FOUR CENTURIES OF

XVI SPANISH XIX ENGINEERING

OVERSEAS

INTRAMUROS ADMINISTRATION

EMBAJADA DE ESPAÑA EN FILIPINAS

Spanish Cooperation

Instituto Cervantes

cíes CONOCIMIENTO E INGENIERÍA DE ESPAÑA

PAMBANSANG MUSEO NG PILIPINAS
NATIONAL MUSEUM OF THE PHILIPPINES

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It is indeed an honor and privilege to welcome this magnificent exhibition that celebrates the legacy and contribution of Spanish engineering in the overseas territories. With eight sections carefully approched, this exhibit guides us through a fascinating journey through four centuries and across four seas, exploring the influence and impact of Spanish engineering in shaping landscapes, infrastructures and societies overseas.

From the construction of cities to the design of hydraulic systems, each section offers a unique window into how Spanish engineering not only transformed the physical environment, but also left an indelible mark on the culture, economy and development of these regions.

Upon going through this exhibit, it is impossible not to be in awe and admiration of the creativity, wisdom and technical prowess of those who defied the unknown and faced monumental challenges. I hope that this exhibition will serve as a source of inspiration and reflection, inviting all visitors to contemplate our shared past with a renewed sense of appreciation and respect for the diversity of cultural and technical contributions that have shaped our world.

It is also a motive of great satisfaction to have been able to count on the collaboration of different Spanish and Philippine institutions, which demonstrates the commitment to highlight our shared history. Allow me to extend special thanks to the Museo de San Agustin, which hosted a first adaptation of this exhibition between March 2024 and May 2025.

The inauguration of the exhibition on June 30, the day of the commemoration of the Spain-Philippine Friendship Day, only reinforces, if possible, this spirit of friendship that characterizes our relations.

May this exhibition be a lasting reminder of the importance of preserving and valuing our historical and cultural heritage, and may it inspire present and future generations to continue to explore, learn and collaborate in pursuit of a common future of understanding and cooperation.

Miguel Utray Delgado
Ambassador of Spain in the Philippines

¡Mabuhay! It is with great pride that we welcome you to the exhibit, “Four Centuries of Spanish Engineering,” held at the historic Centro de Turismo Intramuros.

This exhibit stands as a testament to the enduring legacy of Spanish engineering and its profound influence on the development of Intramuros and the Philippines at large. From fortifications and enduring civic structures to grand churches and planned streetscapes, Spanish engineers shaped the very foundations of our Walled City, many of which continue to define its character and resilience to this day.

The Centro de Turismo is a fitting venue for this exhibit, serving as a historic space that connects our heritage with the public. As a former colonial structure, now reimagined as a hub for cultural engagement and education, it reflects the very themes of transformation and preservation that this exhibition celebrates. More than a retrospective, this exhibit serves as an invitation to reflect on how heritage and innovation can go hand in hand. It reminds us of the value of preserving history not just as memory, but as a living guide for present and future generations.

We are especially grateful for the support and collaboration of the Embassy of Spain in Manila and other partner institutions that made this exhibit possible. Their contribution reinforces the spirit of cultural exchange and shared history that strengthens our national identity within a global context.

As the Intramuros Administration continues its work in heritage preservation, cultural education, and innovation in public service, we hope that exhibits like this deepen the appreciation of our built heritage and inspire Filipinos to become active stewards of our shared past.

Atty. Joan M. Padilla
Administrator of the Intramuros Administrator

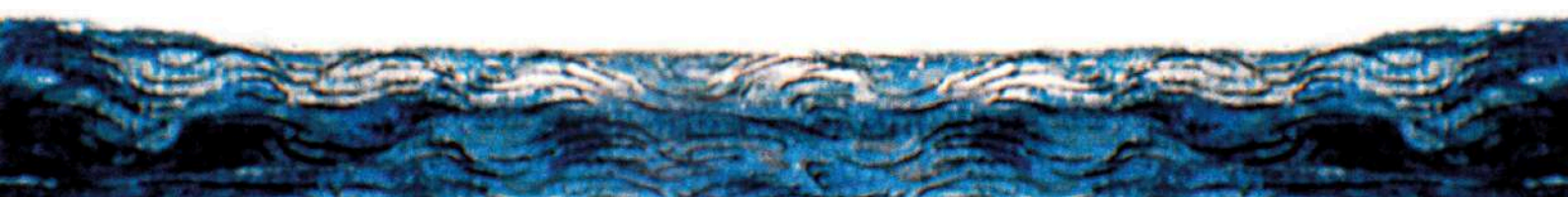
INTRODUCTION

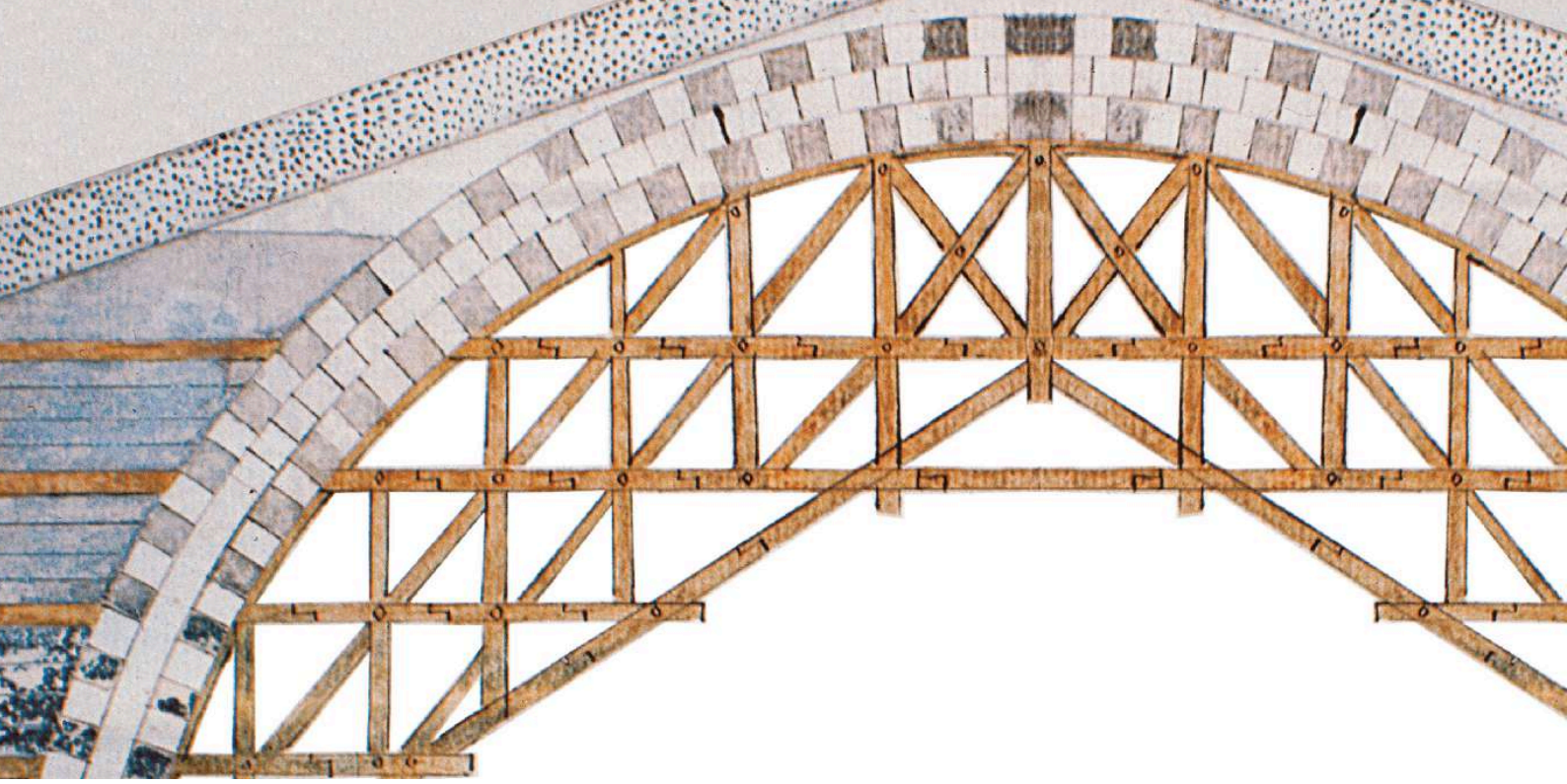
Engineering consists of applying knowledge to enable: supplying water to people, cultivating fields, organizing the territory, communicating it, defending it, improving industrial processes, transforming raw materials, transporting goods and merchandise, preventing natural disasters, harmonizing the growth of cities with the environment, and innovating.

These are essential and definitive activities for human development and economic progress; activities that engineers have been practicing discreetly and anonymously for centuries. Through this exhibition, a continuation of the one held at the General Archive of the Indies on the occasion of the tricentennial of the first engineering ordinances promulgated in Spain in 1718, and in the magnificent cloister of the Convent of San Agustín, within the walls of Manila in 2024-2025, the aim is to recognize the work of those individuals who used their knowledge to improve the quality of life for others, designing infrastructure and machines that transformed the society of their time, envisioning the future.

The projects, reports, and work carried out by engineers in the service of the Spanish Crown in Overseas Provinces, which the participating institutions here carefully preserve, constitute one of the greatest technological heritages in the history of humanity, as very few nations in the world shaped a continent and an archipelago. Therefore, an enormous work is presented in terms of territory: America and the Philippines, and in the time period: 16th to 19th centuries.

We greatly appreciate the hospitality of this Intramuros Tourism Center for hosting the exhibition in this magnificent building located in the reconstructed Church of San Ignacio, where visitors can gain a comprehensive view of the history of engineers and the different branches that existed during the study period across eight areas.





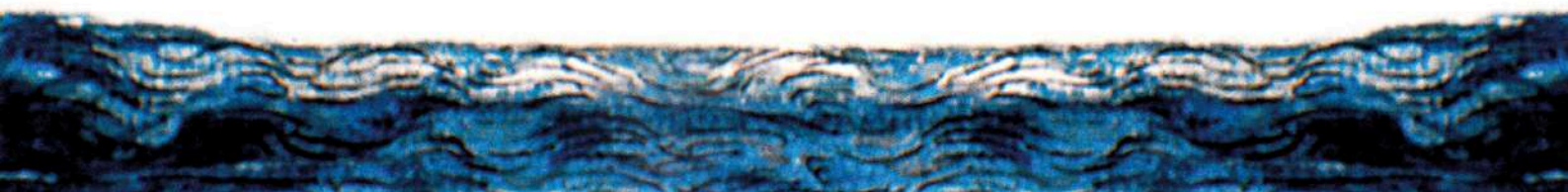
Starting with their military and civil legacy, we will journey through urban planning and territorial organization, hydraulic works, communications, mining, industry, ports, and fortifications, culminating in naval engineering.

In addition to the enormous work of the engineers, the commendable intervention of religious orders in numerous public works and their cartography over the centuries must be added, with prominent figures such as the Augustinian father Fray Lucas de Jesús María, who designed the old Alcaicería of San Fernando in Manila for the accommodation of the sangleyes arriving from China for the annual trade, or Pedro Murillo Velarde y Bravo, the Jesuit who designed the beautiful map of the Philippines in 1734, along with the Tagalog engraver Nicolas de la Cruz Bagay.

We hope that this journey captivates the youth to study engineering, adults to consider and respect it for its value as a fundamental pillar of social well-being, and inspires researchers to explore new avenues of study in the fascinating and rich history that the Philippines and Spain share.

María Antonia Colomar Albajar
Exhibit Curator

Ignacio Sánchez de Mora y Andrés
Exhibit Curator



THE LEGACY OF THE ENGINEERS IN AMERICA AND THE PHILIPPINES

The organization of the Spanish Empire was forged in the 16th century. By the end of the century, most of the urban network in the Spanish overseas provinces had already been established, with the city becoming a fundamental element in a complex web of administrative, political, economic, cultural, defensive, and other relationships. This led to the implementation of hydraulic infrastructure for agricultural, urban, and industrial supply, land, river, and naval communication systems, as well as coast protection and defense systems for ports and cities. All of this ultimately forms the basis for the planning and construction of the territory.

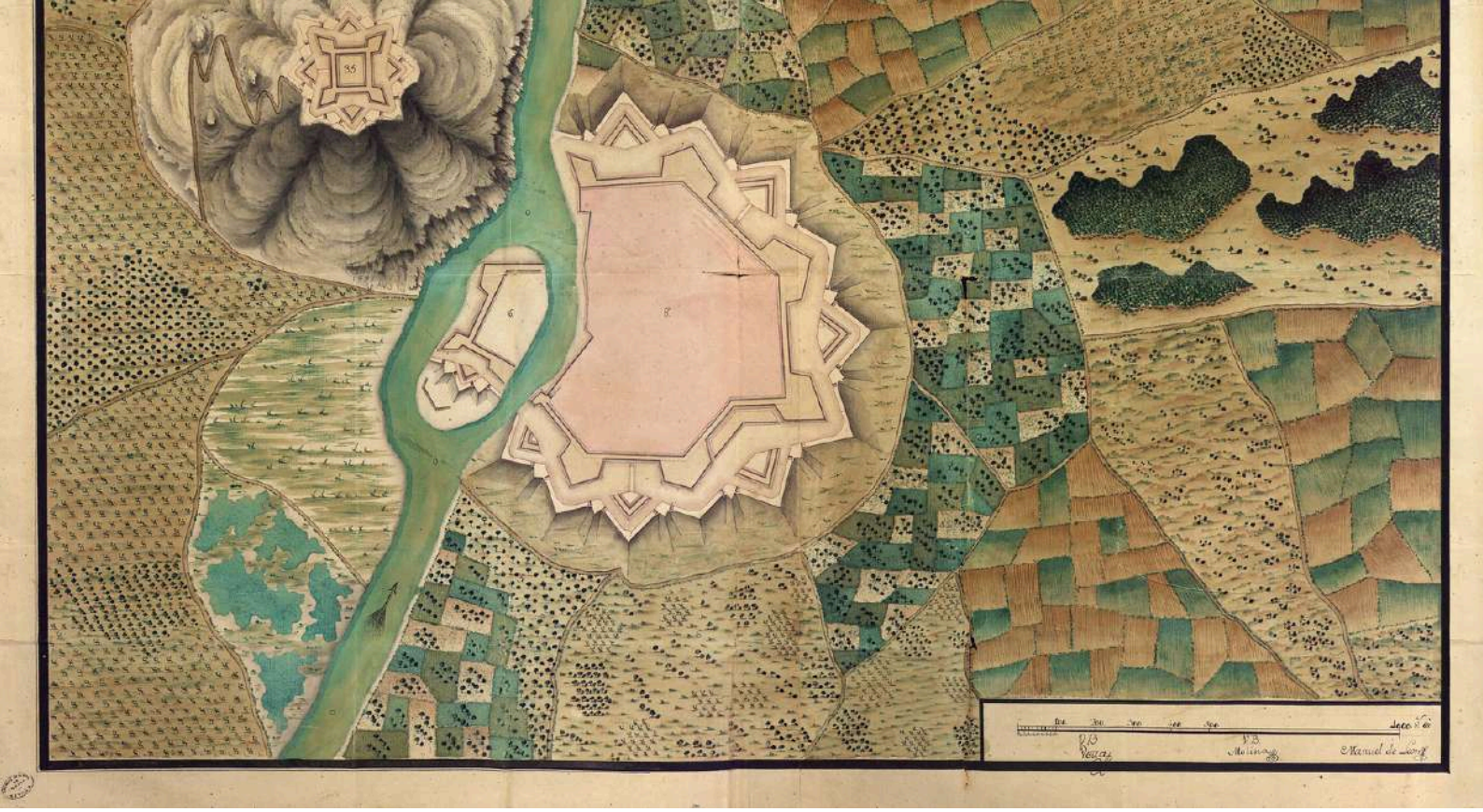
In these processes, military engineers served the administration in military tasks, primarily in fortification works and in industrial installations linked to the army. However, they also devoted themselves to civil works as technicians of the Crown: in the 16th and 17th centuries as military personnel without affiliation to any organic entity; in the 18th and 19th centuries, within the Corps of Military Engineers founded in 1711 and, from 1799 onwards, also as civilian engineers, effectively supporting the monarchy's development policy with participation in public works and civil infrastructure and construction projects.

At the end of the 19th century, there were seven public works districts in the Philippines with 69 officials, among them 16 engineers, the most prominent of whom were Carlos de las Heras y Crespo, Eduardo López Navarro, Genaro Palacios y Guerra, José García Morón, and Antonio de la Cámara.

Military Engineers of the Crown
The Pioneers. 16th-17th Centuries

During the 16th and 17th centuries, under the rule of the Habsburgs, military engineers of the State were tasked with the defense of the empire. Overseas, due to piracy, their primary focus was on fortifying cities and ports that served as repositories for the gold and silver from the viceroyalties of Mexico and Peru. These locations served as terminals for the fleet of New Spain and the galleons of Tierra Firme, respectively. Foreign engineers in the service of the Spanish Crown, along with local engineers, executed the strategic defense plan for the Caribbean, Gulf of Mexico, and ports in the Pacific.

To address the shortage of Spanish engineering officers in their armies, Philip II facilitated the establishment of the Academy of Mathematics and Military Architecture in Madrid in 1582, founded by Tiburcio Spannocchi, where Cristóbal de Rojas taught. However, despite their limited numbers in America, military engineers occasionally collaborated on civil projects alongside architects, construction foreman, non-engineer military personnel, mathematicians, or cosmographers with scientific training and knowledge.



The Corps of Military Engineers 18th-19th Centuries

The enlightened policy of the Bourbon dynasty shall oversee at the defense and security of overseas possessions and the promotion and exploitation of economic resources. During this period, military engineers become key pillars of defense and reforms, especially after being unified as a corps in 1711 by the engineer José Próspero de Verboom. The Ordinances of 1718 not only granted them their military duties but also many of the civilian duties of the era, including territorial recognition and intervention, particularly through structural public works.

Other subsequent ordinances and regulations (1768, 1774, 1791, 1803) define the evolution of the Corps, its division into three branches (1774), its reunification with General of Engineers José de Urrutia y de las Casas (1791), or its relationship with the Artillery branch. They also supervise the training of engineers in the Mathematics Academies of Barcelona (1720), Oran (1732), and Ceuta (1742); the examination-based entry system, requiring the acquisition of necessary knowledge; promotion based on merits in a hierarchy with the following ranks: general engineer, director engineer, chief engineer, second engineer, ordinary engineer, extraordinary engineer, delineator, assistant, and, outside the organization, voluntary engineer. They also deal with the development of their cartography and even matters such as their uniform.

Civil Engineers
Technical Developments. 19th Century

Civil engineering emerges as a branch of military engineering, as the latter cannot fulfill all its commitments in public works. The formal birth of Spanish civil engineering takes place in 1799 with the creation of the Corps of Engineers of the General Inspection of Roads, which complements and expans the mandate of the General Directorate of Roads established in 1785.

In 1802, Agustín de Betancourt y Molina founds the School of Engineers of Roads and Canals in Madrid, following the example of L'École Nationale des Ponts et Chaussées in Paris. In 1836, the Regulations of the Corps of Road Engineers are published, including those of the School, regulating its operation, duration of studies and the strict discipline to which students have to adhere. Throughout the rest of the century, there is a proliferation in its various branches.

Due to its late creation, the scope of action of civil engineers in territories overseas is limited to the islands of Cuba, Puerto Rico, and the Philippines, once the continental territories gained independence. However, military engineers initially prevail in public works, despite the Ordinance of 1803 limiting their functions to military tasks.


DESCRIPCION GEOMETRICA
DE LA CIUDAD Y CIRCUNVALACION
DE MANILA Y DE SUS ARRABALES

CITY AND TERRITORY

In the process of Spanish colonization of overseas provinces, reduced by successive laws for their administration, the conqueror transforms into a pacifier and settler. They become attached to the land and establish cities, a deed reflected in the “Act of Foundation” which, with the layout of the new population, becomes the symbol of settlement and colonization of the territory in the new lands.

From the beginning, cities are the nerve centers of all administrative divisions and the seats of civil and ecclesiastical bodies. Their role is to organize the territory according to their urban functions, serving as a supply base and commercial exchange factor, a bridgehead for deeper penetrations, a link in a broad chain of foundations, an element of control and consolidation of the indigenous population, ultimately a focal point of land ownership dominance (The City, 1989). The materialization of these attributes is reflected in the forms of spatial organization and relationships with the surrounding territory, planning the main infrastructures, which are the object of engineering.

Founded by the Spanish conqueror Miguel López de Legazpi on June 24, 1571, the City of Manila, on the island of Luzon, became the capital of the Spanish East Indies and the bridge connecting Spain with the Far East through the route known as the Galleon of Manila, Nao of Acapulco or Nao of China.

The City in the process of Territorial Construction. 16th-17th Centuries

The main overseas populations were planned according to a geometric model, using a ruler and string. However, in almost contemporary evolution, irregular cities coexist—, especially spontaneous growth mining towns—, semi-conventional, and conventional cities. In the most important populations, this latter model prevails, with rectangular or mainly square blocks, the “Classic Model of the Hispanic-American City” in a grid that seems to begin with the second foundation of Guatemala and consolidates in the city of Lima. Whether in the center or not, the main square constitutes the core of city life where military, civil, religious, or mercantile activities take place, and it is where the main civil and religious buildings are located.

This city structure can already be glimpsed in the order decreed made by Emperor Charles V in 1523, although it is modified in the Ordinances issued by Philip II in 1573 when the urban network is already established. The typology of populations can also be established based on other parameters such as their location (maritime like Havana or Manila, inland like Mexico) or their predominant activity (commercial, mining, etc.). There are also mixed race cities (Mexico, Cuzco, and Quito), Indian towns, or towns with indigenous people converted to Christianity in whose layout a greater development of religious spaces is evident. These typologies determine the predominant infrastructures in each case.

Enlightenment and the City 18th Century

As a result of Enlightenment policies brought along by the Bourbon dynasty, a new urban thrust impulse emerges, driven by colonial growth and demographic increase. Starting with the first Administrative Ordinances issued for Cuba in 1764, reflecting those of 1718 and 1749 for Spain, administrators progressively shall assume various urban functions, including:

- Modernization of cities. Implementation of water supply infrastructures, communication networks, sanitation systems, street lighting, disaster prevention, etc.

- Beautification of the urban landscape. Construction of important buildings, embellishment of streets and squares with monuments and fountains, creation of green spaces such as parks, promenades, and botanical gardens, and improvement of poorly-designed public spaces.

- Effective organization of cities. Division into “quarters” and neighborhoods with their own “Ordinances,” regulations for the cleanliness of streets and facades, and the establishment of good order and organization within the cities.

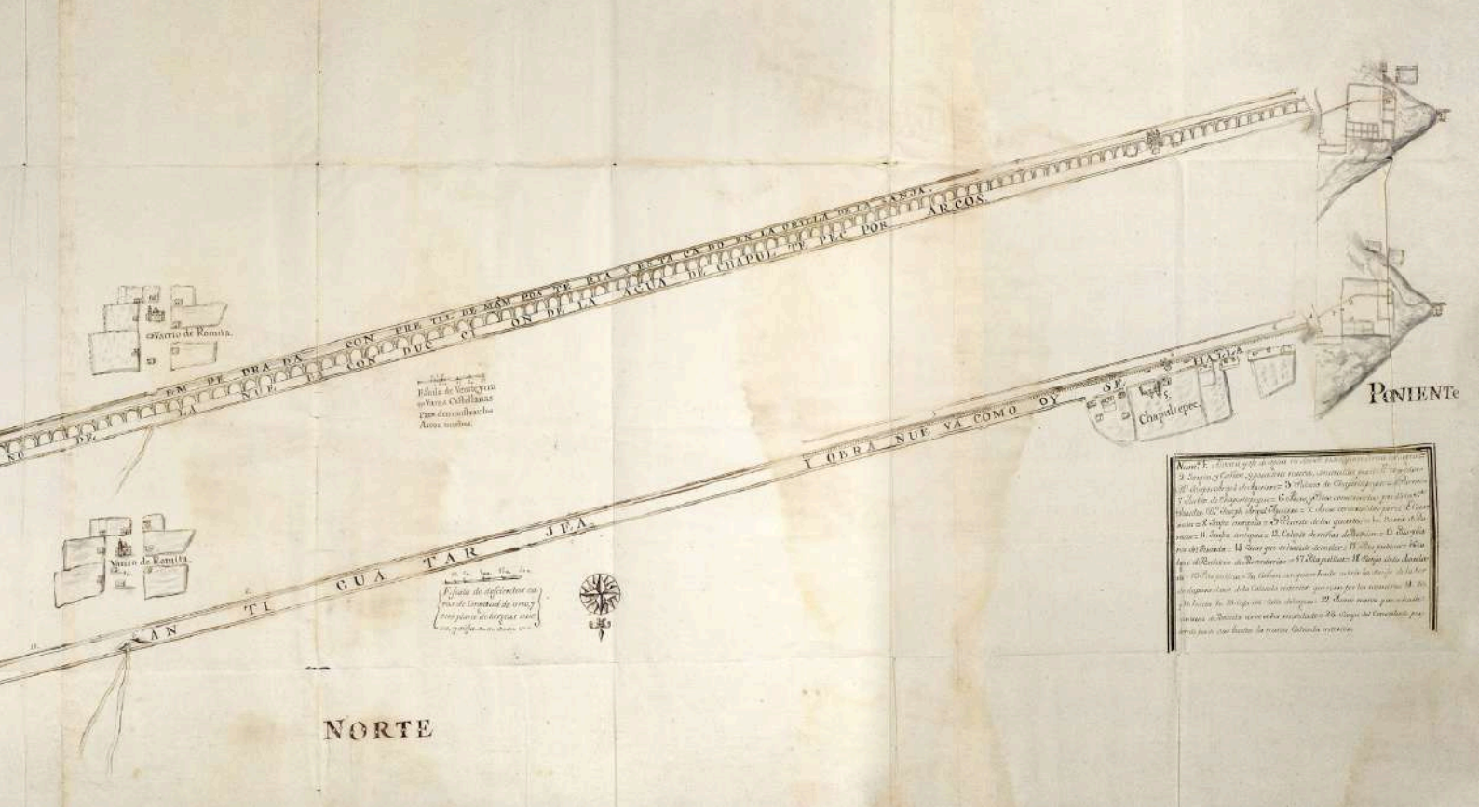
- New institutional aim. Reinforcement and defense of borders, expansion of provincial boundaries through colonization or repopulation of marginal areas, and the rebuilding of destroyed cities like Guatemala and Concepción de Chile.

HYDRAULIC WORKS

The Spanish brought significant knowledge of hydraulic infrastructure to America, but in many cases, they had to adapt them to the environment and those of the established cultures, which were highly developed in some aspects, causing admiration among the Spanish forces. The technical expertise of the Aztecs stands out in techniques implemented for water supply, agricultural production in chinampas, and for sanitation and protection against disasters (Tenochtitlan). Similarly, the Incas demonstrated advanced techniques in their cultivation on ridges or platforms and in terracing.

There was a mixed engineering approach that involved the application of European instruments, especially in the construction of aqueducts, using water wheels and weirs. However, indigenous techniques were also employed in other works such as supply channels. Elements of hydraulic engineering were also applied to industrial engineering, including mining operations.

According to the definitive project of engineer Genaro Palacios Guerra (1872), among the hydraulic infrastructures built in the Philippines, the remarkable water supply system of Manila stands out in which the steam engine was already used, in addition to siphons and aqueducts.



The Productive Landscape

During the viceroyalty period, water capture was carried out using European systems: weirs at the level of the aquifer and types of water-lifting wheels. For irrigation, in Mexico the pre-Hispanic supply network was maintained, with large reservoirs (jagüeyes) and canals (apantles). In the Peruvian viceroyalty, Inca irrigation networks were reused.

For urban supply infrastructures were used, also compatible with rural supply, of capture, storage (dams), conduction or aqueduct (canal or arches) and pipes, and finally by fountains or spouts. Notable are the Olla and Santos dams in Guanajuato, the striking aqueducts by arches of Mexico, such as those of Chapultepec and Cempoala, and the remarkable channels of the Zanja Real of Havana, the Maipo in Santiago de Chile and late one of Manila (1869).

Sanitation
Key to Public Health

Sanitation comprises the set of works, techniques, and devices aimed at establishing, improving, or maintaining appropriate sanitary conditions. From the perspective of civil engineering, efforts in overseas were focused on combating diseases and epidemics, which were causes of demographic catastrophe, through direct measures supported by the legislation of the Ordinances of Intendants:

- Establishment of cemeteries away from the core of populations.
- Street paving. During the Enlightenment Period, major colonial cities undertook paving and cobbling works: La Guaira in Venezuela, Lima, or Havana, the latter using granite cobblestones from Boston.
- Cleaning services outlined in administrative and city ordinances.
- Sanitation of marshlands through drainage with ditches or drainage channels or wells. Also, facilitating the continuous circulation of water, as in the case of the town of Yuririapúndaro.
- Establishment of sewerage systems, a very late phenomenon, with the exception of the city of Santo Domingo, equipped with them since the 16th century.

Floods
The Indomitable Force of Water

Overflow and floods were prevented with levees or channeling walls and channel cleanings, as well as, drainage works, such as the one for the Mexico City Lake.

This colossal hydraulic engineering project, the most important of the colonial period, took place between the 16th and 19th centuries. It involved draining the lake basin where the city of Mexico-Tenochtitlan was located, subject to severe and recurrent floodings due to the silting of the surrounding lakes (Zumpango, Xaltocán, San Cristóbal Ecatepec, and Texcoco).

The project of partial drainage of the basin, initiated by Enrico Martínez in 1608, diverted the waters of the Zumpango lagoon, near Huehuetoca, towards the Atlantic through a tunnel and then an open channel. After multiple setbacks, including tunnel collapses and new floods, the drainage of the first three aforementioned lagoons was completed in the late 18th century, with the drainage of the Texcoco lagoon and the city's sewerage system still pending. A comprehensive drainage project was proposed in 1773 but was not resumed until 1856, already in the era of independence.

PLANO GENERAL

DEL

CANAL DE CONDUCCION DE AGUAS POTABLES

A

MANILA

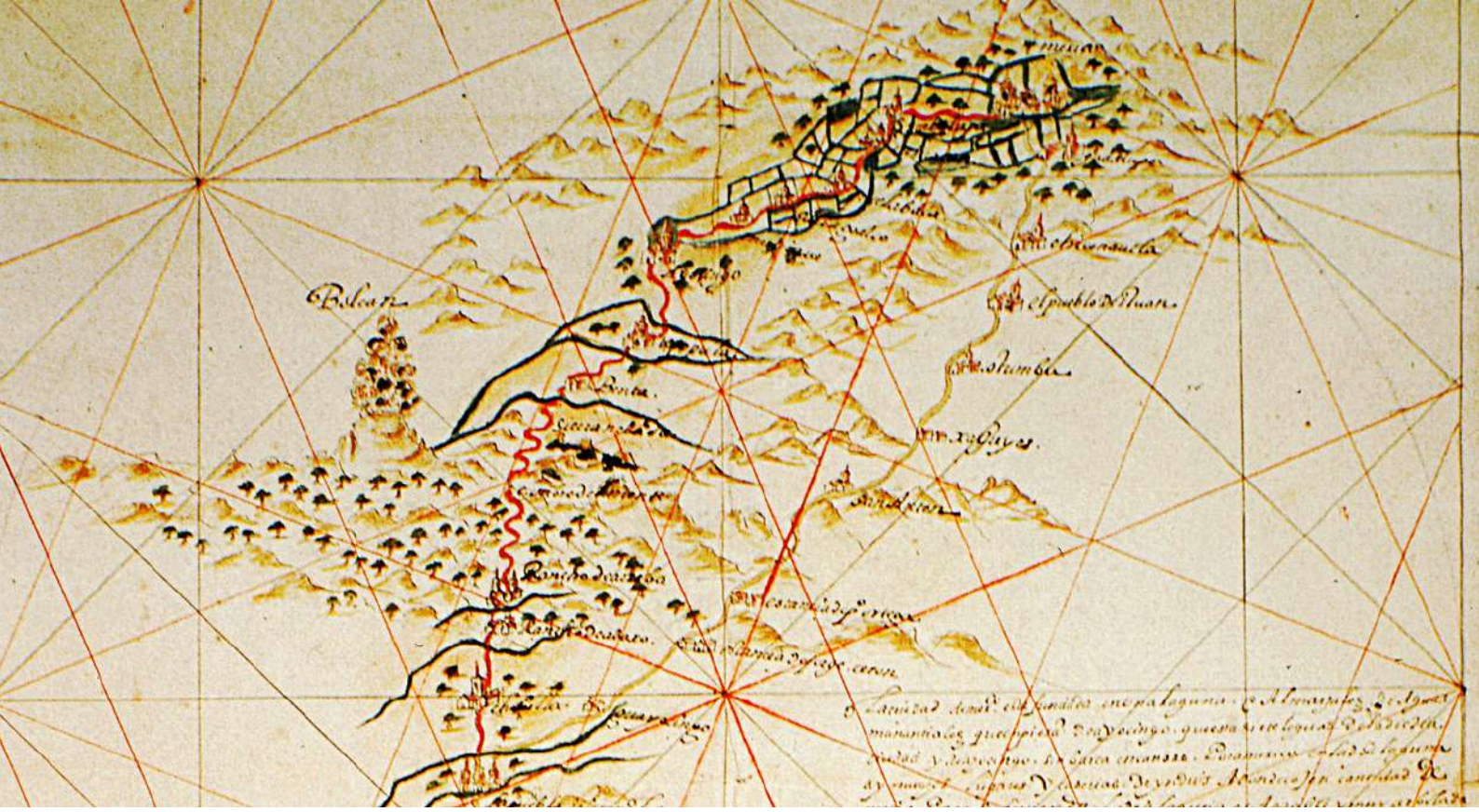
COMMUNICATIONS. ROADS, BRIDGES AND NAVIGATION CHANNELS

Despite the admiration of the Spaniards for the Aztec causeways of Tenochtitlan, Mexico, and the extensive road network of the Incas, most colonial roads were mule or horse trails, traversed on foot, by pack animals, or by tamemes or porters. Vehicular roads were less common, sometimes occupying partial sections of a route. The most important colonial roads were associated with the transport of silver and the fleets of the Carrera de Indias.

The main challenges of the roads were encountered at river crossings, which were often swift-flowing, with unexpected floods and irregular flow patterns. The typology of bridges adapted to the hydrography, orography, topography, and climatology of the territory, combining pre-Hispanic and European techniques in bridges made of wooden beams, and stone and lime.

Navigation on rivers and lakes was common in Spanish America as it offered a less costly and more efficient alternative to challenging overland transportation. Hence, there were projects to open navigation and transportation channels in Colombia (Canal del Dique), Cuba (Canal de Güines), and across the isthmus of the continent (Tehuantepec, Nicaragua, and Panama).

In the Philippines, among the communication routes worth-mentioning are the 19th century roads in the North and South of the island of Luzon as well as the large number of bridges of all types, located mainly on that island and others such as Camiguin, Leyte, Mindanao, Samar and Panay.



Roads.
Arteries of the Territory

The main roads were linked with trade and economic routes:

New Spain
The Camino de Tierra Adentro (Mexico - Santa Fe) and the Camino de los Virreyes (Mexico - Veracruz) were important routes for transporting the silver from Zacatecas, Guanajuato, and other mines, which was sent to the metropolis in the Flota de Nueva España from the port of Veracruz. The Asian Road or the Chinese Road (Mexico-Acapulco) connected the Philippines through the Nao de Acapulco or the Manila Galleon.

Panama
The transportation of Potosi silver was carried out through the isthmus routes (Panama - Nombre de dios and later Portobelo) and then was loaded onto the galleons of Tierra FIrme. In the 18th century, this route went into crisis as Potosí silver started to be shipped through Buenos Aires.

New Kingdom of Granada
The challenging geographical conditions determined that the main communications were carried out through the Magdalena River. In Ecuador, with difficult communication with neighboring provinces, the route from Quito to the sea was opened through the Esmeraldas River. In Venezuela, the export of cocoa was carried out through the mule train route road of La Guaira.

Bridges and new forms of transportation in Manila

Bridges
The majority of the bridges built in the Philippines are located in Luzon, coexisting traditional techniques with more innovative ones as seen in the bridges over the Pasig River in Manila:

- Stone Bridge, the Grand Bridge of Manila, in Binondo (1630-1863): was the first and only active colonial bridge during those dates. After its destruction by the earthquake of 1863, it was replaced by a raft bridge and then by the Spain Bridge (1875).

- Hanging bridges, the one of Arroceros or Clavería (1852). It was the second bridge over the Pasig River and the first of its kind in Southeast Asia. Promoted by the company Matía Menchacatorre and Company.

- Lattice bridges, the Quinta Bridge. Made of wood, like this one from Quinta, or metal lattice that thrived with the railway.

- Reduced arch bridges, the Spain Bridge in Binondo (1875). They are bridges with wider openings, featuring lowered arches, like this Spain Bridge which replaces the Grand Bridge.

- Arch bridges, Ayala Bridge or Convalescence Bridge (1872). Consisting of two wooden spans, converging at the island of Convalescence from the opposite neighborhoods of San Miguel and La Concepción.

Railway
Proposed following the General Plan for Railways of the island of Luzon from 1875, with two lines, one to the north, from Manila to Dagupan, completed in 1882, and another line to the south, pending.

Trams
In 1878, the establishment of a five-line tram network was completed in Manila, connecting the city with the suburbs.

Bridges, Land Over Water
New forms of transportation

Land communications were often hindered by having to cross rivers with large flows and uneven regimes. To ford them through bridges, pre-Hispanic techniques coexisted with European ones, sometimes forming mixed techniques:

- Ferries, aerial tramways, gondolas, or cable cars. Cables stretched between the two banks of a river or canal.
- Floating bridges. Laid over rivers with stable currents and flows. Made of boats anchored at their ends with a wooden deck.
- Suspension bridges. Made with liana ropes, they are called crizneja or hammock bridges. Of Inca origin, over very fast and uneven currents.
- Wooden bridges. Pre-Columbian, they are bridges made of logs or beams, very common in Peru. They are the barbacoa bridges and the 'pantalanes' of the Philippines. For soft and swampy terrain.
- Stone bridges. Primarily urban, the safest were lime and stone bridges constructed with keystone forming arches. They required formwork for construction.
- Wood or metal lattice bridges, the latter became the predominant type for railways in the 19th century.
- Suspension bridges with a straight deck of European tradition. With steel cables or iron links.
- Arches of lowered vaults, like the Spain Bridge in Manila.

In the non-emancipated territories, in the 19th century a new transportation system, the railway, is introduced, that will influence the construction of the new bridges.

Navigation Canals.
Major Transport Routes

Completed projects:

Panama Interoceanic Canal. Originally proposed in the early 16th century according to imperial provisions by Emperor Charles in 1533-1534, the canal was not completed until the year 1914. This canal traversed the Panamanian isthmus through the Chagres River and the land strip between it and the Pacific Ocean.

Dique Canal, Colombia. The project for a canal between the city of Cartagena and the Magdalena River to facilitate communication with the interior of the territory became a reality in 1650, thanks to the efforts of engineer Juan de Somovilla y Tejada, with subsequent restoration work by other engineers.

Unimplemented Projects:

Güines and Batabanó Canal in Cuba. Planned between Havana and Güines to boost the trade of wood, tobacco, and sugar. The project, proposed by Félix and Francisco Lemaur in 1796, was suspended when the first railway line of the Spanish administration was established in the area.

Canal in the Isthmus of Tehuantepec. Suggested in 1774 by engineer Agustín Crame in a report to Viceroy Antonio María de Bucareli.

Nicaragua Interoceanic Canal. A project considered as early as 1620 by the flemish Diego de Mercado, it was discarded in the 1781 leveling plan by engineer Manuel Galisteo due to technical difficulties in resolving the elevation difference between the Pacific Ocean and Lake Nicaragua.

MINING ENGINEERING. THE LIFEBLOOD OF THE EMPIRE

One of the driving forces behind Spanish expansion into the American territories was the discovery of precious metal deposits, giving rise to myths such as El Dorado. By 1560, the main mining centers of the continent had been established. In terms of gold, these included Carabaya, Chuquibo, La Paz, Chayanta, and Zaruma in Ecuador. Regarding silver, notable mines were Taxco (1534), Zacatecas (1546), Guanajuato (1548 - 1558), Pachuca, and Real del Monte (1552) in New Spain. In addition, there were mines like Porco and especially Potosí (1545) in the Charcas province (Bolivia), and Castrovirreina (1555) in Peru.

Starting from 1555, thanks to the experimentation of Bartolomé de Medina from Seville, silver purification would be done through the amalgamation process, which required the use of mercury. For the production of silver in Potosí, mercury from the Peruvian mine in Huancavelica was employed. In New Spain, the mercury from Temascaltepec, Sierra de Pinos, and Chilapa couldn't meet the Mexican production needs, leading to regular shipments from Almadén (Ciudad Real) and occasional ones from Idrija (Slovenia).

As a volcanic country, the Philippines is rich in mineral resources, among which gold, copper, iron, and coal stand out. The Spanish administration promoted the mining of these minerals, as well as the transport of silver from Mexico through the Manila Galleon.

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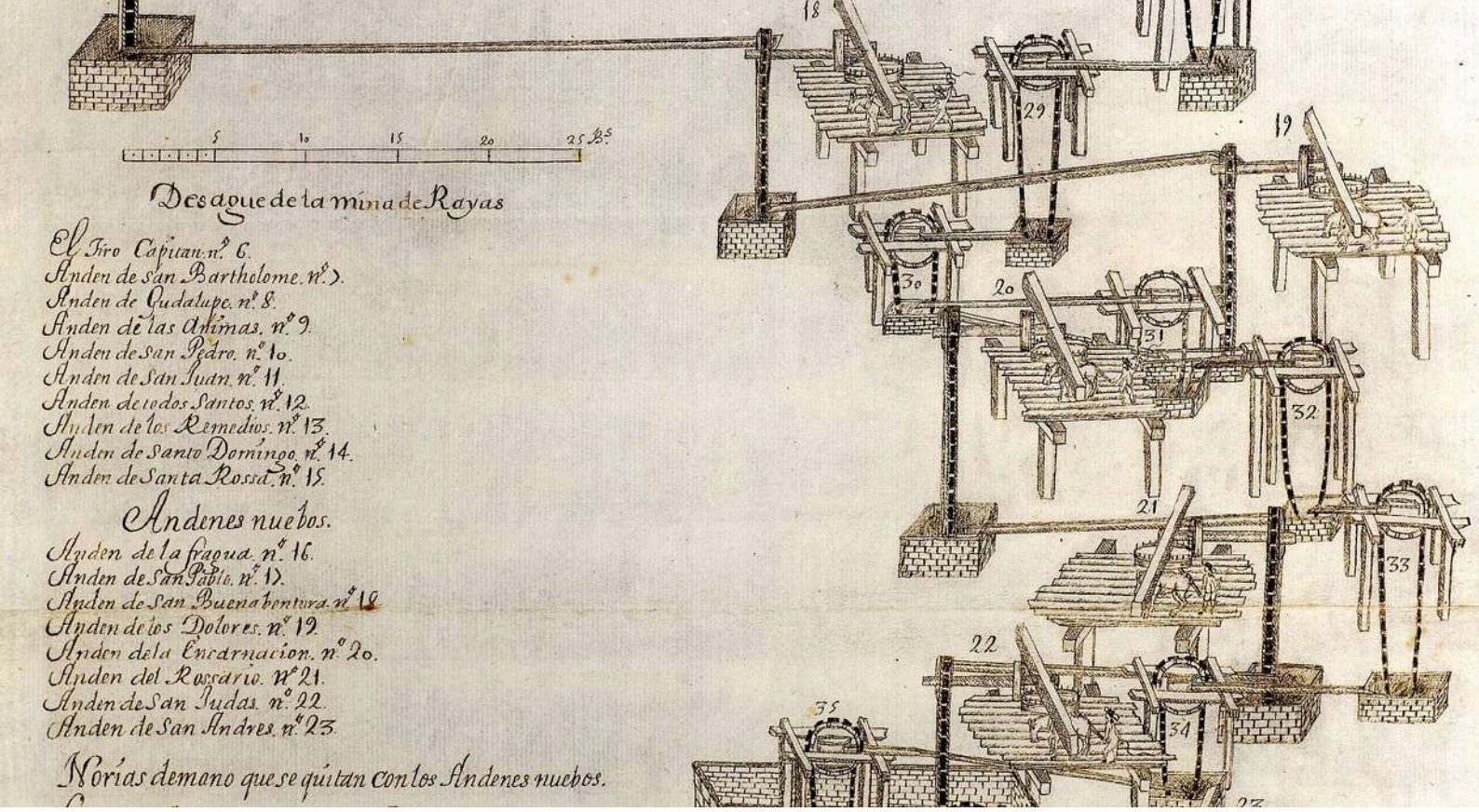


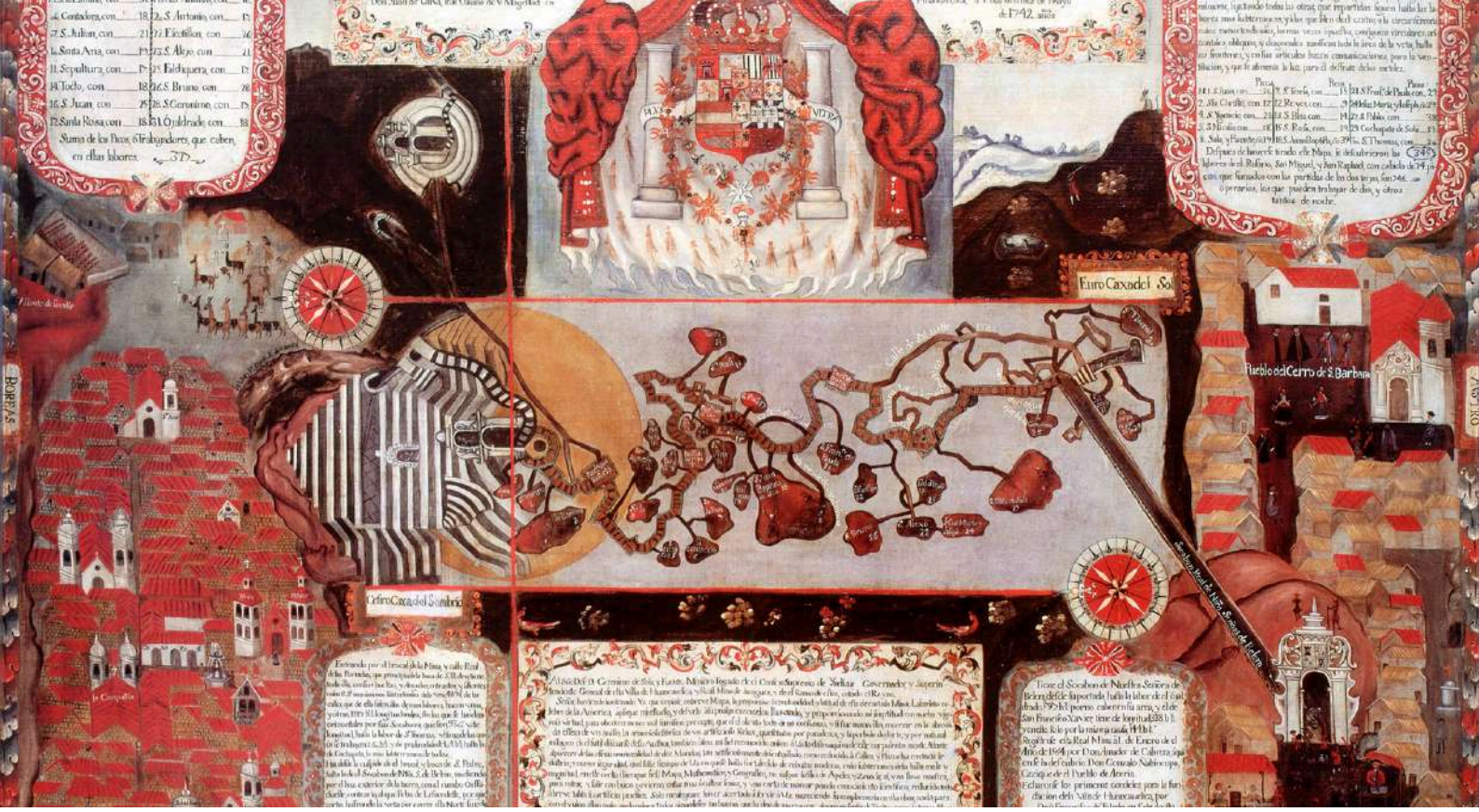
Mercury Extraction and Metallurgy

Mercury mining, much like silver mining, faced challenges in prospecting and operations, involving open-pit excavations, shafts and inclined tunnels. Material extraction to the surface was carried out using a contraption called “malacate.” Mechanization for internal transport was difficult due to the irregular layout of tunnels and galleries. In Almadén, various types of carts of increasing capacities for transporting ore can still be found.

Regarding mine drainage, initially, manual winches were used in Almadén mines to collect water in animal skin bags. These winches were later replaced by pumps, and in 1805, a steam engine was introduced – the first in Spanish mining. It was under construction from 1787 and operational until 1878.

Mercury production had its own technique, which traveled back and forth between Spain and America. The “jabeca” furnaces used in Almadén in the mid-16th century were introduced in Huancavelica in 1596 and later replaced by reverberatory furnaces, which were highly polluting.

To avoid their significant toxicity, in 1633, Lope de Saavedra Barba, known as “el Buscón,” designed the so-called “horno busconil” or “aludel furnace,” which was more profitable and pollution-free. In 1647, the mine steward of Huancavelica, Juan Alonso de Bustamante, introduced these furnaces to Almadén under the name “hornos Bustamante.” The employed system came to be known as the “Almadén method.”

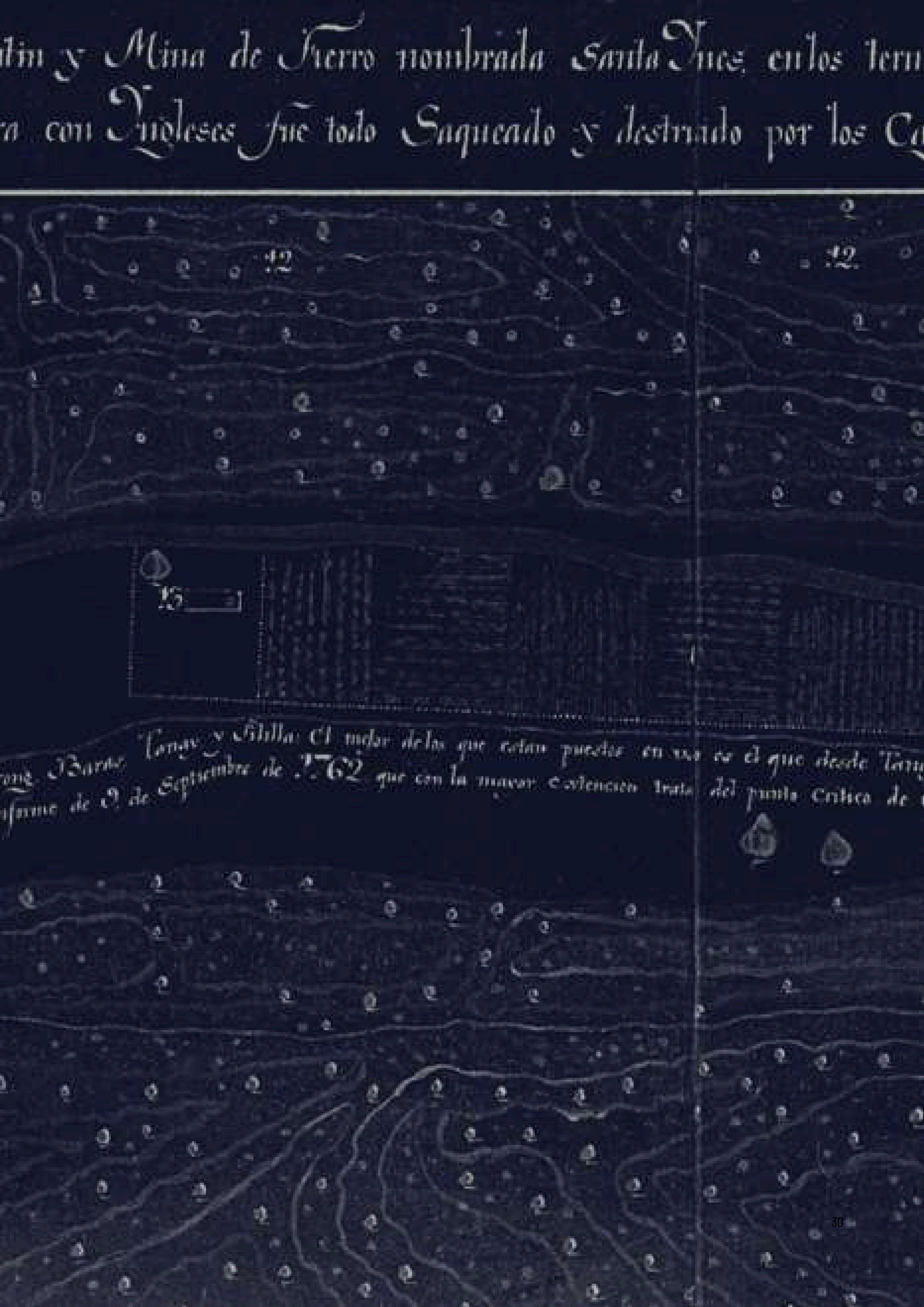


Exploitation of Precious and other Metals

In general, during the colonial era, deficient techniques were employed in the prospecting and mining operations. In excavation, the vein was followed from its outcrop with open-pit workings or through inclined tunnels and shafts, creating large chambers without proper exploitation or safety plans. The irregular layout of tunnels and galleries prevented the mechanization of ore and water transport for a long time. These tasks were primarily carried out manually by workers, initially on their shoulders and later using wheelbarrows.

Water drainage in hills with high-altitude veins could be achieved through drainage galleries that emptied by gravity. Where this solution was impractical, various types of water drainage machines were used, which were adopted late in the overseas territories: stepped manual winches, operated by one or two men, were prevalent until the early 18th century; waterwheels powered by draft animals, as seen in San Juan de Rayas, Guanajuato; windlasses or winches, a significant advancement in Mexican mining in the 18th century; and finally, steam engines, which were also used for material extraction.

In silver metallurgy, initially, Castilian melting furnaces and reverberatory furnaces were used in Mexico, along with indigenous Peruvian “guairas.” To process low-grade ores, the amalgamation system was widely adopted (Bartolomé de Medina, 1555), later perfected under the name “beneficio de patio,” with mercury as a fundamental element for purification.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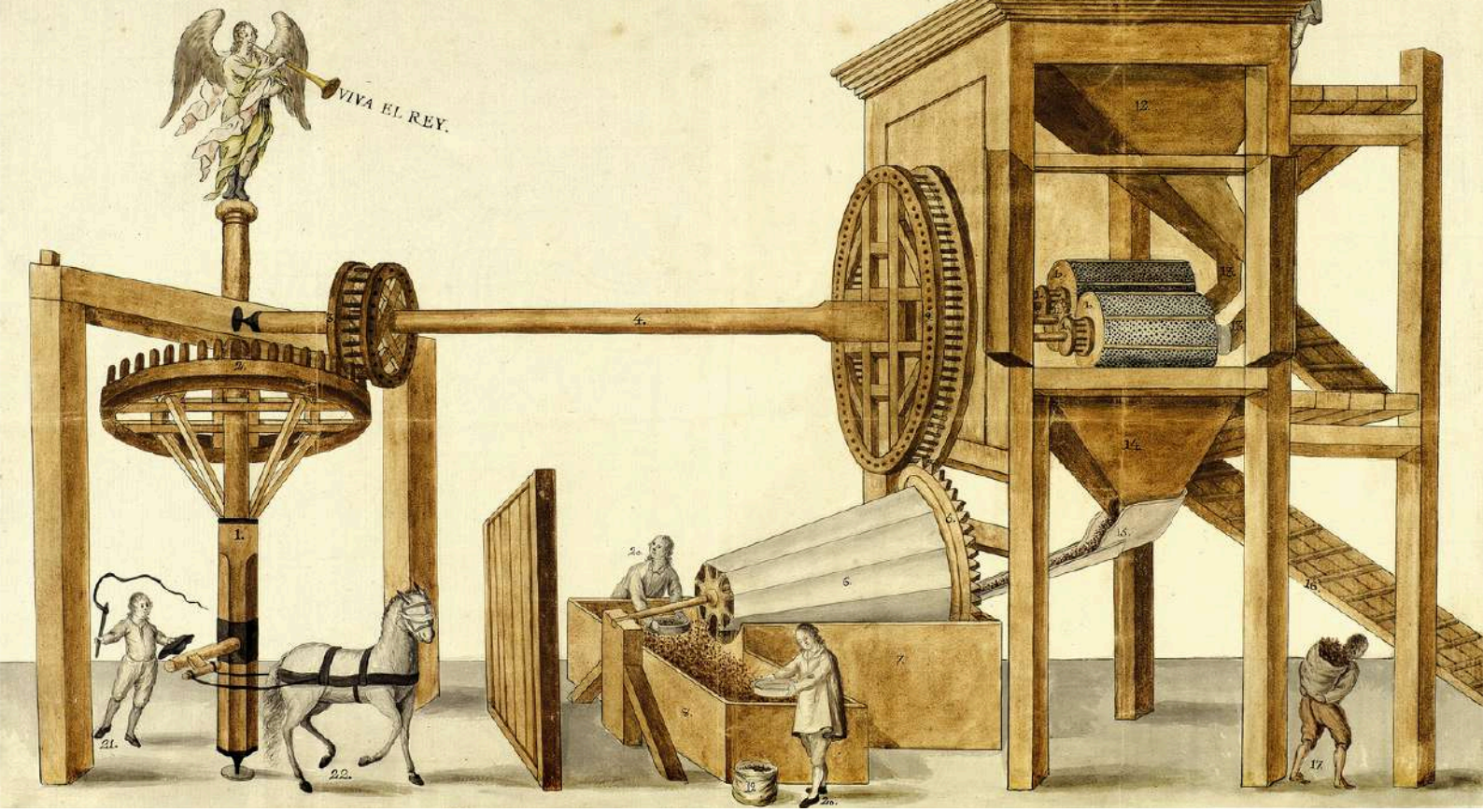
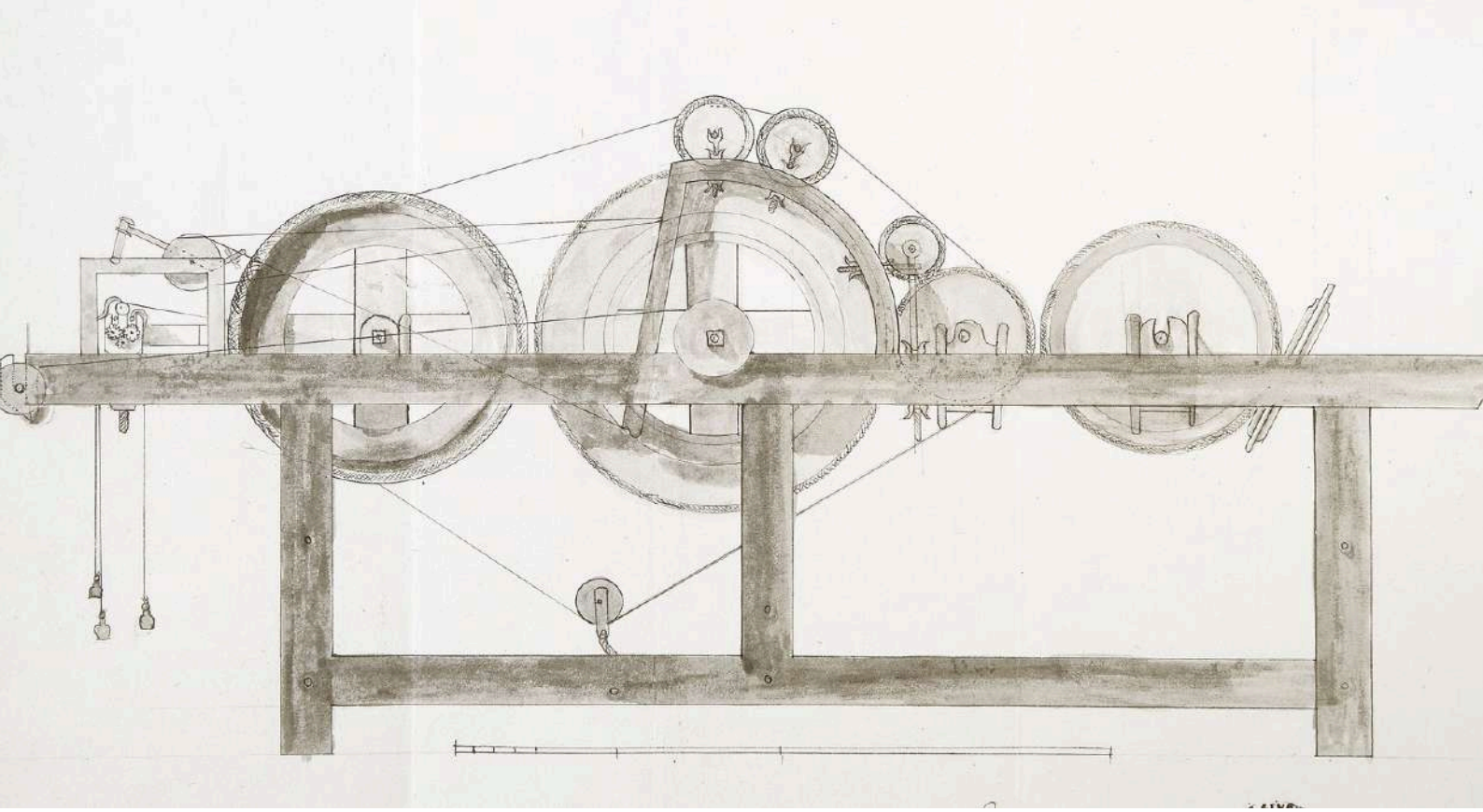


ENGINEERING AND INDUSTRY

The relationship between engineering and industry constitutes one of the most significant processes of knowledge transfer, a two-way exchange crucial for economic development and the consolidation of societies. Much like there was a pre-engineering phase based on craftsmanship and experience, there was also a pre-industrial era grounded in craftsmanship. Both evolved, incorporating scientific foundations, transitioning from versatility to specialization, until the disruption brought about by the institutionalize of technical education and the industrial revolution.

The new Spanish territories in the Americas and the Pacific region became a large scale laboratory where a significant portion of theoretical frameworks and practical applications developed in Europe since the 16th century, and known as the Scientific Revolution from the 17th century onwards, were tested, applications that were enriched by the exchange with indigenous techniques. Over four centuries, overseas territories witnessed the development of inventions, innovations, and technologies resulting from the constant exchange of people, products, artifacts, and ideas between Europe and the New World

The expansion of international trade in Philippine products served as an incentive in the 19th century for Filipino industrialists, such as Domingo Roxas y Ureta, to establish on the islands companies and factories dealing in gunpowder, iron, tobacco, paper and textiles.



Currency, Tobacco, Flour and Bread, Sugar and Spirits

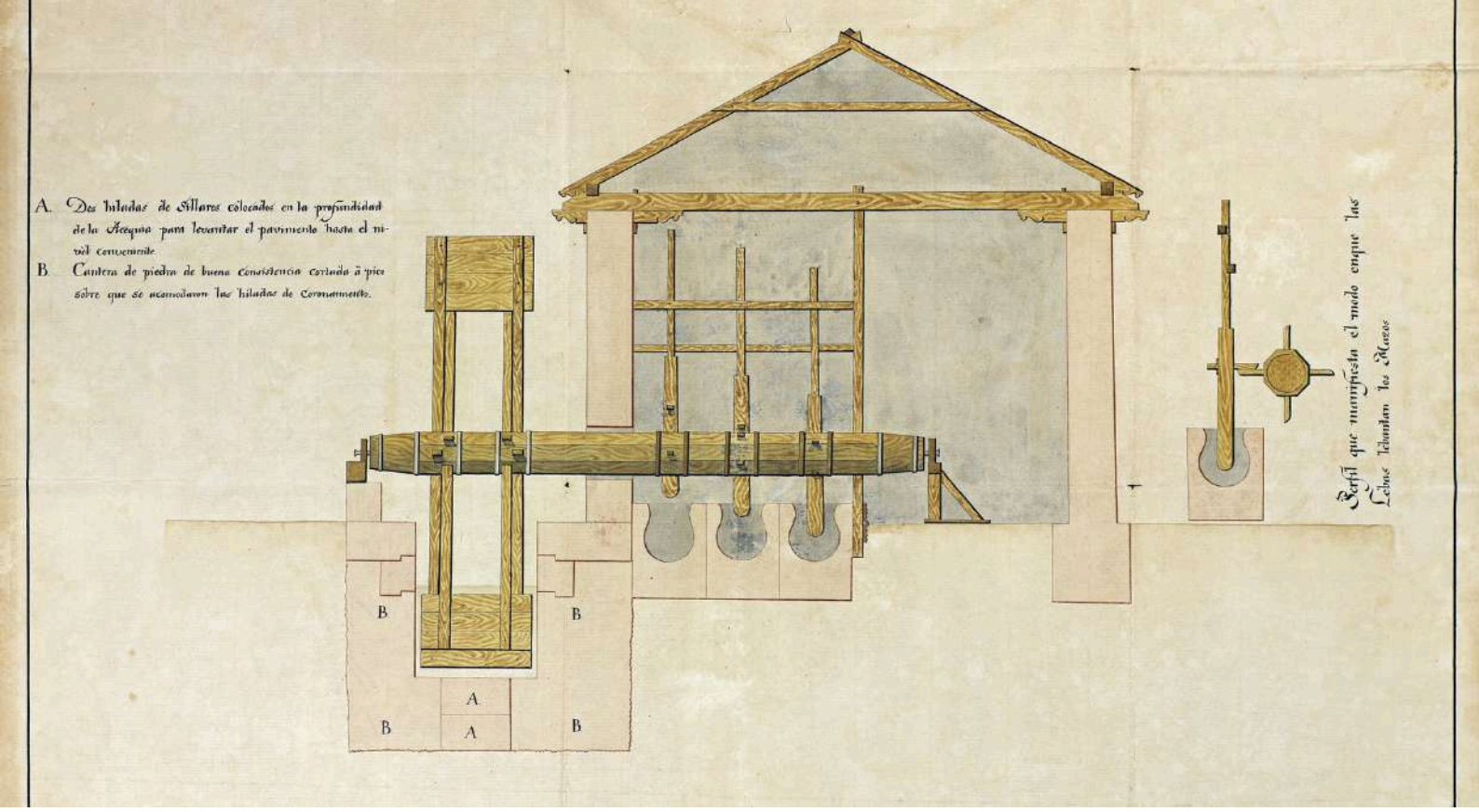
Currency. To circulate gold and silver wealth, conversion into currency was required at official mints. In America, these were gradually founded: Mexico (1535), Santo Domingo (1536), Lima (1565), La Plata (1573), Potosí (1574), Santa Fe de Bogotá (1626), Cartagena (1630), Cuzco (1697), Popayán (1729), Guatemala (1731), Santiago de Chile (1743), and Manila (1861).

Tobacco. This new “medicine” sparked great interest in Europe. The first tobacco factory opened in Seville (1636). In America, key sites included Havana’s Royal Factory (1717) and Mexico’s Royal Factory of Cigars and Cigarettes (1769).

Flour and Bread. The mill, a pre-industrial machine, arrived in America by the mid-16th century. Spanish models were soon adapted, and local innovations improved efficiency and output.

Sugar. The sugar industry illustrates transatlantic technical exchange, evolving from 16th-century mills to 19th-century steam power. In Cuba, private mills or “Ingenios” thrived and helped establish the first Spanish railway (1837), from Güines to Havana.

Spirits. Tied to sugarcane and grape production, distilleries emerged across the continent. Notable were those in Guayaquil and Leyva (Boyacá), the latter relocated from Tunja in 1779, with facilities for public service, administration, housing, storage, and distillation.



Factories in the Philippines. Iron, Gunpowder, Paper, Textile and Dyes

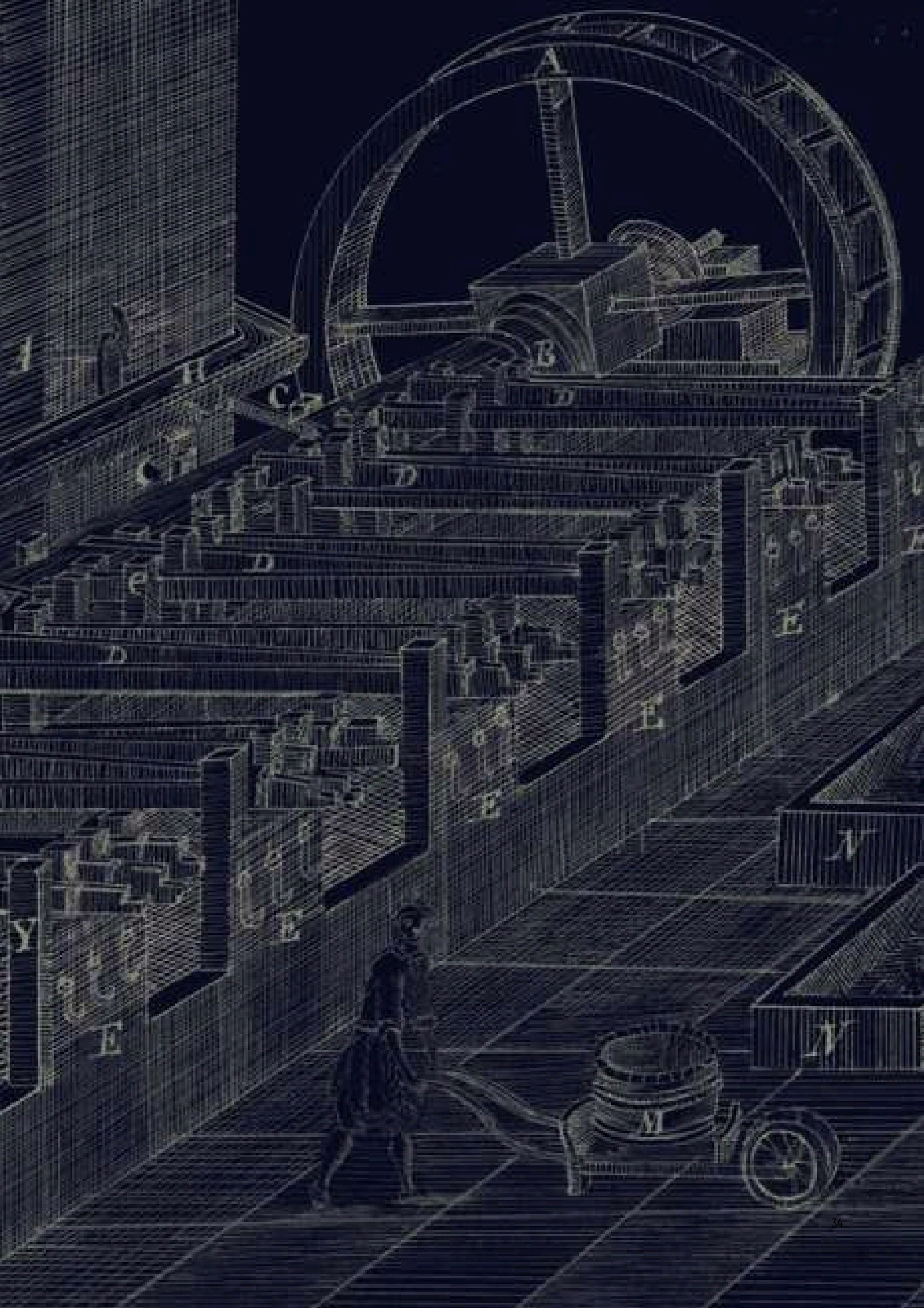
Since the late 18th century and especially in the last third of the 19th century, the intensification of trade in products abundant in the Philippine archipelago encouraged Spanish investments and the creation of companies and factories in those islands.

Iron. It was initially used for tools and then for amalgamation. In the 19th century, the Tanay factory was built in Rizal, following Western patterns, but operated by the Chinese community.

Gunpowder. Although shipments from the Peninsula to Overseas were frequent, the San Juan Bautista factory was built in Calambá, Bay Laguna province (1773), based on the model of the one in Villafeliche, Aragón.

Paper and textiles. The factories of Domingo Roxas and Ureta. European rag paper was regularly sent overseas and was mainly used for official documents. In 1820, the Filipino industrialist Domingo Roxas and Ureta requests the granting of a patent for a paper manufacturing machine and a spinning machine, both with the most advanced technologies.

Dyes. Annatto, cochineal, dyewood or Campeche wood, and indigo are ultramarine dyes primarily used for textile purposes. In 1777, Francisco Javier Salgado, a resident of Manila, was granted exclusive rights to exploit indigo in his factory at Laguna de Bay.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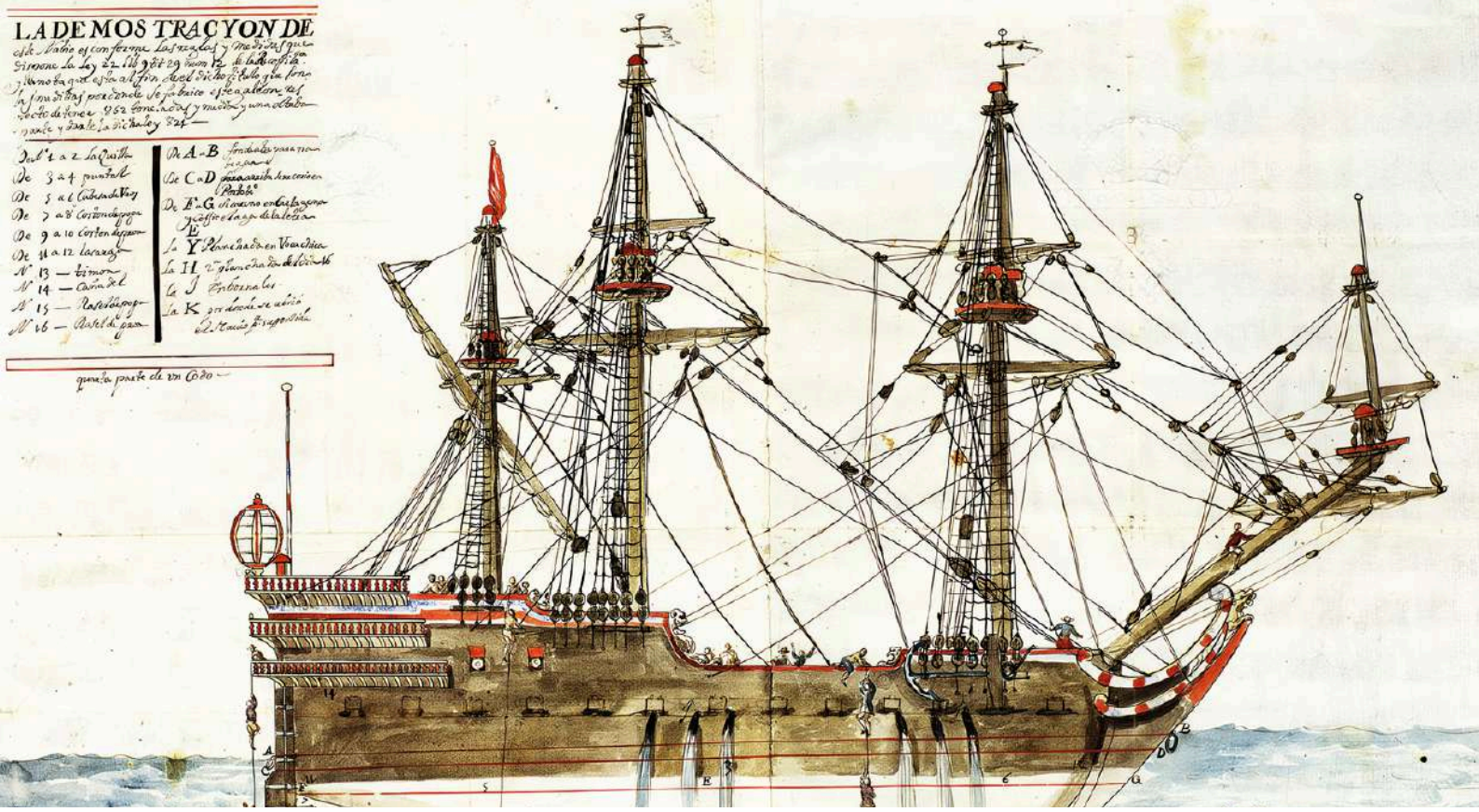


NAVAL ENGINEERING

The Spanish expeditions to the New World were able to successfully outline coasts and overseas lands thanks to their prominent naval technology. Over four centuries of Spanish presence, naval construction transformed from the almost medieval conception of the early ships to the engineering that made possible the manufacturing of the largest passenger and war vessels. It is a continuous and cautious evolution, as the sea poses the dual danger of the waters and enemy ships. From the ship's carpenter, the transition occurred to the naval architect incorporating the laws of mechanics and geometry, and from there to the naval engineer who mastered new disciplines that progress made indispensable, such as metallurgy, thermodynamics, and electricity

Three types of naval enterprises would determine the class and number of ships: fleets for the Carrera de las Indias, squadrons and flotillas for discovery and exploration expeditions, and those destined for conquest actions. Maritime traffic became the vital artery of the Empire, leading Spain to become the first nation in Europe to produce regulations, instructions, and treaties for naval construction and navigation.

In this area, the arsenal of Cavite stands out, with the nearby Subic inlet and its timber region very suitable for shipbuilding, and the shipyard of Cebu, where the San Diego galleon was built.

Shipbuilding and Ship Maintenance Facilities

The need to create an efficient and powerful Navy led to the establishment of multiple infrastructures dedicated to both ship maintenance and shipbuilding, including rigging, rigging components, canvas, etc. Two main factors determined their location: the proximity of forests with high-quality wood and the availability of sufficient drafts between the open sea and the shipyards. Thus, numerous arsenals and shipyards were founded in the overseas territories: Realejo, Guayaquil, Havana, Veracruz, San Juan de Puerto Rico, San Blas, Cartagena de Indias, Montevideo, and Manila. These complex facilities could bring together up to thirty specialized guilds, considered by some authors as the first industry in Spain. Technical developments were continuous: slipways, gates for closing arsenals, drainage systems using tidal amplitude or pumps, and machines and devices for the handling and placement of large pieces.

Looking after the maintenance and repair of ships was as crucial as their construction, as the durability of the fleet depended on it. Consequently, numerous facilities were designed and built for hull maintenance, which primarily involved cleaning, replacing worn-out parts, and caulking or waterproofing the hull. Dry-docking methods included using slipways and docks, “keeling over” on a sandy bed and tilting the ship to one side, or even afloat, using large deadweights to heel the vessel.

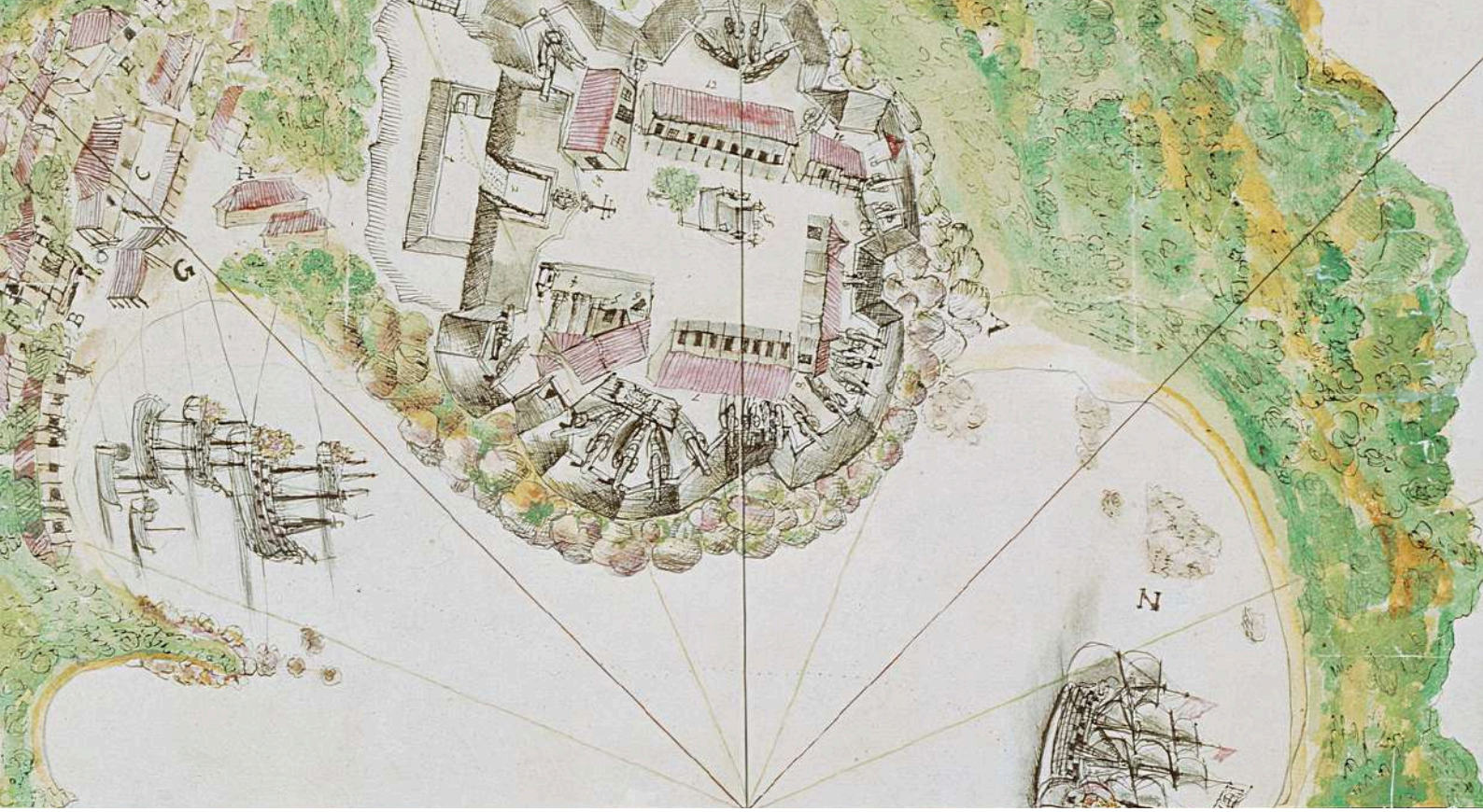
Ships: Regulations, Technology, Types, and Systems

An unmistakable symbol of Spanish technology, based on a long tradition of Mediterranean coastal navigation and oceanic voyages along African coasts and European seas, shipbuilding evolved from the vessels of exploration, consisting of caravels and naos, to larger galleons and ships intended for the Carrera de Indias. However, for centuries, ship design was influenced by the geographical feature of the Sanlúcar bar that provided entry to the port of Seville, a hub of global trade.

Each purpose had its own design, so in addition to the aforementioned ships, vessels were crafted for exploration and conquest with caravels and brigantines, for the Pacific or South Sea with galleons equipped with generous sides, for the Caribbean with frigates and merchant boats, and for settling and trading with the genuine "Spanish galleons." In the 19th century, iron and steam competed against wood and wind, giving rise to the best examples of the latter equipped with technology destined for obsolescence.

Treatises like Diego García de Palacio's and technical instructions from experts such as Antonio Garrote, Antonio de Gaztañeta, Jorge Juan, Francisco Gautier, José Joaquín Romero y Fernández de Landa, Julián Martín de Retamosa in the 18th century, and Isaac Peral in the 19th century, are part of the world heritage in shipbuilding. They designed unique construction systems, representing successive advances in the performance, robustness, and ship's crew.


ARSENAL DE CAVITE



PORT ENGINEERING AND DEFENCE

Maritime communications between the overseas territories and the metropolis fueled the development of coastal cities that served as terminals for the Spanish treasure fleets. These cities benefited from the trade and transportation of gold and silver:

In the Caribbean and Gulf of Mexico, the port of Havana, a naval base for those seas, became the hub for the fleets returning to Seville. Veracruz and its port of San Juan de Ulúa, connected to the Fleet of New Spain, ensured the cross-traffic of mercury from Almadén and silver from Mexican mines. In Panama, the Atlantic ports of Nombre de Dios and then, Portobelo, linked to the Galleons of Tierra Firme, controlled the transportation of Potosí silver arriving from the Pacific ports of Arica, Lima, Guayaquil and Panama through the isthmus routes.

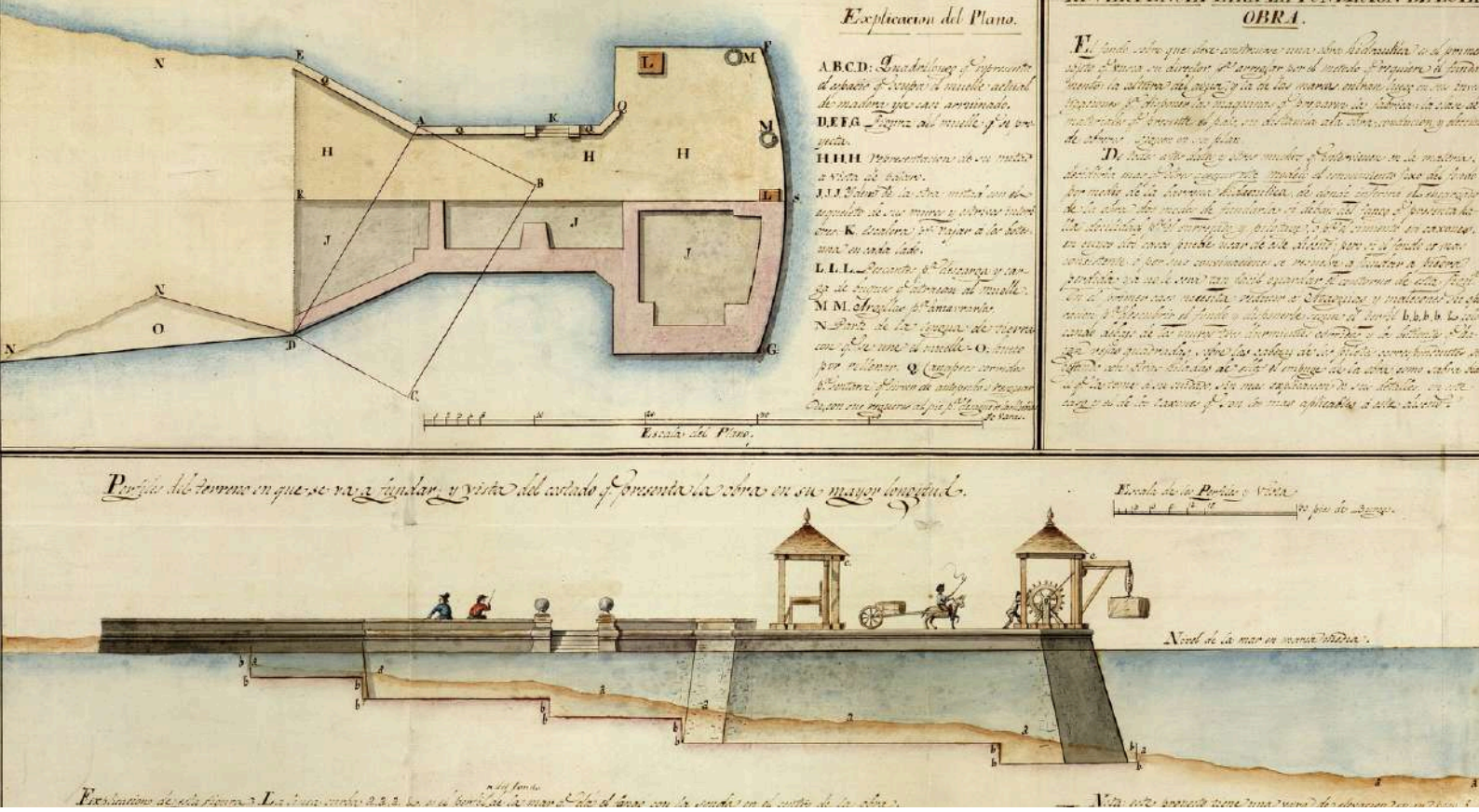
In the Pacific, the ports of Acapulco in Mexico and Manila in the Philippines were, for centuries, the avenues of relations with the East, monopolizing a trade route in which Mexican silver played a significant role through the so-called Manila Galleon.

The Spanish monopoly on world trade led to the emergence of smuggling and piracy, prompting the establishment of defense and fortification systems in strategic ports.

Shelter and Coastal Protection Works. Lighthouses

These works were used to correct the deterioration caused in the coastal areas by the action of the sea and the wind: foundation erosion as in the closing of the Bocagrande canal in Cartagena de Indias (Colombia), or sedimentation processes as in the mouth of the Pasig River, in Manila. All kinds of dikes and dredges were applied for its neutralization in a significant technical evolution.

The use of lighthouses in the New World was late, from the end of the 18th century. The ones from San Juan de Ulúa in Mexico (late 18th century), Montevideo (1802), and the Castle of Morro in Cuba (1845) stand out. In the Philippines, after the Lighting Plan of 1885, there were 19 lighthouses of six orders, like the one at Cape Bojeador in Ilocos Norte.



Shelter and Coastal Protection Works. Docks

The construction of docks in harbours mooring the ships was also belated and an innovation that was only within reach of the most important cities. Very few ports had stone docks, especially in the 16th and 17th centuries. The traditional method for loading and unloading goods was done using small boats. Thus, the stone dock of Callao, built in the 17th century by the Augustinian friar Pedro de la Madrid, stands out. It was equipped with rings similar to those on the wall of San Juan de Ulúa. Despite its solidity, it soon became unusable for deep-draft vessels due to silting and rapid deterioration.

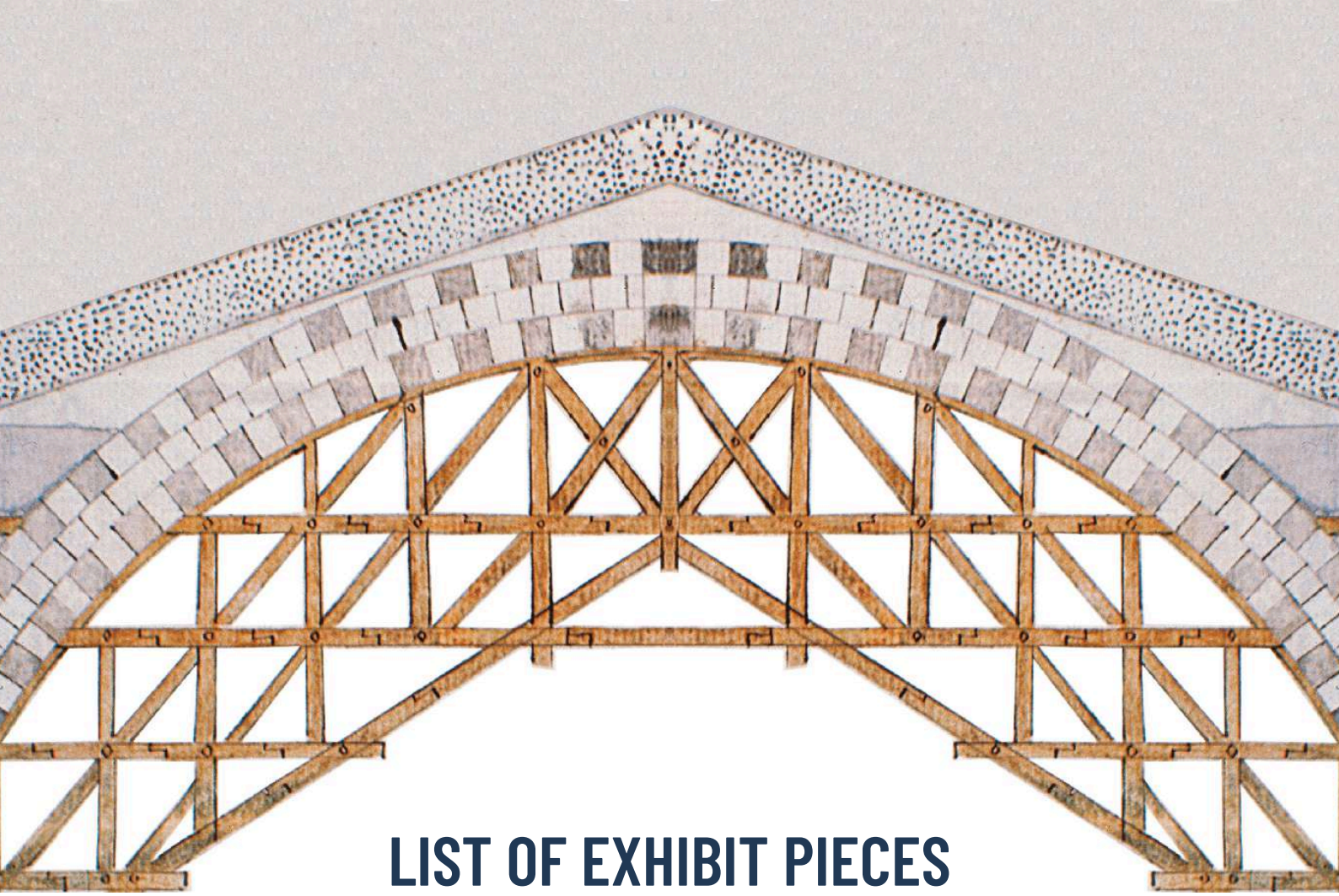
Among the ports that had docks of various utilities are Veracruz (16th century) and Buenos Aires, La Guaira, Puerto Cabello, Marimelena, and Santiago de Cuba in the 18th century. In the 19th century, mention must be made of the San Francisco dock in Havana, designed by Lieutenant Colonel Juan María Muñoz in 1841. Also noteworthy is the construction of the outer harbor of Manila with a large breakwater, a smaller counter-dike, and two basins of different drafts, according to the project by Eduardo López Navarro (1876 - 1882). In both cases, the use of hydraulic concrete is highlighted, and in Manila, the use of a steam engine for construction and dredging is noteworthy.

Fortified Ports
Defense of America and its Trade

The structure of the commercial monopoly of the Spanish administration in the Overseas Territories, supported by the fleet system, led to the development of smuggling and piracy in the 16th and 17th centuries. Successive involvement of the French, English, and Dutch characterized this period. Faced with repeated attacks, the Crown had to ensure the defense of ports, especially those that had become strategic hubs for transporting royal treasure and commerce. Key ports included the terminals for the fleets of New Spain, the Galleons of Tierra Firme, and the Galleon from Acapulco to Manila. Appropriate fortification systems were implemented to safeguard these ports.

During these centuries, advancements in artillery techniques necessitated the adoption of a new defensive system known as “bastioned fortification.” Its application in the Overseas Territories was promoted by Italian technicians in the service of Spain, such as the Antonelli family. Bautista Antonelli, commissioned by Philip II in response to attacks by Francis Drake, developed a strategic defense plan for the Caribbean in 1588. This plan influenced the fortifications of key locations like Havana, Santo Domingo, Puerto Rico, Veracruz, San Juan de Ulúa, Cartagena, Portobelo and Araya.


PUERTO EN PROYECTO
Darsena de Maquinas
Darsena de cabotage



LIST OF EXHIBIT PIECES

THE LEGACY OF ENGINEERS IN AMERICA AND THE PHILIPPINES

FIRST MAP OF THE CITY OF MANILA

Geometric description of the city and ring road of Manila and its suburbs: close-up of the city on paper
1671
By Fray Ignacio Muñoz, OP

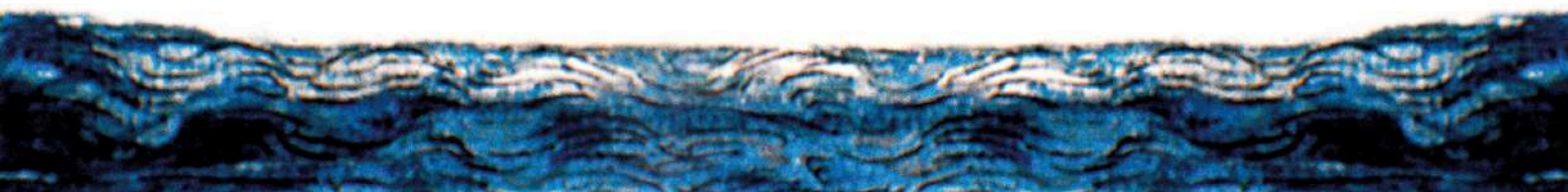
Archivo General de Indias, Sevilla, España. MP-Filipinas, 10

THE PIONEERS: CRISTOBAL DE ROJAS

Torres Pardo
Portrait of the Captain Engineer Cristóbal de Rojas (1555 - 1614)
1943

Copy of a 1929 painting by Teodoro Dublang Uranga, Engineer and painter (1874 - 1940).

Museum Collection of the Academy of Engineers, Hoyo de Manzanares, Spain (Inv. ETE2-47)



THE CORPS OF MILITARY ENGINEERS: JOSÉ PRÓSPERO DE VERBOOM

Román García Rodrigo (1933 - 2013)
Portrait of José Próspero de Verboom, founder of the Corps of Military Engineers (1665 - 1744).
1959

Museum Collection of the Academy of Engineers, Hoyo de Manzanares, Spain(Inv. ETE2-192)

UNIFORM OF THE CORPS OF ENGINEERS

Uniform used by the Corps of Military Engineers.
1751
Juan Martín Cermeño (1700 - 1773)
Facsimile reproduction

General Archive of Simancas, Spain. MPD. 15, 055, 01

ENTRANCE EXAM TO THE CORPS OF ENGINEERS

Plan of a fortification exercise for access to the engineering profession, carried out by Manuel Fernández de León, distinguished artilleryman of the Personnel and Volunteer Engineers Company of Lima
1792
Manuel Fernández de León
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP-Teóricos, 69

JOSÉ DE URRUTIA Y DE LAS CASAS, GENERAL ENGINEER

Francisco de Goya y Lucientes (1746 - 1828)
Portrait of the General and Engineer José de Urrutia y de las Casas (1739 - 1803), Civil Engineering driver.
Circa 1798
Facsimile reproduction

Prado Museum, Madrid, Spain. Nº P000736

CIVIL ENGINEERING: AGUSTÍN DE BETANCOURT Y MOLINA

Lucio Sobrino (1925 - 2017)
Portrait of Agustín de Betancourt y Molina (1758 – 1824), founder of the School of Civil Engineering in 1802.
20th Century.
Copy of another one made from the original by Kagynobr in 1859

Association of Civil Engineers, Madrid, Spain

UNIT OF MEASUREMENT IN CARTOGRAPHY

Yardstick: graduated measuring stick
[n.d.]
J. Rabone & Sons.
Bone and metal, circa 16 x 3 cm

Pablo Sánchez de Mora y Pérez Collection, Malaga, Spain

UNIFORMS OF CIVIL ENGINEERS

Miniature of the civil engineer gala uniform of Agustín de Betancourt.
20th Century
Created by the Association of Civil Engineers

Ignacio Sánchez de Mora y Andrés Collection, Málaga, Spain

CITY AND TERRITORY

PHILIPPINES: TERRITORY AND CITY

Pedro Murillo Velarde (S J) (1696-1753)
"Hydrographic and Chorographic chart from the Philippines". In grid: maps of Manila and Cavite (Luzon) and the Zamboanga Fort (Mindanao)
Manila, 1734
Printed by Tagalog printer Nicolas de la Cruz Bagay (18th Century)
Facsimile reproduction

Philippine Map Collectors Society (PHIMCOS), Manila, Islas Filipinas

THE CITY: THE BASIS FOR TERRITORIAL PLANNING

Map of the parishes of Tonala and San Pedro Tlaquepaque and their district in New Spain, present-day Mexico, which shows the role of cities in the organization of the surrounding territory with its infrastructures
Tonala, 23 November 1772
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Mexico, 285

THE CITY AND INFRASTRUCTURE

Design of the new city of Veracruz, presented on the site of the Ventas de Buitrón and on the road to Mexico, with its grid layout as well as water supply and communications infrastructures
28 February 1590
Pedro Ochoa de Leguizamo, engineer
(2nd half of the 16th century - beginning of the 17th century?)
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Mexico, 38

THE URBAN MODEL: HAVANA

The City of Havana, the naval base of the Caribbean, with demarcation into parishes within its semi-irregular layout
Circa 1691
Juan de Císcara y Ramírez, Engineer (circa 1671 – 1720)
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Santo Domingo, 97

THE URBAN RECTANGULAR MODEL: MEXICO CITY

Form and layout of Mexico City, capital of New Spain
1628
Juan Gómez de Trasmonte (c. 1595 – 1647)
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Impresos, 22

THE URBAN MODEL: THE GRID IN THE CITY OF LIMA

Map of the City of Lima, capital of the Viceroyalty of Peru, and its fortifications.
14 October 1687
Pedro Nolasco (O of M), based on the original by Juan Ramón Connick
With the royal coat of arms and the coat of arms of the city of Lima
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Peru y Chile, 13

TOWN PLANNING: DIVISION OF CITIES INTO BARRIOS

Map of Mexico City divided into barrios or quarters for better organization.
Mexico City, 12 December 1782
Manuel Villavicencio, printer (fl. 1753 - 1818)
With the royal coat of arms and the coat of arms of the city of Mexico
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Mexico, 387

BEAUTIFICATION OF CITIES: PANAMA

Map of the main square of Panama City, decked for the proclamation of King Fernando VI.
1748
With the coat of arms of Panama City
Facsimile reproduction

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Façade of the Manila Cathedral, based on the reconstruction project and variations introduced during its construction
Manila, 27 November 1877
Eduardo López Navarro, engineer

National Archives of the Philippines. Complex Cathedral of Manila 1839 1898, SDS 19085

YMAFRONTE DE LA CATEDRAL DE MANILA

National Archives of the Philippines. Manila Complex Cathedral de Manila 1839-1898. SDS. 19085.

PLAN FOR THE TRIBUNAL OF STA. MARIA, EDIFICIOS DE ESTADO

National Archives of the Philippines. SDS. 5661, S-457.

PLAN OF THE HARBOUR MASTER'S OFFICE OF THE PORT OF MANILA

National Archives of the Philippines. PUBLIC WORKS, 1867-1898, 313/312. SDS. 17073.

HYDRAULIC WORKS

URBAN IRRIGATION: MANILA

Map of Manila and its suburbs with the outline of its water supply
Manila, 30 November 1869
Genaro Palacios, Second Engineer and later Chief Engineer, Director of Public Works in the service of the City Council of Manila (1839 - ?)
Facsimile reproduction

National Historical Archive, Madrid, Spain. Ultramar, MPD. 4537

IRRIGATION OF CULTIVATED LANDS IN SANTIAGO DE CHILE

Convento de Monjas Carmelitas de San Rafael y sus alrededores en el barrio de la Cañadilla, en Santiago de Chile, con el abastecimiento de agua directamente desde el río Mapocho.
[1773]
Reproducción facsimilar

Archivo General de Indias, Sevilla, España. MP-Perú y Chile, 257

AGRICULTURAL AND URBAN SUPPLY: MAIPO OR SAN CARLOS CANAL, CHILE

Agricultural and urban supply: Maipo or San Carlos Canal, Chile
Land between the city of Santiago de Chile and the Maipo River, with the project of the Maipo or San Carlos Canal to supply water from the said river to the Mapocho River in the said city
Santiago de Chile, 1 August 1800
Agustín Caballero, Engineer (fl. 1796 - 1800)
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Peru and Chile, 141

URBAN WATER SUPPLY: THE CHAPULTEPEC AQUEDUCT IN MEXICO

Old drain pipe and new water pipeline from Chapultepec to the City of Mexico through arches
11 August 1761
Lorenzo Rodríguez and others
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Mexico, 715

AGRICULTURAL AND URBAN WATER SUPPLY: LA MOCHICA IRRIGATION CANAL IN TRUJILLO, PERU

City of Trujillo and Chimu Valley in Peru with water pipelines to the city and its territory for irrigation and city supply
1760
Miguel Feijóo de Sosa, Chief Magistrate of Trujillo (1718 - 1791)
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Peru and Chile, 39

SANITATION OF THE YURIRIAPUNDARO LAKE, GUANAJUATO, MEXICO

Town of Yuririapundaro and other areas dependent on it, with the large lake cleaned up by Fray Diego de Chávez y Alvarado (OSA) by channeling the Lerma River
1580
Cristóbal de Vargas Valadés [attribution]
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Mexico, 24

SANITATION SYSTEMS IN HAVANA, CUBA

Paving and sewerage of the city of Havana
10 July 1824
Arsène Lacarrière-Latour, French architect (1778 - 1837)
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Santo Domingo, 745

DRAINAGE OF THE MEXICO LAKE BASIN

Mexico City with ditches, rivers, springs and drains intersecting the city and the project to prevent the city from flooding
1753
Domingo de Trespalacios y Escandón (1706 – 1777)
Facsimile reproduction

Royal Academy of History, Madrid, Spain. Canvas - 36, N° 285

PLAN FOR THE BRIDGE OF ISABEL II

National Archives of the Philippines. SDS. 4278, folio 572.

COMMUNICATIONS: ROADS, BRIDGES, NAVIGATION CHANNELS

MANILA STONE BRIDGE

Stone bridge of Manila built between 1626 and 1630 over the Pasig River and partially destroyed later by the 1863 earthquake.
1847
José Honorato Lozano, Filipino painter (1821 - 1885)
Facsimile reproduction

National Library, Madrid, Spain. DIB/15/84/4

THE WAY OF THE VICEROYS: FROM VERACRUZ TO MEXICO CITY

Projected road from the Ventas of Buitron in Veracruz to the City of Mexico.
Mexico, 8 March 1590
Bautista Antonelli, military engineer (1547 - 1616)
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Mexico, 39

ROADS OF COLOMBIA

Road from Nueva Valencia and Valldupar to Santa Marta
1767
José Aparicio Morata
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Panamá, 354

SANTA SUSPENSION BRIDGE IN PERU

Outline and plan of the Santa Bridge: Reconstruction of the bridge projected by José Coquette Gallardo
28 January 1811
Antonio de Ugartevidea
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Peru and Chile, 167

STONE BRIDGE OVER THE PAPAGAYO RIVER, NEW SPAIN

Plan and elevation of the bridge over the Papagayo River on the Road to Asia from Mexico to Acapulco
28 May 1784
Rafael Vasco, Lieutenant Colonel of the Asturias Regiment
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Mexico, 394

STONE BRIDGE OVER THE APURIMAC RIVER IN PERU

Stone bridge over the Apurimac River in Peru with the armature for its construction.
1619
Bernardo Florines, Engineer, and Diego Guillén, Master Mason. With the coat of arms of Francisco de Borja y Aragón, Viceroy of Peru
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP – Peru and Chile, 203

MANILA STONE BRIDGE

Stone bridge of Manila built between 1626 and 1630 over the Pasig River and partially destroyed later by the 1863 earthquake
1847
José Honorato Lozano, Filipino painter (1821 - 1885)
Facsimile reproduction

National Library, Madrid, Spain. DIB/15/84/4

MANILA STONE BRIDGE

Proposed systems for the reconstruction of the stone bridge over the Pasig River, whose central part caved in due to the earthquake of 1863
12 April 1847
Casto Olano Irizar, Civil Engineer (1834 – 1909)
Facsimile reproduction

National Historical Archive, Madrid, Spain. Ultramar, MPD. 5594.

QUINTA BRIDGE IN WOOD LATTICEWORK

Two-span wooden lattice bridge known as Quinta Bridge in San Miguel outside the walls of Manila
1847
José Honorato Lozano, Filipino painter (1821 - 1885)
Facsimile reproduction

National Library of Spain, Madrid, Spain. DIB/15/84/11

ARROCEROS SUSPENSION BRIDGE

View of the Suspension Bridge over the Pasig River, taken from Escolta
15 May 1859
Baltasar Giraudier, Lithographer
Facsimile reproduction

National Library of Spain, Madrid, Spain. ER/2241 (8)

BRIDGES WITH LOWERED VAULTS: THE SPANISH BRIDGE

Project for the Spanish Bridge over the Pasig River in Manila
Manila, 30 September 1869
Casto Olano Irizar, Civil Engineer (1834 - 1909)
Facsimile reproduction

Historical Archive, Madrid, Spain. Ultramar. MPD. 4162

ARCH BRIDGES: AYALA BRIDGE OR THE BRIDGE OF CONVALESCENCE

Section of the Ayala wooden bridge along with another section from the San Miguel district intersecting on the Convalescence Island.
1876
Eduardo López Navarro, Civil Engineer, Manila Port Director (1841 - 1919)
In “Collection of Maps...General Inspectorate of Public Works of the Philippine Islands. 1876”

University Library UPM – ETSI Roads, Madrid, Spain

NEW FORMS OF COMMUNICATIONS: LUZON RAILWAY

General railway plan with the proposed layout for Luzon Island
1876
Eduardo López Navarro, Civil Engineer, Manila Port Director (1841 - 1919); Developer: Genaro Palacios
Facsimile reproduction

National Historical Archive, Madrid, Spain. Ultramar, MPD. 6908

MANILA TRAMWAY LINES

Graphic design of the Manila Tramway created by León Moussour, consisting of five blood traction lines, one of them being converted into steam traction in 1882
Madrid, 22 April 1878
León Moussour. Approved by Inspector General Manuel Ramírez Bazán
Facsimile reproduction

National Historical Archive, Madrid, Spain. Ultramar, MPD. 6460

THE PASSENGER CARRIAGES ON MANILA STREETCARSÇ

Design of the first- and second-class car of the Manila trams
Madrid, 22 April 1878
León Moussour

National Historical Archive, Madrid, Spain. Ultramar, MPD. 6464

FIRST NEWS OF A CANAL IN PANAMA

Decree of King Charles I to the technical personnel authorities of the land between the Chagres River and the South Sea (Pacific Ocean) to investigate the possibility of opening a navigable canal between the two
Toledo, 20 February 1534
Facsimile reproduction

General Archive of the Indies, Seville, Spain. Panama, 234, L.5, f.143 r-v

PROVINCE OF NICARAGUA

Province of Nicaragua, its lagoon and its drainage through the San Juan River, where a canal between the mentioned oceans was projected
3 October 1716
Sebastián de Arancibia, Governor of Nicaragua
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Guatemala, 17

NICARAGUA CANAL BETWEEN THE ATLANTIC AND PACIFIC OCEANS

Calculated leveling plan between the South Sea (Pacific Ocean) and Lake Nicaragua for the project to establish a communication channel
1781
Manuel Galisteo, engineer
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Guatemala, 465

PLAN FOR THE BRIDGE OF ISABEL II

National Archives of the Philippines. SDS. 4278, folio 572.

MINING ENGINEERING. THE LIFEBLOOD OF THE EMPIRE

IRON ORE MINING IN THE PHILIPPINES

Plan of the Lanatin Valley and the iron mine called Santa Inés in the state it was in in 1762 when it was looted and destroyed during the war with the English.
1773
Miguel Antonio Gómez, Engineer
With file on the establishment of iron ore mines and factories

Archivo General de Indias, Sevilla, España. MP-Filipinas, 85 BIS

MERCURY MINE OF ALMADEN, SPAIN

Interior plan of a mine with its galleries and hand winches and exterior of the mine where the Bustamante furnaces are located with their aludel pipes, possibly from Almadén
1752
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP – Minas, 57

MERCURY MINE OF HUANCAVELICA, PERU

Graphic and planimetric analysis of the quicksilver mine of Huancavelica in Peru
1742
Esteban Oliva
Facsimile reproduction

Minas de Almadén y Arrayanes S.A. (MAYASA) Board Room, Madrid, Spain

MERCURY METALLURGY

Santiago furnace of the mercury mine of Real de Minas of Nuestra Señora de la Concepcion in New Spain, ready to remove the metal without reverb glasses or pots
Santiago 1648
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Minas, 54

THE SILVER MINING PITS OF REAL DE GUANAJUATO, MEXICO

Map and geographic chart marking off the pitheads, posts and shafts or pits of the Mellado, Saucedo and Quebradilla silver mines in Real de Minas de Guanajuato
1704
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Minas, 102

DRAINAGE IN SILVER MINES. REAL DE GUANAJUATO, MEXICO

Design of the works for the drainage of the San Juan de Rayas mine in Guanajuato, showing the project for the replacement of the manual system of waterwheels with new platforms with winches moved by animal traction
27 September 1704
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Mexico, 96

POTOSÍ MOUNTAIN, BOLIVIA

The Imperial City of Potosi with its Cerro Rico and the 21 reservoirs built on the Cari-Cari and Nicaua mountain ranges that supplied water to move the mining mills
18 century (ca. 1770)
Francisco Javier Mendizábal
Facsimile reproduction

Museum of the Army, Toledo, Spain. N° 43245

MINING SYSTEMS

New method of operating mines in Peru, proposal made by Sergeant Major Gaspar Sabugo in the process of modernization of the extraction and refining of metal and systematization of work in underground mines at the end of the 18th century
1790
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Peru and Chile, 121

ENGINEERING AND INDUSTRY

PAPER MILL ON THE PHILIPPINE ISLANDS

Paper mill in the Philippines: mallet machine for grinding the material from which paper is made in the factory proposed by Domingo Roxas y Ureta, Filipino creole industrialist (1782 - 1843)
1822
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Ingenios, 108B

POTOSI ROYAL MINT, BOLIVIA

Floor plan, profiles and façades of the Royal Mint of Potosi, completed by Interim Superintendent Pedro de Tagle, Judge of Charcas, Year 1772
18 May 1773
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Buenos Aires, 276

TOBACCO MANUFACTURING MACHINE. ORIZABA, MEXICO

Tobacco sifting machine at the Real Fabrica de Cigarros in Orizaba, Mexico, the first to have mechanized machinery handled by five operators and moved by animal traction
1787
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Ingenios, 162

FLOUR MILL WITH IMPELLER OR WHEEL. MEXICO

Perspective of the flour sifting and bread kneading machine invented by Francisco Antonio de Horcasitas in Mexico.
1786
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Ingenios, 193

TANAY IRONWORKS. RIZAL, LUZON ISLAND

Partial map of the site assigned over the Tanay River for the setting-up of smithy, anchor factory, artillery and cast-iron foundries
Manila, 16 January 1773
Miguel Antonio Gómez, Engineer (1731 – late 18th century)
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Filipinas, 84

GUNPOWDER MILL. FACTORY IN CALAMBA, LUZON ISLAND

Gunpowder mill of the Estancia de San Juan Bautista factory in Calamba in the Province of Laguna de Bay, patterned after the town of Villafeliche in Zaragoza
Manila, 14 January 1773
Miguel Antonio Gómez, Engineer (1731 – late 18th century); Dionisio Kelly, Engineering Director (1732 - 1798)
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Filipinas, 81BIS

YARN AND CLOTH FACTORY IN PHILIPPINES

Cotton combing machine proposed by Domingo Roxas and Ureta, a Filipino creole industrialist, to take advantage of the quality of the cotton grown on the islands.
29 October 1822
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Ingenios, 110

INDIGO FACTORY. PROVINCE E LAGUNA, LUZON

Site of San Isidro de Calauan and surrounding mountains in La Laguna with rivers, waterholes and dams for the irrigation indigo plantations and workshops of the factory based on the model of Guatemala as proposed by Francisco Javier Salgado, resident of Manila
9 May 1783
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Philippines, 122

SUGAR FACTORIES ON THE ISLAND OF CUBA

Flor de Cuba Sugar Factory (Boiler House), property of Mr. and Mrs. Arrieta, In “Collection of views of the main sugar mills on the island of Cuba ...” by Cantero, Laplante and Marquier, 1857
Drawn and lithographed by Eduardo Laplante (1818-1860?); published by Luis Marquier and Eduardo Laplante
Facsimile reproduction

National Library of Spain, Madrid, Spain. ER/4461

LIQUOR FACTORY

Liquor factory in Nueva Granada, Colombia with design of a device for distillation
1803
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP-Ingenios, 188

NAVAL ENGINEERING

SHIPBUILDING: FRIGATE IN SHIPYARD

Representation of a frigate in the shipyard with all its elements
1719 -1739
In “Dictionary of All Modern Naval Architecture” by Juan José Navarro de Viana y Búfalo, Marquis of La Victoria (1687 - 1772)
Facsimile reproduction

Naval Museum, Madrid, Spain. Ms. 2463

BUILDING MATERIALS: WOOD

Map of Manila Bay and Subic Inlet, discovered by Sergeant Major José Cortés Monrroy and a timber-producing area suitable for the establishment of a dockyard and shipyard
15 May 1715
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Filipinas, 146

HAVANA ARSENAL, ISLAND OF CUBA

Havana arsenal, with its sheds, slipways and buildings for auxiliary work and water pipeline from a water system of the Royal Ditch (Zanja Real) to power the hydraulic saw
4 August 1827
Honoratus de Bouyon y Serze, Naval Engineer (1753 - 1849)
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Santo Domingo, 768

FORMATION LINE OF THE FLEETS OF THE INDIES

Summary of the cargo carried by the flotilla under the command of Lieutenant General Andres Reggio that left Havana on May 13, 1749
1749
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Varios, 23

REGULATED SHIPBUILDING

Nautical instruction for the proper use and governance of ships, their design and management based on the altitude of Mexico.
Diego García de Palacio (ca. 1595)
Pedro Ocharte, 1587
Facsimile reproduction

Naval Museum, Madrid, Spain. MNM CF 136

NAVAL CONSTRUCTION RULES

Nuestra Señora de la Mar Galleon, one of the ships of the Armada of General Marqués del Vado, built in accordance with the regulations of the Compilation of the Laws of the Indies (Recopilación de las Leyes de Indias)
1695
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Ingenios, 318

NAVAL CONSTRUCTION SYSTEMS: FRANCISCO ANTONIO GARROTE

Plan and view of the stern for the construction of a 60-gun war frigate in Veracruz
14 November 1690
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Ingenios, 13B

NAVAL CONSTRUCTION SYSTEMS: ANTONIO DE GAZTAÑETA ITURRIBALZAGA

Descriptions of the main beam and mirror of the entire flat stern up to its crown, profile of the completed side and plan of a warship capable of mounting seventy cannons.
1720
Antonio de Gaztañeta Iturribalzaga, Military and Naval Engineer (1656 - 1728)
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Ingenios, 136B

NAO VICTORIA

Model of Nao Victoria based on studies by Ignacio Fernandez Vial and Francisco Monsalvete

National Museum of the Philippines Collection

SAN DIEGO GALLEON

Model of the San Diego Galleon based on the digital reconstruction by Philippe Thomé

National Museum of the Philippines Collection

PORT AND DEFENSE ENGINEERING

NEW PORT AND PIER IN MANILA

Map of Manila and suburbs with the new port and pier project
1877
J. Oppel Lit.; copy by Bernardino de los Santos
Facsimile reproduction

Historical Archive of the Navy - J.S. de Elcano, Madrid, Spain. MN-76-4

CLOSURE OF THE BOCAGRANDE CANAL. CARTAGENA DE INDIAS, COLOMBIA

Breakwater under construction on November 11, 1771 for the closure of the Bocagrande Canal, entrance to the Bay of Cartagena de Indias with sand deposits formed in its cove by the sea
Santa Fe, 28 February 1775
Copy by Pedro de Ureta based on the original by Antonio de Arévalo (1715-1800) made in Cartagena on December 31, 1774
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Panama, 189

EMBANKMENT AT THE MOUTH OF THE PASIG RIVER, MANILA

Manila and its environs, with the dike built to neutralize the progressive silting up of the river port at the mouth of the Pasig River
4 January 1814
Ildefonso de Aragón y Abollado, Commanding Engineer (1760 - ?)
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Filipinas, 133

MORRO LIGHTHOUSE IN HAVANA, CUBA

Morro Lighthouse in Havana, Cuba
View of the Morro Castle Lighthouse in Havana illustrating the design of its extension with a small tower to improve its optics and scope
1796
Carried out by the Commander of Civil Engineers
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Santo Domingo, 584

FIRST-CLASS LIGHTHOUSE OF CAPE BOJEADOR, LUZON ISLAND

First-class lighthouse of Cape Bojeador in Ilocos Norte on Luzon Island, with the proposed and approved tower
1 April 1890
Guillermo Brockman, Chief Engineer of the Lighthouse Services of the archipelago (1856 - 1930)
Facsimile reproduction

National Historical Archive, Madrid, Spain. Ultramar, MPD. 6059

PORT OF CALLAO, PERU

Dock at the Port of Callao, made by the master builder of the Royal Factories in the said port, Pedro de la Madrid (OSA)
1696
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Peru y Chile, 15

SANTIAGO DE CUBA PIER

Plan of the stone pier projected for the Port of Santiago de Cuba
1810
Carlos Boudet, Official of the Secretariat of the Government of Cuba
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP- Santo Domingo, 689

FORTIFICATIONS OF HAVANA, CUBA ISLAND

Havana in perspective with the Castle of the Royal Force and at the entrance of the harbor, the Cubo and the Watchtower, future locations of the Punta Fort and the Three Kings Castle of El Morro
28 January 1567
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Santo Domingo, 4

FORTIFICATIONS OF SAN JUAN DE ULÚA IN MEXICO

San Juan de Ulua Island, off the coast of the town of Veracruz, in Mexico with its existing defense system and the one proposed for its improvement.
27 January 1590
Bautista Antonelli, engineer (1547 – 1616)
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Mexico, 35

FORTIFICATION OF PORTOBELO IN PANAMA

New town of Portobelo with its bastions and the Santiago and San Felipe Castles at the mouth of the bay for its defense
22 October 1688
By Juan Bautista de la Rigada, based on a plan by Luis de Venegas Osorio
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Panama, 97

DEFENSES OF CAVITE IN MANILA BAY, LUZON ISLAND

Cove and square of Cavite with improvements to be implemented for its defense
Probable date: 11 February 1663
By Juan de Somovilla y Tejada (f. S. XVII-1670), based on plans by Ricardo Carr and others
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Filipinas, 8

DEFENSES OF THE PORT OF ACAPULCO, MEXICO

Acapulco with its town and the San Diego Fort, on the coast of the South Sea (Pacific Ocean) in Mexico, continental port of the Manila galleon route
2 March 1730
Francisco Álvarez Barreiro, Military Engineer
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Mexico, 125

FORTIFICATIONS OF HAVANA, CUBA

City and port of Havana with the San Cristóbal Castle, the fortress of La Cabaña, already completed, and the latest project on the hill of Aróstegui.
8 May 1776
By Luis Huet Lambert (1721 – 1798) under the direction of Silvestre Abarca (1707 – 1784), both engineers
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Santo Domingo, 412.

FORTIFICATIONS OF CARTAGENA DE INDIAS, COLOMBIA

San Felipe de Barajas Castle located on the hill of San Lázaro in Cartagena de Indias, with innovations introduced in 1762 to improve its defense and that of the city.
15 May 1763
Antonio de Arévalo y Porras, Engineer (1715 - 1800)
Facsimile reproduction

General Archive of the Indies, Seville, Spain. MP - Panama, 171

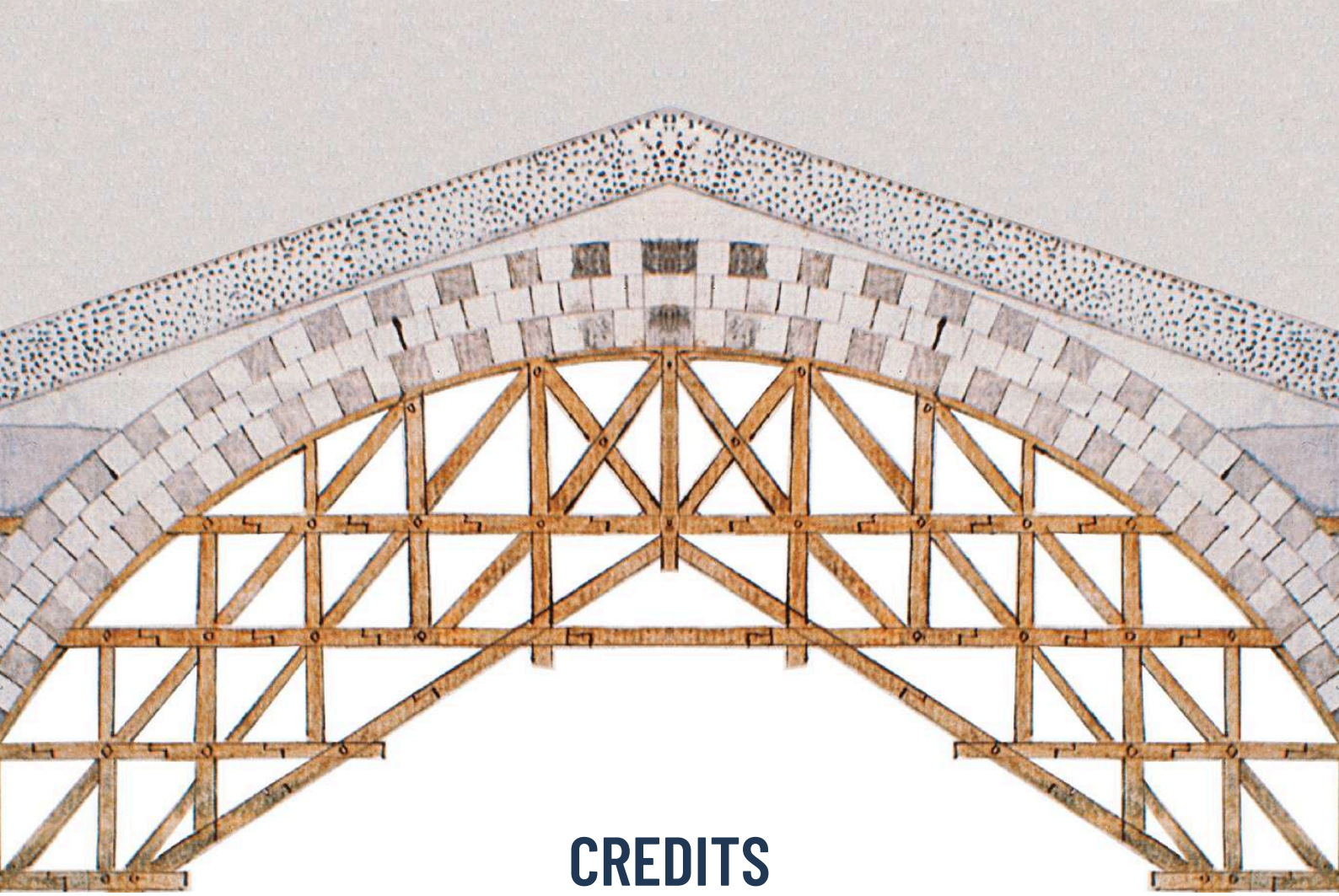
OUTER HARBOR OF THE CITY OF MANILA

Map of the anchorage of the Port of Manila and the river bar passage in which the location of the artificial port is projected
Manila, entre 1880 y 1883
Eduardo López Navarro
Facsimile reproduction

National Archives of the Philippines. PUBLIC WORKS, 1867-1898, 313/312. SDS. 17073.

LIGHT BEACON OF SAN NICHOLAS SHOAL

National Archives of the Philippines. PUBLIC WORKS, 1877-1893, 468/952. SDS. 17228.



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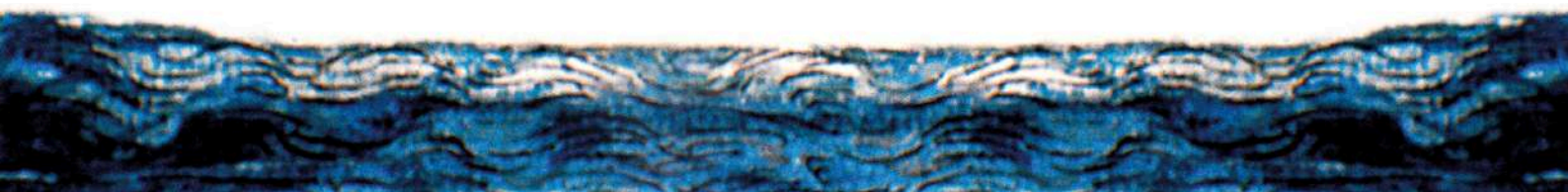

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FOUR CENTURIES OF

XVI SPANISH XIX ENGINEERING

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