eyeballing it all the way.[13]

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[11] García de Palacio 1944a, 91-1v.
[12] Escalante de Mendoza 1985, 38.
[13] Clayton 1980, 65.

It is likely that one of García de Palacio's objectives in publishing the *Instrucción náutica* was to standardize shipbuilding in the New World by outlining suitable proportions of ships for various purposes, if not for the shipwrights themselves, then for the administrators overseeing the construction. This concern with regularizing ship types and sizes to create better naval and merchant fleets presages the shipbuilding *ordenanzas* legally prescribed by the Spanish crown in the early 17th century.

García de Palacio centers his discussion around a *nao* of 400 *toneladas*, a size that he considered to be ideal for both warfare and trade.[14] *Naos* were multi-purpose vessels used in a wide variety of activities, including trade, fishing, exploration, and warfare.[15] As García de Palacio himself admits, there was no definitive pattern for a *nao*, but rather the term included a range of ships with varying characteristics designated by a general term.

According to Carla Rahn Phillips, there were five principal dimensions used in defining the form of Spanish ships: *manga* (maximum breadth), *quilla* (length of the flat keel), *esloria* (length at the level of the lower deck), *plan* (width of the flat floor of the master frame), and *puntal* (depth of hold). García de Palacio's text discusses proportional rules used to derive the breadth (*manga*), depth of hold (*puntal*), and length at the level of the main deck (*esloria*) of the proposed 400-*tonelada* ship from the length of the keel. The explanation is accompanied by a series of woodcuts that illustrate the shape and dimensions of the 400-*tonelada* ship described in the text and of another 150-*tonelada* vessel that is briefly referenced, but not discussed, by García de Palacio (figs.

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[14] García de Palacio 1944a, 90.
[15] Barkham 1985, 113.

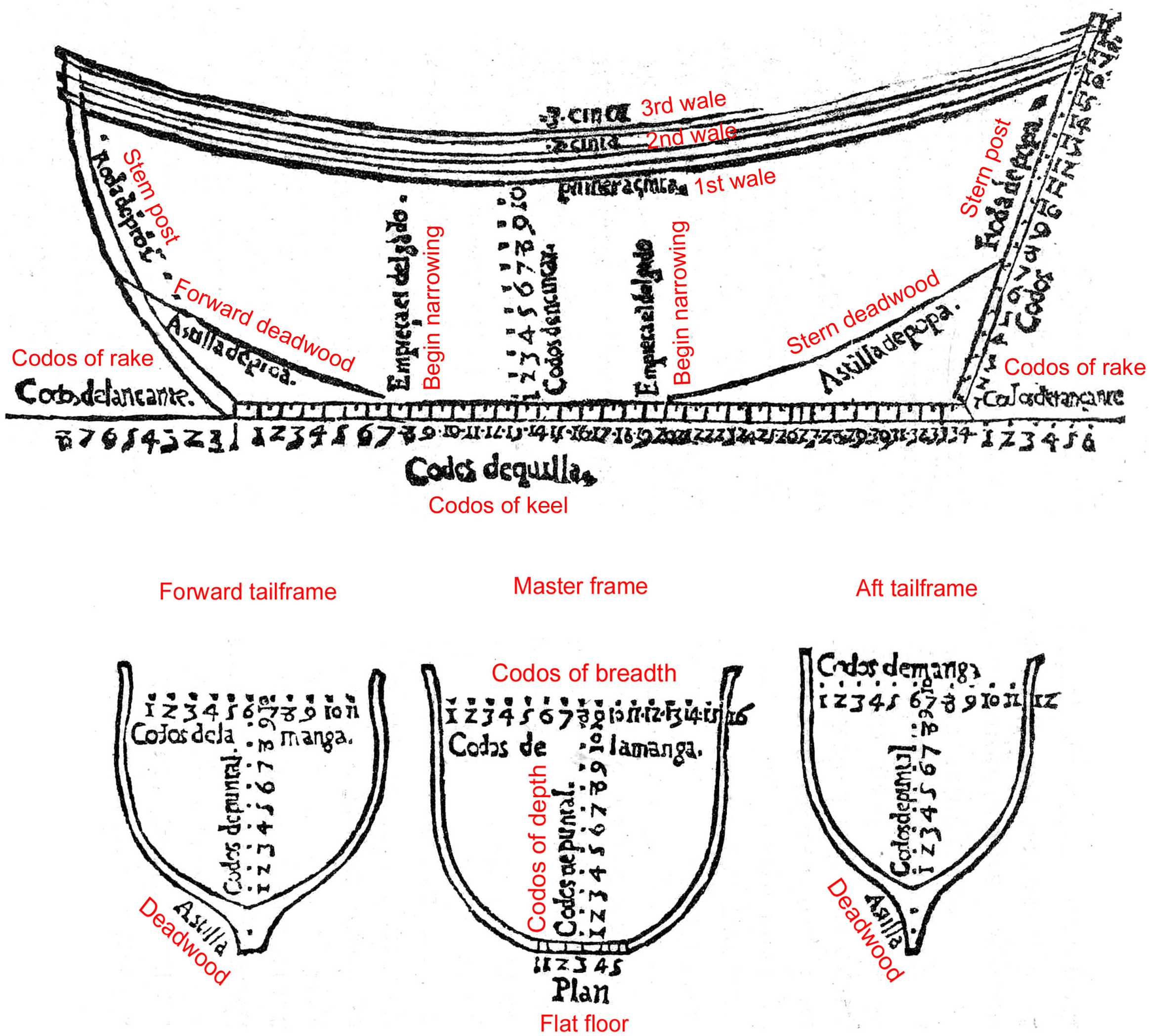

Fig. 5.1. Sheer view and sections of the 400-*tonelada* ship.
(After García de Palacio 1944a, 93v-4)

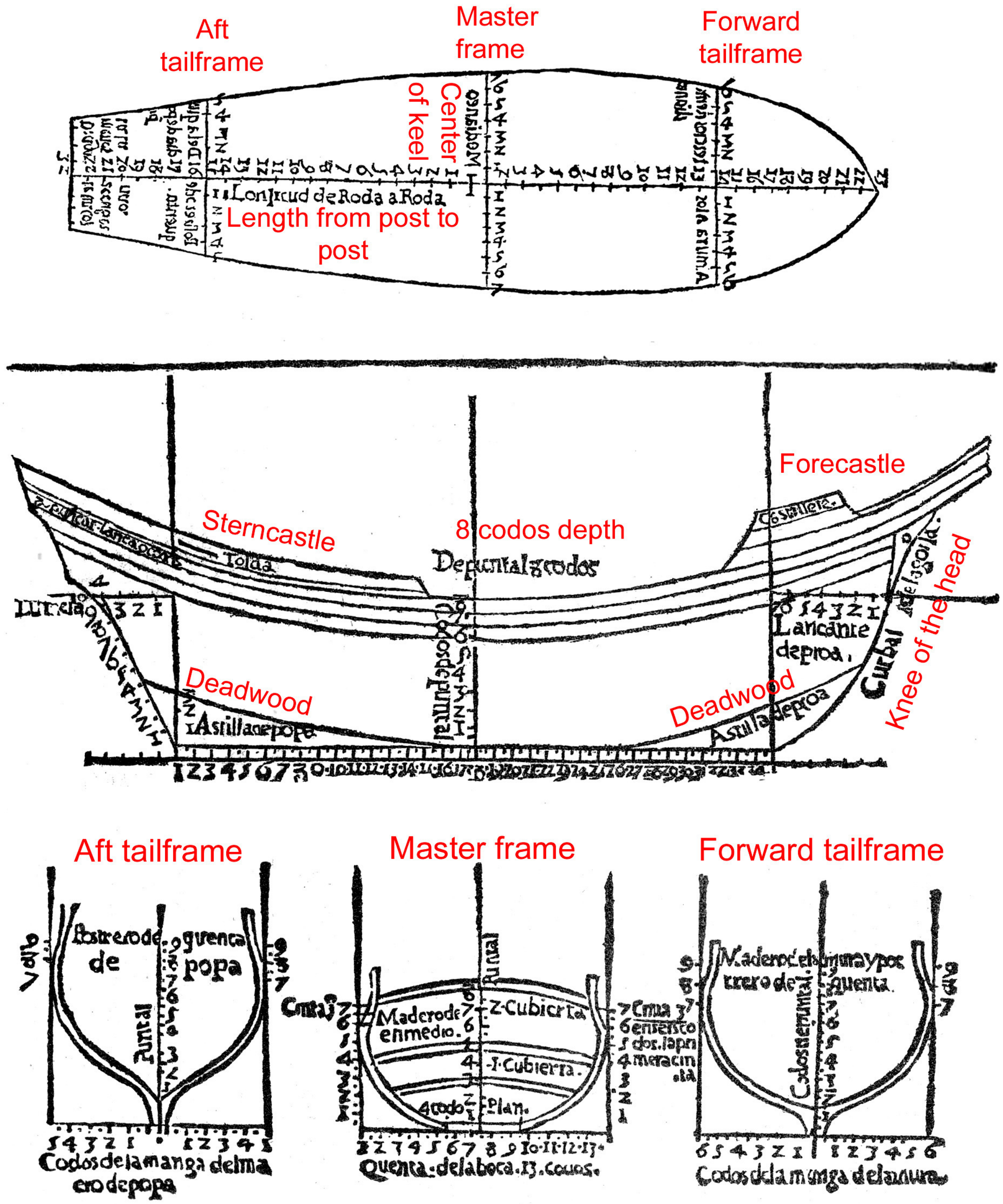

Fig. 5.2. Plan view, sheer view, and sections of the 150-*tonelada* ship.
(After García de Palacio 1944a, 96-7)

5.1 and 5.2). Notably, both ships have the same length of keel, but they vary markedly in breadth, depth of hold, and length of the main deck. The larger ship has more than twice the capacity of the other, due mainly to the greater depth of hold.

Table 5.1 provides a comparison of the principal dimensions of the 150-*tonelada* and 400-*tonelada* vessels as derived from the *Instrucción náutica*. There are significant discrepancies between the text and illustrations for many of the measurements given for the larger vessel, and the values given in table 5.1 reflect the dimensions outlined in the text rather than those illustrated. Because they are not discussed in the text, the dimensions for the smaller ship are derived from the illustrations. All measurements in the *Instrucción náutica* are given in *codos* (cubits) equivalent to the distance between a man's elbow and the tip of his middle finger. The standard value of the official *codo real* in 16th-century Spain was about 56 cm.[16]

The dimensions of the larger ship reflect the very rough rule of thumb for the traditional proportions of Iberian ships of *as*, *dos*, *tres* (1 : 2 : 3) for the ratios of the breadth, keel, and length of the main deck.[17] For the 400-*tonelada* vessel the ratio is 1 : 2.1 : 3.2. However, the much greater length to beam ratio of the 150-*tonelada* distorts these proportions, producing values of 1 : 2.6 : 3.5.

Designations of tonnage used by the Spanish in the 16th century referred to the burden or capacity of the vessel rather than its displacement. For this reason, it is important to note that the values for the *puntal* (depth of hold) specified by García de

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[16] Smith 1993, 56.
[17] Phillips 1987, 294.

Table 5.1. Principal dimensions of ships from the *Instrucción náutica.*

Dimension	**150-*tonelada* ship**	***400*-tonelada *ship***
Length of keel *Quilla*	34 *codos*	34 *codos*
Rake of stem *Lanzamiento de proa*	7 *codos*	11 1/3 *codos*
Rake of sternpost *Lanzamiento de popa*	4 *codos*	5 2/3 *codos*
Length of keel and rake at lower deck [*esloria*] *Roda a roda*	45 *codos*	51 1/3 *codos* [sic]
Maximum breadth *Manga*	13 *codos*	16 *codos*
Width of flat floor *Plan*	4 *codos*	5 1/3 *codos*
Height of orlop deck *Primera division*	3 *codos*	4 1/2 *codos* (height of 3 *pipas*)
Height of lower deck *Primera cubierta*	2 *codos*	3 *codos* (height of 2 *pipas*)
Height of upper deck *Puente* or *segunda cubierta*	3 *codos*	3 *codos* (height of 2 *pipas*)
Depth of hold *Puntal*	8 *codos*	11 1/2 *codos*

Palacio refer to the total height of the hull, rather than the capacity of the hold as used in calculating tonnage.[18] Normally, the depth used in calculating tonnage was the distance between the keel and the first fixed deck (*primera cubierta*), and this seems to be

[18] Burlet and Rieth 1988, 467; Phillips 1987, 293-5.

reflected in the tonnages given by García de Palacio.[19] As A.G. Mawer has demonstrated, without realizing it, García de Palacio's discussion of the ships reflects a method of calculating capacity based on the number of *pipas* (wine barrels with a capacity of half a *tonelada*) that can be stowed in the hold.[20]

In the frame-first carvel-planked tradition described in the *Instrucción náutica*, ship construction began with a set of carefully pre-designed and pre-assembled frames, referred to as *maderos de quenta* (calculated timbers) by García de Palacio, erected on the central portion of the keel, with the shape of the frames used in the narrower ends of the vessel determined largely by eye. The shipwright conceived of the hull in three parts: a wide central section and the two ends of the vessel where the frames narrowed toward the stem and sternpost. According to García de Palacio, the master frame was to be positioned 2 *codos* forward of the midpoint of the keel.

The drawings of the two ships represent an early attempt to graphically illustrate this complex empirical system of hull design. Notably, these drawings appear to be the first published drawings of ships that include a scale.[21] A sheer view and three sections (master frame and forward and aft tailframes) are given for the larger vessel (fig. 5.1), while the drawings of the smaller ship also include a plan view at the level of the lower deck (fig. 5.2), presaging the sheer, body, and half-breadth plans of modern lines drawings although the information that they convey about hull form is much less comprehensive.

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[19] Phillips 1987, 295.
[20] Mawer 2006.
[21] Burlet and Rieth 1988, 473.

The shapes of each of the designed frames were determined using a set of moulds and empirically-derived algorithmic scales that gradually increased the rising and narrowing of each frame as one moved from the master frame towards the tailframes, or the last designed frames forward and aft.[22] In order to produce lines with a fair curvature that gradually steepened towards the ends of the vessel, 15th-century Italian shipwrights had developed several methods of graphically determining the required algorithmic scales, including the *mezzaluna*, a pattern shaped like a half moon. The drawings in the *Instrucción náutica* clearly suggest the use of such a device to determine the shapes of the designed frames and to calculate fair narrowing and rising lines, but these techniques are not discussed in the text. García de Palacio specifies only that the deadrisings for the bow and the stern were to begin nine frames forward and six frames aft of the master frame and gives the height at which they were to intersect with the posts. He states only that their shape was "somewhat arched" but does not explain the method for deriving the appropriate curvature.[23]

Careful consideration of the text and plates suggests that the illustrations are only loosely related to the text. Of the 19 dimensions of the 400-*tonelada* ship mentioned in the text, only five correspond with the values depicted in the corresponding figures.[24] While it is clear that García de Palacio understood the importance of proportions for determining the tonnage, overall shape, and handling qualities of ships, the more technical aspects of ship design that are imbedded in the drawings are not discussed in

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[22] See Rieth 1996 for a thorough discussion of the method.
[23] García de Palacio 1944a, 116.
[24] Burlet and Rieth 1988, 472.

the text and seem to have escaped his comprehension. As mentioned above, García de Palacio does not address the means of determining the curvature of the bow, the frame shapes, or the rising and narrowing of the frames. Given the level of detail with which García de Palacio addresses other subjects such as rigging, the lack of discussion regarding these aspects of ship design is curious. Such techniques were closely guarded by shipbuilders and, without careful explanation, can seem inscrutable to even a patient observer.

The most plausible explanation is that the ship illustrations in the *Instrucción náutica* are not based on drawings made by García de Palacio himself, but were adapted from earlier manuscript sources or were provided to the author by expert informants. It is possible that García de Palacio had access to earlier manuscripts prepared by shipwrights or naval architects who were intimately familiar with the intricacies of ship design. Illustrations in early books often had only a tenuous relationship with the text, and reusing pictures from older manuscripts by inserting them into new books was common practice in the 16th century.[25] Other known contemporary shipbuilding manuscripts, such as Fernando Oliveira's *Livro da fábrica das naos* (ca. 1570-80) and Mathew Baker's "Fragments of Ancient English Shipwrightry" (ca. 1580), contain numerous illustrations of frame shapes, rising lines, and other elements of ship design similar to those embodied in the woodcuts of the *Instrucción náutica* (figs. 5.3 and 5.4). Interestingly, it is believed that Mathew Baker may have visited Mediterranean shipyards in Greece and Italy and that this experience is reflected in his approach to

[25] McKitterick 2003, 60.

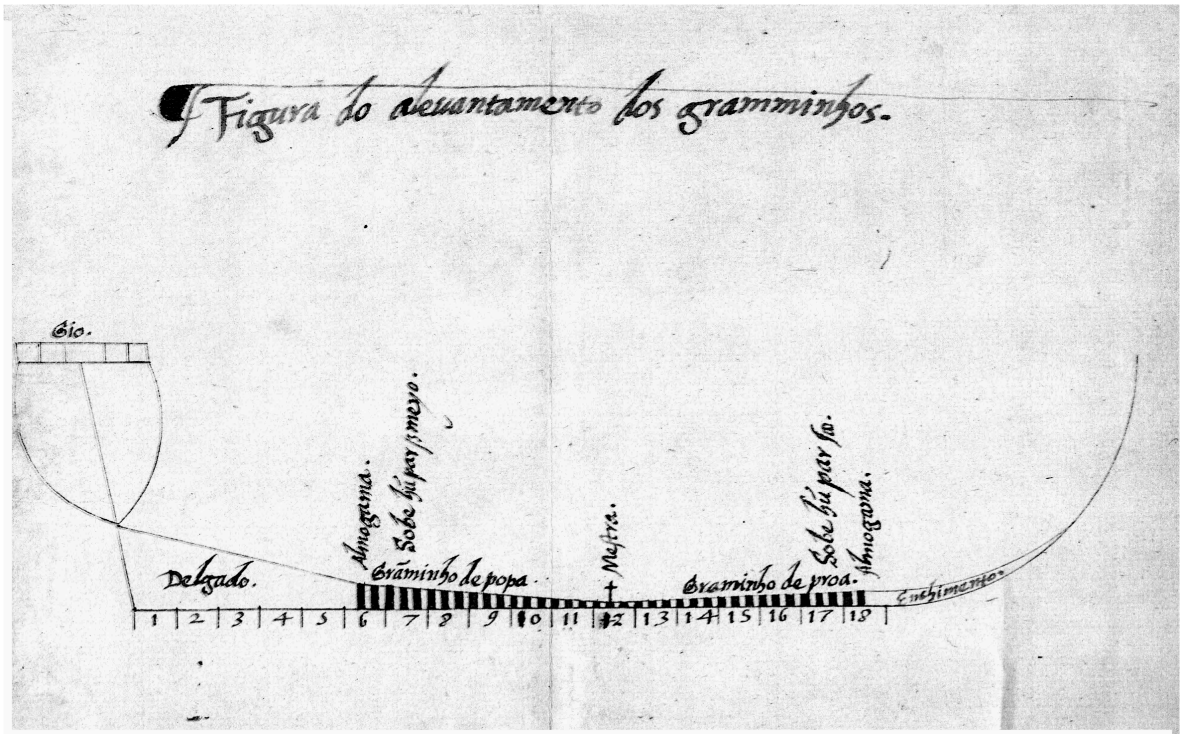

Fig. 5.3. Fernando Oliveira's method of calculating deadrising (ca. 1580).
Note the similarity to the sheer view of García de Palacio's 150-*tonelada* ship.
(After Oliveira 91, 99)

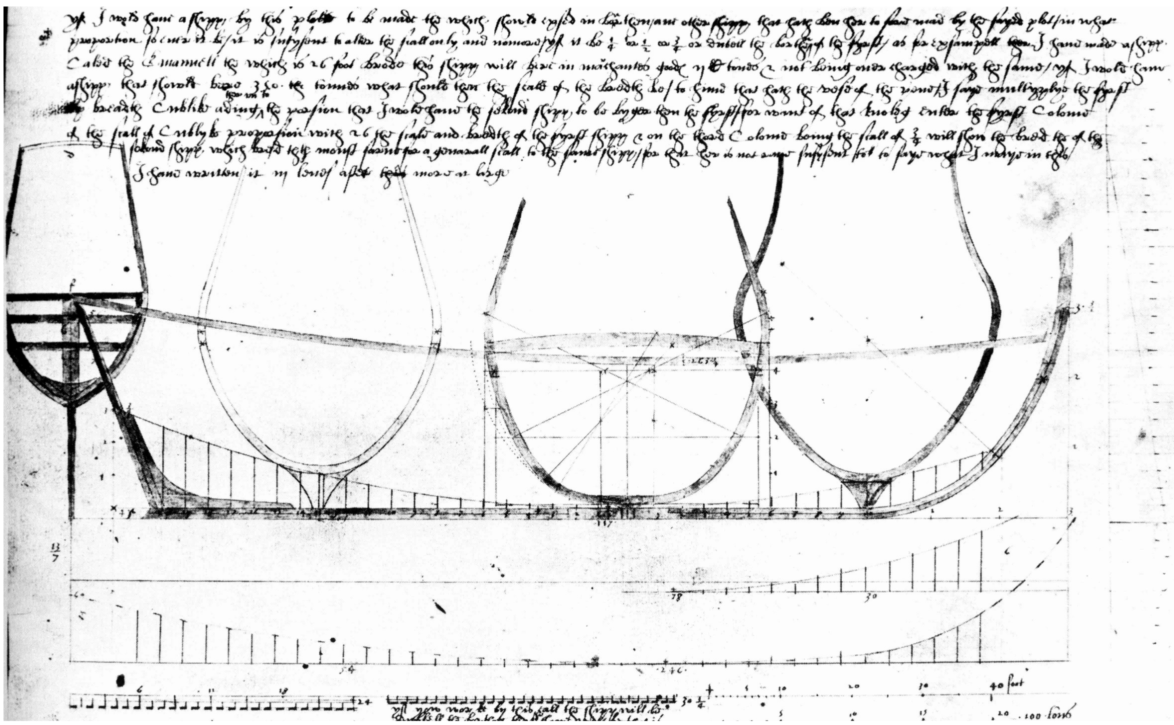

Fig. 5.4. Sheer view and sections of a ship from Mathew Baker (ca. 1580).
Note similarity to the method of portraying hull form used by García de Palacio.
(After Howard 1979, 51)

naval architecture.[26] Although no exact matches are known for the illustrations in the *Instrucción náutica*, these images have sufficient similarities to suggest some common lineage.

Despite the questions regarding their provenance, the illustrations in the *Instrucción náutica* can be considered reliable reflections of 16th-century ship design. René Burlet and Éric Rieth used the information embodied in the drawings of the 400-*tonelada* ship to recreate the form of the hull using a half-breadth scale model.[27] During this process, they noted a lack of symmetry in the drawings and distortion of up to 6 percent in the dimensions.[28] Because woodcut plates were made of softwood, the plates wore quickly, reducing the quality of later impressions.[29] In addition, most methods of woodblock printing involve placing the block face down on the paper and then hammering the back, causing the block to shift slightly and distorting the image. Despite these challenges, they were able to model the form of the ship based on these drawings, and the model was in turn used to recreate the hypothetical lines of the vessel. With some minor adjustments to the positions of the tailframes, Burlet and Rieth were able to produce a fair hull shape based on the information provided by García de Palacio. Preliminary reconstruction of the 150-*tonelada* ship by this author also yielded successful results that supported the reliability of the drawings.

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[26] Castro 2005, 41.
[27] Burlet and Rieth 1988.
[28] Burlet and Rieth 1988, 473.
[29] Lindley 1970, 13.

Assembling the Ship

Despite its importance for understanding 16th-century shipbuilding, in actuality the *Instrucción náutica* provides relatively little information regarding the process of building a vessel, particularly when compared to the level of detail provided by García de Palacio regarding a ship's rigging. The discussion of ship construction is limited to an inventory of the principal timbers of a ship, and no guidance is provided regarding the selection of appropriate materials, numbers or dimensions of scantlings, assembly sequence, methods of fastening, or other important details.

As enumerated by García de Palacio, the fundamental timbers of a ship included the following:[30]

- *codaste* (sternpost)
- *quilla* (keel)
- *roda* (stem)
- *estamenaras* (futtocks)
- *barraganetes* (top timbers)
- *forcazes* (stern crutches)
- *cinglones* (forward crutches)
- *baos* (beams)
- *latas* (carlings or ledges)
- *durmentes* (shelf clamps)
- *cintas* (wales)

[30] García de Palacio 1944a, 90.

- *madres* (core structural timbers)

- *corvatones* (hanging knees)

- *corvatones de reves* (lodging knees)

- *corvatones de gorja* (knees of the head)

- *contra quillas* (keelsons)

- *contra durmentes* (clamps)

- *aletas* (fashion pieces)

- *llaves* (standing knees)

- *vorne para la tablaçon del costado* (hull planks)

- *tablas para las cubiertas y camaras* (deck and cabin planks)

- *trancaniles* (waterways)

- *tacadas* (chocks)

There are a number of omissions in García de Palacio's list, the most obvious being the floor timbers. He does not use the typical Spanish term *varenga*, instead apparently including the floor timbers within the term *estamenaras*. The word *plan* appears in the Fourth Book and in the glossary to describe the flat portion of the floor of the hull. Many of the timbers included in the above list do not appear in the glossary (e.g., *barraganetes*, *forcazes*, *latas*, *madres*, *tacadas*), while other terms not included in this list appear only in the glossary, including *arbitana* (stemson), *buarcamas* (floor riders), *buçarda* (breasthook), and *palmejares* (thick stuff). Enough discrepancies exist between the text of the Fourth Book and the glossary to suggest the use of multiple sources in preparing the two sections.

Notably, many of the terms that García de Palacio uses to refer to the ship's timbers are of Mediterranean origin, with a possible Italian influence. For example, rather than using the more typically Spanish terms *genol* or *ligazon* to refer to the futtocks, García de Palacio chooses the word *estemenara*, from the Italian *estamanale*.[31] Similarly, he uses the Italian word *dragante* to refer to the transoms,[32] in preference to the more common Spanish term *yugo.* Rather than employing the Spanish terms *pique* or *horquilla* for the Y-shaped stern crutches, García de Palacio uses the term *forcaze*, after the Italian *forcazzi.*[33] The glossary also includes a number of terms that refer specifically to Mediterranean ship types, including *caraba*, "a large vessel, like those used in the Levant"; *esquilazo*, "a certain type of ship that is used in the Levant"; and *fustas*, "vessels used by the Moors and Turks."[34] Like the text, the woodcuts include some terms that are typically Italian. For example, the quarterdeck of the 150-*tonelada* ship is labeled with the Italian term *tolda*, rather than with the Spanish term *alcaçar*.

Because García de Palacio was born in Cantabria, the information presented in the *Instrucción náutica* is often assumed to be representative of the shipbuilding traditions of northern Spain. Based on what is known about García de Palacio's life and on the appearance of technical terms of Mediterranean origin in the text, this assumption must be carefully evaluated. Although the possibility cannot be discounted, García de Palacio would have had little cause to visit the shipyards of northern Spain while he was a young man preparing for a legal career. He never claims to have personally traveled in

[31] O'Scanlan 1974, 295.
[32] García de Palacio 1944a, 92; O'Scanlan 1974, 564.
[33] O'Scanlan 1974, 141.
[34] García de Palacio 1944a, 137v, 142, 144

the Mediterranean, and it is likely that most of his personal exposure to ship construction occurred during his sojourn in El Realejo, where the majority of the European residents may have been of Genoese origin (see Chapter II).[35] In addition to García de Palacio's direct experience with ship construction in Nicaragua, the text and images appear to reflect information from other unpublished shipbuilding manuscripts and consultation with expert informants. Did García de Palacio receive tutoring in shipbuilding from Genoese shipwrights while in El Realejo? Indeed, the overall impression is that much of the shipbuilding information embodied in the text and illustrations of the *Instrucción náutica* reflects a Mediterranean, and perhaps specifically Italian, influence. While the degree to which methods of ship construction differed between the Atlantic coast of Spain, Mediterranean Italy, and the Pacific coast of New Spain in the 16th century is difficult to determine, some caution must certainly be exercised regarding the geographical origins of the information contained in the *Instrucción náutica*.

What was the intent of García de Palacio, a colonial bureaucrat, in publishing a manual containing shipbuilding information that was already familiar to most of the skilled, but typically illiterate, workers in the shipyards? It is unlikely that the shipbuilding information provided in the *Instrucción náutica* would have attracted much interest from experienced shipwrights. The discussion would, however, have been of value and interest to a colonial elite who required a general understanding, rather than practical mastery, of such matters. Indeed, the *vizcaíno* specifically asks the *montañés* to discuss matters related to ships and their operation in a manner that is comprehensible to

[35] Salvatierra 1939, 302.

a layman, given the "amazement and consternation" with which these matters are held by those who do not understand them.[36] Similarly, architectural books published in the 16th century were read primarily by the elite, rather than by practitioners, and their publication did not lead to substantive changes in architecture or construction.[37] A handbook like the *Instrucción náutica* would have been helpful to a colonial administrator assigned to oversee a ship construction project, a situation that García de Palacio had personally experienced in El Realejo. Shipbuilding orders issued by viceroys usually specified only the general dimensions and tonnage of the ship, along with the authority to procure the required materials and labor.[38] While their control over the shipbuilding process was administrative rather than technical, insight into the specialized activities of the shipyard may have been of practical interest to such individuals.

[36] García de Palacio 1944a, 89.
[37] Morresi 1998, 265.
[38] Clayton 1980, 23.

CHAPTER VI

RIGGING

The *Instrucción náutica* includes a surprisingly accurate and exhaustive description of the spars, rigging, and sails of a 16th-century Spanish full-rigged ship. Among Iberian nautical texts, García de Palacio's descriptions appear to be unique in both the level of detail and the range of elements described. While a number of 16th- and 17th-century Iberian authors, including Juan Escalante de Mendoza and Tomé Cano, give proportional values for the lengths of masts, yards, and tops,[1] no other known source discusses the specifics of the running and standing rigging in a manner approaching the richness provided by García de Palacio. The descriptions correspond precisely with contemporary images of Spanish vessels and are extremely useful in interpreting this otherwise poorly documented aspect of seafaring technology.

Masts

García de Palacio specifies that masts must be chosen from straight, solid timbers without knots or other defects.[2] He recommends the use of pole-masts hewn from a single timber over "made" masts, while noting that the latter were common. The masts were to be lashed with wooldings every *codo* along their length to provide additional strength.[3] While mainmasts and foremasts were typically woolded, mizzen masts were

[1] Escalante de Mendoza 1985, 42-3; Cano 1964, 72-6.
[2] García de Palacio 1944a, 95.
[3] García de Palacio 1944a, 95.

not, and the bowsprit likely had a single woolding placed between the stem head and the gammoning.[4]

The masts discussed in the *Instrucción náutica* are indicated in figure 6.1. The lengths of the masts are given as proportions of the length of the keel, while the lengths of the yards are calculated relative to the maximum breadth of the midship frame. The examples given by García de Palacio are specifically calculated for the larger 400-*tonelada* ship. Notably, because the 150-*tonelada* and 400-*tonelada* ships have the same length of keel but differ significantly in length overall, breadth, depth of hold, and tonnage, the rules given by García de Palacio cannot be considered universally valid. The sizes of the spars proposed by García de Palacio, while plausible for the larger ship, are clearly too long for the 150-*tonelada* vessel. Although he mentions that the small 50-*tonelada fregatas* used in the Windward Islands were to have a mainmast no longer than their keel, no other guidance is offered by García de Palacio regarding an appropriate means of reducing the spars for smaller vessels.[5] Therefore, the formulas given in the *Instrucción náutica* should only be applied to other vessels with caution.

> The mast, or mainmast, of any ship, must have the length of the vessel's keel and rake, which according to our calculation, comes out to 46 *codos*; however, it may be somewhat less than the length of the keel and rake, and I always want it to be somewhat less, so that the ship becomes more seaworthy, and the rigging and masts more secure, and what is subtracted from it can be added to the topmast; because in tempests and times of need, it is less inconvenient and more useful.[6]

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[4] Anderson 1994, 28-9.
[5] García de Palacio 1944a, 91v.
[6] García de Palacio 1944a, 94v.

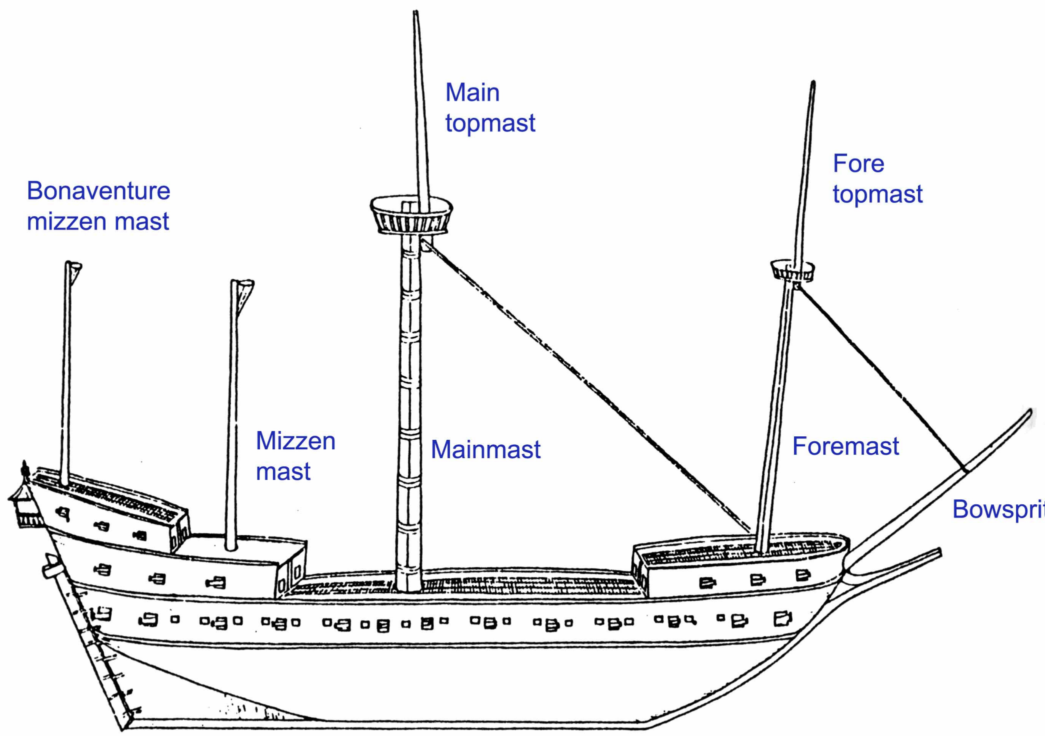

Fig. 6.1. Masts described in the *Instrucción náutica*. This drawing of a galleon is dated to 1589 and is from the Archivo General de Simancas. The masts are smaller than those proposed by García de Palacio, with the mainmast having approximately the length of the keel. (After Casado Soto 1991, 112)

Following the rule proposed by García de Palacio, the *mastil mayor* (mainmast) of the 400-*tonelada* ship should measure 46 *codos*, or about 25.6 m, in length. This results in a proportion of 3.3 to 1 for the length of the mainmast relative to the breadth of the vessel (46 *codos* to 14 *codos*). This is considerably greater than the length specified 30 years later in the *ordenanzas* of 1618, which state that the mainmast was to have the length of the keel plus 2 *codos*.[7] The tone of the passage implies that García de Palacio had discussed and debated the matter with others and that the proportions were not exact rules but guidelines with some leeway for adjustment. He gives his personal opinion that such a long mainmast was dangerous, and indicates his preference that it be shortened with the additional length added to the topmast. While the proportions specified by García de Palacio are extreme even by his own estimates, 16th-century Spanish vessels may have carried masts that would be considered overly long by later standards.

According to García de Palacio, the *trinquete* (foremast) is equal to the length of the keel (34 *codos*), or slightly more than three-quarters of the length of the mainmast. The height of the foremast relative to the mainmast seems to have gradually increased over time, possibly because mainmasts became shorter. According to the *ordenanzas* of 1618, the foremast was equal to the length of the mainmast minus 4 *codos*, which would require 42 *codos* for the vessel in question.[8] In the first half of the 17th century, Englishman Henry Mainwaring suggested that the height of the foremast should be four-fifths that of the mainmast,[9] which would give a value of about 37 *codos*.

García de Palacio's *baupres* (bowsprit) and *messana* (mizzen mast) are each one-fifth shorter than the foremast. At this time, the bowsprit would have been stepped to one side of the foremast, and would have rested on a bowsprit pillow rather than on the

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[7] Phillips 1986, 231. Anderson gives a typical proportion for 17th-century vessels as 2.5 times the breadth of the mainmast for large ships or up to 3.0 times the breadth for smaller vessels (Anderson 1994, 15).
[8] Phillips 1986, 231.
[9] Manwaring and Perrin 1922, 186.

stem.[10] As shown in figure 6.1, the bowsprit was typically steeved at an angle anywhere between 30º and 45º, with the angle slowly decreasing over the course of the 16th century.[11] No spritsail topmast is mentioned by García de Palacio; their earliest known appearance on Spanish ships was in 1611.[12]

García de Palacio also calls for a *contra messana* (bonaventure mizzen), the smallest, aftermost mast on a four-masted ship, which he gives a length one-third less than the mizzen. As observed by Mainwaring, "some great long ships require two mizzens."[13] While García de Palacio does not mention the use of a boomkin, they are common in the images of the period, and one may have been required to lead the sheets for the aftermost mizzen sail.

The *gavia* (topmast) has a length one and one-half times the breadth of the midship frame, or 21 *codos*, which is reduced by one-fifth to about 17 *codos* for the fore topmast. Mainwaring suggests that the topmasts should be about half as long as the masts to which they are attached,[14] resulting in values of 23 *codos* for the main topmast and 17 *codos* for the fore topmast, which correspond well with the values given by García de Palacio.

As noted above, the topmasts could be removed in bad weather, suggesting that they were not lashed to the lower masts as in earlier periods, but that a mast cap was used to simplify the process of striking the upper spars. Although the first appearance of the mast cap is unknown, according to popular lore, the mast cap was first introduced

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[10] Manwaring and Perrin 1922, 198.
[11] Howard 1979, 63.
[12] Phillips 1986, 71.
[13] Manwaring and Perrin 1922, 188.
[14] Manwaring and Perrin 1922, 246; see also Anderson 1994, 44.

into England by John Hawkins in the 1570s in order to allow the topmasts to be lowered at sea.[15] Their earliest appearance on Spanish ships is uncertain. Because García de Palacio specifically mentions that the ties must pass through sheaves set into the cheeks of the masts, it is unlikely that rounded mast caps designed for holding the ties were used. Instead, it is probable that simple rectangular mast caps were used at the heads of the mainmast and foremast.

Topgallant masts and mizzen topmasts are not mentioned. While mizzen topmasts were used during the reign of Henry VIII, they seem to have served primarily as flagstaffs and had virtually disappeared by the late 16th century.[16] Although the Spanish used topgallant masts in the 16th century,[17] they were only carried on very large ships and are not mentioned by García de Palacio for the 400-*tonelada* vessel. The lengths of the various masts are summarized in table 6.1.

Yards

An *entena* or *verga* (yard) is a long straight spar, round in section, attached perpendicularly to the mast that is used to support and spread the sails. During the early 16th century, Iberian vessels carried yards composed of two overlapping pieces seized with wooldings, but these seem to disappear by about 1530 in favor of single-piece yards.[18] Like the masts, the lengths of the yards are calculated as proportions of the hull

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[15] Howard 1979, 64.
[16] Howard 1979, 65.
[17] Phillips 1986, 71.
[18] Mondfeld 1989, 230; Smith 1993, 103.

by García de Palacio, although the maximum breadth rather than the length of the keel is used as the basic measurement. The lengths of the yards are given in table 6.2.

Table 6.1. Proportional lengths of masts from the *Instrucción náutica*.

Mast	**Proportion**	**Length**
Mainmast *Mastil mayor*	length of keel and rake	46 *codos*
Foremast *Trinquete*	length of keel	34 *codos*
Bowsprit *Baupres*	1/5 less than length of foremast	28 *codos*
Mizzen mast *Messana*	equal to bowsprit	28 *codos*
Bonaventure mizzen *Contra*	1/3 less than length of mizzen mast	19 *codos*
Main topmast *Gavia*	breadth plus one half	21 *codos*
Fore topmast *Borriquete*	1/5 less than length of main topmast	17 *codos*

According to García de Palacio, the main yard was to be as thick in the middle as the mainmast. This would seem enormous by modern standards. However, Carla Rahn Phillips notes that in practice, some 17th-century Spanish yards were made 25 to 50 percent thicker than the values prescribed in the 1618 *ordenanzas*.[19] The reason for this preference for heavy yards is not known. The yards may have had stepped yard arms to

[19] Phillips 1986, 73.

prevent the braces, lifts, and clews from sliding inwards, as wooden sling cleats did not become common until the 17th century.[20]

Table 6.2. Proportional lengths of yards from the *Instrucción náutica*.

Yard	**Proportion**	**Length**
Main yard	2 1/3 times breadth	33 *codos*
Fore yard	1/3 less than main yard	22 *codos*
Main topsail yard	equal to breadth	14 *codos*
Fore topsail yard	1/3 less than main topsail yard	9 *codos*
Spritsail yard	3/4 less than fore yard	16.5 *codos*
Mizzen yard	length of mizzen mast plus 1/3	36 *codos*

Standing Rigging

The standing rigging formed an adjustable framework that was used to fix the masts against the enormous strains of the yards and sails. García de Palacio provides an exceptional amount of detail regarding not only the arrangement of the standing rigging, but also the appropriate weights of the lines used for each component.

Obenques (shrouds) are heavy lines running from the mastheads to the sides of the vessel or the tops to brace the masts laterally. While medieval ships had their shrouds fastened inboard, the development of the full-rigged ship required that the shrouds be moved to the outside of the hull to reduce the tension on the standing

[20] Anderson 1994, 56; Mondfeld 1989, 230.

rigging.[21] According to García de Palacio, 12 shrouds were needed on each side of the mainmast, while the foremast had eight shrouds per side.[22] While excessive by modern standards, evidence suggests that early 16th-century vessels carried large numbers of shrouds, which may have been required given the length of the masts.[23] Peter Kirsch suggests that improvements in the quality of rope may be the cause for the steady decrease in the number of shrouds from the 16th to the 18th centuries.[24] The shrouds were linked and joined together with *enflechantes* (ratlines) to form a ladder for climbing to the tops. No shrouds are mentioned for the mizzen mast, although it is possible that movable tackles were fastened inboard onto iron rings in the bulwarks.

The lower tackles of the shrouds consisted of iron *eslabones* (chains) that were securely bolted to the hull. García de Palacio describes chains consisting of four or five links, each measuring about a *palmo* (21 cm) in length.[25] The uppermost link of each chain was formed into a teardrop-shaped strop fitted around a *vigota* (wooden deadeye or heart block). The term *vigota*, used frequently by García de Palacio, appears to be a generic term that could refer to deadeyes, thimbles, or hearts depending on the context. Each shroud had a matching *vigota* spliced into its end that was attached to the corresponding chain with an *acollador* (lanyard). As the shrouds stretched due to strain or moisture, they could be tightened by shortening the lanyards.

In order to reduce abrasion, the chains were held away from the hull by heavy timbers called chainwales. García de Palacio specifies that the *mesas de guarnición*

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[21] Smith 1993, 99.
[22] García de Palacio 1944a, 98.
[23] Howard 1979, 66.
[24] Kirsch 1990, 43.
[25] García de Palacio 1944a, 98.

(chainwales) for the mainmast were to be placed on the uppermost wale, in order to ensure that the shrouds were spread as much as possible to reduce strain and to diminish wear.[26]

García de Palacio discusses the use of futtock shrouds, which he also calls *obenques*, for fastening the topmasts. The main topmast had six per side, while the fore topmast had five.[27] The deadeyes for the futtock shrouds projected above the rim of the top and were fastened with ropes measuring a fathom in length. It is likely that these futtock shrouds consisted of deadeyes spliced into ropes seized to the shrouds below, unlike in later periods, when futtock shrouds were fitted onto the lower shrouds with iron hooks.[28]

Notably, García de Palacio provides what is possibly the first reference to bobstays or bowsprit shrouds, which he calls *blandeles*: "…in order to fortify the bowsprit, two thick cables are installed… on each side."[29] In the early 17th century, Mainwaring stated that "the boltsprit hath no shrouds."[30] Elsewhere these features have been considered an innovation of French origin first appearing in the late 17th or early 18th century.[31]

Another interesting rigging component mentioned in the text is the *amantes* (pendant tackles or runners):

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[26] García de Palacio 1944a, 98.
[27] García de Palacio 1944a, 99v.
[28] Howard 1979, 67.
[29] García de Palacio 1944a, 101.
[30] Manwaring and Perrin 1922, 226.
[31] Lees 1979, 159; Mondfeld 1989, 276.

> where [the shrouds for the mainmast] join the top, another three ropes of 60 strands must come out on each side, which they call pendants, and have half of the length of the mast, and there is a block at the end of each one, with a single sheave, and through each block is passed another line, of 40 strands, that they call a runner, long enough to reach the deck of the ship, and this will also have a block with two sheaves, and through it will be passed a line of 24 strands, which passes through another block with another two sheaves, which will be as long as the said runner, and this last block, will be fastened to a brace of strops, and it and the runners will be fastened to a timber which they call a chain rail, which is fixed in the side above the aforementioned chainwales…[32]

Similar tackles are described for the foremast and main topmast. Tackles like those discussed by García de Palacio were found lashed to a timber above the chainwale on the *Mary Rose*, a large English warship that sank in 1545 (fig. 6.2). Such tackles could have been used for hauling boats and cargo and would also have served to reinforce the masts in a manner similar to backstays.

The arrangement of the *estays* (stays) is also clearly described by García de Palacio. Stays consist of strong ropes used to support the masts along the longitudinal axis, leading from the mastheads to attachment points at the bow and stern of the vessel where they were lashed to blocks, deadeyes, or hearts. Interestingly, he mentions the use of a *contra estay*, apparently an early form of preventer or spring stay, that was lashed to the same block to reinforce the mainstay.[33] The earliest evidence for the use of preventer stays cited by R.C. Anderson comes from Dutch etchings dating to about 1650.[34] However, the type of preventer stay discussed by García de Palacio differs from the typical later design. Later preventer stays run well above the main stay and are fixed to the foremast, rather than the knee of the head, making them completely independent.

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[32] García de Palacio 1944a, 98-8v
[33] García de Palacio 1944a, 99.
[34] Anderson 1994, 96.

The line discussed by García de Palacio is lashed to the same point at the knee of the head as the main stay, requiring that they both run at the same level.

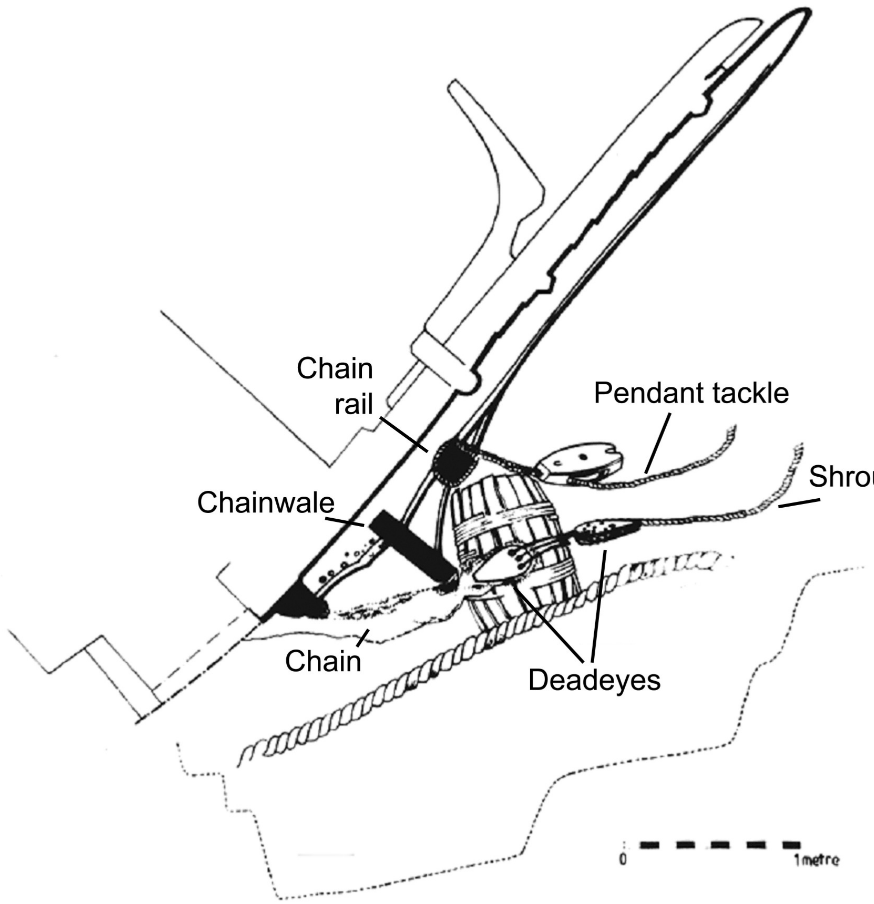

Fig. 6.2. Chain assembly of *Mary Rose* (1545). Note intact shroud with teardrop-shaped deadeyes and pendant tackle lashed to chain rail. (After Rule 1982, 141)

Running Rigging

At the time that García de Palacio wrote the *Instrucción náutica*, a tie and halyard system was used to lower the heavy yards whenever bonnets were added or removed to lengthen or shorten the sail. García de Palacio provides a detailed description of the *ustagas* (ties), heavy ropes fastened to the center of the yards that were run through sheaves set into the cheeks of the mast and which ended in a large block. The *triça* (halyard) was fed through the block and used when raising and lowering the sails and yards.

Amantillos (lifts) were attached to the yardarms assisted in raising the yard. More importantly, they were used to adjust the yardarms so they sat perpendicular to the mast. According to García de Palacio, "lifts serve to support and hold the main yard straight like a cross."[35] *Braças* (braces) were also attached to the yardarms and were used to adjust the horizontal swing of the yards when shifting the sails around the mast. *Escotas* (sheets) were attached to the clews, or lower corners, of the sails and were used in conjunction with the braces to hold the lower edge of the sail against the wind.

Escapuchines (tack lines) were attached at the same points on the sails as the sheets, but ran forward to counteract the effect of the sheets by holding the clews forward when sailing close-hauled. *Volinas* (bowlines) had a similar function as the tack lines, but were attached midway along the leech of the sails and led forward to the bowsprit. They held the weather edge of the sail steady when sailing close-hauled.

Sails

The mainmast and foremast carried square sails, while the mizzen and bonaventure masts required lateen sails, and a small square sail was mounted on the bowsprit. The *Instrucción náutica* provides a series of illustrations shows the form of

[35] García de Palacio 1944a, 100v.

the *papahigo* (mainsail) and its *boneta* (bonnet), the *vela de gavia* (main topsail) and the *vela de mezana* (mizzen sail) (figs. 6.3 and 6.4). The drawings clearly illustrate how the sails were formed from long strips of canvas joined together lengthwise, with the edges of the sail folded over to form tablings to which the bolt ropes were affixed.[36] Figure 6.5 shows a late 16th-century Spanish ship carrying sails identical to those described by García de Palacio.

The mainsail and bonnet were rectangular, while the topsail had a trapezoidal shape. Looped ropes, called *puños*, were attached to the leeches of the mainsail to act as attachment points for the sheets and tacks and for the bonnet (fig. 6.3). The bonnet was attached by first passing the large ropes attached to its upper corners through the lower loops. Next, the series of *caxetas* (loops) sewn into its upper edge were laced through a series of corresponding holes in the lower edge of the mainsail. Every tenth loop is marked with the word *clave* (key) and designated with a letter in the progression A-M-G-P, which was marked on both the bottom of the mainsail and the top edge of the bonnet. These letters stood for *Ave María, Gratia Plena* ("Hail Mary, full of grace"), and served to ensure that the sailors connected the bonnet to the proper points on the mainsail.[37] This method of attaching the bonnet ensured that it could be released quickly in bad weather.

[36] Smith 1993, 104.
[37] Smith 1993, 106.

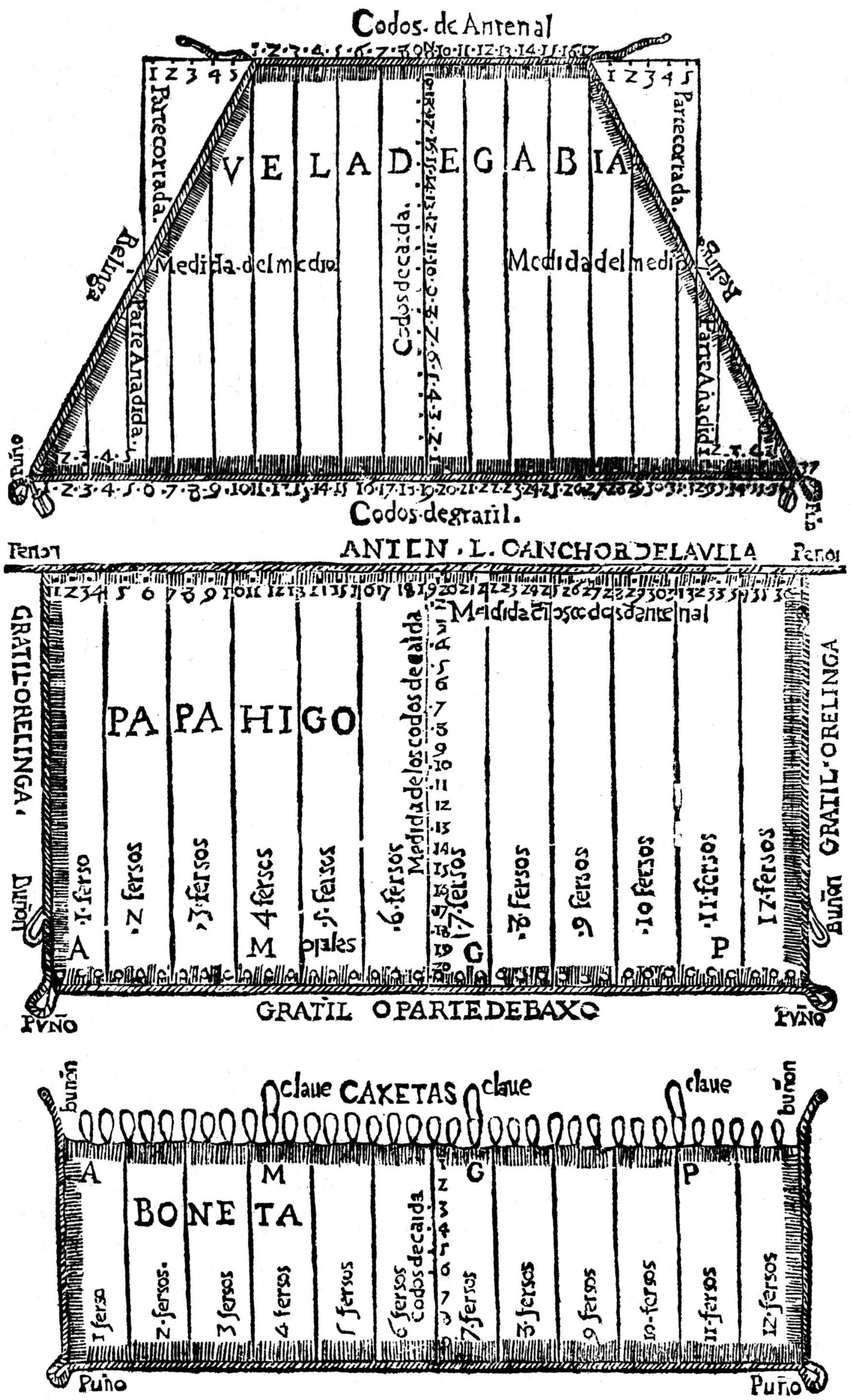

Fig. 6.3. Square sails from the *Instrucción náutica*. From top to bottom, these are the main topsail, main course, and bonnet for the main course. (After García de Palacio 1944a, 104-4v, 106v)

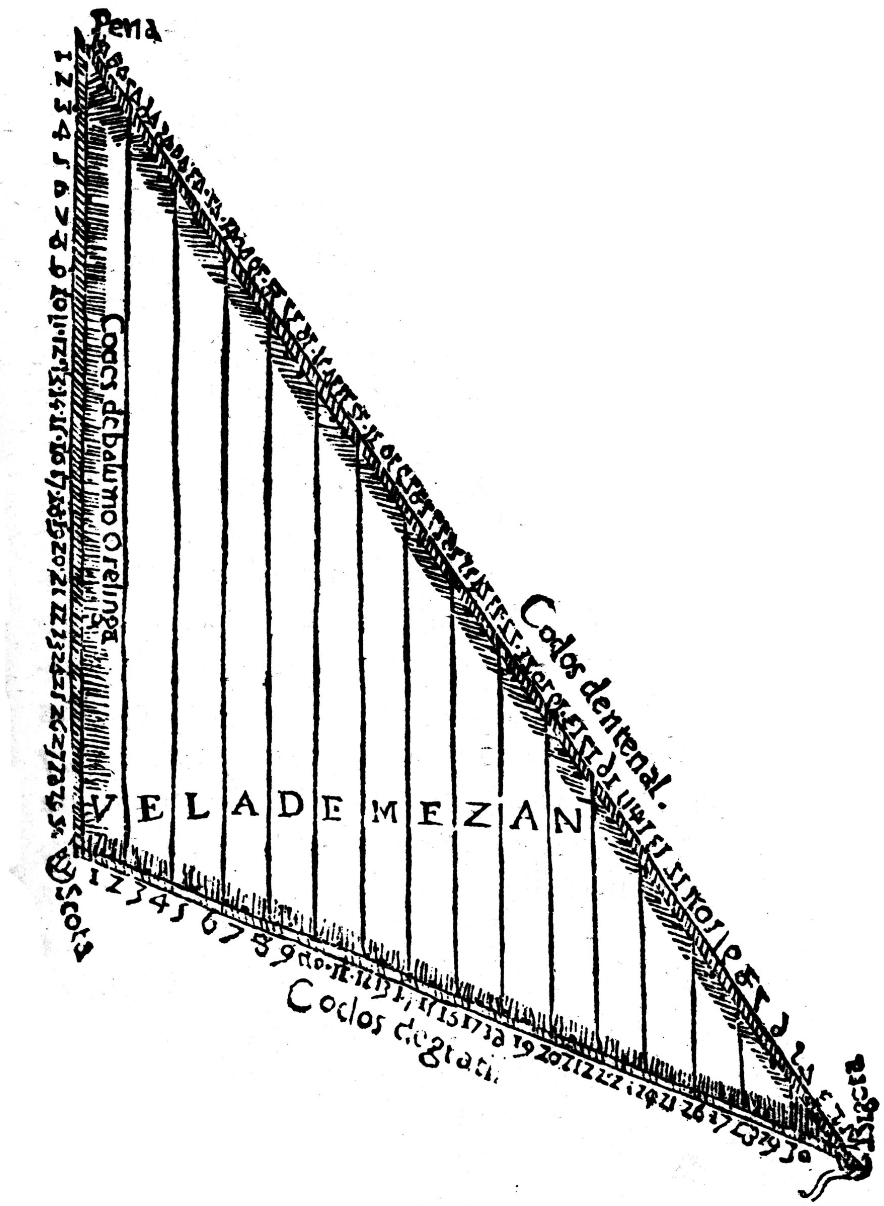

Fig. 6.4. Mizzen sail from the *Instrucción náutica*. (After García de Palacio 1944a, 107)

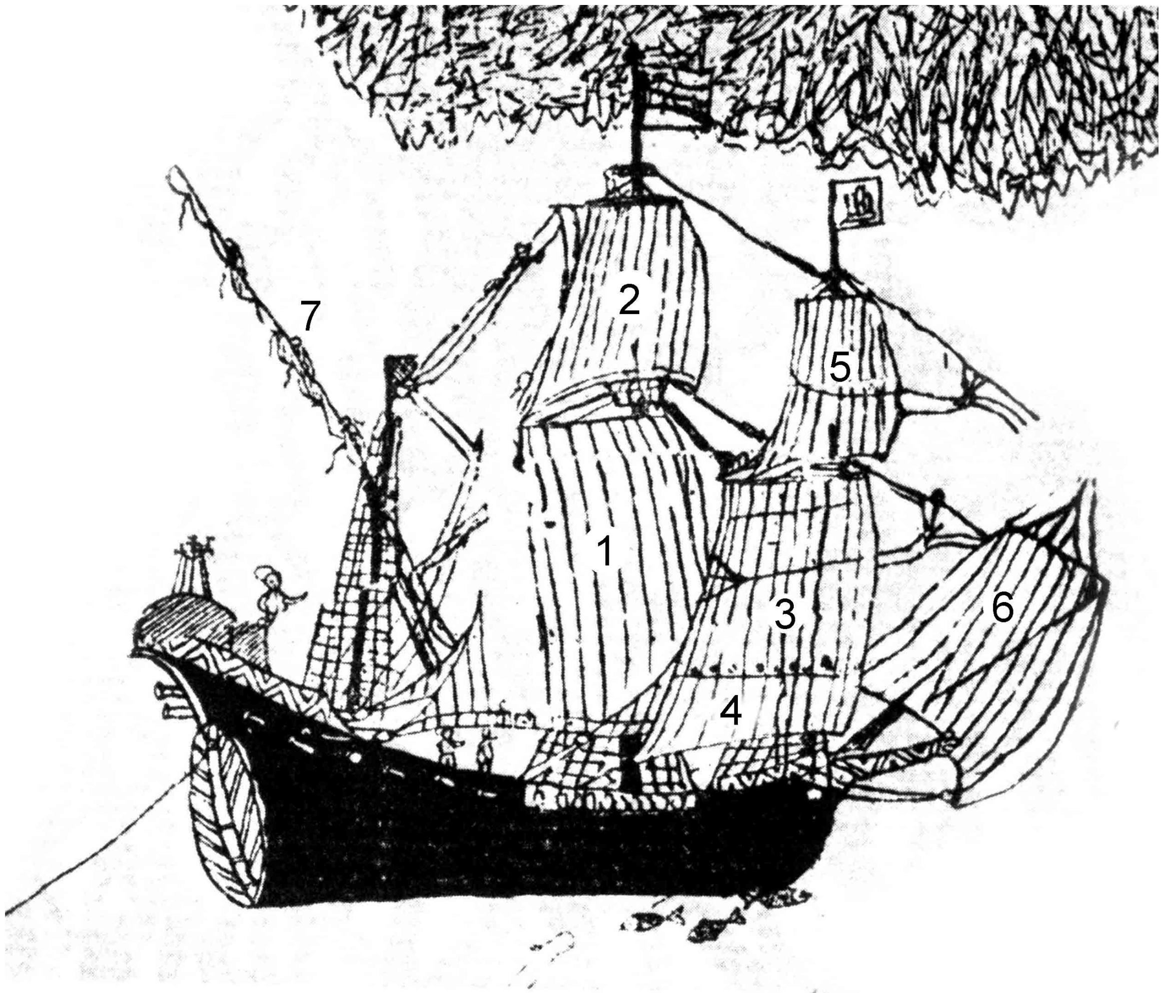

Fig. 6.5. Late 16th-century Spanish galleon. Note the similarity between the sails and those illustrated in the *Instrucción náutica*: 1. mainsail; 2. main topsail; 3. foresail; 4. foresail bonnet; 5. fore topsail; 6. spritsail; 7. mizzen sail furled to the yard. There is no bonaventure mizzen mast. Many elements of the standing and running rigging, including the shrouds, stays, lifts, braces, sheets, and bowlines are also clearly shown. (After Phillips 1986, 45)

The illustration of the topsail clearly shows how its characteristic trapezoidal shape was derived from a rectangular sail (fig. 6.3). The text explains the process in detail. The initial width of the sail was the average of the lengths of the topsail yard and the mainsail yard.[38] The portions of the sail that exceeded the length of the topsail yard were cut diagonally to a point halfway down the leech. The two triangular pieces were then inverted and stitched to the lower edges of the sail. A more complicated explanation is given for deriving the shape of the mizzen sail from the length of the mizzen yard.

The significance of the *Instrucción náutica* for understanding 16th-century Spanish rigging cannot be overstated. Compared to the brief discussion of the construction of the 400-*tonelada* hull, which is limited to an enumeration of the major structural timbers, this section of the text is painstakingly thorough. Considering García de Palacio's natural curiosity and demonstrated talent for producing accurate written descriptions of complex phenomena based on direct personal observation, it is possible to imagine that this section is the product of an active and inquisitive mind held captive during a long oceanic voyage. While it is not known what sources García de Palacio may have consulted, this appears to be the most original section of the entire document.

[38] García de Palacio 1944a, 105.

CHAPTER VII

OFFICERS AND CREW

Twelve chapters of the Fourth Book are dedicated to describing the desirable qualities and assigned responsibilities of the officers, petty officers, and crew, providing a detailed account of the social hierarchy found aboard a 16th-century Spanish ship. Using a favored metaphor of Renaissance scholars, García de Palacio compares a ship to a human body, with the timbers forming the skeleton, the rigging serving as the nerves, and the sails representing the tissues. He continues on to compare the crew to the soul of the ship, with the officers serving as the faculties because, "as in man, some are controlled by others."[1]

His discussion describes the personnel of a typical merchant vessel, rather than a warship,[2] and as such omits many of the positions characteristic of naval fleets, including, for example, the *capitán general* (fleet commander), the *almirante* (admiral), and the *soldados* (infantrymen), who formed a separate fighting force under the command of their own officers.

Officers

A ship's captain (*capitán*) on a 16th-century Spanish ship was often an owner of the vessel and was not necessarily expected to have extensive nautical expertise. It was not unusual to find a well-connected *hidalgo* or a respected military officer with little

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[1] García de Palacio 1944a, 89; Bankston 1986, 114.
[2] García de Palacio 1944a, 120.

seafaring knowledge in command, although he was expected to consult with the more experienced officers on important matters. Notably, García de Palacio's reference in the *Instrucción náutica* to the discussion of the qualities of a captain that he had provided in the *Diálogos militares* indicates that there was little difference in the qualities desired of a captain whether on land or at sea.[3] Pablo Pérez-Mallaína describes the typical captain as "a distinguished gentleman who traveled on board like a passenger, by which [appointment] they intended to do him honor but not to assign him to a post with real authority."[4] García de Palacio may have written the *Instrucción náutica* in part to prepare such individuals for life at sea.

The ideal captain was a devout Christian, modest, honest, and discreet. Unless sailing in a fleet, he was the ultimate disciplinary authority, although he was required to turn violent criminals over to the Crown rather than administering justice himself.[5] While the captain had general responsibility for and control over the ship and the men, García de Palacio is careful to specify that he was to defer to the pilot on all matters relating to navigation.

Unlike the captain, the *maestre* (master) had to be an experienced seaman since he was directly responsible for the handling of the ship. In addition to ensuring the proper functioning of the crew and equipment, the master of a merchant ship had a number of administrative responsibilities, such as ensuring that the cargo, ballast, and provisions were properly laded and that adequate supplies of food and drink were

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[3] García de Palacio 1944a, 111.
[4] Pérez-Mallaína 1998, 92.
[5] García de Palacio 1944a, 111v.

acquired for the voyage.[6] However, unlike in the Mediterranean, where these administrative duties overshadowed the master's role in the sailing of the ship, in the Indies "the master was a mariner first and the ship's business manager second."[7] The master was also expected to be able to carry out the duties of the captain or the pilot on ships that lacked either of these officers.[8]

Third in command was the *piloto* (pilot), who was responsible for setting the course and navigating the ship to its destination. The activities of the pilot were related to the navigational techniques described in Chapter IV. García de Palacio uses this opportunity to rail against the irresponsibility of pilots who undertook their duties without sufficient training or experience and he explicitly contends that anyone can use published documents to become a moderately skilled pilot.[9] According to the *Instrucción náutica*, the ideal pilot was an older man with extensive experience and preferably some training in astrology, mathematics and cosmography. He had to constantly anticipate changes in weather and sea conditions that could affect the course, adjust the rudder and sails as required, and ensure the security of the rudder and foremast, which were crucial to proper steering. Because of the danger to all those on board should the pilot fail in his duty, he was required to be exceptionally brave, but also wary of potential dangers from storms and running ashore. While he was expected to undertake his duties with confidence, he was also encouraged to consult with the other officers and the most experienced seamen in uncertain situations. Even the best pilots

[6] García de Palacio 1944a, 112.
[7] Phillips 1986, 127.
[8] Escalante de Mendoza 1985, 57.
[9] García de Palacio 1944a, 112v.

relied on dead reckoning, which was an inexact art, so pilots sailing in fleets consulted frequently with each other. Pilots who lost a ship as a result of misconduct or neglect could face the death penalty.[10]

Petty Officers

The highest ranking of the petty officers was the *contramaestre*, or master's assistant. This position combined the responsibilities of a boatswain with many of those of a quartermaster. The primary responsibility of the *contramaestre* was to communicate the orders given by the master and pilot to the crew. According to García de Palacio, he was also responsible for ensuring that all cargo and ballast was properly placed in the ship and for entering all merchandise into the manifest, requiring that he be literate.[11] In port, he ensured that the cables and the sails were kept dry and free of vermin. In the evening, he ensured that the cooking fire was extinguished, the pumpwell was emptied, the boats were secured, the hatchways were closed, and the rigging was inspected and properly set. While on watch, he was responsible for supervising the tackle forward of the mainmast. His typical station was at the foot of the mainmast, where he could hear the pilot and relay his orders to the crew with his whistle.[12] In return for his extensive responsibilities, he was accorded the honor of sitting with the officers at the head of the table during meals.

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[10] Phillips 1986, 131.
[11] García de Palacio 1944a, 113v.
[12] Phillips 1986, 134.

The *guardián* was the assistant to the *contramaestre*, occupying a position analogous to that of a boatswain's mate. An experienced sailor, he helped to relay the orders to the crew and assisted in the inspection and maintenance of the rigging while at sea and of the cables and sails when in port. He had to maintain order among the apprentices and pages, and was expected to be strict to ensure that they would respect him.[13] He had direct authority over the operation and maintenance of the ship's boat, and assembled crews of apprentices to fetch cargo, water, and firewood.

The *despensero* (steward or purser) oversaw the stores of food, alcohol, and water, and García de Palacio therefore hoped that he would be a man with moderate eating and drinking habits.[14] He supervised the distribution of the daily rations and may have been directly responsible for food preparation as no specialized cooks are enumerated among the personnel of Spanish vessels.[15] Indeed, García de Palacio specifically mentions that he was responsible for ensuring that any salted fish and legumes that were to be consumed the following day were put to soak. The *despensero* also supervised the pages in reciting the evening prayers and trimming the lantern wicks.

The *carpintero* (carpenter) was responsible for keeping the ship in good repair while at sea. In addition to being able to repair the hull and rudder, he had to know how to design and build a replacement for the ship's boat, as well as blocks and other tackle as required. Somewhat surprisingly, he was recruited from the ranks of the sailors,

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[13] García de Palacio 1944a, 115.
[14] García de Palacio 1944a, 115v.
[15] Pérez-Mallaína 1998, 81; Phillips 1986, 136.

rather than from the shipyards, as García de Palacio considered experience at sea to be more important in making repairs than specialized carpentry skills.[16]

Whenever possible, the *calafate* (caulker) was also expected to be an experienced mariner. In addition to repairing leaks in the hull with oakum, pitch, and lead sheeting, he was given special responsibility for maintaining the pump. In port, he was expected to maintain the caulking of the decks, ceiling, and hull planking to ensure that they remained watertight.

García de Palacio assigned the roles of *barbero* and *chirujano* to a single position (barber-surgeon). Ideally, the *barbero* was to have some experience in the treatment of ailments typically encountered on ships, such as fevers, seasickness, ulcers, and injuries resulting from life at sea.[17] The *barbero* would have also trimmed the men's hair and beards for a small fee.[18]

The position of *condestable* (master gunner) was found on both merchant vessels and warships. The *condestable* was responsible for maintaining the artillery and munitions and supervising the *lombarderos* (gunners). He was expected to be knowledgeable not only in the operation of the guns but also in the manufacture of gunpowder, shot, and incendiary devices. The *lombarderos* fell somewhere above the sailors in the shipboard hierarchy. Unlike the soldiers that were carried on warships, the gunners were part of the naval chain of command and were required to be expert sailors as well as skilled artillerymen.[19] The gunners maintained the guns and their carriages

[16] García de Palacio 1944a, 116v.
[17] García de Palacio 1944a, 117v.
[18] Phillips 1986, 139.
[19] Pérez-Mallaína 1998, 79.

and ensured that adequate supplies of powder and shot were always on hand. Each gunner could be responsible for a many as six or seven guns which were operated with the assistance of less experienced sailors and soldiers.[20] Many *lombarderos* and *condestables* were foreigners who had served as mercenaries in the Spanish military, and it was not unusual to find Germans, Flemings, and Italians in these positions.[21]

Crew

The designation *marinero* (able seaman) was reserved for men who had the experience required to steer the ship and work the rigging. Most sailors were in their mid-20s, although some served until the age of 50 years.[22] As in other times and places, sailors in the 16th-century Spanish empire were not held in high esteem, and had a reputation as coarse and illiterate men. However, a considerable amount of skill was required to carry out their duties effectively. According to García de Palacio, sailors had to be able to steer the helm, make and attach any rigging line or sail, mount the topmasts, attach and remove the bonnets, stow cargo in the hold, handle the ship's boat, and manage the cables and anchors.[23] To stand watch, he was also expected to possess basic navigational skills, including reading the compass and setting a course, taking sightings with an astrolabe or quadrant and predicting the effects of the moon and the tides.

García de Palacio provides approximate manning ratios for the sailing crews of ships ranging from 100 to 600 *toneladas* in size, which are summarized in table 7.1. While these numbers may have been adequate for merchant vessels, warships would

[20] Phillips 1986, 145.
[21] Pérez-Mallaína 1998, 79.
[22] Pérez-Mallaína 1998, 78.
[23] García de Palacio 1944a, 119-9v.

Table 7.1. Crew ratios from the *Instrucción náutica*.

	100 – 300 *toneladas*	**300 – 500 *toneladas***	**500 – 600 *toneladas***
Able seamen *Marineros*	20	35	50
Apprentice seamen *Grumetes*	13	23	33
Pages *Pajes*	2	4	5
Total	35	62	88

have been much more heavily manned. On routes with high mortality rates, it is likely that additional men were recruited at the outset of the voyage to ensure that the crew would remain operational as their numbers were reduced by illness, combat, and desertion.

The number of *grumetes* (apprentice seamen) was equal to two-thirds of the number of *marineros*. The majority of the apprentices were young men between the ages of 16 and 20 years,[24] although their ranks included some older men who had failed to attain the status of *marinero*. The apprentices did much of the heavy labor on the ship, such as hoisting yards, climbing aloft to trim the sails, working the pumps, and handling the anchors and cables.[25] They also served as the crew for the ship's boats and might be sent to fetch cargo, water, or supplies from shore. According to the *Instrucción náutica*, they were expected to be familiar with all of the parts of the rigging, to execute

[24] Phillips 1986, 143.
[25] García de Palacio 1944a, 119v.

the commands of the pilot and master, and to be able to splice ropes. As mentioned above, the apprentices fell under the direct command of the *guardián*, who was authorized to use fear of the lash to ensure that they were appropriately diligent in their duties and lessons. At about 20 years of age a diligent apprentice could expect to receive a document signed by the ship's officers that certified his elevation to the level of *marinero.*[26]

For every 10 *marineros,* a ship was expected to carry one *paje* (page), who were ideally boys between the ages of 12 and 16 years.[27] García de Palacio distinguishes between two types of pages.[28] The first group was of higher social standing and acted as personal servants for the officers.[29] They were often relatives of the officers or owners of the ship, and were groomed to take on positions of authority when they reached an appropriate age. The second group of pages were typically orphans or from poor families. They were responsible for sweeping the decks and cabins, setting up the mess table, serving the meals, and manufacturing cordage. Under the supervision of the *despensero*, they also recited prayers each morning and evening. Although not mentioned by García de Palacio, they were expected to stand watch with the other sailors, and were responsible for turning the sandglass every half hour.[30] Any *marinero* or *grumete* could order a page to help them with their work as required.

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[26] Pérez-Mallaína 1998, 78.
[27] Escalante de Mendoza 1985, 50.
[28] García de Palacio 1944a, 120.
[29] Phillips 1986, 143.
[30] Phillips 1986, 144.

CHAPTER VIII

NAVAL TACTICS

In order to supplement his discussion of the personnel and operations of a merchant vessel (see Chapter VII), García de Palacio uses the final three chapters of the *Instrucción náutica* to describe naval ships and fighting tactics. His explanation of naval strategy is interesting because it was published 16 years after the Battle of Lepanto, the last major naval battle that relied on ramming and boarding, and just one year before the Spanish Armada of 1588, where the English victory is popularly accepted to have been partly a result of their strategy of standing off from the Spanish ships and battering them with long-range guns.[1] Thus, the *Instrucción náutica* is situated at the cusp of the transition between early methods of naval warfare, which relied on boarding and hand-to-hand combat, and the development of broadside tactics dependent on artillery fire.

In considering this section of the text, it is worth recalling that García de Palacio, although twice appointed *capitán general* of fleets sent to pursue English raiders in the Pacific, lacked practical expertise in naval combat and seems to have been more successful in writing about naval strategy than in its execution. The information he presents was more likely derived from observation and discussion with skilled practitioners than from direct experience gained in battle.

García de Palacio describes the structural characteristics of the purpose-built warship as being generally similar to those of a merchant ship, but with the first two

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[1] See, e.g., Potter 1981, 13.

decks set one *codo* lower to provide more headroom for operating the artillery mounted on the gun deck.[2] His advice reflects the widespread lack of differentiation between merchant and naval vessels in the 16th century, which had the advantage of facilitating the integration of merchant ships into naval fleets, but which limited speed and maneuverability and thus the effectiveness of artillery. While some purpose-built warships were being built in the late 16th century, they were the exception rather than the rule.

The *Instrucción náutica* provides little discussion of the sailing maneuvers that would become important in 17th-century naval engagements and which eventually led to the development of the line of battle. While García de Palacio mentions the need for the pilot to gain the weather gauge, the perceived advantage was less the ability to turn downwind to deliver an effective broadside than to be well-situated to come abreast of the enemy ship to facilitate grappling and boarding.[3]

The majority of the discussion is devoted to the preparations required prior to a boarding engagement. A *xareta* (boarding net) was fixed from bow to stern, and on warships a second *xareta falsa* (false boarding net) was mounted above the first.[4] The second net was designed to be quickly released after members of the opposing force had jumped upon it, making them easy prey for men stationed below armed with long *dardos* (pikes). The upper portion of the rudder was shielded with mattresses to protect the pilot and helmsman from enemy fire. Men stationed in the tops were equipped with

[2] García de Palacio 1944a, 120v-1.
[3] García de Palacio 1944a, 125.
[4] García de Palacio 1944a, 122v.

arcabuzes (arquebuses) and an arsenal of projectiles that included *gorguezes* (javelins), *granadas* (grenades), *flechas de fuego* (flaming arrows), and *piedras* (stones). In order to prevent loss of control over the masts, yards, and sails in the event that the rigging was shot away, preventers were installed to reinforce the sheets, lifts, and halyards. Tubs of water and vinegar were placed at convenient locations for extinguishing fires and for cooling the guns.

Once all of the preparations were made, the men on a ship preparing to attack were divided into two equal parts. The first half served as a battalion that was ordered to remain on the ship and defend it all costs. The other half of the men were divided into two squadrons for the boarding attack. Ideally, each man was armed with a *mosquete* (musket) or an arquebus, in addition to his *espada* (sword), *daga* (dagger), and *rodela* (shield).[5]

When defending the ship, the men were likewise divided into several groups. According to García de Palacio, the largest and strongest force was placed amidships under the direction of the captain, while the smaller squadrons were stationed on the quarterdeck, on the foredeck, and in the tops.[6] The system was described by William Monson, an officer who served in the English fleet against the Armada of 1588, as follows: "[t]he Spaniards imitate the form of their discipline by land; namely a head-front or vanguard, a rearguard, and a main battle. The forecastle they count their head-

[5] García de Palacio 1944a, 123v.
[6] García de Palacio 1944a, 127v.

front for vanguard, that abaft the mast the rearguard, and the waist their main battle wherein they place their principal force."[7]

The *Instrucción náutica* provides an enumeration of the ordnance, small arms, and incendiary devices required for such engagements. Both muzzle- and breech-loading bronze and iron guns are mentioned.[8] In discussing iron ordnance, García de Palacio states his belief that only cast-iron guns could be used safely, suggesting that he was aware of the tendency of wrought iron pieces to explode when fired. The following types of guns are mentioned: *sacres* (sakers); *medios sacres* (demi-sakers); *cañonetes* (small cannon); *falcones* (falcons); *medios falcones* (falconets); and *versos* (swivel guns). A swivel gun was to be mounted near each of the larger to guns to allow alternate firing. Two large chase guns were also mounted in the bows. His preference for the use of "powder… of the fine type that they use for the arquebuses, because it requires less, and makes a better shot, with more violence, and speed, and momentum"[9] is presumably a reference to the superiority of corned powder. Corned powder resisted deterioration at sea better than the serpentine powder more commonly used for larger guns.[10] Smaller quantities of corned powder were required to obtain the same firepower as an equivalent quantity of serpentine powder, and it was this innovation that made small-caliber weapons such as arquebuses effective.[11] Corned powder was ground and sieved to

[7] Transcribed in Kirsch 1990, 71.
[8] García de Palacio 1944a, 121-1v.
[9] García de Palacio 1944a, 122.
[10] Smith 1993, 150-1.
[11] Partington and Hall 1998, xxvii.

obtain different grain sizes, with the finest used in small arms and the coarser grains employed in larger guns.[12]

Generally speaking, guns were used primarily as a defense against or prelude to boarding. Despite García de Palacio's concerns about leaks caused by shot hitting the vessel below the waterline, 16th-century ordnance was generally inadequate for sinking an enemy ship even at close range.[13] Instead, the goals were to cause confusion among the opposing forces, damage the protective castles, knock down the boarding nets, and inhibit the enemy's ability to maneuver by disabling their rudder and damaging their rigging.[14] The range of guns in the 16th century was relatively short and, by some accounts, Spanish crews were not trained to reload under enemy fire.[15] Typically, the gunners fired a single broadside as the ships approached each other, then attended to the matter of boarding or defending the ship as required. As such, García de Palacio plainly describes a style of naval warfare that relied on traditional methods of man-to-man combat, in which ordnance was used to facilitate boarding, rather than the broadside techniques used to overcome enemy vessels by concentrated firepower that would predominate in the 17th century.

[12] Eckhardt 2001, 26.
[13] Kirsch 1990, 67.
[14] Glete 2000, 36.
[15] Glete 2000, 35.

CHAPTER IX

SUMMARY AND CONCLUSIONS

The biography of Diego García de Palacio, set against the backdrop of New Spain, provides an opportunity to consider conditions of elite life in the 16th-century Spanish colonies. His career was adventurous and wide-ranging, taking him from his tiny hometown in northern Spain to the University of Salamanca, the colonial courts of Santiago de Guatemala and Mexico City, the remote native villages of Central America and Mexico, the abandoned Mayan ruins of Copán, a shipyard in Nicaragua, the Pacific port of Acapulco, and a *hacienda* in Coatzacoalcos. While he appears to have taken his bureaucratic responsibilities seriously, García de Palacio also actively sought extralegal opportunities to increase his own fortune and prestige and those of his family. As a result of his innate intelligence and inquisitive nature, he produced texts on a wide variety of subjects that continue to be of great interest to scholars today, including the *Instrucción náutica* of 1587.

The navigational information included in the *Instrucción náutica* reflects information previously published elsewhere, and much of the content appears to have been adapted from existing sources. By the 16th century, navigational treatises were relatively common due to Spain's increasing need to ensure safe passage as the empire expanded across the Atlantic and Pacific oceans. Despite their lack of originality, these sections of the *Instrucción náutica* provide a solid overview of the most common techniques of navigation in use at the time. Significant innovations made by García de

Palacio include the calculation of dates using the Gregorian calendar introduced in 1582 and the computation of a lunar almanac specifically for the meridian of Mexico City.

The *Instrucción náutica* is widely recognized as the first published book that includes an extensive discussion of ship design and construction. While the text includes a discussion of the sizes and proportions of small trading vessels used in New Spain, García de Palacio centers his discussion around a ship of 400 *toneladas*, a size that he considered to be ideal for both warfare and trade. The explanation is accompanied by a series of woodcuts that illustrate the shape and dimensions of the 400-*tonelada* ship and of another 150-*tonelada* vessel, representing an early attempt to graphically depict the complex empirical system of hull design in use at the time. Notably, many of the technical terms used by García de Palacio are of Italian origin, raising the possibility that the text reflects information gleaned from Genoese shipwrights working in El Realejo. García de Palacio's discussion of ship design and construction is clearly intended for a non-specialist audience and would not have attracted much interest from experienced shipwrights. However, the discussion would have been of value to a colonial elite who required a general understanding, rather than practical mastery, of such matters.

In terms of technical knowledge, the most original contribution of the *Instrucción náutica* may be its thorough description of the rigging configuration used on Spanish ships in the late 16th century. The content and detail of this section appears to be unprecedented in both published and manuscript sources. Because no parallels have been identified, it is proposed that this section may be based on direct personal observation of rigging made by García de Palacio during shipboard voyages to and around New Spain. While his descriptions agree well with contemporary depictions and can be considered reliable, caution must be used in applying the proportional rules provided by García de Palacio for masts and yards to vessels that differ significantly in size from the 400-*tonelada* ship that serves as the basis for the discussion.

The *Instrucción náutica* includes a comprehensive enumeration of the officers, petty officers, and crew found aboard a merchant ship, ranging from the *capitán* to the lowliest *paje* and including skilled specialists such as the *piloto* and *carpintero.* In addition to listing the officers and crewmen, he describes the duties assigned to each position and the attributes desired in an individual filling each position. Although brief, García de Palacio's discussion of naval strategy is of historical significance due to its juxtaposition between the Battle of Lepanto in 1571, the last of the great naval battles fought primarily with boarding tactics, and the English victory over the Spanish Armada of 1588, which epitomized the movement toward increasing reliance on the broadside. The *Instrucción náutica* clearly reflects a dependence on the older techniques of grappling and hand-to-hand combat in which artillery fire served as a prelude to boarding, rather than on the growing use of ordnance as an independent means of achieving victory.

Far from being a glorification of scientific superiority, research into seafaring technology seeks to understand the material basis through which European nations were able to pursue colonial ventures. The publication of the *Instrucción náutica* was a significant event in the history of early modern nautical technology, and García de

Palacio has been respectfully designated the "author of the first technoscientific work in the Americas."[1] Navigation, along with medicine, was one of the first technical disciplines to apply theoretical scientific principles to solving practical problems, and the printing press was crucial to the dissemination of this knowledge.[2] However, a gap between practice and theory emerged during the early period of printing, and many supposedly practical handbooks in fact contained faulty information.[3] As with any historical document, it is therefore crucial to consider the social and political context of the *Instrucción náutica* and the motivations and background of its author. Significantly, García de Palacio was an observer and administrator of navigation and ship construction, rather than an expert practitioner, and this should be remembered when evaluating the content of his book. When it came to applying his theoretical knowledge in practical situations, García de Palacio met with mixed success. Nevertheless, despite these reservations, the information presented in the *Instrucción náutica* is generally very accurate, justifying its reputation as one of the best contemporary resources for understanding Spanish nautical practices in the late 16th century.

García de Palacio's motives for publishing the *Instrucción náutica* appear to have been complex. He seems to have had a genuine interest in learning and he conscientiously recorded his understanding of matters as diverse as the geography of Central America, the political structure of Mayan villages, the archaeological ruins at Copán, the correct training of foot soldiers, and proper recipes for gunpowder. Careful

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[1] Rodríguez-Sala 1994, 182.
[2] Carriazo Ruiz 2003, 11.
[3] Eisenstein 1983, 33.

examination of the text and illustrations of the *Instrucción náutica* suggests that, like García de Palacio's other texts, this book combines knowledge obtained from a variety of sources, including existing published navigational manuals, consultation with expert practitioners, personal observation and, possibly, information from unpublished manuscripts.

Who was the intended audience for the *Instrucción náutica*? Based on its instructive style and the inclusion of a glossary, the book was clearly intended for non-specialists. While different sections of the book would have appealed more or less to different readers, García de Palacio seems to have written the book with men very much like himself in mind. For example, an ideal reader might be a *hidalgo* or merchant who, although lacking in seafaring experience, nevertheless finds himself serving as *capitán* of a ship in the Indies fleet. Although he would not be expected to navigate the ship himself, a book like the *Instrucción náutica* would help him make informed decisions about the operation of the ship. The sections of the book dealing with navigation and nautical astronomy would have been of practical interest to a literate seaman seeking to elevate himself to the post of pilot, and the section on ship construction would be useful to a bureaucrat overseeing the construction of galleons in a colonial shipyard. Notably, the book was published at a time when Philip II was attempting to reorient the education of the nobility away from a focus on humanist philosophy towards a practical curriculum that emphasized technical knowledge of architecture, artillery, combat, cosmography, and navigation that could be applied to the Crown's advantage in practical situations.

Undoubtedly, García de Palacio was interested in personal advancement as much as he was in scholarship. Both of his books dealt with practical matters that were of concern to the colonial administration and served as a means of soliciting political and economic favors from the king and the viceroys. He unabashedly stated that his intention in writing the *Diálogos militares* was not only to train other Spaniards in the methods of warfare, but also to convince the king of his competency to undertake the military conquest of the Philippines. Similarly, the *Instrucción náutica* was an opportunity to demonstrate his expertise in the technical knowledge required for building and managing the Manila galleon fleet. Given his appointment as *capitán-general* of the Pacific fleet on two separate occasions and his success in securing control over the trade route to the Philippines, the book seems to have achieved its political objectives.

Nautical archaeologists and maritime historians have long been interested in early modern treatises and books relating to ship construction and seafaring. In-depth study of these early treatises in their own right is crucial for developing a synthetic understanding of early modern shipbuilding and navigation. While its contents should be interpreted thoughtfully, the reputation of the *Instrucción náutica* as one of the most reliable and comprehensive sources of information on 16th-century Spanish seafaring practices is well justified.

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APPENDIX A

BIOGRAPHICAL TIMELINE

The following chronological list summarizes significant documented events in the life of Diego García de Palacio for the convenience of the reader. See Chapter II for discussion of these events and of the sources consulted. Dates in square brackets are inferred or estimated from available information.

1540	Marriage of Pero García de Palacio and María Sanz de Arce
[1542?]	Diego García de Palacio born near Santander
[early 1560s]	Studies law at the University of Salamanca
1567	Appointed to civil service in Spain
30 April 1572	Appointed *fiscal* (crown attorney) in the Audiencia de Guatemala
September 1572	Departs Spain for Audiencia de Guatemala
1573	Council of the Indies sends instruction to colonies regarding conduct of *visitas*
6 March 1574	García de Palacio writes to king from Santiago de Guatemala to explain that he was detained in Hispaniola, but has now arrived in Guatemala.
15 February 1575	Reports on disposition of property of the deceased as *juez de bienes de difuntos*
10 February 1576	*Cédula real* issued for conquest of Tegucigalpa
8 March 1576	Writes detailed letter to the king about inhabitants of Audiencia de Guatemala, describing ruins at Copán
4 December 1576	Contract singed with Diego López in Trujillo, Honduras, for the conquest and colonization of province of Tegucigalpa
2 May 1577	Travels to El Realejo in Nicaragua to begin construction of two galleons for the Manila trade

	galleons for the Manila trade
8 March 1578	Solicits king for right to conquer Philippines, and for transfer of trans-isthmian route from Panama to Honduras; mentions that he has written a book about military matters
11 April 1578	Council of the Indies nominates García de Palacio as *alcalde de crimen* (criminal court judge) of Audiencia de México
30 April 1579	Writes to king from El Realejo describing attacks by Francis Drake
1580	Conducts a *visita* in Nicaragua
22 December 1580	Presents the *cédula real* appointing him as *alcalde del crimen* to the Audiencia de México
24 January 1581	Receives doctorate from Real y Pontificia Universidad de México
October - November 1581	Testimony given before the Inquisition regarding the purity of the bloodlines of García de Palacio and his wife Isabel de Hoyo
10 November 1581	Appointed rector of Real y Pontificia Universidad de México
1582	Construction of galleons *Santa Ana* and *San Martín* completed in El Realejo
5 February 1582	Brother Lope de Palacio receives permission from the Casa de la Contratación to travel to New Spain
16 January 1583	Viceroy Conde de Coruña confers license to publish the *Diálogos militares* in Mexico City
7 February 1583	*Cédula real* appoints García de Palacio to undertake a *visita* in Yucatán, Cozumel, and Tabasco
6 February 1583	Baptism of son Alonso in Mexico City
November 1583	Produces a detailed census of Yucatán, Cozumel, and Tabasco
25 December 1583	Ends *visita* early to return to Mexico City
1584	Falls under scrutiny of *visita* of Pedro Moya de Contreras
25 March 1585	Baptism of daughter Isabel in Mexico City
18 January 1586	Moya de Contreras charges García de Palacio with corruption

[February?] 1586	Moya de Contreras suspends García de Palacio from his post as *oidor*, apparently with little effect
10 May 1586	Viceroy Villamanrique writes to king explaining that he has arranged sale of *San Martín* to Lope de Palacio
15 June 1586	Baptism of son Lope in Mexico City
7 February 1587	Viceroy Villamanrique confers license to publish the *Instrucción náutica*
13 February 1587	Lope de Palacio writes to Villamanrique about obtaining permission to undertake a voyage to China
20 April 1587	García de Palacio writes to the king from Mexico City that he has completed the *Instrucción náutica*
10 September 1587	Villamanrique appoints García de Palacio as *capitán general* of fleet dispatched from Acapulco to pursue Thomas Cavendish
4 November 1587	*Santa Ana* captured by Cavendish off Baja California during return from Philippines
22 February 1589	García de Palacio convicted by Council of the Indies on 72 charges
19 April 1589	García de Palacio suspended from position as *oidor* for nine years
14 July 1590	Son Diego petitions for permission to travel from Spain to New Spain to live with his father, "an *oidor* in Audiencia de México"
1591	*San Martín* sinks off Macao
15 November 1595	García de Palacio's funeral oration read in the church of the Santísima Trinidad in Mexico City
26 May 1596	Council of the Indies considers request from Isabel de Hoyo asking for a royal favor to offset financial hardship
1599	Isabel de Hoyo seeks permission to remove cattle from her hacienda at Coatzacoalcos

APPENDIX B

IBERIAN NAVIGATIONAL TREATISES

The following is a chronological list of Iberian navigational treatises of the 16th and 17th centuries. This list was compiled with reference to the following sources: Barrera-Osorio 2006, 147-50; Carriazo Ruiz 2003; and González-Aller Hierro 1998.

Author	**Title**	**Publication**
Alfonso Córdoba	*Tabulae astronomicae Elisabeth Regine*	Venice: Petrus Liechtenstein, 1503
Martín Fernández de Enciso	*Suma de geographía que trata de todas las partidas y provincias del mundo: en especial de las Indias, y trata largamente del arte del marear juntamente con la esphera en romance, con el regimiento del sol y del norte, agora nuevamente emendada de algunas defectos que tenia la impression passada*	Seville, 1519 Rev. ed., Seville: Juan Cromberger, 1530
Felipe Guillén de Castro	Carta al Rey de Portugal [discusses longitude, declination, and the use of the compass]	Seville, 1525
Alonso de Chaves	*Quatri partitu en cosmografía práctica, y por otro nombre, Espejo de navegantes*	Seville, ca. 1530
Francisco Faleiro	*Tratado del esphera y del arte de marear: con el regimiento de las Alturas: con algunas reglas nuevamente escritas muy necesarias*	Seville: Juan Cromberger, 1535
Pedro de Medina	*Arte de navegar, en que se contienen todas las reglas, declaraciones, secretos y avisos que a la buena navegación son necessarios, y se deven saber*	Valladolid: F. Fernández de Córdova, 1545

Author	**Title**	**Publication**
Joannes de Sacrobusco	*Tractado de la sphera*	c. 1230 Reprint, Seville, 1545
Jerónimo de Chaves	*Chronographia o repertorio de los tiempos*	Seville, 1548
Pedro de Medina	*Suma de cosmographía*	1550
Martín Cortés Albácar	*Breve compendio de la sphera y del arte de navegar, con nuevos instrumentos y reglas, exemplificado con muy subtiles demostraciones*	Seville: Antón Álvarez, 1551 2nd. ed., 1556
Pedro de Medina	*Regimiento de navegación, en que se contienen todas las reglas, declaraciones, y avisos del libro del arte de navegar*	Seville: Juan Canalla, 1552 Seville: Simón Carpintero, 1563
Bernardo Pérez de Vargas	*Repertorio perpetuo*	Toledo, 1563
Juan Pérez de Moya	Arte de navegar	Manuscript, 1564
Alonso de Santa Cruz	Libro de las longitudines y manera que hasta agora se ha tenido en el arte de navegar, con sus demostraciones y ejemplos	Manuscript, 1566 Seville: Zarzuela, 1921
Juan Escalante de Mendoza	Ytinerario de navegación de los mares y tierras occidentals	Manuscript, 1575
Rodrigo Zamorano	*Compendio del arte de navegar*	Seville: Alonso de Barreda, 1581
Francisco Vicente de Tornamira	*Chronologia y repertorio de los tiempos, a lo moderno*	Pamplona: Thomas Porralis de Sauyoa, 1585
Rodrigo Zamorano	*Cronologia y repertorio de la razón de los tiempos*	Seville, 1585

Author	**Title**	**Publication**
Andrés de Poza	*Hydrografia la mas curiosa que hasta aqui ha salido a la luz, en que de mas de un derretero general, se enseña, la navegación por altura y derrota, y la del Este Oeste, con la graduación de los puertos, y la navegación al Catayo por cinco vias diferentes*	Bilbao: Mathías Mares, 1585
Diego García de Palacio	*Instrucción náutica para el buen uso y regimiento de las naos, su traça, y govierno conforme a la altura de Mexico*	Mexico City: Pedro Ocharte, 1587
Baltasar Vellerino de Villalobos	*Luz de navegantes donde se hallarán las derrotas y señas de las partes marítimas de las Indias, isles, y tierra firme del Mar Océano*	1592
João Baptista Lavanha	*Regimento naútico*	Lisbon: Simão López, 1595
Simón de Tovar	*Examen y censura del modo de averiguar las alturas de las tierras, por la altura de la estrella del norte, tomada con la ballestilla, en que se demuestran los muchos errors que ay en todas las reglas, que para esto se an usado hasta agora, y se enseñan las que conviene usarse, y guardarse en nuestros tiempos, y el modo como podra hazerse en los venideros*	Seville: Rodrigo de Cabrera, 1595
Antonio de Herrera	*Historia de los hechos de los castellanos en las isles y tierra-firme del mar oceano con una descripcion de las Indias orientales y sus mapas*	Madrid, 1601
Pedro de Syria	*Arte de la verdadera navegación, en que se trata de la machina del mundo*	Valencia: Juan Chrysostomo Carriz, 1602

Author	**Title**	**Publication**
Andrés García de Céspedes	*Regimiento de navegación mando hazer El Rey Nuestro Señor por orden de su Consejo Real de las Indias*	Madrid: Juan de la Cuesta, 1606
Francisco Suárez de Argüello	*Ephemerides generales de los movimientos de los cielos por doze años, desde el de MDCVII hasta el de MDCXVIII segun el Serenisimo Rey don Alonso en los quarto planetas inferiores y Nicolao Copernico en los tres superiores que mas conforma con la verdad y observaciones, como se dira en el prologo*	Madrid, 1608 [written 1582]
Andrés Río y Riaño	*Tratado de un instrumento por el cual se conocerá la nordestacion, o noruestacio de la aguja de marear, navegando por la mayor altura del sol, o de otra estrella, o por dos alturas iguales, y de la utilidad que se ha de seguir*	Seville, 1608
Lorenzo Ferrer Maldonado	*Imagen del mundo, sobre la esfera, cosmografia, y geografia, teorica de planetas, y arte de navegar*	Alcalá de Henares, 1626
Antonio de Nájera	*Navegación especulativa y práctica, reformadas sus reglas, y tables por las observaciones del Ticho Brahe, con emienda de algunos yerros essenciales*	Lisbon: Pedro Craesbeeck, 1628
Pedro Porter y Casante	*Reparo a errores de la navegación española al excellentissimo Señor Don Fadrique de Toledo Ossorio*	Zaragoza: María de la Torre, 1634
Lázaro de Flores	*Arte de navegar, navegación astronómica, theorica, y practica*	Madrid: Julian de Paredes, 1673
Francisco de Seysas y Lobrera	*Theatro naval hidrographico, de los fluxos, y refluxos, y de las corrientes de los mares, estrechos, archipielagos, y passages*	Madrid: Antonio de Zafra, 1688

VITA

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Education

Present	Ph.D. student, Historical Archaeology Program, Dept. of Anthropology College of William & Mary, Williamsburg, VA
2008	Master of Arts, Nautical Archaeology Program, Dept. of Anthropology Texas A&M University, College Station, TX
1996	Bachelor of Arts, Department of Archaeology Simon Fraser University, Burnaby, BC
1995	Nautical Archaeology Society Level I and Tutor Training
1994	PADI Open Water Scuba Instructor
Awards:	Regent's Fellowship, Dept. of Anthropology, Texas A&M University Ingrid Nystrom Award, Dept. of Archaeology, Simon Fraser University

Professional Experience

2005-2007	Provincial Marine Archaeologist, Ministry of Culture, Toronto, ON
2004	Teaching Assistant, Quarterpath Field School, Colonial Williamsburg
2003	Archaeologist and Divemaster, Dominican Republic Survey Project
2003	Laboratory Instructor, Scientific Diving Course, Texas A&M University
2002	Archaeologist, Parks Canada St. Lawrence River Survey, Quebec
2000-2001	Archaeologist and Divemaster, Angra Bay Shipwreck Project, Azores
1999-2001	Archaeologist, Pepper Wreck and Cais do Sodre Project, CNANS, Lisbon
1999-2001	Librarian, Nautical Archaeology Program, Texas A&M University
1997-1999	Consulting Archaeologist, Golder Associates Ltd., Burnaby, BC
1996	Assistant Archaeologist, Arcas Consulting Archeologists, Coquitlam, BC
1995-1996	Director of Education, Underwater Archaeological Society of BC
1995-1996	Assistant, Archaeobotanical Laboratory, Simon Fraser University
1995	Tsini Tsini Field School, Simon Fraser University, Bella Coola, BC