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Port of Cavite (Carta hydrographica y chorographica de las Yslas Filipinas: dedicada al Rey Nuestro Señor por el Mariscal d. Campo D. Fernando Valdes Tamon Cavallo del Orden de Santiago de Govor. Y Capn (1734). Murillo Velarde, Pedro (1696–1753), Bagay, Nicolás de la Cruz (1701–ca. 1771)

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Galleons Crossing the Pacific and the 'Manila Galleon System' (Sixteenth to Early Nineteenth Centuries)*

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Introduction

This paper describes the technologies of the Spanish galleons that worked the 'Manila galleon system' between Acapulco in New Spain and Manila in the Philippines from 1565 to 1815. The Manila Galleon system can be understood both in terms of geographic routes and as a set of rules and regulations, forming a legal framework.[1] It was a system of multiple actors and distribution points, connecting Spanish America with East and Southeast Asia. And it went far beyond a pure economic exchange of silver for silks and porcelains, but included transfers of scientific and technological knowledge and skills, cross-cultural interaction, such as mutual impacts on food cultures or clothing, or human movements and migration.[2]

After a general introduction to the political-economic context of this trading system, the paper will focus on the development of galleon design and construction. It will also examine the evolution of the dimensions, tonnages, and hull ratios of the galleons in order to acquire insights into the variations and changes to the ships' design over time. Finally, this paper will investigate the establishment and, as far as our sources go, the development of the shipyards where the galleons were constructed, both in the Philippines and on the Pacific coast of Spanish America.

Information on the historical context, local circumstances, and concrete maritime technologies used in the construction of the 'Manila galleons' stem from archival documents, manuscripts, and

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[1] This has been stressed by Cuauhtémoc Villamar in his book *Portuguese Merchants in the Manila Galleon System, 1556–1600* (London, New York: Routledge, 2021).

[2] It is not the purpose of this article to describe the legal and administrative framework of the Manila galleon trade. For those questions, we would like to refer the interested reader to a selection of existing literature with excellent overviews; see Ricardo Padrón, "A sea of Denial: The Early Modern Spanish inventions of the Pacific Rim", *Hispanic Review*, 77:1 (2009), 1-27; Ubaldo Iaccarino, "The 'Galleon System' and Chinese Trade in Manila at the Turn of the 16th Century", *MingQing yanjiu* 106 (1011), 95-128; Cuauhtémoc Villamar, "Redes mercantiles e intercambio cultural en la ruta del Galeón de Manila, 1565–1600 / Mercantile networks and cultural exchange on the Manila Galleon Route, 1565–1600 / Redes Mercantis e Intercâmbio Cultural na Rota do Galeão de Manila, 1565–1600", *Universitas Humanística* 89 (2021), doi: https://doi.org/10.11144/Javeriana.uh89.rmic; Cuauhtémoc Villamar, "El Galeón de Manila y el comercio de Asia: Encuentro de culturas y sistemas / The Manila Galleon and the Asian Trade: Encounter of Cultures and Systems", *Sino-Iberoamerican Interactions* 2:1 (2022), 85-109, doi: https://doi.org/10.1515/sai-2022-0008; Guadalupe Pinzón Ríos, Eberhard Crailsheim, María Baudot Monroy, "Conexiones filipinas: La afluencia de rutas marítimas en torno a un Archipiélago (siglos XVI–XVIII) / Philippine Connections: The Abundance of Maritime Routes Around an Archipelago (16th–18th Centuries)", *Vegueta. Anuario de la Facultad de Geografía e Historia* 20 (2020), 11-19; Manuel Perez-Garcia, "Beyond the Silk Road: Manila Galleons, trade networks, global goods, and the integration of Atlantic and Pacific markets (1680–1840)", *Routledge Atlantic Studies* 19:3 (2022), 373-383; still recommendable for an overview is the classic publication by William Lytle Schurz, *The Manila galleon* (New York: E. P. Dutton & Co., Inc., 1959).

shipbuilding treatises. These sources demonstrate the intangible value of the historical transition in shipbuilding for the Manila Galleon trade, which can be evaluated using tangible archaeological data, including the shipyards and remaining shipwrecks in the Philippines.

Historical Context

The Manila galleons plied the Pacific Ocean between Acapulco (New Spain) and Manila (Philippines) between 1565 to 1815. This was Spain's alternative sea route to the Spice Islands in Southeast Asia and ports in China, after the world and its oceans had been divided into a Portuguese and a Spanish half by Pope Alexander VI (1431–1503) in the 'Treaty of Tordesillas' in 1494. The treaty was seen as an agreement to settle conflicts over newly discovered or explored lands overseas. Accordingly, the eastern Atlantic and the Indian Ocean maritime space and the land masses located therein belonged to the Portuguese sphere. The Spaniards consequently first crossed the Atlantic, established themselves in America (New Spain, Peru) and then crossed the Pacific to reach Southeast Asia, making the bay of Acapulco the major departure point in the Americas and Manila Bay and its port of Cavite the major port in Southeast Asia. As early as 1521, a Spanish expedition led by Ferdinand Magellan (1480–1521) had sailed across the southern tip of the American continent (the 'Magellan Strait') and then crossed the Pacific westward. The expedition was the first recorded European contact with the Mariana Islands and the Philippines, territories that were subsequently claimed for Spain.

Due to specific winds and currents in the Pacific Ocean, the major difficulty consisted in finding a way back to the American continent, specifically to Acapulco, from Asia. This return route was called the *tornaviaje*, literally 'return voyage'. It was finally discovered by the Spanish navigator Andrés de Urdaneta (1508–1568). He had been part of an expedition commanded by Miguel López de Legazpi (1502–1572), Governor-General of the Spanish East Indies, to conquer the Philippines in 1564 and had received an explicit order to find a return route.

As is well known, the Spanish first conquered large parts of the American continent, where they established administrative units and viceroyalties (New Spain, Peru) and in 1645 discovered the world's richest silver deposits in Potosí (modern Bolivia). The silver mined there was not only shipped back to their home country, but was used to pay local administrative expenses in America and the Philippines and also served to pay for imports from Asia. These included, above all, silks, brocades, damasks and many other textiles, ceramics, spices (such as cinnamon, pepper, cloves, nutmegs), ivory, furniture, fans, and a wide array of other goods and handicraft products, as well as also iron, mercury, wax, slaves, Asian plants and even animals, musk, and samples of books, paintings, or art objects for European collections, all of which were mainly paid for with the silver extracted from Potosí. But it was not only silver that reached Asia from America.

The galleons coming from America also transported plants and botanical products, such as medicines, cochineal (used for dyeing), the sweet potato, corn (maize), the tomato, tobacco, chickpeas, and cacao. Because of the importance of Chinese goods, these ships are also known as *Naos de China* ('China Ships') in Spanish sources. The galleons, of course, not only transported goods and objects but also people, especially Jesuit, Franciscan, and other missionaries from Spain and New Spain, craftsmen, voyagers, and other passengers, also serving as a medium of knowledge and technology transfer, and last but not least diseases. This trade and exchange system is known as the 'Manila galleon system', a trading system that was more complex than it might appear at first sight. Although initiated and officially carried out by the Spanish, actors and merchants of many countries and ethnicities were also involved.

While Acapulco and Manila constituted the major ports, we must keep in mind that many other ports were also part of the system: Lima and its port of Callao in Peru, Huatulco, Zihuantanejo or since its foundation in 1768 San Blas in Mexico, Arica in Chile, Realejo in Nicaragua, Sonsonate in Guatemala, and Guayaquil in Ecuador, to mention just a few of the more important ones. On the Asian side of the Pacific, the ports of Macao and Xiamen (Amoy) were especially closely linked to the galleon trade, but the *naos* de China also called at Japanese harbours and visited Pacific islands, such as the Marianas (Islas de los Ladrones). In order to protect Spanish merchants, above all from Seville, and their transatlantic business, direct trade between Peru and China was already prohibited in the late sixteenth century.[3] Despite the official prohibition, however, ships continued to sail between Callao and Acapulco, serving the Peruvian market with Chinese goods. Smuggling and unofficial trade and exchange were part and parcel of this transpacific connection. Sailing across the Pacific was a challenging undertaking, but also sailing along the Pacific coast from New Spain south to Peru was considered "one of the most difficult regions on earth", more difficult even than the voyage from New Spain to Manila.[4]

The trade between China, Asia and Peru can be divided into several phases that cannot always be clearly defined: first (1), a period of relative liberal trade that lasted until approximately 1581; second (2), the period between 1581 and 1634, when the Spanish Crown ordered the definitive closure of commercial relations between Mexico and Peru, which may perhaps be characterised as a period of indirect trade flows; third (3), the period between 1634 and 1698, when foreign merchants came to control the maritime routes along the Latin American coast and started to provide Peruvian markets with Asian (and European) goods from ports in Guatemala and Nicaragua;[5] fourth (4), a period of increasingly clandestine trade between the viceroyalties of New Spain and Peru between 1680 and 1740, with a so-called phase of "French commerce" between 1698 and 1725, when French merchants established a triangular trade between Europe, Peru, and China, with direct links between Peru and Canton; fifth (5), the phase of registered ships (*navíos de registro*) and the gradual decline of Asian commerce between 1740 and 1760, especially during the colonial conflict between England and Spain;[6] and sixth (6), the period of the gradual liberalization of trade relations.

Finally, it is important to stress that not only Spanish, Filipinos, Mexican (New Spanish), Peruvian, and Chinese merchants were involved. We also observe a well-organised network that included Portuguese, French, Japanese, Indian, Southeast Asian, and Armenian merchants, the local Chinese community in the Philippines, the so-called Sangleyes, and other European and Asian merchants, who all participated in one way or the other in this lucrative business. Moreover, the sailors on board or the craftsmen constructing the galleons, like carpenters, were multi-ethnic and from various origins. Above all, we find Filipinos who built galleons locally and composed the ships' crews. But we also find, for example, Greek navigators on board Spanish ships.[7]

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[3] "Prohibición de ir navíos del Perú a China" [Prohibition of sailing ships from Peru to China], 1593, AGI, Patronato, 25, R. 56.

[4] Woodrow Borah, "Early Colonial Trade and Navigation Between Mexico and Peru", *Ibero-Americana* 38 (1954), 29. He provides an overview over prevailing winds, etc.

[5] Woodrow Borah, *Comercio y Navegación entre México y Perú en el Siglo XVI* (México: Instituto Mexicano de Comercio Exterior, 1975), 244; William Lytle Schurz, "The Spanish Lake", *Hispanic American Historical Review* 5:2 (1922), 181-194.

[6] This war between Spain and England was known as "War of Jenkins' Ear", 1739–1748.

[7] As Wim De Winter has discovered in the course of our project, the Spanish used, for example, the expertise of Greek island sailors, who obviously possessed specific navigation skills that the Spanish recognised and used in trans-Pacific sailing. Wim De Winter, *Transpacific Wayfinding*, forthcoming monograph.

Galleons – The Ships Crossing the Ocean – and Shipyards

While several remains of Manila galleons have been found, especially in the wider Philippine Archipelago, only a few of them have been archaeologically excavated. Most have been salvaged by commercial companies, whose explorations have been haphazard and have not improved current knowledge. Major Spanish wrecks include the wreck of Baja California (*San Juanillo*?, 1578), *San Agustin* (Drake's Bay, 1595), *Santa Margarita* (1601), *San Francisco* (1609), *Nuestra Señora de la Vida (*1621), *Nuestra Señora de la Concepción* (1638), and the Beeswax wreck (*Santo Cristo de Burgos*?, 1693, Oregon).

Alonso Sánchez, a fifteenth-century Spanish mariner and merchant, designed a new policy for Asia for Philip II (r. 1556–1598) which focused, first, on building a defensive wall around Manila, and then on constructing a shipyard near the city's natural port, in the bay of Cavite, to regulate, in a restrictive way, the Manila galleon trade.[8]

As Woodrow Borah has shown, the principal maritime routes along the Pacific coast in the sixteenth century comprised cargo and passengers between Panama and Peru, galleons anchoring on the Atlantic side of the Isthmus at Nombre de Dios.[9] Since the 1520s, ships were built in Nicaragua, where suitable timbers could be found in the forests close to the coast, while shipbuilding elsewhere along the west coast of Mexico developed only slowly. Hernán Cortés (1485–1547) selected Tehuantepec and Acapulco as permanent shipyards. In the early 1530s, another shipbuilding centre was developed at Iztapa (Zihuantanejo) in Guatemala and at Acajutla in San Salvador. Huatulco developed as a major Pacific port in the in the late 1530s, and in the mid-1540s, it was possible to build ships there. Local, indigenous people, so-called 'Indians', were employed for hard tasks, while European artisans completed the skilled work. By the late 1530s, merchant ships were sailing regularly from the port of Realejo (Nicaragua) to Peru with provisions and goods. Towards the end of the sixteenth century, Guayaquil (Quito) became a notable shipbuilding centre, though Peru lacked coastal forests with the required timber. By the 1540s, repair facilities existed on the island of Puna. In the course of the sixteenth century, gradually also some other shipyards were constructed. Legazpi's ships were built at La Navidad and left from there.[10]

Spaniards repeatedly petitioned to have shipyards constructed in the Philippines and to send more carpenters and ship constructors, who were a rare and precious human resource on the island, although local expertise was abundant.[11] The Spanish recognised and exploited Filipino sailing and shipbuilding expertise, but they obviously paid them so little in the end, and even mistreated them, that many sought to escape working on galleons, as Francisco Ignacio Alcina (1610–1674), a Spanish Jesuit missionary active in the Philippines, speculates: "Although in the beginnings they were well

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8 Manel Ollé, "A Gift for the King: Maritime East Asian Spanish Perspectives in the Boxer Codex", paper presented at a conference organised by Patrizia Carioti, Paola Calanca and Ubaldo Iaccarino in Napoli in 2013 and partly included in Manel Ollé, *Islas de plata, imperios de seda Juncos y galeones en los Mares del Sur* (Barcelona: Editorial El Acantilado, 2022).

9 Woodrow Borah, "Early Colonial Trade and Navigation Between Mexico and Peru", *Ibero-Americana* 38 (1954), 1-170, here 1.

10 An overview of the early developments is provided by Woodrow Borah 1954; For information about the construction of El Carbón shipyard in Tehuantepec (Oaxaca) by Hernán Cortés and the ships built there in 1535, see Jose L. Casabán and Roberto Junco, Early Sixteenth-century Shipbuilding in Mexico: Dimensions and tonnages of the vessels designed for Pacific Ocean navigation, *The Mariner's Mirror,* 106:2 (2020), 133-145, DOI: 10.1080/00253359.2020.1736395.

11 "Petición de Juan Quijano para que se envíen fabricantes de naos a Filipinas" (1686-04-23), AGI, Filipinas, 44, N. 23.

paid, rightly so, today they are given so little that hardly any native can be found who would be foolish enough to take the risk of being killed or hung for something that might not turn out well. This is how poorly they are paid."[12] Spanish manuscripts are full of requests to send more shipwrights for galleon construction to the Philippines.

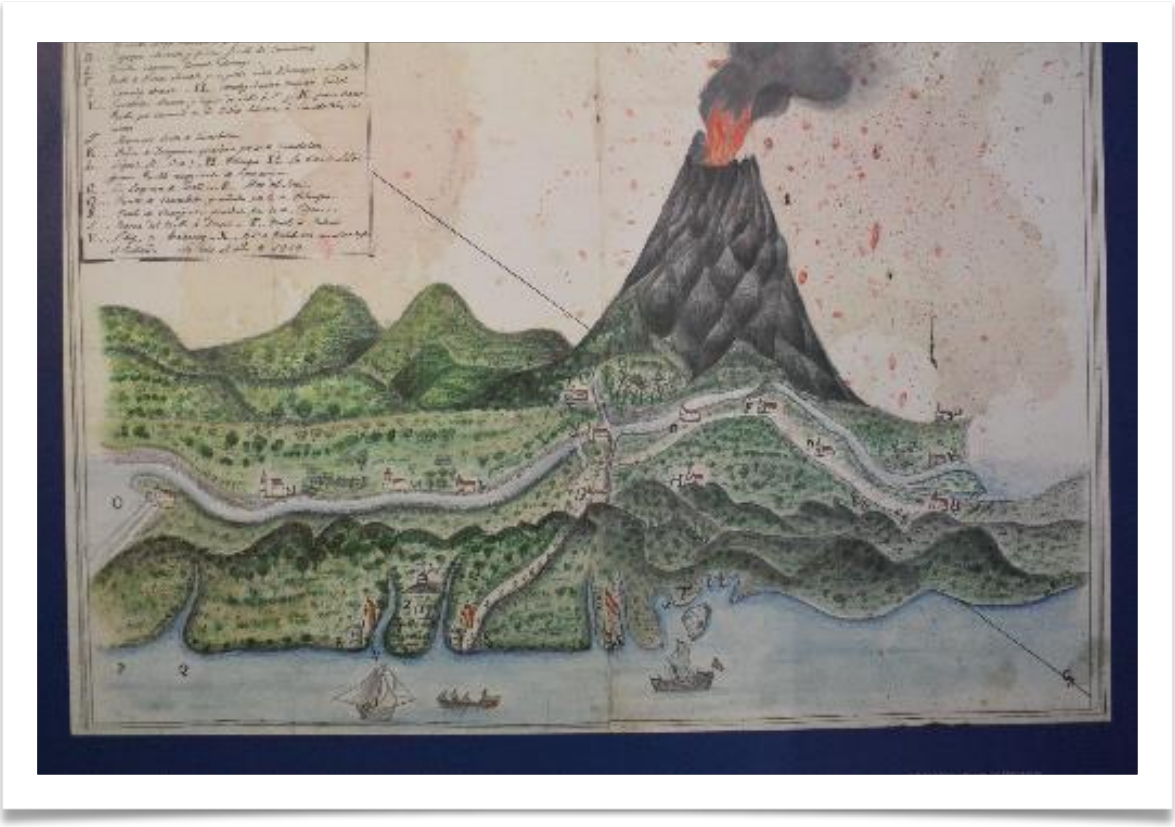

Fig. 1. Mayon Volcano and seascape of Bicol Region with estuaries, rivers, and coves where watchtowers and warehouses were located (unknown source, drawn in 1839, Courtesy of the National Museum of the Philippines, Bicol).

The Spanish had shipyards in Cavite, Sorsogon, and the Visayas. But as the costs of using these Philippine shipyards were extremely high, both in terms of supplies and labor, plans emerged to construct the galleons elsewhere too, for example in Japan. The Spanish general and diplomat Sebastián Vizcaíno (d. 1627) was sent on a mission to Sendai in order to find a good harbour and a shipyard for the Manila Galleons.[13]

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[12] Francisco Ignacio Alcina (1610–1674), *Historia de las islas e indios de Bisayas del Padre Alcina*, 1668. Translated by C. J. Kobak and L. Gutierrez. Part One, Book 3, Volume 3 (Manila: UST Publishing House, 2005), 69-71. See also Ligaya Lacsina, *Examining pre-colonial Southeast Asian boatbuilding: An archaeological study of the Butuan Boats and the use of edge-joined planking in local and regional construction techniques*, PhD thesis, Department of Archaeology, Flinders University, Australia, 2016, 73.

[13] Ubaldo Iaccarino, "Tokugawa Ieyasu's 'Spanish Policy' Revisited: Trade, Diplomacy, and Knowledge Exchange between Japan, Mexico and the Philippines during the Keichō Era (1596-1615)", paper presented at the International Conference on *Maritime East Asia in the Light of History, 16th-18th Centuries. Sources, Archives, Researches: Present Results and Future Perspectives*. held in Naples at the city's "L'Orientale" University on 30 September-2 October 2013.

Japanese carpenters worked in the Spanish shipyard of Cavite,[14] and more generally carpenters and engineers from many countries were hired for constructing the galleons.[15] Also Chinese (Sangleyes) were employed, as were native Filipinos. They provided shipbuilding industries with labor as blacksmiths or as carpenters (*carpintero Sangley*).[16] The construction of the galleons can therefore be considered an international business. Galleons were also sometimes built elsewhere, not only because of the labor problem but also due to the availability or lack of the necessary timbers ("conveniencia de comprar naos en Bengala y Cochín donde las hacen de madera incorruptible, y emplear a marineros lascares").[17]

The *Santo Cristo de Burgos* was built and paid for in 1687–1688 in the Philippines, at the royal shipyard of Solsogón (Sorsogon), on the island of Bagatao at the mouth of Solsogón (Sorsogon) Bay. Costs: 65,243 pesos.[18]

The evolution of galleons' dimensions, hull ratios, and designs (early seventeenth-century)

Since the establishment of Manila in 1571, the Spanish ships that sailed across the Pacific Ocean between Manila and Acapulco in the late sixteenth and early seventeenth centuries were built in shipyards of the American Pacific coast and the newly established shipyards in the Philippines. Unfortunately, the information available about the design and construction of these vessels, especially their tonnages and main dimensions, is limited and sparse. However, it is still possible to examine the evolution of these vessels' dimensions, tonnages, and hull ratios based on written sources.

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[14] Nineteen Japanese workers were employed in Cavite for 145 days to repair royal ships. Their salaries, the document says, would be paid in Japan, in the presence of a notary, upon their return. See Juan Gil, *Hidalgos y Samurais: España y Japón en los siglos XVI y XVII* (Alianza: 1991), 149, with reference to AGI, Contaduría, 1209, fol. 195r., and "Carta de D. Juan de Silva del 24 de julio de 1609", AGI, Mexico 2488.

[15] "Carta de Diego Salcedo sobre materias de Hacienda", AGI, Filipinas, 9, R. 3, N. 41, fol. 11v, speaks of an English carpenter called Juan; on another occasion, 66 slaves from Siam (now Thailand) were employed as carpenters; see Ostwald Sales Colín, "Las Actividades Médicas en las Filipinas durante la Primera Mitad del Siglo XVII", *Perspectivas Latinoamericanas* 2 (2005), 182.

[16] See, for example, Emma Blair and James Robertson, *The Philippines Islands 1493–1898*, vol. XVI (Cleveland, Ohio: The Arthur H. Clark Company, 1904), 196, online https://www.gutenberg.org/cache/epub/27127/pg27127-images.html, states that Sangley carpenters and sawyers were "working in the port of Cabite and other places"; see also "Carta de los oficiales reales sobre varios asuntos" (1636-06-26, Manila, Luzón, Filipinas), AGI, Filipinas, 30, N. 27, image 46, no pagination; "Autos sobre barcos portugueses San Pablo y Nuestra Señora de la Piedad" (1696-05-25), AGI, Filipinas, 70, N. 1, 50r, 205r, speaks of Sangley carpenters. In 1757, the King of Joló, Bantilan, requested the Spanish governor to send, among other craftsmen 20 carpenters from the Sangley community ('que le envíe de los sangleyes, un platero, veinte maestros carpinteros, diez calafates, veinte aserradores, un dulcero o confitero, dos tejedores, zapateros y cereros, Joló, 1 de septiembre de 1756'); see "Expediente sobre la embajada del rey de Joló" (1757-07-24, Manila), AGI, Filipinas,199, N. 5. For Chinese craftsmen including carpenters in Manila, see also Lucille Chia, "The Butcher, the Baker, and the Carpenter: Chinese Sojourners in the Spanish Philippines and their impact on Southern Fujian (Sixteenth-Eighteenth Centuries)", *Journal of the Economic & Social History of the Orient* 49:4 (2006), 509-534; AGI, Filipinas, 200, N. 206, cited in Ivan Valdez-Bubnov, "Las islas Filipinas y la etapa formativa de la construcción naval española en Asia (1519–1657).", *Obradoiro de historia moderna* 28 (2019), 14; Emma Blair and James Robertson, *The Philippines Islands*, vol. 28, 173-176.

[17] "Petición del procurador Ríos Coronel sobre varios asuntos", AGI, Filipinas, 27, N. 51 (probably 1605-07).

[18] Cameron La Follette, Douglas Deur, "The Galleon's Final Journey: Accounts of Ship, Crew, and Passengers in the Colonial Archives", *Oregon Historical Quarterly* 119:2 (2018), 210-249, 217.

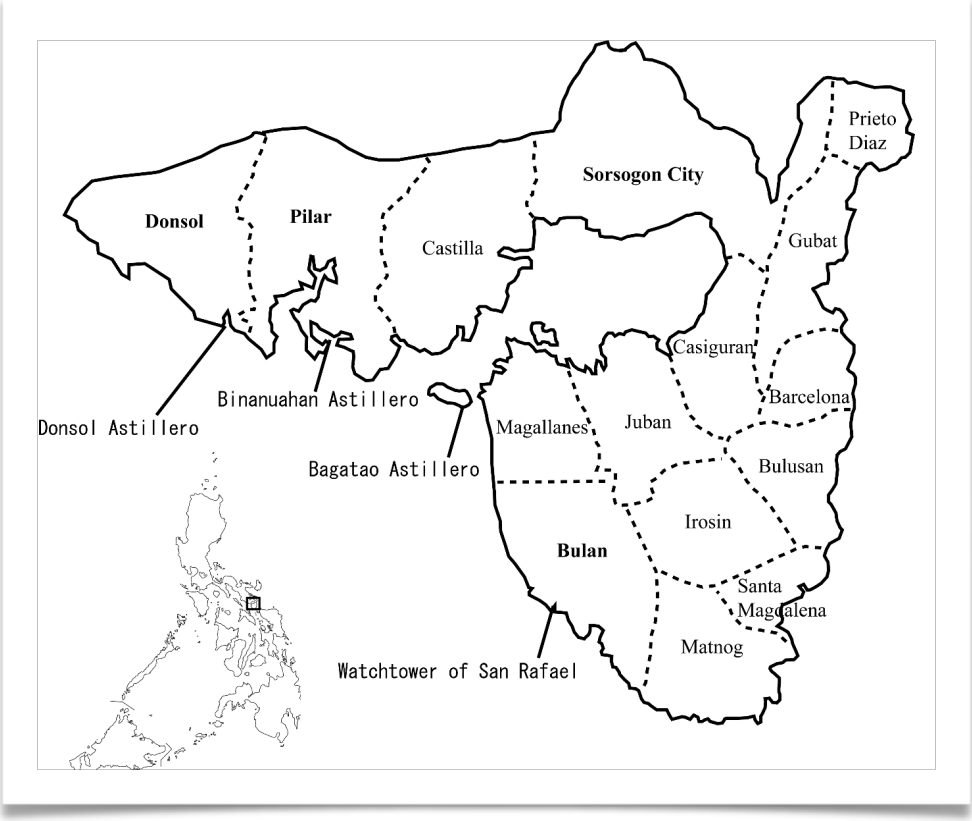

Fig. 2. Archaeological heritage of *astilleros* in modern districts in Bicol Region. Map drawn by Kimura Jun.

In 1578, Diego García de Palacio (1542–1595) arrived in the shipyard of El Realejo, Nicaragua, to begin the construction of two galleons, *Santa Ana* (400 tons) and *San Martín* (500 tons).[19] These two galleons were completed in 1582, at a much higher cost than initially expected, and were employed on the Manila-Acapulco trade route during the following years.[20] In 1587, Thomas Cavendish captured and burned *Santa Ana* off the coast of Baja California, during its return voyage from Manila to Acapulco, while *San Martín* sank in Macau in 1591.[21] The galleons' design and main dimensions are unknown except for their tonnages. However, in 1587, García de Palacio published in Mexico a navigation and shipbuilding treatise, *Instrucción náutica para navega*r, in which he described the theoretical design of a 400-ton *nao* (ship), which he considered the most appropriate for

19 Archivo General de Indias (AGI), Guatemala, 10, R. 5, N. 49; Juan Mario Garnier, *El arte de navegar en la Nueva España* (México: Los libros de Homero, 2010), 20; José Antonio Cervera, "Los planes españoles para conquistar China a través de Nueva España y Centroamérica en el siglo XVI", *Cuadernos de Intercambio sobre Centroamérica y el Caribe* 10:12 (2013), 219.

20 Maria Luisa Rodríguez-Sala, *Raíces de la cultura científica nacional: Los primeros científicos de la Nueva España, siglo XVI* (Mexico City: Consejo Nacional de Ciencia y Tecnología, 1994), 190; Othón Arróniz, *El despertar científico en América: La vida de Diego García de Palacio* (Universidad Autónoma Metropolitana, México, D.F., 1980), 77; Erika Laanela, *Instrucción Náutica (1587) by Diego García de Palacio: An Early Nautical Handbook From Mexico* (Master's Thesis, College Station: Texas A&M University, 2008), 19-20.

21 Othón Arróniz, *El despertar científico en América: La vida de Diego García de Palacio* (Universidad Autónoma Metropolitana, México, D.F., 1980), 127; Erika Laanela, *Instrucción Náutica (1587) by Diego García de Palacio: An Early Nautical Handbook from Mexico* (Master's Thesis: Texas A&M University, 2008), 25.

the Atlantic and Pacific Oceans sailing routes.[22] Therefore, Palacio's theoretical ship design, as outlined in his treatise, could be used to study the design and construction of contemporary vessels used in the Transpacific trade, since he was also in charge of the construction of *Santa Ana* and *San Martín* in El Realejo.[23]

In his description of a 400-ton nao, García de Palacio provided the ship's main dimensions in '*codos castellanos*' (Castilian cubits).[24] During the sixteenth century in Spain, two main linear units were used to measure vessels: the *codo castellano*, which was 0.557 meters long, and the *codo de ribera*, which was 0.575 meters long. The *codo castellano*, equivalent to two-thirds of a *vara castellana* (Castilian yard) or 32 *dedos* (fingers), was mostly used on the Atlantic coast of southern Spain for the ships that went to the Indies.[25] The *codo de ribe*ra measured two-thirds of a *vara castellana* plus one thirty-second of the *vara* or 33 *dedos* and was used in the shipyards along the northern coast of Spain. In 1590, the *codo de ribera* became the official linear unit, known as the *codo* real, for surveying and calculating ships' tonnages in Spain to prevent fraud.[26]

The volume unit used in García de Palacio's treatise to indicate that the cargo capacity of the vessel was the *tonelada* (ton), or *tonelada de carga* (cargo ton), of the Atlantic coast of southern Spain, which equaled 8 cubic *codos castellanos* (1.3844 cubic meters) or 2 Sevillian *pipas*. A *pipa* was a type of cask 2.5 *codos castellanos* (1.39 m) in length and with a maximum diameter of 1.5 *codos* (0.8359 m). In Seville, the capacity of a *pipa* used to store water or wine made in the quarter of La Carretería was 27.5 *arrobas* (443 liters). On the other hand, the volume unit used in northern Spain was called *tonel macho* and equaled 8 cubic *codos de ribera* (1.5183 cubic m).[27] In sixteenth-century Spain, the terms *toneles*, *toneladas de carga*, and *toneles machos* were used to measure ships' volumes or cargo capacity. The tonnage was typically based on the volume of the ship's hold. Additionally, the *tonelada* could also refer to a unit of account or *tonelada de sueldo* when an extra 20 or 25 percent was added to the official cargo capacity of the vessel. This percentage was added to the tonnage of privately owned merchant vessels when rented or embargoed for royal service in exchange for a monthly fee (*sueldo)* per ton and inclusion of the space between the main and upper deck. After Philip II unified the naval units of measurement in Spain in 1590, the *tonel* macho became the official unit of volume, being converted into *toneladas* when an extra 20 percent was

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22 Diego García de Palacio, *Instrucción náutica para navegar (1587)* (Madrid: Ediciones Cultura Hispánica, 1944), 90-92.

23 Roberto Junco Sánchez, "On a Manila Galleon of the 16th Century: A Nautical Perspective", in Wu, Chunming (eds.), *Early Navigation in the Asia-Pacific Region* (Springer, Singapore, 2016), 103-4, 108-112.

24 Diego García de Palacio, *Instrucción náutica para navegar (1587)*, 89.

25 The '*vara castellana*' measured 0.8359 m. See José Luis Casado-Soto, "Atlantic Shipping in Sixteenth-century Spain", in María José Rodríguez-Salgado and Simon Adam (eds.), *England, Spain and the Gran Armada 1585–1604: Essays from Anglo-Spanish Conferences, London and Madrid 1988* (Savage, Md.: Barnes & Noble Books, 1991), 103–104.

26 José Luis Casado-Soto, "Atlantic Shipping in Sixteenth-century Spain", 103-4.

27 AGI, Patronato 260, 2, R. 41; J. L. Casado-Soto, *Los barcos españoles del siglo XVI y la Gran Armada de 1588* (Madrid: San Martín, 1988), 67, 270; Diego García de Palacio, *Instrucción náutica para navegar (1587),* 90; Escalante de Mendoza, Juan, *Itinerario de navegación de los mares y tierras occidentales 1575* (Madrid: Museo Naval, 1985), 45; Instituto Geográfico y Estadístico (IGE), *Equivalencias entre las pesas y medidas usadas antiguamente en las diversas provincias de España y las legales del sistema métrico decimal* (Madrid, 1886), 7; The Carreteria was a neighborhood in Seville, situated near the arsenal and facing the Guadalquivir River, which specialised in making wooden barrels for the ships that sailed to the Indies. Carmen Mena, "Nuevos datos sobre bastimentos y envases en Armadas y Flotas de la Carrera", *Revista de Indias,* 64:231 (2004), 459.

added.[28] Finally, since the Spanish shipbuilding ordinances of 1607, the extra 20 percent was applied only to vessels with more than one deck to consider the space between the decks and the upper structure.[29]

García de Palacio's 400-ton *nao*, designed as a merchant vessel, had a length of 51 1/3 *codos* (28.64 m), a keel of 34 *codos* (18.97 m), a breadth of 16 *codos* (9.93 m), and a flat of the floor of 5 1/3 *codos* (2.98 m). The deck configuration included a level of unplanked beams (*baos vacíos*) at 4.5 *codos* (2.51 m) to reinforce the lower part of the hull, a lower deck (primera cubierta) at 7.5 *codos* (4.19 m), and a second deck (puente), also referred as main deck (*cubierta principal*), at 11 ½ *codos* (6.42 m). If the *nao* was to be a warship, it could also have an upper deck (*jareta*) that would be located at 14 1/5 *codos* (8.09 m) and 3 *codos* (1.67 m) above the second deck (puente) (Table 1).[30] The *nao* was also fitted with a bowsprit (*bauprés*) and four masts: the foremast (*trinquete*), the mainmast (palo mayor), the mizzenmast (*mesana*), and the bonaventure mizzen (*contramesana*).[31]

The 400-ton *nao* had a length-to-breadth ratio of 3.21:1, a length-to-keel-ratio of 2.13:1, a depth of hold-to-breadth ratio of 0.72:1, and a flat of the floor-to-breath ratio of 0.33:1 (Table 2). These ratios are similar to the traditional As-Dos-Tres rule that, according to Cano (1607), regulated sixteenth-century ship design in Spain, Italy, and other nations. This rule determined that each breadth unit had two units of keel and three of length.[32] Similarly, the depth of hold-to-breadth and flat of the floor-to-breath ratios also followed the traditional ship designs of the late sixteenth century in Spain, which equaled 2/3 and 1/3 of the breadth respectively.[33] Therefore, the design recommended by García de Palacio for transpacific vessels closely resembled the hull ratios used in Spain at the end of the sixteenth century.

While García de Palacio was constructing *Santa Ana* and *San Martín* in El Realejo, Nicaragua, ships were also being built in the newly established shipyards of the Philippines. According to various sources, ships could be built in the Philippines at a lower cost than in Mexico due to the abundance of wood and the low price of iron imported from China. In 1579 and 1580, two 500-ton *naos, La Trinidad* and *Santa María de Jesús*, were constructed in Manila and Otón (Ilocos) respectively, and two more vessels of over 500 tons had been built in the Philippines before the end of the decade.[34]

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[28] José Luis Casado-Soto, *Los barcos españoles del siglo XVI y la Gran Armada de 1588* (Madrid: San Martín, 1988), 67-71; idem, "Atlantic Shipping in Sixteenth-century Spain", in María José Rodríguez-Salgado and S. Adam (eds.), *England, Spain and the Gran Armada 1585–1604: Essays from Anglo-Spanish Conferences, London and Madrid 1988* (Savage, Md.: Barnes & Noble Books, 1991), 103-104.

[29] Martín Fernández de Navarrete, *Colección de documentos y manuscriptos compilados*, vol. 23 (Nendeln, 1971), doc. 47, fols. 288-297.

[30] Diego García de Palacio, *Instrucción náutica para navegar (1587)*, 90-93.

[31] Ibid., 95.

[32] Thomé Cano and Enrique Marco Dorta, *Arte Para Fabricar Y Aparejar Naos: 1611* (La Laguna: Instituto de Estudios Canarios, 1964), 62.

[33] José Luis Casabán, *The Twelve Apostles: Design, Construction, and Function of Late 16th-Century Spanish Galleons* (PhD dissertation, College Station: Texas A & M University, 2017), 168-235, 243-294, 358-363; Carla Rahn Phillips, "Spanish Ship Measurements Reconsidered: The Instrucción Náutica of Diego García De Palacio (1587)", *The Mariner's Mirror,* 73:3 (1987), 294-295. Rahn Phillips also proposes for the 400-ton nao a depth of hold-to-breadth ratio of 0.47:1 based on the height of the lower deck (primera cubierta), which would provide a tonnage closer to 400 tons.

[34] AGI, Filipinas, 29, N.38; AGI, Filipinas, 29, N. 32; AGI, Filipinas, 29, N. 33; AGI, Filipinas, 339, L. 1, fols. 354v–355v; John T. *Wing, Roots of Empire: Forests and State Power in Early Modern Spain, c.1500-1750* (Leiden: E. J. Brill, 2015), 114.

Between 1593 and 1604, several restrictions were placed on the number and size of Manila galleons that could transport goods between the Philippines and New Spain. In 1593, only two 300-ton galleons were permitted to travel annually between Manila and Acapulco.[35] The number of vessels and their tonnages remained the same in 1602, but each vessel could transport only 200 tons of goods.[36] Finally, in 1604, the tonnage of the two vessels that were allowed to conduct transpacific trade was reduced to just 200 tons.[37] These regulations were designed to safeguard the economic interests of Sevillian merchants who traded with America from Spain. However, it seems that these restrictions were never implemented, as the size of Manila galleons increased from 500 to 1,000 tons before 1614. This was because the merchants in Manila and Mexico refused to limit their trade volumes in order to maximise their profits.[38] The loss of the two major Spanish ships shows that tonnage restrictions were not strictly applied during the early seventeenth century. The first ship, the 500-ton flagship *Santiago el Mayor*, built in Marinduque, sunk in the Strait of San Bernardino on June 19, 1608, while the second, the 1000-ton flagship *San Francisco*, was lost off the coast of Japan the following year.[39]

At the beginning of the seventeenth century, three different shipbuilding ordinances were also issued in Spain in 1607, 1613, and 1618. These ordinances aimed to regulate the design, dimensions, tonnages, and construction of vessels that could serve in the Armada of the Ocean Sea (*Armada del Mar Océano*) and the Indies run (*Carrera de Indias*) in the Atlantic Ocean on military or commercial functions. However, none of these ordinances specifically referred to ships built for the transpacific trade or Pacific Ocean navigation. The ordinances also provided the ships' dimensions in *codos reales* or *de ribera* (0.575 m) and the tonnages in *toneladas* that equaled *toneles* machos plus 20 percent.[40] In addition, a new set of regulations and arithmetic formulas for calculating ships' tonnages were issued in 1613.[41]

The ordinances of 1607 established the specifications for ships with breadths ranging from 10 to 22 *codos* (5.75 to 12.65 m) and tonnages between 150½ and 1351 5/8 *toneladas*.[42] The ordinances of 1613, on the other hand, specified the designs for ships with breadths between 8 and 22 *codos* (4.6 to

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35 William Lytle Schurz, *The Manila Galleon* (New York: E. P. Dutton, 1939), 193; AGI, Filipinas, 1, N. 23.

36 Cesareo Fernández Duro, *Armada Española Desde La Unión De Los Reinos De Castilla Y De Aragón*, vol. 5 (Madrid: Museo Naval, 1972–73), 283-284.

37 AGI, Filipinas, 43, N.1; Ivan Valdez-Bubnov, "Crown, Trade, Church and Indigenous Societies: The Functioning of the Spanish Shipbuilding Industry in the Philippines, 1571–1816", *International Journal of Maritime History* 31:3 (2019), 563.

38 William Lytle Schurz, *The Manila Galleon,* 194.

39 AGI, Filipinas, 29, N. 100; AGI, Filipinas, 193, N. 3.

40 Martín Fernández de Navarrete, *Colección de documentos y manuscriptos compilados,* vol. 23 (Nendeln, 1971), doc. 47, fols. 288-297; AGI, Indiferente, 2595; Fernando Serrano Mangas, *Función y evolución del galeón en la carrera de Indias* (Madrid: Editorial MAPFRE, 1992), 211–236; *Recopilación de leyes de los reinos de las Indias*, Tomo 3 (Madrid: Boix, 1841), 20-32.

41 *Recopilación de leyes de los reinos de las Indias*, Tomo 3 (Madrid: Boix, 1841), 33-37.

42 Martín Fernández de Navarrete, *Colección de documentos y manuscriptos compilados*, vol. 23 (Nendeln, 1971), doc. 47, fols. 288-297.

12.65 m) and tonnages from 55 *toneles* machos and 1073 1/3 *toneladas*.[43] The 1618 ordinances, valid till the end of the seventeenth century, provided the main dimensions and construction characteristics for ships with breadths between 9 and 22 *codos* (5.17 to 12.65 m) and 80 ¾ and 1074 ¾ *toneladas*.[44] Each set of ordinances also restricted the maximum size of the ships that could sail to the Indies fleets to a breadth of 16 *codos* (9.2 m) and a tonnage of 567 *toneladas* in the case of the 1607 ordinances, 17 *codos* (9.8 m) and 539¼ *toneladas* in 1613, and to 18 *codos* (10.3 m) and 624⅛ *toneladas* in 1618.[45] The size limitations of the vessels on the Indies Run were due to the sandbar of Sanlúcar de Barrameda, at the mouth of the Guadalquivir River, which limited the draft of ships sailing to and from Seville, the principal port of the Indies Run.[46] Nevertheless, the chronic shortage of ships for the fleets of the Indies run often made it necessary to employ any ship available independently of its tonnage.[47] In contrast, the size restrictions that were intended to be imposed on the Manila galleons in the late sixteenth and early seventeenth century were based on economic criteria. They aimed to limit the amount of valuable Asian goods imported from the Philippines into New Spain.

The Spanish shipbuilding ordinances also introduced a series of modifications in the conception and design of ocean-going vessels. To address the deep draft issues observed in late sixteenth-century vessels, changes were made to the ships' hull ratios. These changes focused on modifying the depth of hold, the location of the ship's maximum breadth, the angle of the first futtocks (*joba*), and the keel and floor lengths.

The 1607 ordinances extended the ships' length, which became longer and narrower, although their lengths were shortened again in 1613 until the second half of the seventeenth century, when it increased again. In the same way, the keel length also increased in relation to the ship's breadth and length. At the same time, the height of the hulls was reduced so that the depth of the hold and the flat of the floor would equal half the breadth. The 1613 ordinances also introduced the application of the *joba*, which determined the tilting of the head of the futtocks forward and aft of the master frame with respect to their lower end without modifying their original curvature. Applying the *joba* increased the vessel's stability and cargo capacity, reducing its draft and the need for ballast while increasing its speed.[48] The ordinances introduced a new classification for ships based on their purpose: merchant or warship. This classification was based on the height of the ship's maximum breadth. The maximum breadth was located at the same level as the main deck for merchant ships and ½ *codo* (0.29 m) below the main deck for warships to ensure enough distance between the waterline and the gunports

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43 AGI, Indiferente, 2595; Serrano Mangas, *Fernando, Función y evolución del galeón en la carrera de Indias* (Madrid: Editorial MAPFRE, 1992), 211-236; Small ships provide the tonnage in toneles machos because they only had one deck, which prevented the extra 20% from being added.

44 Recopilación de leyes de los reinos de las Indias, Tomo 3 (Madrid: Boix, 1841), 20–32.

45 The shipbuilding ordinances provide the ships' dimensions in *codos de ribera* (0.575 m), and the tonnages are calculated based on a new set of formulas issued in 1613. Martín Fernández de Navarrete, *Colección de documentos y manuscriptos compilados*, vol. 23 (Nendeln: 1971), doc. 47, fols. 288-297.

46 John Horace Parry, *The Spanish Seaborne Empire* (Berkeley: University of California Press, 1990), 54.

47 Fernando Serrano Mangas, *Función y evolución del galeón en la carrera de Indias* (Madrid: Editorial MAPFRE, 1992), 24.

48 Antonio de Gaztañeta e Iturribalzaga, Fernando Fernández González, *Cruz Apestegui Cardenal, and Fernando Miguélez García. Arte De Fabricar Reales*, vol. 1 (Barcelona: Lunwerg, 1992), 22-23; *Thomé Cano and Enrique Marco Dorta, Arte Para Fabricar Y Aparejar Naos: 1611* (La Laguna: Instituto de Estudios Canarios, 1964), 80, 104-105, 108.

for the artillery.[49] The 1618 ordinances adopted a single design for warships and merchantmen while reducing the ship's length and keel, but tonnages remained nearly unchanged from 1613. The galleons only had two decks, but those with breadths ranging from 20 to 22 *codos* (11.5 to 12.65 m) had two rows of unplanked beams instead of one, below the main deck. These beams could also be planked to create provisional decks.[50]

These changes are anticipated to have impacted the design and construction of ships used for the transpacific trade since they represented a new shipbuilding philosophy, regardless of whether they were explicitly mentioned in the different sets of ordinances. Although the changes might not affect the size of the vessels, they could still be reflected in their hull ratios. However, contemporary documents describing ships built in the Philippines in the early seventeenth century reveal that their designs and linear units differed from those used for the Atlantic vessels. For instance, a document from 1616 concerning Governor Juan de Silva's (in office 1609-1616) Armada to Singapore lists ship's dimensions in *codos castellanos* of 2/3 of a *vara*, including a graphic representation of half a *codo* on one page.[51]

Another report dated to 1619 and prepared by Sebastian de Pineda, the master shipwright of Cavite's shipyard (*capitan de la maestranza de la fábrica de naos de las islas Filipinas*), also listed the vessels mentioned in the 1616 document and one *nao* stationed in the Philippines. The document provides the ships' main dimensions, including their length, keel, breadth, flat of the floor, depth of hold, and even the transom (Table 1).[52] The document lists all the dimensions in *codos* but does not specify the type of *codo* used. However, the dimensions listed in this document have many similarities with the measurements mentioned in the 1616 document, which may suggest that they are *codos castellanos*.[53] The date of this report and the construction dates mentioned in the 1616 document indicate that most ships were built between 1612 and 1615. Therefore, the ships were built immediately before or after the 1613 ordinances were in effect. The ships listed in Pineda's report were built in different shipyards in the Philippines, except the *nao San Laurencio*, built in India (Table 1). Pineda also confirmed that at least the galleon *Espíritu Santo* sailed from Acapulco to Manila in 1618 because the newly appointed Governor of the Philippines, Alonso Fajardo de Tenza (in office 1618–1624), arrived in Manila on this galleon.[54]

All the ships, except the flagship *Salvador*, have dimensions similar to the measurements listed in the 1607 and 1613 ordinances, although any galleon matches exactly the sets of dimensions provided in the ordinances for a specific ship's breadth. The main differences correspond to their depth of hold and floor length. These variations also result in different hull ratios and ships' tonnages

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[49] Fernando Serrano Mangas, *Función y evolución del galeón en la carrera de Indias* (Madrid: Editorial MAPFRE, 1992), 214-221.

[50] AGI, Indiferente, 2595; Fernando Serrano Mangas, *Función y evolución del galeón en la carrera de Indias* (Madrid: Editorial MAPFRE, 1992), 211-236; *Recopilación de leyes de los reinos de las Indias*, Tomo 3 (Madrid: Boix, 1841), 20-37.

[51] AGI, Filipinas, 37, N. 37.

[52] Filipinas, 340, L. 3, fols. 209r-210v. Sebastián de Pineda was appointed master shipwright of the Philippines in 1619; AGI, Filipinas, 38, N. 12; Blair and Robertson, 187-188.

[53] Despite the *codo castellano* (0.557 m) being slightly shorter than the *codo de ribera* or *codo real* (0.575 m), the comparative analysis of the ships' dimensions has been conducted based on the measurement provided in Pineda's document. It should be noted that, regardless of the type of *codo*, the resulting hull ratios remain the same.

[54] AGI, Filipinas, 38, N.12; Emma Blair and James Robertson, *The Philippines Islands 1493–1898,* vol. XVIII, 187-188.

(Tables 1 and 2). *Salvador'*s main dimensions, on the other hand, surpassed any of the measurements proposed in any of the ordinances for the largest ships, which were the 22-*codo* (12.65 m) breadth and 1,351 3/8-*tonelada* galleons listed in the 1607 ordinances. *Salvador* was 4 *codos* (2.3 m) wider than the largest galleons listed in the ordinances and 10 *codos* (5.75 m) longer. Its keel was 6 *codos* (3.45 m) longer, with only 1 *codo* (0.575 m) added to the flat of the floor. Pineda indicated in his report that *Salvador's* depth of hold (*puntal*) was 19 *codos*, with the first deck (*primera cubierta*) at 15 *codos* (8.62 m) and the last (*postrera cubierta*) deck at 19 *codos* (10.92 m) with a height between decks of 4 *codos* (2.3 m). Based on the location of the first deck, the galleon had to have at least two rows of unplanked beams below the first deck to reinforce the lower part of the hull due to its deep depth of hold (Table 1).

The breadths of the remaining ships included in the report range between 19 and 23 *codos* (10.92 and 13.22 m), with deviations between ½ and 1 *codo* (0.29 and 0.575 m) with respect to any set of ordinances in the cases of *Espíritu Santo*, *San Felipe*, *Santiago*, *San Juan Bautista*, and *San Miguel*. *Nuestra Señora de Guadalupe* and the *nao San Laurencio* had breadths identical to those listed in the ordinances at 21 and 19 *codos* (12.07 and 10.92 m) respectively (Table 1). The difference in length is only ½ *codo* (0.29 m) in relation to the 1613 ordinances in the cases of *Espíritu Santo*, *San Felipe*, *Santiag*o, and *San Juan Bautista*. The lengths of the *San Miguel*, *Nuestra Señora de Guadalupe*, and *San Laurencio* are 2 ¼ *codos*, 4 ¾ *codos*, and 3 ¼ *codos* shorter respectively. The galleons with breadths between 23 and 22 ½ *codos* (13.22 and 12.94 m) have keel lengths between 4 and 5 *codos* (2.3 and 2.87 m) shorter than in the ordinances, but the difference increases up to 7 *codos* (4.02 m) for the 21-*codo* (12.07 m) breadth *Nuestra Señora de Guadalupe*, while the keel of the 19-*codo* (10.92 m) breadth *San Laurencio* is only 3 *codos* (1.72 m) shorter than the vessels with the same breadth (Table 1). The flat of the floor for the galleons with breadths between 23 and 22 ½ *codos* (13.22 and 12.94 m) is only 1 *codo* (0.575 m) shorter than in the 1613 ordinances, while the 21-*codo* (12.07 m) breadth *Nuestra Señora de Guadalupe* has a flat of the floor 1½ *codos* (0.86 m) shorter, though *San Laurencio*'s floor length was not mentioned in Pineda's report (Table 1).

According to Pineda's report, all the galleons had two decks, except the *nao San Laurencio*, which had three. Pineda listed the height at which the first deck (*primera cubierta*) was located, the height between the first and last deck (*postrera cubierta*), and the ship's depth of hold (*puntal*) measured up to the second or last deck (*postrera*), but he did not mention which deck corresponded to the main deck (*cubierta principal*). However, the 1607, 1613, and 1618 shipbuilding ordinances clearly specified that galleons with breadths like those listed in Pineda's report had two decks: the main deck (*cubierta principal*) and the upper deck (*puente*). Their depth of hold was also measured up the ship's maximum breadth, which was located at the level of the main deck or ½ *codos* below it, and the depth of hold corresponded to half the ship's breadth. Nevertheless, analysis of the depths of hold and height between decks listed in Pineda's report would indicate that the first deck (*primera cubierta*) corresponded to the main deck (*cubierta principal*) and that he listed the total depth of hold of the vessel by measuring it up to the upper deck. This hypothesis is supported by the dimensions of late sixteenth-century 20-*codo* breadth galleons whose upper deck is almost the same height as the last deck mentioned in Pineda's reports (Table 1).

The depths of hold listed for 22 ½ -*codo* (12.94 m) breadth galleons, measured at the first deck's level, are only ½ *codo* (0.29 m) higher than in the 1613 ordinances. However, in the case of the 23-*codo* (13.22 m) breadth galleons, the difference increases to 2 and 3 *codos* (1.15 to 1.72 m). On the other hand, the 21-*codo* (12.07 m) breadth *Nuestra Señora de Guadalupe* had a depth of hold 1 *codo* (0.575 m) lower than the ordinances (Table 1).

Pineda's report also omitted the height of the ship's breadth and the rows of unplanked beams that should be located beneath the main deck. According to the ordinances, ships with breadths between 20 and 22 *codos* (11.5 and 12.65 m) should have two rows of unplanked beams equally distributed between the floor and the main deck, while ships up to 19 *codos* (10.92 m) have only one row located at a height equal to half of the depth of the hold.[55] Therefore, most of the galleons listed in Pineda's report should have two rows of unplanked beams to reinforce the lower part of the hull, especially considering their deep depth of hold. On the other hand, the *San Laurencio*'s depth of hold was 12 *codos* (6.9 m) and included a three-deck configuration. However, Pineda did not specify the deck at which the depth of hold was measured. Therefore, the *San Laurencio* might not have a row of unplanked beams but a lower deck if its depth of hold corresponded to the main deck between the lower and upper deck. Finally, the height between decks for the 23-*codo* (13.22 m) breadth galleons is 4 *codos* (2.3 m), ¾ *codos* (0.43 m) higher than in the ordinances, while for the 22 ½ - and 21-*codo* (12.94 and 12.07 m) breadth ships is only ¼ *codo* (0.14 m) higher (Table 1).

It was common for ships in the sixteenth and seventeenth centuries to exceed their theoretical dimensions, often becoming larger than expected.[56] This occurred because the vessels were built by eye instead of following construction plans. The different sets of ordinances issued in the early seventeenth century attempted to solve this issue by proposing a series of rules, and even the 1618 ordinances established that the maximum allowed breadth increment during the construction of a ship should not exceed 0.5 *codos* (0.29 m).[57] However, this problem lasted until the eighteenth century, since it was extremely difficult to build a ship in a perfect manner, and almost impossible to construct two identical ships, even if the exact same dimensions and rules were followed.[58] Hence, differences in the galleons' dimensions of up to 1 *codo* (0.575 m) in the ships' breadth and depth of hold, and up to 2-3 *codos* (1.15 to 1.72 m) in their lengths compared to the ordinances could be attributed to the galleons' construction process. However, larger variations, such as the differences in the lengths of the galleons' keels and the extra-large dimensions of the *Salvador*, resulted from intentional design choices made by the shipwrights and constructors.

The hull ratios of the galleons listed in Pineda's report also deviate from the ratios that result from the measurements of the 1613 ordinances. The length-to-breadth ratios of the vessels in the report range between 3.15:1 to 2.96:1. The *Salvador* and the *nao San Laurencio* have the highest ratios, while the *San Miguel* galleon shows the lowest. These ratios are closer to the late sixteenth-century large galleons and the later 1618 ordinances than the 1613 and 1607 designs in which the ships became longer and narrower (Table 2). The keel-to-breadth ratios vary between 2.42:1 and 2.13:1, which, once again, show values closer to the late sixteenth century than to any of the ordinances, except in the case of the *nao San Laurencio*, whose 2.42:1 ratio is the closest to the values resulting from the 1607 ordinances.

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55 AGI, Indiferente, 2595; Fernando Serrano Mangas, *Función y evolución del galeón en la carrera de Indias* (Madrid: Editorial MAPFRE, 1992), 224; *Recopilación de leyes de los reinos de las Indias,* Tomo 3 (Madrid: Boix, 1841), 27.

56 Juan Escalante de Mendoza, *Itinerario de navegación de los mares y tierras occidentales 1575* (Madrid: Museo Naval, 1985), 38.

57 AGI, Indiferente, 2595; Fernando Serrano Mangas, *Función y evolución del galeón en la carrera de Indias* (Madrid: Editorial MAPFRE, 1992), 211-236; *Recopilación de leyes de los reinos de las Indias*, Tomo 3 (Madrid: Boix, 1841), 25-26.

58 Gervasio de Artíñano y de Galdácano, *La Arquitectura Naval Española, en madera: Bosquejo de sus condiciones y rasgos de su evolución, etc.* (Madrid: Por el autor Madrid, 1920), 74.

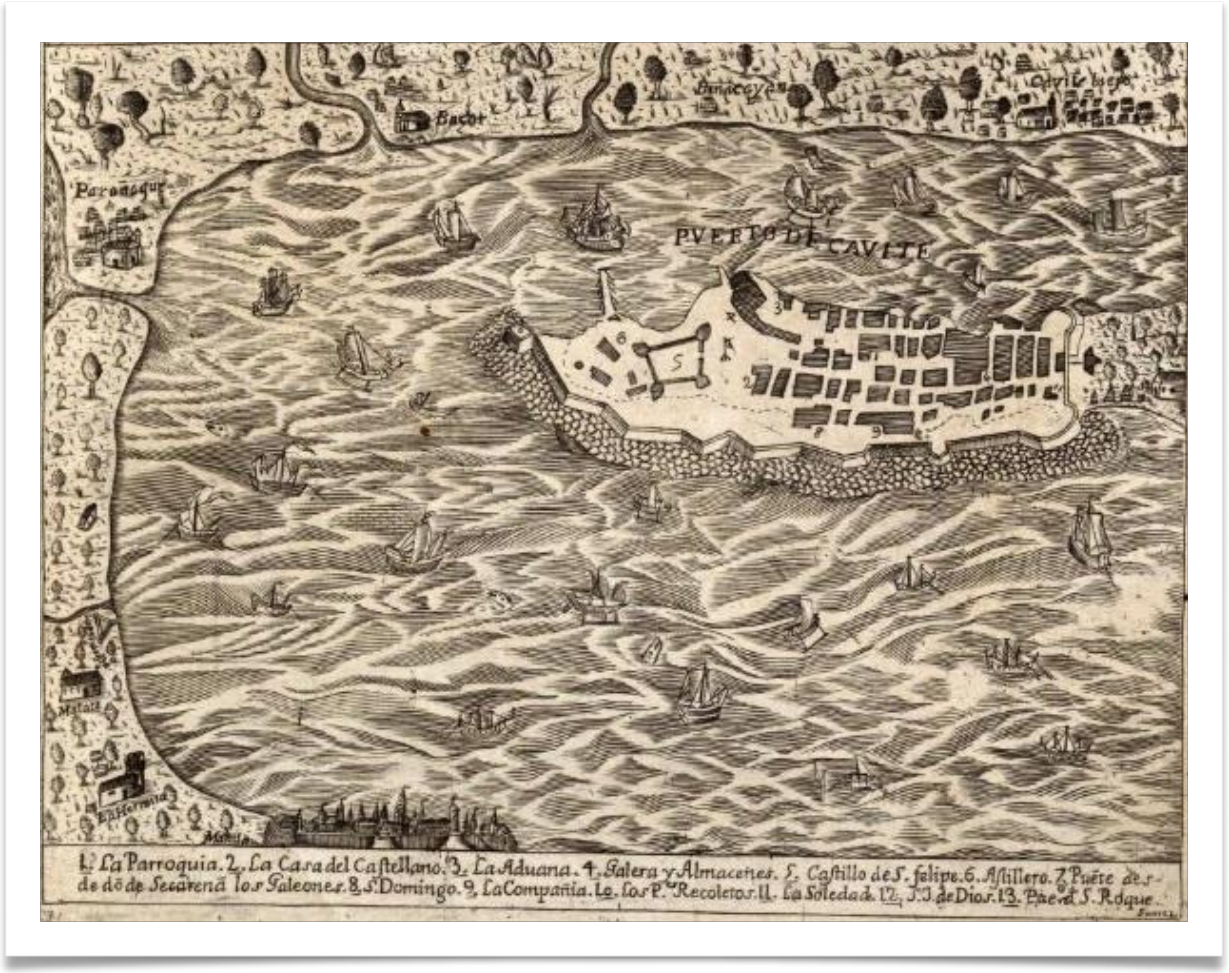

Fig. 3. Port of Cavite (Carta hydrographica y chorographica de las Yslas Filipinas: dedicada al Rey Nuestro Señor por el Mariscal d. Campo D. Fernando Valdes Tamon Cavallo del Orden de Santiago de Govor. Y Capn (1734). Murillo Velarde, Pedro (1696–1753), Bagay, Nicolás de la Cruz (1701–ca. 1771). Online resource of the Library of Congress, https://www.loc.gov/resource/g8060.ct003137/?r=-0.567,0.067,2.134,1.115,0.

The depth of hold-to-breadth ratios of these ships range between 0.63:1 to 0:51:1 when the depth of hold is measured up to the first deck or the middle deck in the case of the *San Laurencio*. The ratios of this *nao* and the *San Miguel* galleon are closer to the traditional 2/3 ratio of the previous century. The remaining vessels show ratios compatible with those from the ordinances, especially the 1607 ordinances. However, in the cases of the *Salvador* and *Espíritu Santo*, the value is almost equal to 2/3 of the ships' breadth (Table 2). Finally, the floor-to-breadth ratios of the ships listed in Pineda's report are more uniform, ranging between 0.46:1 and 0.43:1, with the Salvador having the highest ratio. These values are closer to the 1/2 ratio of the ship's breadth specified in the ordinances rather than the 1/3 ratio of the late sixteenth century, though still below it (Table 2).

Pineda did not mention the ships' tonnages in his report. However, the approximate tonnage of the vessels can be calculated based on their main dimensions and the tonnage formulas issued in Spain in 1613.The main dimensions used to calculate their tonnages were the ship's length, breadth, depth of hold measured at the first-deck level (*primera cubierta*), floor length, and keel length (Table 1).

When the 1613 formulas are applied, the resulting tonnages vary between the 1,935 *toneladas* of the Salvador to the 753 7/8 *toneladas* of *Nuestra Señora de Guadalupe*, and almost all the vessels have tonnages over 1,000 *toneladas* (Table 1). The tonnage of *Salvador* almost doubles the largest tonnages mentioned in the 1613 ordinances, which correspond to the 22-*codo* breadth galleons.

However, the tonnage calculated for *Salvador* is similar to the tonnages mentioned in two documents dated to 1616 and 1617, which are 1,700 and 1,900 *toneladas* respectively.[59] The tonnage of the 22 ½-*codo* breadth galleons is almost identical to that listed in the ordinances despite the differences in their main dimensions. In contrast, the 23-*codo* breadth galleons have tonnages around 200 t*oneladas* higher than those listed in the 1613 ordinances but only 50 tons larger than the 1607 tonnages. The galleon *Nuestra Señora de Guadalupe* has a lower tonnage due to its smaller dimensions. However, the final volume of the ship is about 200 tons less than specified for 21-*codo* breadth galleons in the 1613 ordinances and around 400 tons less than indicated in the 1607 ordinances.

The Maritime Archaeological Heritage of the Manila Galleons

There are remains in the Philippines which well represent the Spanish periods of coastal occupation and maritime trades, and as part of the trans-Pacific history they are as significant as Manila's protected built heritage. These remains are maritime archaeological heritage consisting of shipyards, the maritime cultural landscape, and shipwrecks of Manila galleons.

A few *astilleros*, the Spanish term for shipyards, were established along the sailing routes in southern Luzon. The galleon shipyards are located in modern Sorsogon in the Bicol Region,[60] a good geostrategic position for both inbound and outbound Manila galleons. A vast portion of the region was gifted with estuaries and coves connecting riverine systems inland (Figure 1).

Areas around Sorsogon Bay provided galleons with a safe refuge from the strong waves of the Embocadero or San Bernardino Strait before they headed out into the Pacific. The 'royal *astilleros*' were set up in the estuaries around the bay and along the coasts of the archipelago, including Bagatao Island, as well as in the Masbate and Ticao Islands, which also served as a port of call for the galleons. Juan de Silva (in office 1609–1616), the fourteenth governor-general of the Philippines, founded a number of these *astilleros*. One of the more renowned galleon shipyards in Sorsogon can be found on Bagatao Island, Magallanes, a so-called '*astillero real*' (designated as belonging to and favoured by the King of Spain) (Figure 2).

It is estimated that the shipyard started operating during the incumbency of Juan de Silva in 1610. It was in this astillero in Bagatao that such prominent galleons as San Felipe and Santiago were built (theses ships were also believed to be among the first to be built in the shipyard), and they were subsequently used in battle against the Dutch in 1616–1617 at Playa Honda in Zambales. The *astillero* became famous for the construction of the galleons *Nuestra Senora del Rosario, Los Santos Reyes* and *Nuestra Senora de Loreto*, although it achieved even greater reputation building *Santisima Trinidad* and *Senora del Buen Fin* in 1750. This ship was the biggest galleon to engage in the Manila-Acapulco trade route for eleven years. Other galleons built in Bagatao including *San Juan Bautista*, *San Francisco Javier*, *Santa Rosa*, *Santo Nino*, and *Santo Cristo de Burgos*.

To build a large galleon of over 2,000 tons, the workers in the *astilleros* had to cut and haul lumber from the surrounding mountains or islands. Sorsogon was also chosen because of the rich forest sources for ship timbers, while hardwoods from the family of *Dipterocarpaceae* (mainly tropical lowland rainforest trees) were preferred in building seaworthy galleons. These trees were known as *narra*, *apitong*, *molave*, *yakal*, *lauan*, and *guisok*. The forest sources were, however, easily consumed and many large hardwoods vanished quickly for constructing the galleons.

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59 AGI, Filipinas, 37, N. 37; AGI, Filipinas, 7, R. 4, N. 52.

60 On Spanish shipyards, see for example, Raffi Banzuela, *Bikol in the Galleon Times: A history of colonization, deforestation and depopulation* (J & E Printing Press, 2014).

Another important industry in the region was the production of 'Manila hemp' from the fibre of the *abacá* (*Musa textilis*), banana plants endemic to the Philippines. The supply of ropes for riggings and gun stoppers equipped with galleons started to be crucial for the royal *astilleros*. The cultivation of *abacá* in Sorsogon showed the growth, following the introduction of a hemp-stripping machine by a Spanish missionary, Father Pedro Espellargas (d. 1675), in 1669. Libon in Albay became a trading hub for the exportation of *abacá*.

The people of the area, the Bicolanos, were renowned for their skills in ship construction, a skill that was passed on from even before the age of conquest and was developed and refined over time. While the Spaniards favoured the galleon trade for bringing revenues to the colonial coffers, it caused hardship to the people of the area, especially those who were forcibly recruited as a labor force to service the *astilleros*. It is not surprising that those who were coerced into forced labor in the construction of galleons would later participate in rebellions.

Its shipyards led to Cavite becoming a major port, with its fortifications and shipbuilding industries, showing the prosperity with the complexity of maritime infrastructure in the eighteenth century (Figure 3). Today the Cavite shipyard is located within the nation's naval base, access to which is limited. Its coast has been extensively used by naval forces and was substantially developed over centuries, which limits the possibility of finding archaeological evidence of the shipyards dating back the early Spanish colonial period and earlier.

Archaeologists of the National Museum of the Philippines have nonetheless investigated three shipyards (*astilleros*) in modern Pilar and Donsol in the province of Sorsogon.[61] Their detailed examination, with a focus on the function of these *astilleros*, is available in the written reports: for example, it has been concluded that the remains of the Binanuahan Astillero, located on the tip of the Pilar Peninsula at the bottom of Pilar Bay, are indicative of its administrative role.[62] They include palisades to defend the area and the ruins of a stone structure with a floor area surrounded by thick walls. The stone structure represents characteristics of the Spanish colonial period's architecture, and such buildings could have a roof covered with tiles. Riverine stones and adobe tuff were also used in constructing the thick walls of the buildings in an *astillero*.

The Panlatuan Astillero of Pilar, located in a cove, is considered to have been a construction and smelting site.[63] The site has yielded iron nails, chain rings, sheathings, iron tools, and a large concentration of slag. Many skilled blacksmiths traditionally working in the Bicol Region could sustain the shipbuilding industry. A few wells in the vicinity of the site are well-preserved, being said to date back to the Spanish construction. For comparison, it is worth referring to the surviving structure of the watchtower in the estuary at the modern village of San Rafael, Bulan in Sorsogon (See Fig. 2). The structural remains of Manila galleon shipyards for construction and repair work is not explicitly exposed, nor is it detectable without a full excavation, but the surviving watchtowers are a landmark indicating their probable location.

The Donsol Astillero had been developed by reclaiming mangrove swamps at the mouth of the Donsol River. According to the archaeological report, a land excavation by the museum's researchers has successfully exposed a number of artifacts related to carpentry or likely ship repairs or construction, including the discovery of iron nails and spikes, and copper sheathings,.[64] A smelter is

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61 Mary Jane Louise Bolunia, "Astilleros: The Spanish Shipyards of Sorsogon", *Proceedings of the 2nd Asia-Pacific Regional Conference on Underwater Cultural Heritage* (Honolulu: 2014).

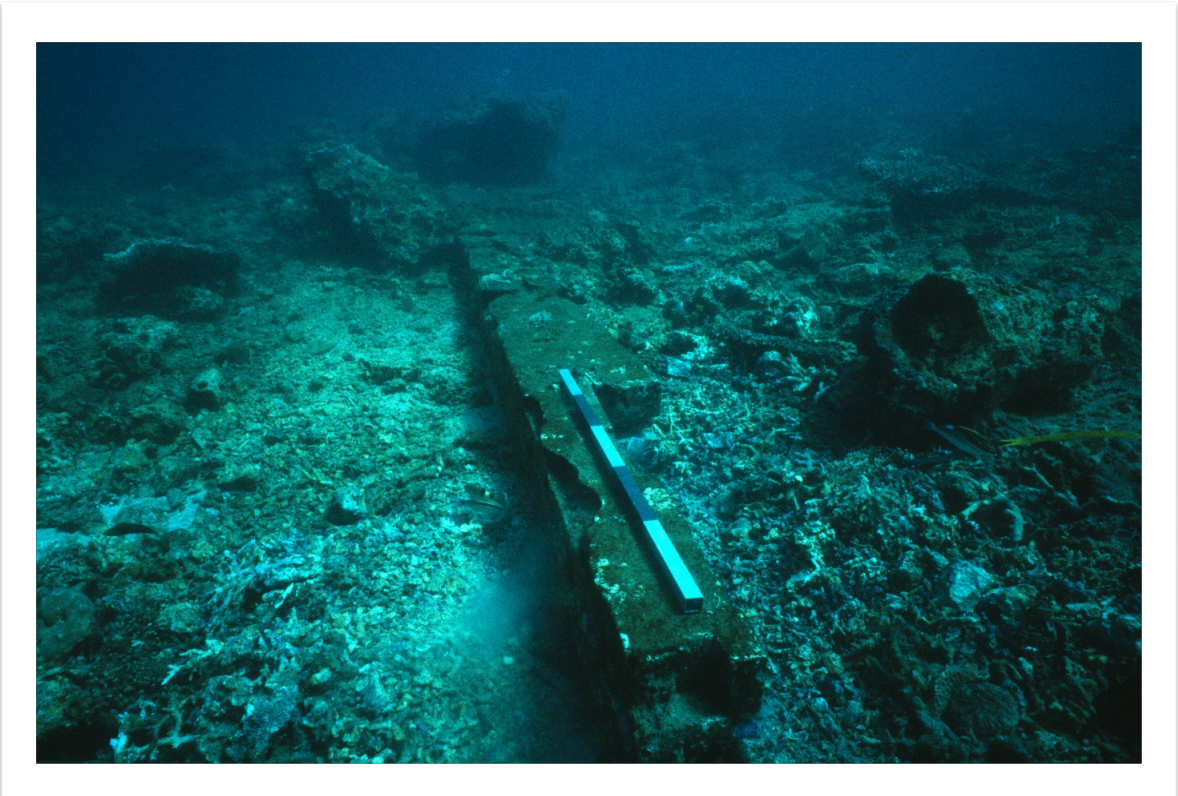
62 Ibid., 8.

63 Ibid., 8-10.

64 Ibid., 10-11.

evident at the site, as is the base of a furnace with large quantities of slag and fuels, including coal, coke, and charcoal. Notably, a large Spanish anchor was also recovered from the site and is now stored at the City Museum of Sorsogon. The estuary of the area has already been fully developed, and unfortunately it is difficult to trace the original seascape.

Fig. 4. Maritime Cultural Landscape drawing of the Manila Galleon trading period (see also Fig. 1. Unknown source, Courtesy of the National Museum of the Philippines, Bicol).



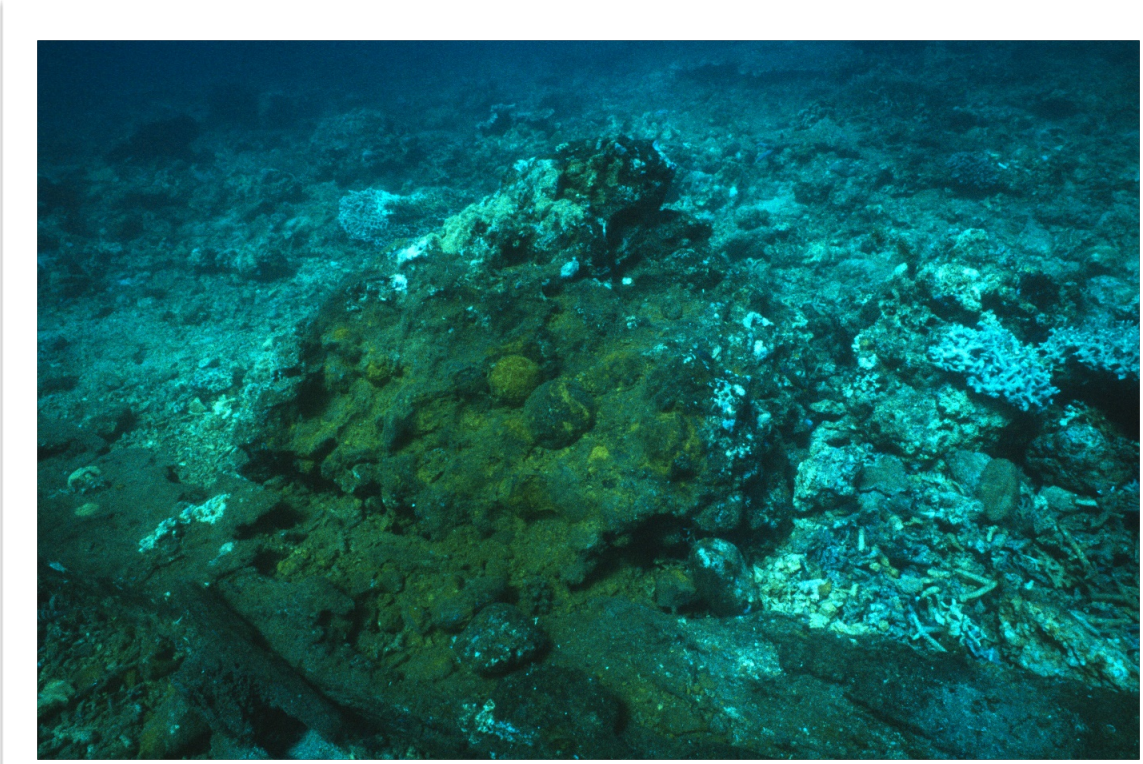


Fig 5. Underwater photograph of the La Vida's keel member (top) and concretion with dead coral mounted on the floor timbers (bottom). Courtesy of the Western Australian Museum.

Fig. 6. A broken piece of a blue and white porcelain of the early seventeenth century's Jingdezhan at the wreck site of the *La Vida*, Verde Island (Photo by Dr. Kimura Jun, 2019).

The complex of some of the astilleros' remains at the estuary that still survive today can be studied by referring to what is depicted in iconography. The location of the remains of these astilleros suggested that the Spanish benefitted from their establishment because of the local environment and topography (Figure 4). Apart from the surrounding rich forests, the peninsulas, coves, and rivers provided a safe anchorage as well as naturally protected shore environments for constructing and repairing ships. Archaeological ruins illustrate that, without the skilled ships' carpenters and blacksmiths, these facilities could not have been sustained.

The archaeological remains of the sunken galleons are a surviving vestige for examining what was recorded in the historical resources above. There have been a few attempts to locate Manila galleon wreck sites in the waters off the coasts of the Pacific rim, yet two shipwrecks are the most relevant for current purposes. The wreck of *San Diego* (which is not a Manila galleon) is one of the best-preserved Spanish wrecks ever found. A merchant ship built at Cebu at the end of the sixteenth century, it was modified as a warship to serve as a flagship in combatting a Dutch incursion in the Philippines in 1600. The ship was overloaded and commanded by Antonio de Morga Sánchez Garay (1559–1636), who was a Deputy Governor of the Philippines, but it sank near Fortune Island (Batangas) during a naval engagement against Oliver van Noort's (1558–1627) ship Mauritius. Almost four hundred years after the loss, the *San Diego* wreckage was located one kilometre off Fortune Island in Batangas outside Manila Bay and was investigated by an international joint team of French scholars and experts from the National Museum of the Philippines. The published data based on the underwater excavation helps us to understand the proportions of a hull designed by late sixteenth-century Spanish shipbuilders in the Philippines.[65] According to the report, the length of the keel is approximately 42 *codos* (cubits), equivalent to 23.73 meters. A keelson measuring 17.50 meters long was identified, broken into three segments. It has a roughly rectangular shape with a width of 20-25 centimetres and a height of 25-35 centimetres. It has also been suggested that the hypothetical dimension of the hull of *San Diego* could be a length of 37 meters equaling 65.5 *codos*, a breadth of 11.3 meters equaling 20 *codos*, and a depth of hold of 5.6 meters equaling 10 *codos*), with the upper deck located at 7.6 meters equaling 13.5 *codos*. This suggests that the tonnage of the San Diego ranged between 688 and 778 *toneladas* depending on the formula applied.

Nuestra Señora de la Vida is another important shipwreck that can be studied as an example of a Spanish *nao*. It is considered to have been designed and constructed for early seventeenth-century voyages across the Pacific. La Vida was lost in 1621 in the Verde Island Passage, a strait separating the islands of Luzon and Mindoro in the Philippines which was used as a major route for the eastbound voyage to return to Acapulco. The ship was reportedly lost along the southwest coast of Verde Island due to navigation errors, having run aground onto the shore of the island. It is said that the hull was dismantled, and the cargo was salvaged over time following the grounding. The National Museum of the Philippines surveyed the site in the 1980–90 with the involvement of Australian researchers.[66] A survey report confirmed that the site appeared to have been heavily disturbed and

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[65] Michel L'Hour, "Naval Construction: A Makeshift Galleon", in *Treasures of the San Diego*, edited by Jean-Paul Desroches, Gabriel Casal, Franck Goddio, Albert Giordan, and the National Museum of the Philippines (Paris: Association Française d'Action, 1996).

[66] Eduardo Ty Conese, *Annual Report: Puerto Galera Underwater Archaeological Project* (Manila: National Museum of the Philippines, 1983); National Museum of the Philippines, *Preliminary Summary Report of the Nuestra Señora de la Vida Wreck, Isla Verde Island, Philippines* (Manila: National Museum of the Philippines, 1985); Nicolas, Norman. C. *A Brief Report on the Sampling done among the Timber Remains of a Shipwreck in Isla Verde* (Manila: National Museum of the Philippines, 1986); Eduardo Ty Conese, *Field Report on the Official Travel Conducted in Verde Island, Batangas City* (Manila: National Museum of the Philippines, 1987); Eduardo Ty Conese, *Underwater Archaeology in the Philippines* (Manila: National Museum of the Philippines, 1987).

continuously pillaged for the commercial purpose of recovering the precious cargo. Apart from the position of the site, the ceramics assemblage including blue and white porcelain of Jingdezhan and jars from the Maenam Noi kilns of Thailand, representative export commodities of the early seventeenth-century Manila galleon trade. Their typological study helps experts determine the date of the site. Researchers from the Underwater Archaeology Section of the Museum and Australian experts conducted underwater archaeological recordings which successfully yielded a photomosaic of the site complementing the Museum's site plan.[67] A large solid piece of timber proved to be in fairly good condition when examined underwater (Figure 5). The identified remains, which could have been abandoned after being dismantled, lay at a depth of 4-6 meters. The remaining part measured 21 meters long. Two large concretions of iron cannonballs, limestone, and ballast stones, which were covered by coral with the presence of mercury, lie on top of the remains. They are composed of the keelson, two counter-keels, and the floor timbers.

Based on recognition of the importance of the keel members and the risk to them at the original site, attempts were made to preserve them by the National Museum of the Philippines.[68] The keel remains of *La Vida* were transferred to Puerto Galera in 1990. It is said that two wooden remains were left at a depth of - 6 meters in front of Sabang Beach of Puerto Galera, while the keel (timber) was deposited in a large vat on Bouquete Island. The keel was later brought to Sabang with the other remains after conservation experts found difficulties in conservation. This site was investigated in 2019. While there were still ceramic shards on the shore in Verde Island indicating the potion of the wreck event (Figure 6), the keel or associated artefacts could not be found underwater, raising the question of whether the keel is still in the area. The state of the other timbers on Bouquete Island could not be confirmed either.

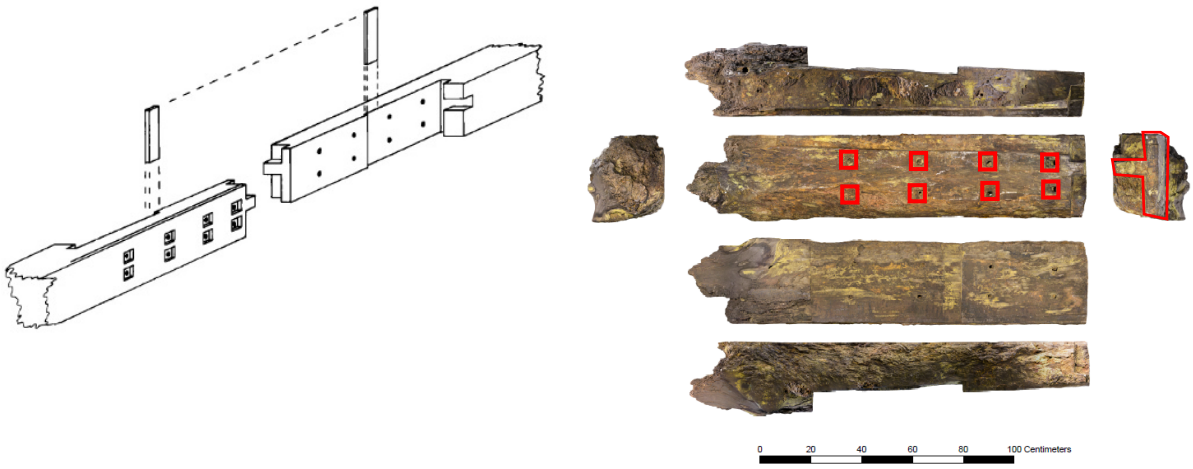

Fig. 7. A schematic drawing of the interpretation of the joint of the La Vida keel member (after Clark et al.1989) and the photogrammetry recording of the remaining part of the joint (Photos: Jun Kimura. Photogrammetric model: Jose L. Casabán).

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67 Paul Clark, Eduardo Ty Conese, Norman Nicolas, and Jeremy Green, "Philippines Archaeological Site Survey, February 1988", *International Journal of Nautical Archaeology and Underwater Explorations* 18:3 (1989), 255-262; Eduardo Ty Conese, *Brief Report on Fieldwork in Bolinao, Verde Island, and Puerto Galera Underwater Archaeological Sites* (Manila: National Museum of the Philippines, 1988).

68 Eusebio Z. Dizon, *Accomplishment Report on the Transfer of the Keel of De la Vida Galleon from Boquete Island to Sabang, Puerto Galera* (Manila: National Museum of the Philippines, 1990); Eusebio. Z. Dizon, *A Report: Assessment of the Keel of De la Vida Galleon at Puerto Galera* (Manila: National Museum of the Philippines, 1990).

A small portion of the keel timber was transferred to the National Museum and is now part of the museum's collection, made available for analysis and recording. It is a keel joint with a length of 1.5 meters and a width of 31 centimetres (slightly wider than the keelson of *San Diego*) (Figure 7). The structure of the keel joint of *La Vida* is distinctive in terms of using a hook scarf joint, which is not normally used in Spanish galleons of that period. The present study has assessed the joint which was fastened to other keel portions by eight large bolts from the side. There are remnants of woven or vegetal fiber sheets on the surface of the joint. Fibers and (probably) pitch were used as caulking materials to make joints watertight. The wooden key and bolts prevent slippage of the construction. We possess an example of a hook scarf method adopted for a keel joint in the medieval East Asian shipbuilding tradition, namely in the case of the fourteen-century Shinan Shipwreck, Mokpo, South Korea.[69] But this is still a working hypothesis.[70]

To assist in determining provenance, wood species were identified. Wood samples measuring about 3-5 centimetres were cut from the keel member, and the samples were sent to the University of the Philippines School of Archaeology (then the Archaeological Studies Program) and the Forest Products Research and Development Institute in the Philippines (FPRDI). Analysis of the wood indicates that the timber is a tropical wood, possibly from the Philippines or at least the Southeast Asian region, belonging to either Ziziphus spp. or Artocarpus spp. The construction site of *La Vida* is not clearly known, but study of the keel portion suggests that it was locally built in the Philippines, or certainly with the involvement of Asian shipbuilders. Written sources mention the involvement of Asian carpenters, especially Philippine and Sangley Chinese but also Japanese, in the construction of galleons in the Philippines.[71] The dimension of *La Vida* was similar to that of *San Diego*, but as the keel is incomplete, the correct dimensions are difficult to assess. But as the keel of *La Vida* is incomplete, this is unclear. They both were freighters, massive and seaworthy enough to voyage across the Pacific Ocean.

Conclusion

The comparative analysis of the dimensions of the galleons included in Pineda's report reveals specific similarities with the Atlantic ships' designs proposed in the shipbuilding ordinances issued in the early seventeenth century, provided that their first deck corresponded to the ship's main deck. In that case, the Pacific vessels described by Pineda appear to have been built with depths of hold almost equal to half their breadth. The length of the ship's floor also increased compared to the ratios of the late sixteenth century, although it did not reach half the ship's breadth. Although the ship's length in Pineda's report did not increase as much as recommended by the 1613 ordinances for Atlantic vessels, the resulting hull ratios are like those proposed by the later 1618 ordinances.

The main difference between the Atlantic and Pacific designs is their keel length, which did not increase proportionally to the ships' overall length. Additionally, even though the depth of hold has been slightly reduced compared to the sixteenth-century ratios, the height between decks still exceeded the values specified in the ordinances. These variations in the main dimensions also resulted in larger tonnages than in the ordinances in the cases that the ships had breadths of 23 *codos*

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69 Kimura Jun, *Archaeology of East Asian Shipbuilding* (Gainesville: University Press of Florida, 2016).

70 The scarf of the Shinan wreck is horizontal and dates to the fourteenth century. Keyed hook scarfs have also been used in Europe since ancient times.

71 See footnote 16 above; see also Carlos Peña Tatel Jr. "Patterns of External Exchange in Porta Vaga: Morphometric Analysis of Excavated Tradeware. Ceramics at Porta Vaga Site, Cavite City" (University of the Philippines, 2002).

and above, especially in the case of the Salvador. However, ships with a breadth of 22 ½ *codos* had tonnages similar to those listed in the 1613 ordinances, and some of the variations in the ships' main dimensions could be explained as a result of the construction process. Only the Guadalupe, with a breadth of 21 *codos*, had a smaller tonnage than it should have done. Nevertheless, further research is needed to determine the deck configuration of the vessels and how the depth of hold was measured in the Philippines.

The differences between the designs and dimensions of the early seventeenth-century Pacific galleons and the Atlantic vessels could be attributed to several factors. New Spain and the Philippines merchants required large vessels capable of transporting maximum amounts of Asian goods on two vessels each year to maximise their benefits. Additionally, Pacific vessels did not have the draft limitations caused by the sandbar of Sanlúcar de Barrameda in Spain that affected the design of transatlantic galleons. Finally, there was a delay in transmitting new designs and shipbuilding philosophies from Spain to the Philippines due to the distance between the two places and the chronic shortage of Spanish shipwrights in the islands. Moreover, archival documents reveal that the linear unit used in the early seventeenth century in the Philippines to build vessels was the *codo castellano* instead of the *codo de ribera* or *codo real*, becoming the official shipbuilding linear unit in Spain from 1590.

Pineda's report describes ships with hull ratios that appear to be transitional designs in addition to their large dimensions. These ships incorporate hull ratios from the late sixteenth century and the new designs introduced by the shipbuilding ordinances issued between 1607 and 1613. In any case, Pineda's report provides insights into the evolution of shipbuilding during the early seventeenth century in the Philippines.

Acknowledgements

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APPENDICES

TABLE 1. Ships dimensions and tonnages

Galleon (Shipyard)	Length	Keel	Breadth	Depth of hold		Flat of the floor	Tonnage (Toneladas)
				1st deck	Last deck		1st deck
Salvador (Masbate)	82	60	26	15	19	12	1,935
Espíritu Santo	70	50	23	13	17	10	1,236 1/2
San Felipe (Bagatao)	70	50	22.5	11.5	15	10	1,075 3/7
Santiago (Mindoro)	70	50	22.5	11.5	15	10	1,075 3/7
San Juan Bautista	70	50	22.5	11.5	15	10	1,075 3/7
San Miguel (Cavite)	68	49	23	14	18	10	1,298 3/8
Nra. Sra. de Guadalupe	64	46	21	9.5	13	9	753 7/8
Nao San Laurencio	60	46	19	12		-	-
Galleons/ 17th-cent.				Main deck (maximum	Upper deck		
García de Palacio	51 1/3	34	16	7.5*/11.5**	14 1/5	5 1/3	400*
Large Apostles	64	42	20.5	12.5	16	7	1,159
Ordinances 1607	65	47	19	10	13	9.5	897 3/8
	69	48	20	10.5	13.5	10	1,033
	72	51	21	11	14	10.5	1,184⅝
	75	53	22	11.5	14.5	11	1,351⅝
Ordinances 1613	63 ¼	49	19	9.5 (9) 9.5 (9.5)	12 3/4	9.5	743 (warship) 721 ¾
	66	51	20	10 (9.5) 10 (10)	13.25	10	858⅝ (warship) 833
	68.75	53	21	10.5 (10) 10.5 (10.5)	13.75	10.5	985 (warship) 956⅜
	72.5	54	22	11 (10.5) 11 (11)	14.25	11	1105½ (warship) 1,073⅓
Ordinances 1618	61.5	48	19	9.5 (9)	12.5	9.5	721 3/4
	63	49	20	10 (9.5)	13	10	821⅞
	66	51	21	10.5 (10)	13.5	10.5	946½
	68	53	22	11 (10.5)	14	11	1074¾

* Height of the first deck (primera cubierta)/Tonnage corresponds to this depth of hold.
** Height of the second deck (puente) or main deck (cubierta principal) according to Palacio's

TABLE 2. Ship ratios

Source	Breadths	Length/ Breadth[1]	Keel/ Breadth[2]	Depth of Hold/ Breadth 1st deck	Depth of Hold/ Breadth 2nd deck	Floor/ Breadth[4]
Salvador	26	3.15:1	2.31:1	0.58:1	0.73:1	0.46:1
Espíritu Santo	23	3.04:1	2.17:1	0.57:1	0.74:1	0.43:1
San Felipe	22.5	3.11:1	2.22:1	0.51:1	0.67:1	0.44:1
Santiago	22.5	3.11:1	2.22:1	0.51:1	0.67:1	0.44:1
San Juan Bautista	22.5	3.11:1	2.22:1	0.51:1	0.67:1	0.44:1
San Miguel	23	2.96:1	2.13:1	0.61:1	0.78:1	0.43:1
Nra. Sra. de	21	3.05:1	2.19:1	0.45:1	0.62:1	0.43:1
Nao San Laurencio	19	3.16:1	2.42:1	0.63:1		
García de Palacio (1587)	16	3.21:1	2.13:1	0.47:1*/0.72:1**		0.33:1
Large Apostles (1589)	20.5	3.12:1	2.05:1	0.66:1		0.34:1
				Depth of hold/Breadth Main deck		
Ordinances 1607	19	3.42:1	2:47:1	0.53:1		0.50:1
	20	3.45:1	2.40:1	0.53:1		0.50:1
	21	3.43:1	2.43:1	0.52:1		0.50:1
	22	3.41:1	2.41:1	0.52:1		0.50:1
Ordinances 1613	19	3.33:1	2.58:1	0.50:1		0.50:1
	20	3.30:1	2.55:1	0.50:1		0.50:1
	21	3.27:1	2.52:1	0.50:1		0.50:1
	22	3.30:1	2.45:1	0.50:1		0.50:1
Ordinances 1618	19	3.24:1	2.53:1	0.50:1		0.50:1
	20	3.15:1	2.45:1	0.50:1		0.50:1
	21	3.14:1	2.43:1	0.50:1		0.50:1
	22	3.09:1	2.41:1	0.50:1		0.50:1

* Calculated at the level of the first deck (primera cubierta).
** Calculated at the level of the second deck (puente) or main deck (cubierta principal).

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AGI, Filipinas, 29, N.100; AGI, Filipinas, 193, N. 3.

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