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Historical-architectural analysis of Cartagena de Indias heritage

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Abstract

In the last four decades, the historical heritage of Cartagena de Indias has been at the center of national and international attention due to its classification as a World Heritage Site according to the United Nations Educational, Scientific and Cultural Organization (UNESCO). Many historians and architects in the past have narrated the heroic deeds of the city of Cartagena, its role in the independence of Colombia, as well as the history of its construction. Its history, extension and majesty currently attract hundreds of thousands of tourists each year. Tourism representing the second source of income in the region after industry. However, today the heritage continues to suffer from several challenges that deserve to be faced by the community in general, the scientific community and institutions. Its particular state of conservation and some state of deterioration has generated a call for attention by UNESCO to categorize it as heritage *at risk* due to the effects of climate change (UNESCO 2016), which represented a crucial moment for the authors offering several points of reflection that have given life to this work. Part of the problems of deterioration and decay of the fortifications is due to a deep lack of knowledge on the part of civil society and the authorities about the construction history and the stratification of interventions on the heritage. For this reason, the objective of this paper is to analyze the history of the interventions and modifications of the fortifications, including the submarine defense system of Cartagena de Indias, as well as to evaluate the state of the city at the end of the Spanish viceroyalty. In this work, history, architecture and engineering come together, proposing a journey into the past, a broad vision of heritage and its current problems. In the conclusions, the authors matured a series of recommendations as a result of the present investigation and their personal experience in heritage management. It is considered essential to apply these measures in the short-medium term for the heritage protection and its conservation for future generations.

Keywords Latin America heritage, UNESCO architectural analysis, Historical-architectural knowledge in conservation

Introduction to the architectural heritage and fortifications of Cartagena de Indias

Historical monuments around the world are some of the most important legacies left by our ancestors since they show our human roots and identity. Therefore, its protection and preservation from deterioration must be a priority for humanity. There are numerous examples of emblematic structures that represent the power and testimony of civilization, (UNESCO 2019). Among which the Parthenon in Athens, the cradle of modern civilization, the Great Wall of China embodying the greatness of the eastern empires of the world, while Chichen Itza in Mexico and Machu Picchu in Peru are symbols of the immensity of pre-Hispanic civilizations in Latin America. According to the United Nations Educational, Scientific and Cultural Organization (UNESCO), there are about 897 sites of cultural interest around the world. They were selected for their historical relevance and uniqueness. They all struggle with the surrounding aggressive weather conditions that hasten their deterioration. Currently, 52 of those sites are classified as in imminent danger of collapse due to anthropogenic and natural factors.

For example, the fortifications on the Caribbean side of Panama (Portobelo-San Lorenzo), part of the defensive

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colonial system built by the Spanish Crown to protect transatlantic trade, constitute a valuable example of the military architecture of the seventeenth and eighteenth centuries, whose integrity has been compromised by environmental factors, uncontrolled urban sprawl, development, and lack of maintenance and management. Factors responsible for stressing and damaging monuments and thus inhibiting their conservation are high levels of air pollution in the atmosphere, daily and seasonal cycles of temperature and humidity, marine spray (or sea spray), increased capillary humidity, atmospheric conditions (rainwater, exposure to wind and sunlight).

The present work deals with the architectural heritage and the system of fortifications of Cartagena de Indias (Fig. 1a, b), which have been the subject of various studies and interventions by multidisciplinary groups of professionals, having an isolated impact on their restoration and conservation. For this reason, it has not been possible to combine efforts in the identification of elements to strengthen Cartagena cultural heritage enhancement and identity. Consequently, the management of the heritage faces the risk of political and economic malpractice. The study area includes the fortification system of Cartagena de Indias, 4,500 linear meters of walls, made up of Centro, San Diego, Getsemaní and Espinal sectors. Formerly they were known as Santa Catalina, La Merced, Santo Toribio, San Sebastián and el Arrabal (or Getsemaní), (Fig. 1c). In this spatial framework is the current Historic Center, which has about 100 hectares, are included the spout attached to the Historic Center, the monumental areas of the Castillo de San Felipe and the defensive fortifications of the Cartagena's Bay. Added to this are the dikes or breakwaters of the Center, with an effective length close to 1,500 linear meters.

However, the studies and analysis of the technical and constructive aspects of the structures are limited, while how they were designed, conceived and built is unknown. To provide answers to these concerns, it is necessary to start from the genesis, according to which military, civil, institutional or religious structures should not be studied isolated, since all of them were conditioned by military works, within a conceptual unit called "citadel". Like all the defensive structures located in strategic places, these served to protect the people, wealth and fleets that spent the night under their shelter; but the last ones that were built in the Hispanic period fulfilled a dissuasive function. A defensive city should appear so powerful to the enemy to reconsider the attack.

The fortifications of the Colombian Caribbean, and especially those of Cartagena de Indias, forged cultural identity throughout the colonial period, with a direct relationship between the fortification and society. Protected

Fig. 1 **a** Location of Cartagena de Indias; **b** General location of the study area; **c** Location of the walled center and the castle of San Felipe, (In yellow the perimeter of the currently existing walls). Source: Adapted from Google Earth (2022)

by its walls, the Colombian culture and idiosyncrasy was built for 300 years, becoming the genesis of the Colombian nationality. In addition, Cartagena de Indias was the city that received slaves brought from Africa, which gives the site a great symbolic value. It was also the place where the first independence processes in America took place, by the black maroons, as well as the deeds of the independence of the province of Cartagena. At present, these National Assets of Cultural Interest (BICs, for its initials in spanish) are administered from Bogotá and are managed as an isolated event from other non-military assets of cultural interest, such as churches, houses and institutions, generating a dichotomy management. This puts at risk the monumental complex as a whole, declared "Cultural Heritage of Humanity" by UNESCO in 1984, (UNESCO 1984). Management difficulties, depends in part from the fact that there is still no Special Management and Protection Plan—which is the regulatory instrument contemplated in Colombian legislation, since despite the fact that it has been worked on since 2004, it has not yet been completed. In the present study an analysis of the historical constructions of Cartagena de Indias is presented, analyzing the history of the interventions and modifications of the fortifications, including the submarine defense system of Cartagena de Indias, the most common construction techniques, as well as evaluating the state of the city at the end of the Spanish vice reign.

Interventions and modifications according to historical periods

The analysis of the social–historical conditioning is carried out considering the importance that the fortification system had in the city of Cartagena de Indias, which has transformed the landscape into a partially anthropized cultural landscape, (UNESCO 1998; Terán Bonilla 2004). The study is carried out with a chronological organization criterion, based on documentary analysis and the reading of plans of the time. As documentary sources of this work, the recent studies carried out by Colombian researchers and historians on the city and the historical cartography of Cartagena de Indias and its surroundings are used. It is considered that, by adding its history to a place, made up of the tangible and intangible events of which it has been the protagonist, the heritage object acquires its true essence.

Below is a summary of the periods that characterize the fortifications of Cartagena:

- First period, (Foundation: 1533–1586)
- Second period, (Classicist: 1587–1630)
- Third period, (Baroque: 1631–1750)
- Fourth period, (Neoclassic: 1751–1810)
- Fifth period, (Republican: 1811–to present)

First period, (Foundation: 1533–1586)

While Cartagena de Indias was founded, projects were generated to improve its quality of life. Initially, specific projects were drawn up, which only sought to provide a specific response to a specific problem. This period was the most primitive stage of the fortifications in Cartagena de Indias, which took up the old formulas, seen in Italy, with design models and patterns typical of the medieval period in Europe, (Zapatero López 1985*)*.

Includes the period from the founding of the city by Don Pedro de Heredia in 1533, to the numerous takeovers by corsairs and pirates, which marked the break with those old patterns, since this art of fortification demonstrated not be the most suitable to defend the city. The use of the powerful new gunpowder weapons ends with Sir Francis Drake's bloody takeover of the city in 1586. This was without a doubt, up to that point, the biggest plunder of him. Some builders and works stand out from this first foundational period. Four governors executed in 53 years, nine fortifications, within which six forts stand out. They relied on older masters for their construction, more concerned with building the first churches and convents in the city. There was an almost total absence of military engineers, so there are no vestiges of this period except for a few meager ones from San Felipe del Boquerón, today San Sebastián del Pastelillo, where a few poorly built walls have been detected.

For a long period, the enemies were, indistinctly, French or English depending on the rivalry in turn to the Spanish monarchy. The Caribbean saw the arrival of fear-inspiring characters such as Roberto Baal, Jean Beautemps, John Hawkins and the mythical Francis Drake, who successfully took Santo Domingo, Havana, San Juan and Cartagena de Indias, in Latin America, leaving houses, churches and fortifications destroyed, and the inhabitants in total poverty. In short, Cartagena de Indias was a modest palm and bahareque hamlet with a few useless fortifications. In the space of the city there was a juxtaposition of social classes, where rich and poor, merchants and free workers or slaves lived together in the same block. The city's main pier was located in front of La Caleta, where today the Compañía de Jesús, San Pedro Claver and the Naval Museum of the Caribbean are located. Therefore, the city when the Fleet was docked became a trade fair. The new and prosperous merchants pressed urban changes for their transfer, and before the end of the sixteenth century, a more functional area was built, called the island of Getsemaní, which constituted a better hierarchical morphology of Cartagena society.

Second period, (Classicist: 1587–1630)

This period is identified with the arrival in Cartagena of the first elite of Spanish and Italian military engineers, who influenced civil and military architecture, (called the Academy of the Italian or Renaissance School), belonging to it Juan de Herrera, Tiburcio Espanochi, Agrigento, and Cristóbal de Rojas (treaters). The disciples of this school carried out the first works of the enclosure consisting of the enclosure of the original Historic Center, during a period of relative tranquility, (Zapatero López 1985*).* The engineers of Italian-Spanish origin, Battista Antonelli and Cristofoto de Roda, also stand out, (Zapatero López 1985*).*The American continent was a matter of interest and concern for King Felipe II of Spain and, thanks to this, a first fortification plan was defined for all the strategic ports. It was the engineer Tiburcio Spanochi who started the greatest fortification company of all time. Spanochi entrusted the project and construction of the fortifications to the Italian engineer Battista Antonelli, who began in Cuba, where he left traces of fortified enclosures in accordance with the concepts of the polyorcetic of the time: proportional design of bastions, curtain walls, moats, bridges and ravelins. Antonelli made plans for the fortification of squares with royal enclosures in Havana (1589–1594), Panama (1609), San Juan (1589–1591), Cartagena de Indias (1594) and Veracruz (1590). His work constitutes, without a doubt, a compendium of all the concepts of the Italian school, within the theoretical framework that reflects the teachings and fortification treatises such as that of Cristóbal de Rojas, (Cabrera Cruz 1998).

Carrying out these plans was a great challenge during the last decades of the sixteenth century and although what exists today of these fortifications offers many alterations, applied by successive builders, they did not lose the basic script of the pre-established layout. It can be said that much of the later physiognomy of these American cities was marked by the Felipe II—Spanochi—Antonelli triangle, (Cabrera Cruz 1998).

Third period, (Baroque: 1631–1750)

This stage was marked by the arrival in Cartagena of a group of Spanish military engineers trained at the Royal and Military Academy of the Army of the Netherlands (Flanders or Baroque School), among whom Sebastián Fernández de Medrano. They worked the area of Getsemaní and the fortifications of the bay of Cartagena de Indias, (Zapatero López 1985).

This period lasted approximately 119 years and the engineer governor Francisco De Murga and the engineers Juan Battista Antonelli and Juan de Herrera y Sotomayor worked. More than sixty works were totally or partially executed, the wall cordon was completed, and eleven forts or castles were built within them. These structures were tested in the largest historical takeover of the city: Baron De Pointis's in the late seventeenth century and Vernon's in 1741.

Fourth period, (Neoclassic: 1751–1810)

Consisting of the arrival in Cartagena de Indias of the elite of Spanish military engineers trained in derivation to Paris in the French or Neoclassical School, which are Vauban (treatist), Pagan and Montalenbert.

It is the period of the largest military executions, which gave the city its definitive final image that we see today, with some retouching and interventions. The largest hydraulic works in the Americas were built, such as the Bocagrande, Marina, Dique and Juan de Angola canals, which also guaranteed dynamic stability to the city for the next two and a half centuries, working and saving the city from cam seas or "norths" and hurricanes. From this moment, 93 great built works are counted, including the adaptation of barracks and convents, most of which survive to this day. This stage lasted more than 60 years and its works were carried out by seven great engineers, some like Arévalo, who left a deep technical mark, a governor-engineer like Sala, and the others, Solís, Mac Evan, Deshaux, Anguiano and Crame. At this time, the Castillo de San Felipe acquires its final splendor, and most of the forts of the bay and the historic outskirts are built. This moment extends to the dawn of the independence of Cartagena, in which there was a short republican period, 1811–1815, (Hervás Más 2009; Cabrera Cruz 2017*).*

Fifth period, (Republican: 1811–to present)

After the first half of the nineteenth century, the military fortresses of the 16th and early nineteenth centuries were abandoned, and an important part demolished, as they no longer had any military value. They ceased to be useful and became a nuisance in some cases, quarries of materials for the populations that experienced the process of urban expansion. Therefore, a systematic demolition process was initiated using the arguments of unblocking urban growth and improving public health.

However, in the last years of the nineteenth century, a neo-Gothic tower with a clock was added to one of the city's entrance gates, called the Clock Tower, which has become one of the symbols of the city and the country. From the fourth decade of the twentieth century, the first manifestations of an interest in the conservation of its Monumental Heritage took place. Thus, Law 5 of 1940, Decree 264, 1963 and Law 163, 1959 emerged, which aim to preserve Colombian heritage.

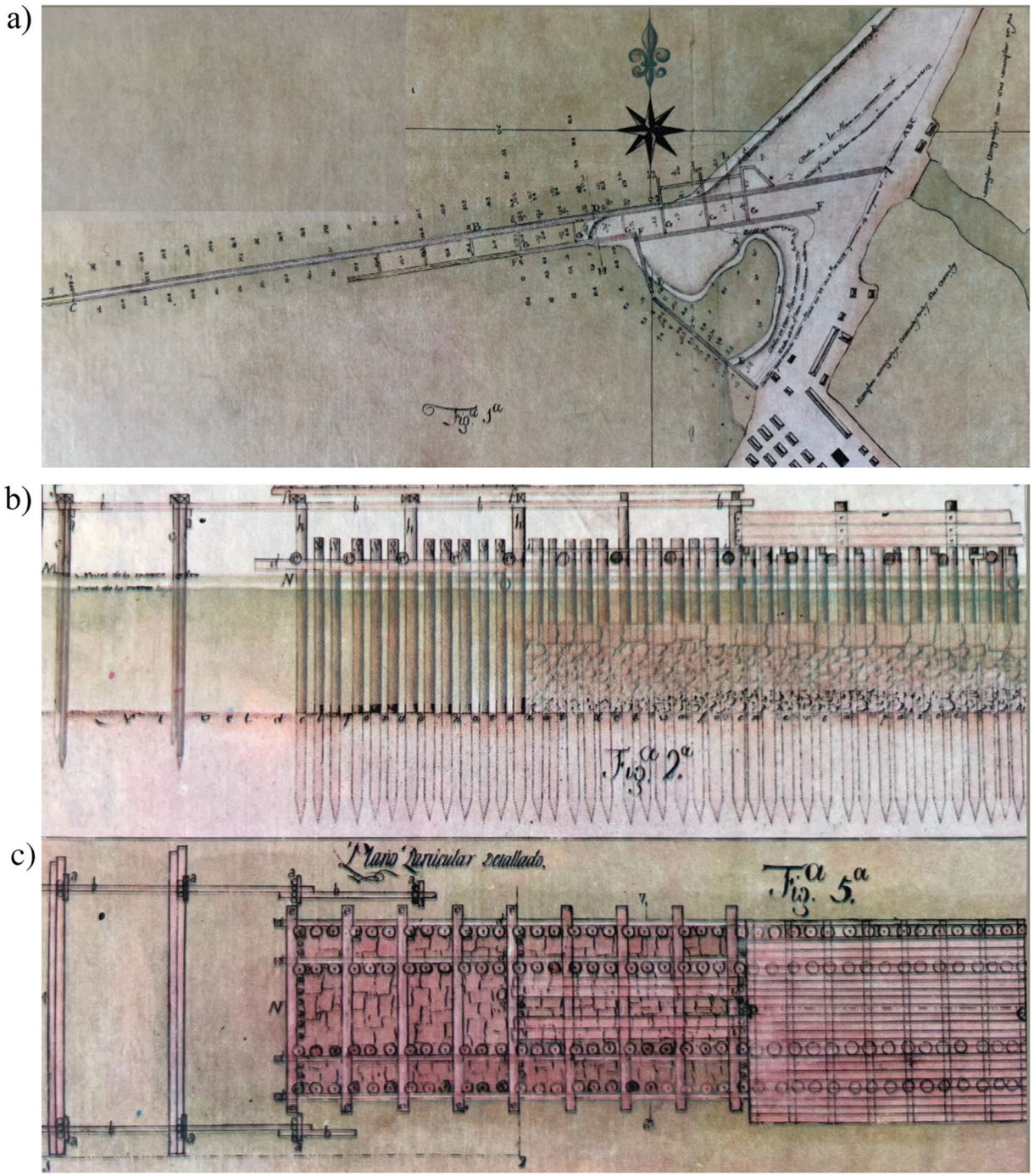

Fig. 2 Original drawings of Antonio de Arévalo from 1773. Taken and adapted form (Zapatero Lopez and García Baquero 1980), **a** Plan of the Bocagrande breakwater design; **b** Breakwater longitudinal profile; **c** Pile plan view

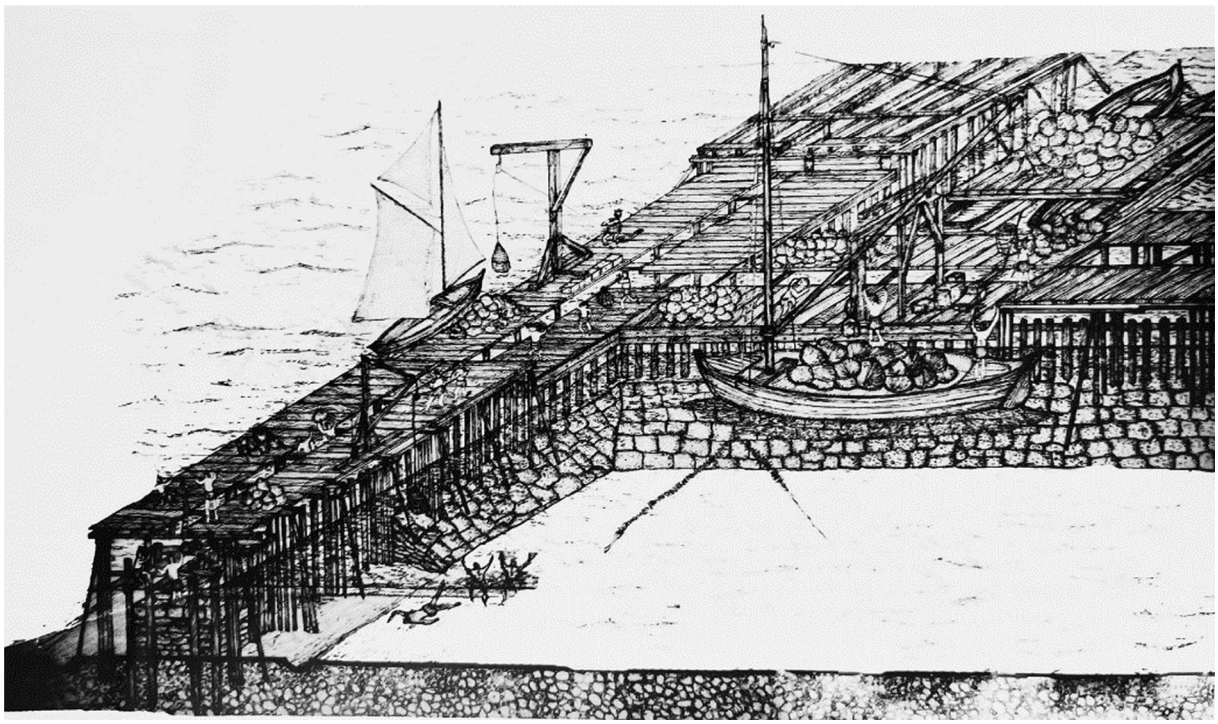

Fig. 3 Isometric view of the construction of the Bocagrande breakwater, hypothetical drawing. Draft taken and adapted from (Cabrera Cruz et al. 2019)

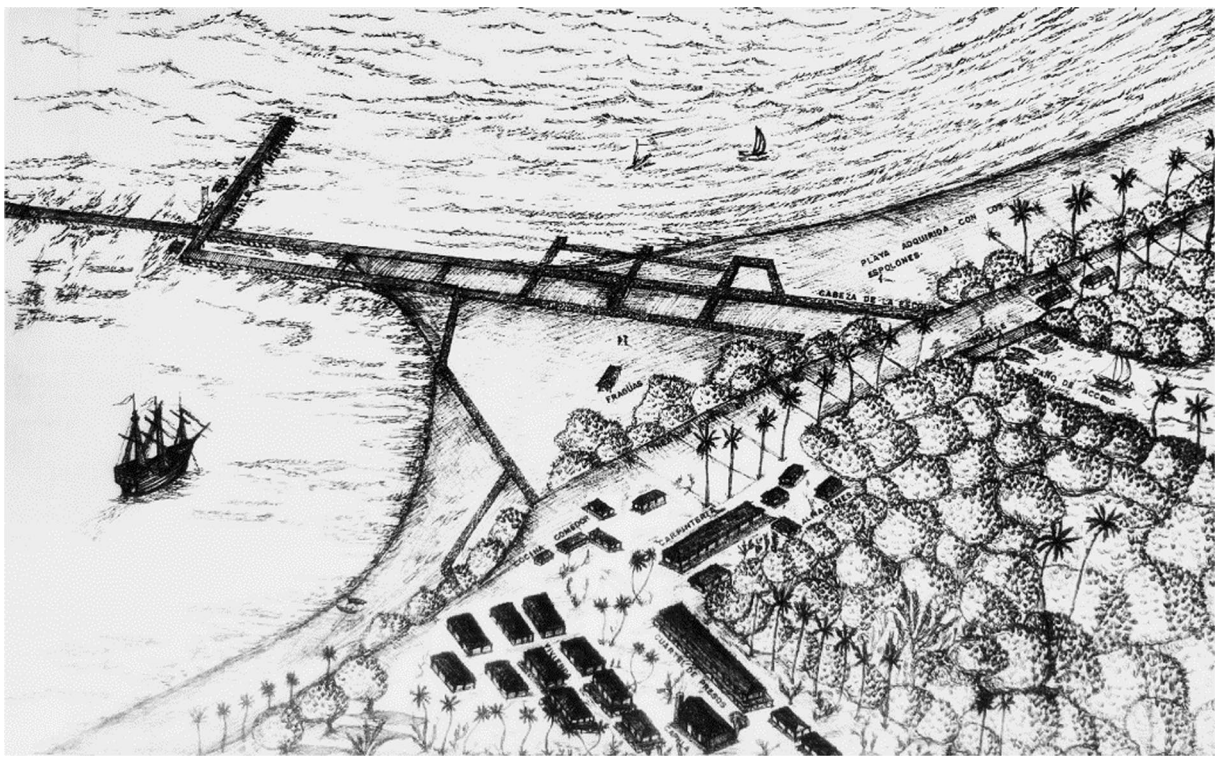

Fig. 4 Camp for the works of the Bocagrande breakwater. Draft taken and adapted from (Cabrera Cruz et al. 2019)

Later, on August 16, 1985, as already mentioned, UNESCO announces that the Intergovernmental Committee for World Heritage in its 8th session in November 1984, declares that the Port, Fortress and group of Monuments of Cartagena de Indias become part of the UNESCO Heritage List. From there, a series of actions aimed at the conservation of the heritage emerged, including the revision of the protection regulations then in force, and it was determined to formulate a new plan for its protection. Finally, Decree 763 of 2009, which regulates Law 118 of 2008 in relation to the Cultural Heritage of the Nation, establishes the implementation of Special Management and Protection Plans (PEMP), as a tool for managing Cultural Heritage, to guarantee its protection, conservation and sustainability, (Presidencia de la República de Colombia 2009). Currently, these plans are being developed, with incredible delays, however, their effects are expected in the next decades.

The underwater defense system

The city of Cartagena has had two systems of walls: 11 km on land, counting the approximate 5 km destroyed by the sea, and 8 km submerged that defend it from the force of the sea, for a grand total of approximately 23 km.

Cartography shows that the fortifications of the historic center of Cartagena de Indias and its outskirts were repeatedly destroyed by hurricane winds and high tides, sometimes combined with rains and tropical storms. Several of these contingencies that occurred at least four times, were recorded, accounting for the damage caused by the storms, since among other constructions the convents of La Merced, Santa Clara, Santa Teresa and Santo Domingo were partially destroyed. In addition to the disasters caused by the force of the winds, the city was also affected by periodic floods, as can be seen in the plans of Antonio de Arévalo dating from the mid-eighteenth century, (Zapatero López 1983).

As noted above, military engineering faced many difficulties in overcoming the strength and durability problems of the walls. In the process of fighting against the sea, between the seventeenth century and the beginning of the eighteenth century, military engineers had repeatedly failed. In 1721, Juan de Herrera y Sotomayor initiated a plan for the protection and defense of the sea borders which, despite not being entirely effective, laid the foundations for the military engineer Antonio de Arévalo to provide a definitive solution to the problem. From there, the initiatives undertaken managed to advance in the solution of the difficulties presented. For example, the total disappearance of the Bocagrande peninsula was avoided, which had already lost approximately 30% of its territory and whose entrance already reached nearly 3,000 m wide in the sector that Juan de Herrera had tried to protect without success. In addition, it was possible to control the access of enemy ships through that area (Fig. 1).

To the south in Bocachica, the Spanish crown had organized the tactical bolt strategy with the fortresses,

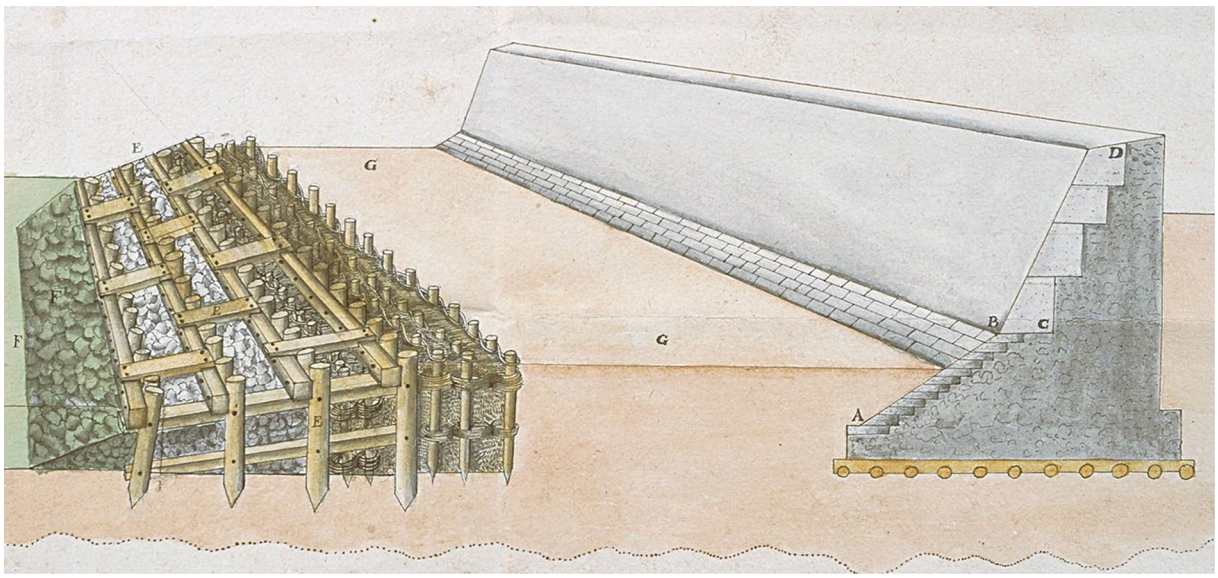

Fig. 5 Orthographic profile of the Wall that is determined to be built along the sea from the Bastion of Santa Catalina to the bastion of the Cross of the City of Cartagena. Arranged by S.M. and under the direction of the Field Master D. Juan de Herrera y Sotomayor, Military and Castilian Engineer of the Castle of S. Phelipe de Barajas by S.M. Year 1721. Taken from (Portal de Archivos Españoles (PARES) 1721)

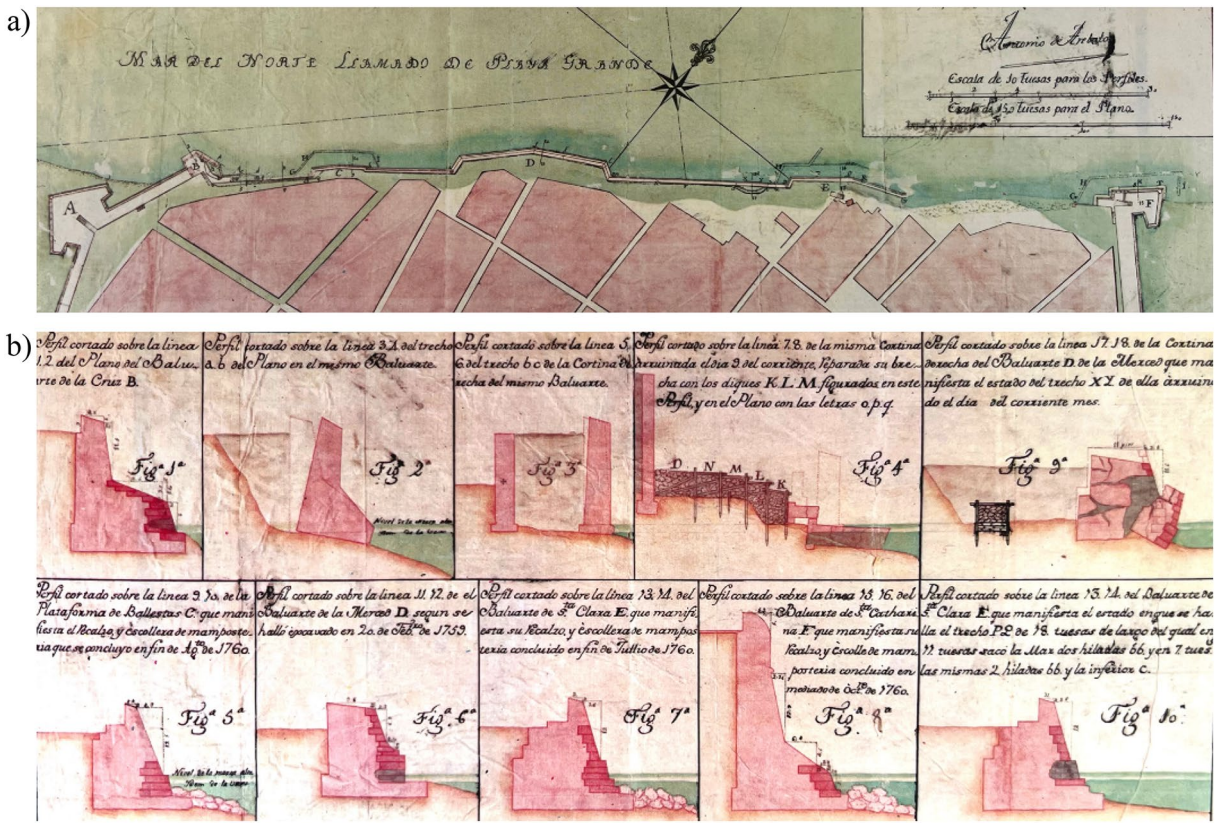

Fig. 6 Original drawings of Antonio de Arévalo from 1761. Taken and adapted form (Zapatero Lopez and García Baquero 1980). Observe in green the flooded areas of the historic center of Cartagena that destroyed parts of the walls. **a** Partial plan of the historic center and flooded areas in green; **b** Ten different profiles of the walls damaged are reported and descripted. For more details about the text in the figures look at the descriptive folder of the Military historical service of Spain, (Zapatero Lopez and García Baquero 1980)

but it was imperative to close Bocagrande, the old entrance, because otherwise the strategy planned by the Crown could go wrong, since the city was subjected to two risks: the first, the disappearance of the isthmus of Bocagrande due to human interventions and the second, the taking of the city by its western access, at the hands of the enemies of the Spanish crown.

For this reason, surface and underwater defenses called breakwaters or dikes were then designed, whose construction immediately produced great benefits, such as the existence of new sea impact buffers, guaranteeing the dynamic and environmental stability of the Bay of Cartagena until today. Through these straits, the oxygenation of its internal waters is achieved, giving the city its profile and strategic importance.

In summary, approximately 40% of the current area of Bocagrande was recovered, some 37 hectares, thanks to the works of Arévalo, including the Castillogrande peninsula. The works for the construction of the breakwater of La Marina were carried out between 1762 and 1771 and those corresponding to the breakwater of Bocagrande, the most important due to its scale, began on November 11, 1771 until its conclusion in 1777, (Cabrera Cruz et al. 2019), (Fig. 2).

The Bocagrande breakwater was designed as an underwater work aimed at preventing the passage of ships through the Bocagrande, between Punta Icacos and the tip of the island of Carex, an old tile of San Bernabé de los Jesuitas (Tierra Bomba island), constituting a one of the most complex hydraulic works carried out in America during the Spanish era. Through the records, the arduous process for its construction is evidenced, which would take about seven years to be completed, being registered the design of one of the most transcendental military engineering works undertaken in the city, (Cabrera Cruz et al. 2019). The main function of the breakwater was to provide security and dynamic stability to the bay of Cartagena, (Fig. 3).

This arduous construction process shows how one of the most outstanding hydraulic works of Spain in South America was developed, which would give the port security in the control of access to the bay of Cartagena, until

Fig. 7 Representation of the city of Cartagena de Indias made in the seventeenth century Source: State Archives, Ministry of Education, Culture and Sports of Spain

today, (Fig. 4). The work camp in the north head or Bocagrande with all the infrastructure and logistics necessary to carry out the work can be seen. This would remain until the twentieth century, when the inhabitants of this village were partially relocated to the Tierra Bomba island.

Description of the underwater defenses model of Antonio de Arévalo in the city

The description of Antonio de Arévalo's model of submarine defenses in the city can be found in several historical documents, as well as in the maps and cartographies mentioned below.

The Bocagrande breakwater was made up of four rows of wooden piles 6″ to 10″ in diameter and 15 to 25 feet high, with a separation of 2″ to 3″ between each one, for a total of 145,142 piles. Above it, it had a platform made of wood or planking and on this structure a bridge with a hole in the center was then placed, to keep the material inside the "casing" of the sheet piling. The paved was formed by providing slight slopes, to cushion the impacts of currents and waves, (Cabrera Cruz et al. 2019*)*.

The whole set acquired an average of 20 m wide, while the wooden sheet piling was 15 feet high, from the coastal bottom (about five meters or depth, within the unstable sea due to bathymetry). In certain complex sites where the depth was greater, this procedure was repeated one or two more times. The construction of the dikes and breakwaters of Arévalo is one of the extraordinary chapters of military engineering in the town. The Marina boardwalk also stands out, whose length reached 1,491 m, along with other minor works at the entrance to Bocagrande, which exceeded 7,300 m, which required some 1,500,000 cubic meters of coral stone (approximately three million tons of stone).

Figure 5 shows a detail of foundation reinforcements on the Marina sector, from 1720, a section corresponding to the bastion of Santa Clara, very detailed, given the great difficulties of building on sandy land. Here a mesh or lattice was proposed, at the base or foundations made

Fig. 8 Original drawings of Battista Antonelli, from 1594 Plan of the City of Cartagena de Indias and its fortifications, showing by yellow lines the fortification or nearby that could be done. Taken and adapted form (Portal de Archivos Españoles (PARES) 1671)

with wood. This system was functional until the arrival of the "norths", in the years 1759, 1760, 1761, destroying an extraordinary work, which, due to not having sufficient solvency in its foundations, was swept away by the surprising sea of Cartagena, undermining the sands, causing their total destruction. In later shots of Arévalo, the magnitude of the damage is highlighted, never seen before at this moment. This leaves us today with one of the most important questions about the future of this material heritage. After more than two hundred and thirty years, now that those defenses have diminished, and no recent work has been done to reinforce them: is this the main circumstance that calls into question the conservation of the entire citadel?

The document that appears in the Fig. 6 it also contains details on the serious damage that forced definitive measures to be taken against this type of phenomenon. From here came the schemes for the most ambitious system of dikes or breakwaters of the Navy-Bocagrande and coastal protections of the viceroyalty, which would begin to be built ten years later from 1771 and masterfully carried out by Arévalo himself. These submerged defensive structures survive to this day fulfilling their function.

In the overlap of 2021–1762, yesterday and today, note that Santander Avenue (Fig. 1c), built in the sixties of the twentieth century, it is sheltered between the breakwater and the walls, it shows some erosion. Therefore, the incessant marine dynamics on the coast have changed little, and today only global warming threatens to destroy the work of the dam and the historic center.

Currently, approximately a quarter of the total height of the walled enclosure on Santander Avenue is buried by the most recent constructions in the city. For a correct appreciation of the wall that is not visible, it is necessary to consider its exhumation in the future, in order to obtain a better reading of the true scale of the walls. To do this, Santander Avenue must be moved away.

The study of the submerged architectural structures of the city of Cartagena de Indias and the techniques with which they were elaborated is little treated from the point of view of history, architecture and engineering. Only in the last twenty-five years have some works begun in

this sense, which are the basis of this research work. Its importance is currently high due to the threat that the city faces due to the rise in sea level as a result of climate change, which forces the search for engineering solutions that allow the conservation of the heritage complex.

The cartography of each period and its interpretation

The cartography of different sources and periods allows interpreting the periods studied with greater clarity. The trace shown in Fig. 7 is the representation of the city of Cartagena made in the seventeenth century. However, it perfectly explains the city of the sixteenth century, which was a city without the walls that we know, having in the foreground the fort of San Felipe del Boquerón or Pastelillo, on the site now occupied by the Fort of San Sebastián del Pastelillo, before of the arrival of the attacker Drake and the Antonelli builders.

While in Fig. 8 the layout of the main project of the engineer Bautista Antonelli is shown who, as already mentioned, based on the concepts of the permanently bastioned modern fortification, came to Cartagena to carry out an in-depth technical and tactical study typical of the Italian school.

To achieve what Cristóbal de Rojas said: "[…] ensure that a few can defend themselves against many, designing bastions that open up the enemy […]",(Cabrera Cruz 1998), it was necessary a very different military fortification. In fact, the city had high walls full of battlements, towers, machicolations and stirrups, not effective against gunpowder. Now the walls had to be lower to expose less area to the new gunpowder weapons, cannons, rifles, bombs, whose effects on a medieval wall were devastating. The walls, then, began to be made with thick front walls reinforced with stone. The counter wall appears, and between it and the wall the compacted embankment is built, on top of which the platform is located. This system proved its effectiveness by ensuring that the vulnerable parts of a fortification could be covered by each other, so that all points could be seen dominated from each other.

The plan consisted, roughly, of reinforcing the entrance to the bay of Cartagena through the Bocagrande route, building forts at the ends of the mouth, one in the southern part of Bocagrande, in a place called Punta de los Icacos, another in the northern part of the island of Carex (today Tierra Bomba). With this, it would be possible to cross fires in the Bocagrande channel. There are no known drawings of the fort of Punta de los Icacos and no archaeological trace remained, since, due to the geomorphology of the site, the sea at different times swept it and even occupied its site for more than a hundred years -between the first half of the eighteenth century and early nineteenth. From written reports it is known that this small fort, made of wood with beams as bastions and terraced with earth and fascine, was square in shape and reached approximately 43 m on each side. The second fort, Tierra Bomba, would have to await the arrival of Battista Antonelli's nephew, Cristoforo de Roda.

The essence of Antonelli's thought is reflected in the proposal to defend the square, consisting of surrounding the city with a real wall with all the innovations of the moment. Twelve bastions stand out in it, with their flanking angles, fixing angles, curtains and six access doors, flanked by bastions. Antonelli also designed three ravelins for access to the fortified city. The Italian engineer decided to retake all the fortifications, already erected, and with them he tried to make a fortified square inscribed in a regular twelve-sided polygon. By trying to accommodate the design of it and adjust it to existing blocks and streets. The result was an irregular polygon, circumscribed to the city. Furthermore, Antonelli's plans and projects suggest the demolition of the fortress built between 1540 and 1550 by Fernández de Busto. The rest of the audacious design proposed building part of the wall and its bastions on the Plaza de los Jagüeyes. This was an inconvenience, since it required the total or partial demolition of seven blocks and left another four of the nascent Santo Toribio neighborhood outside and exposed. It was also proposed, on the other hand, to surround the north front of the Avenida de la Cruz Grande by a large wet moat that would connect the San Anastasio channel with the open sea. This moat would be flanked by four large bastions and would be preceded by three small ravelins, with their covered paths. One of them would coincide with the Plaza de los Jagüeyes, where the sleeper bridge and the access door by land from the north would be.

The plan of Cartagena and the fortification project for the square drawn up by Battista Antonelli in 1595, by

Table 1 Cisterns of the city

	Neighborhood	Cistern	Cubic feet of water
Private cistern (PC)	Santa Catalina	76	226.129
	San Sebastián	77	65.203
	La Merced	78	125.046
	Santo Toribio	79	114.628
	Getsemaní	80	258.382
	Total PC	390	789.388
King's Cistern s (KC)	Santo Domingo	1	31.434
	Santa Catalina	1	40.635
	Total KC	2	72.069
	Total	392	861.457

order of Felipe II, serves as the basis for the fortifications that are built around the island of Calamarí, seat of the primitive Cartagena. However, the engineer did not name the bastions. His nephew Cristóbal de Rodas did it identifying the bastion of the Moors, whose expansion and transformation is today the bastion of San Ignacio. It faces La Caleta and was, at.

There is a great similarity between four of the most important fortifications in Latin America, Antonelli and Roda in part designed:

- Castle of the Three Kings of Morro, Havana. In 1589, Antonelli made the designs and undertook the construction with the help of Roda, and in 1594 he directed the completion of the latter.
- Fortress of San Felipe del Morro, San Juan de Puerto Rico. In 1589, Antonelli undertakes the design and works, and in 1591 Pedro Salazar continues the construction.
- Front of Plaza de la Avenida del Norte or Cruz Grande, bastions of Santa Catalina and San Lucas, Cartagena de Indias. Designed by Bautista Antonelli and made by Cristóbal de Roda from 1602 to 1630.
- Fortress of Santiago de Araya, Araya Peninsula, Cumaná, Venezuela. Designed by Antonelli in 1602 and executed by Roda until 1622.

By superimposing the four floors, the coincidences of form are remarkable. The four fortifications have the following elements in common: a) Hornabeque shape in front of the square, towards the most dangerous place (the hornabeque is the set of defensive elements that separate the first and second enclosures of the Castle and is formed by the glacis, a covered path, the ravelin, among others); b) Semi-bastion with low squares or casemates to flank the front; c) Wet or dry moat depending on the site; d) Plaza front with access door through the curtain, except in Araya Venezuela.

Status of the citadel of Cartagena de Indias at the end of the viceroyalty

In the report of Manuel De Anguiano "Cartagena de Indias", in: "Atlas of Cartagena de Indias", (Anguiano 1895), it can be seen a deep perception of the final moments of the Spanish viceroyalty in Cartagena de Indias, in November 1811. The document defines a base line for the military citadel, which details the particularities of the strategic operation of the plaza, where it establishes the poliorcetic capacities that the citadel had in the face of an eventual takeover of any kind. It is also determined that the entire city was geared to its military function with well-defined roles. It describes a city perfectly prepared for any type of occupation for a long time, guaranteeing an indefinite ability to subsist, which could exceed a year, based on the process of establishing orchards within the enclosure, the existence of the slaughterhouse, the number of cisterns, fruit trees, the furnaces for food and bread and other products that guaranteed that subsistence.

This tour of the resources or materials is the palpable demonstration that in Cartagena de Indias no efforts were spared by Spain, despite being one of the most complex places to locate a city. Here it persisted for almost three centuries and made the citadel viable, even against a hostile environment, since the site only had three abundant resources, which were limestone, clay and sand, as well as the other resources were wood and water and the fruit of tenacity. The water was jealously stored in expensive cisterns, so that the city resisted the siege of the summers. In this arduous process, the best and strongest

Table 2 Number of men and ammunition (Anguiano 1895)

Vaults	Length (Feet)	Width (Feet)	Number of men	Use
7	60	20	300	For 80 barrels of gunpowder
6	60	20	192	For the provisions of the garrison
9	60	20	216	Sick, in the hospital
1	72	21	37	For weapons room
1	42	11		For fireworks, bombs, grenades
2	35	26		
	35	26		
	31	12		For the fortification guns
	31	12		
In the suburb				
2	33	11		For the chief and officers of this front
2	20	16		For the land gate guide
3	33	11		For 500 barrels of gunpowder

timbers were also brought from great distances to complement the reinforcement of the walls and the stone city, glued with lime and sand available on the site, with sea and sky water.

Status of food furnaces

Being supplied with enough food was very important to the resistance strategy. Strategic orchards were organized, as well as the furnaces for the production of bread with wheat flour and corn bread preferred among the foreign and permanent population. Cartagena was able to produce up to 7,821 servings of daily baked bread, completed with a yucca cake, also called casabe, which could last for weeks without being damaged, (Anguiano 1895). This allowed the city to have a supply of basic food for subsistence. In addition, there were fish from the waters adjacent to the bay of Cartagena and cattle.

From this extensive document it can be understood how complex the military administration was, revealing how clear the accounts were regarding the resources

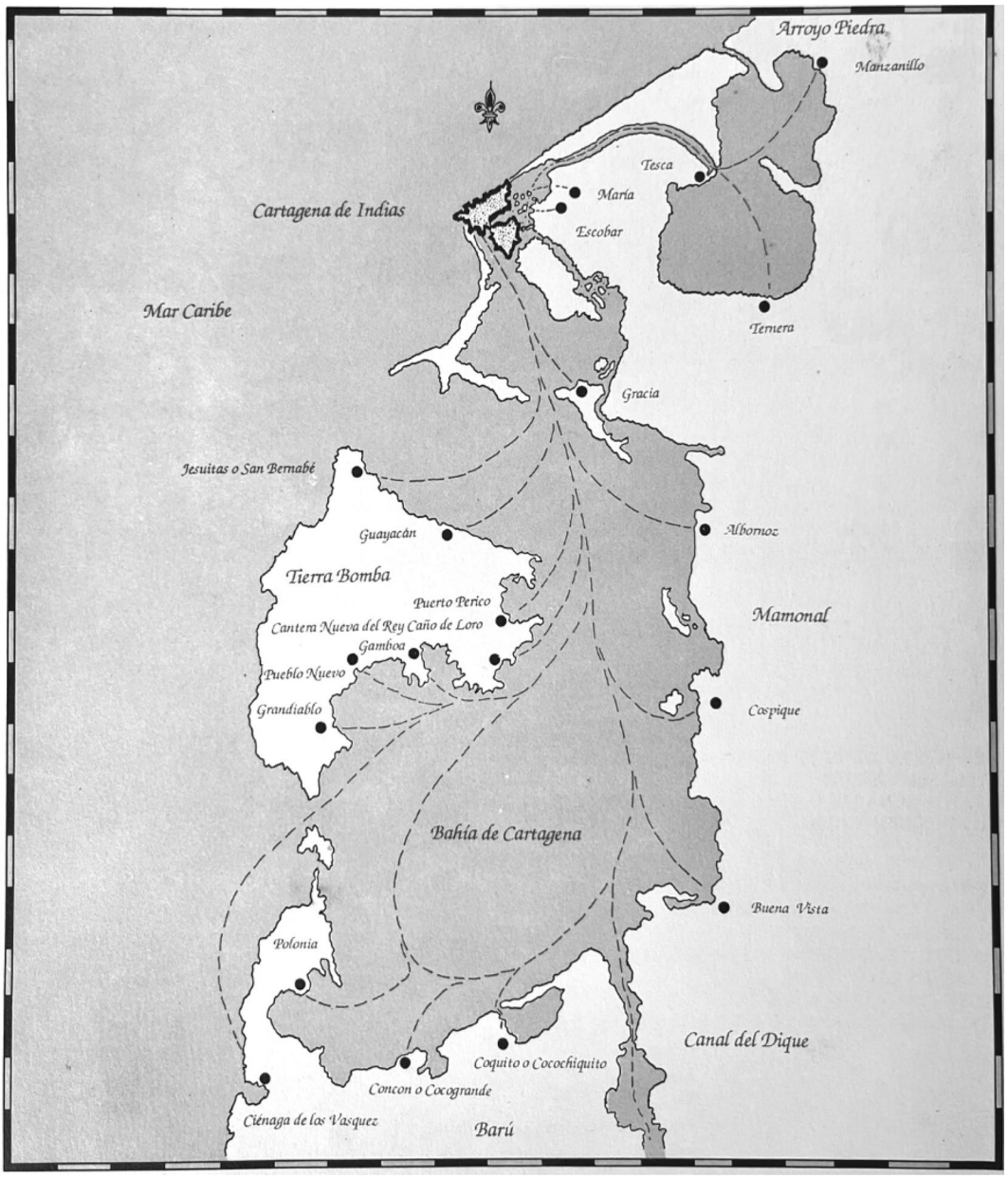

Fig. 9 Quarries and furnaces in the surroundings of Cartagena. Source: Art museum of Cartegena (1993)

Fig. 10 Model of the twin furnaces of Caño del Loro. Source: (Cabrera Cruz et al. 2019)

available and how well prepared the citadel was for any military eventuality.

From this moment, the question remains: why did the patriots of November 11th 1811, (Independence of Cartagena) not prepare their orchards for what was known to come, that is, the siege of Spain?

For this omission the city fell again into enemy hands in a few months. From the available information it seems that only one person handled this knowledge and these strategic procedures, which was the Spanish military engineer linked to the cause of independence, Don Manuel De Anguiano, martyr of his own countrymen. The orchards were always next to the existing barracks and regiments, possibly it was the soldiers who cultivated or managed them. For this reason, it is necessary to continue investigating because this information cannot be confirmed or denied in the text or in other documents.

Water management

Regarding the number of cisterns, Anguiano was very clear about it. It is established by citing the texts written by him, detailing the more than 237 cisterns that stored 24,393 cubic meters of acceptably drinkable water (Table 1 cubic feet reported). At critical times, this was only distributed in the historic center with a minimum daily ration per person of approximately two liters, for a possible population of 11,000 people. In this way, drinking water could last perfectly a year and even consuming more. However, the rains that appear in April in this tropical area ensured that this supply never ran out. On the other hand, the water for other domestic activities was of poor quality from wells, (Anguiano 1895), (Table 1).

Men and ammunition

Within this process of administering the citadel for the purposes of the war, it was necessary to know the war resources available and if they were provided with the amenities, minimum comfort and anti-bomb security in battle, to fully fulfill their defense mission. In that sense, the city had several barracks with the forecasts of withstanding bomb impacts in battle and surviving sustained enemy artillery attacks. But even so, not all the vaults were prepared to withstand the impacts. Two essential activities required this type of protection: the powder magazines or Santa Bárbaras and the field hospitals. In the remaining "anti-bomb" barracks, the best ones were distributed for the officers, even the less special ones for soldiers and militias. The Bosque powder keg was the largest warehouses, located a safe distance from the city on the grounds that are now the San Pedro Claver nursing home, and whose capacity was 3,000 quintals, along with three other huge Santa Bárbaras campaign, located

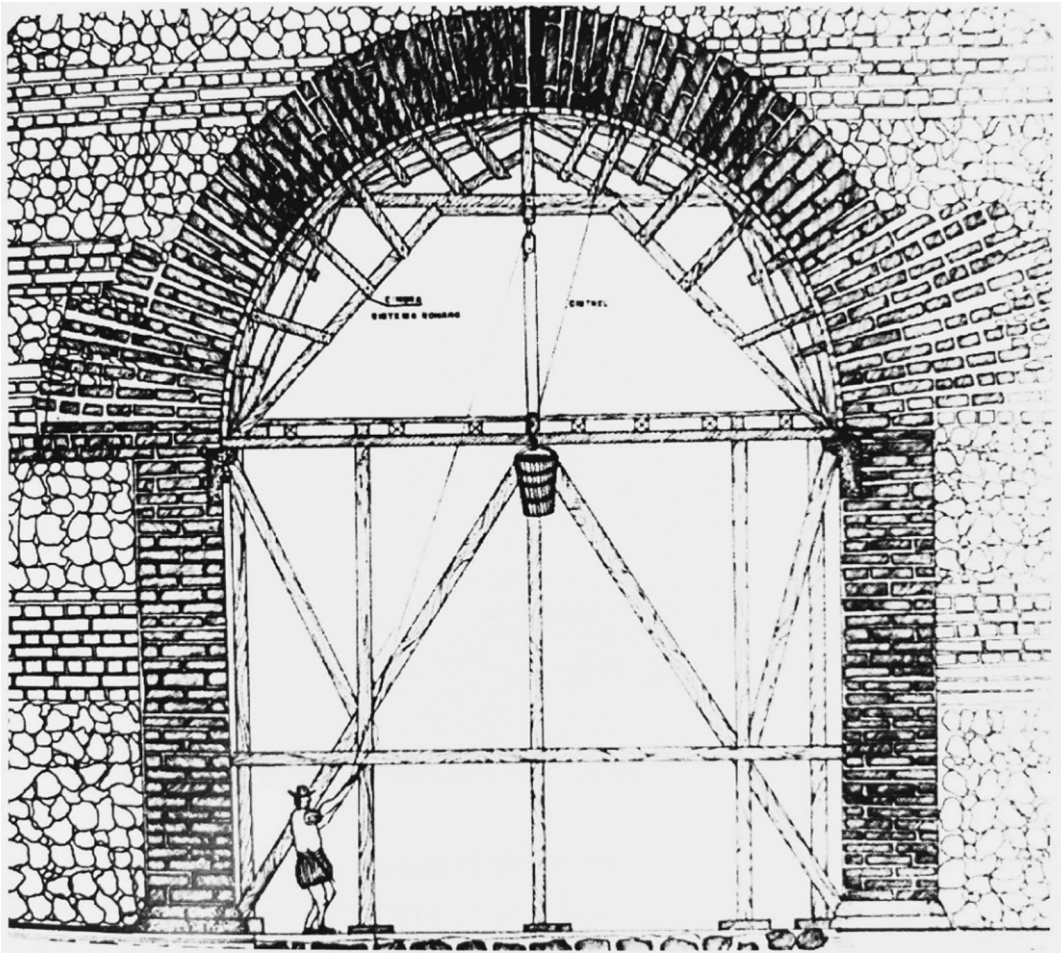

Fig. 11 Half point arch in brick of the San Fernando de Bocachica castle, (Cabrera Cruz et al. 2019)

within the fortified city. The largest was e one adjacent to the Redoubt bastion, with a capacity of about 2,500 quintals, in one of the most depopulated areas of Getsemaní at that time, (Anguiano 1895).

The same attention was paid to the other large powder keg, that of San Miguel de Chambacú, with some 1,500 quintals. Protected by the same ramp that bordered the La Matuna or San Anastasio swamp, which was one of the clearest places in case of a handling error. the number of men and ammunition are reported in Table 2, (Anguiano 1895).

As for the military barracks and convents, the city was prepared to receive some 2407 soldiers comfortably, not counting the support of soldiers from the navy. There remains the issue of the necessary presence of the horses for the traction of the cannons, which needed to be moved to approach the most affected areas of the battle fronts.

Regarding the issue of gunpowder management, only the citadel could manage amounts of gunpowder storage, to serve a large site, 8,500 quintals, for provision of more than 500 cannons and armory in general. The citadel had 143 cannons of 12 and 9 inches with bullets of 25 and 30 pounds including 5 mortars with bullets of about 200 pounds with shrapnel, (Anguiano 1895).

Retrospective of the construction of the walled cordon of Cartagena de Indias

The materials industry

Knowing the materials industry, the application of construction techniques, the historical references and their archaeological location is pertinent for a better appreciation of the significance of the fortifications and to guarantee their better conservation. Among the main materials used we find limestone, lime, bricks, mortar and wood. More details on this topic can be found at (Cabrera Cruz

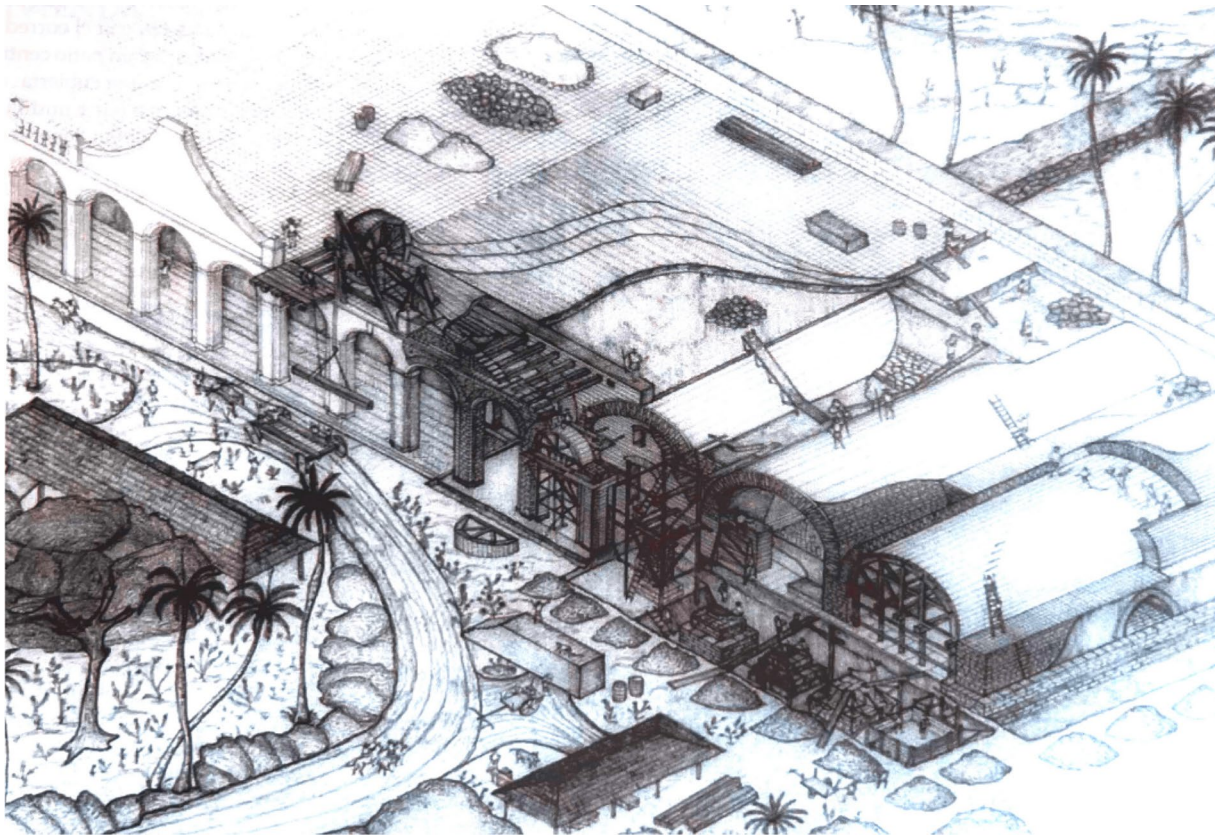

Fig. 12 The Vaults of Santa Clara or Barracks of the Vaults, (Cabrera Cruz et al. 2019)

2017; Saba et al. 2019a, b, c). Among these is the study and location of the lime kilns, (Cabrera Cruz et al. 1992).

The fortifications of Cartagena would not have been possible without the support of this infrastructure, such as dikes, skirting boards, breakwaters, abutments, cisterns, vaults, ravelins, earth gates, batteries, hornworks, moats, tunnels, glasis, cemeteries and an infinity of possible vestiges.

The production centers of the materials with which the city of Cartagena de Indias was built were one of the great viceregal manufactures of Cartagena de Indias, made up of haciendas, ranches, tiles, with multiple functions such as: quarries, lime and brick furnaces, among others. These were usually located near bodies of water to facilitate their transportation, and in strategic places to obtain charcoal. This suggests that wood and water were essential raw materials for the fortification and survival of the city. For all of the above and as a result of this analysis, it is necessary to incorporate the furnaces system into the city's heritage since they were structures that belonged mostly to the Spanish crown and formed a strategic part of the fortifications and military buildings of Cartagena. Other essential materials such as sand and fresh water, so scarce in the city, were found at a great distance from the work centers (between seven and twenty kilometers on average). That was undoubtedly another reason why Cartagena de Indias was recognized in August 1984 as a Historical and Cultural Heritage of Humanity by UNESCO for its Port, fortress and group of monuments.

Below is shown a plan of the Cartagena's Bay from 1742 (author Simón Deshaux Army Geographic Service Corps of Engineers). The presence of the northern part of the island of Barú (bottom left of image) and some of the production centers is notable and clearly defined (black points connected by the sea route), (Figs. 9 and 10).

Regarding to the transport system used, by water loading platforms were used duly gagged and taped on rafts and rafts with several rowers. The pole was used in swamps, but in greater depths the oar and sail were used. The Goletillas both for sea and river, were used to transport materials over long distances, such as between Cartagena and Barú. On land, the transportation of materials was given by teams, they were carts with four solid wheels with metal rims and thick planking, pulled by oxen, donkeys or horses. The simple carts were used

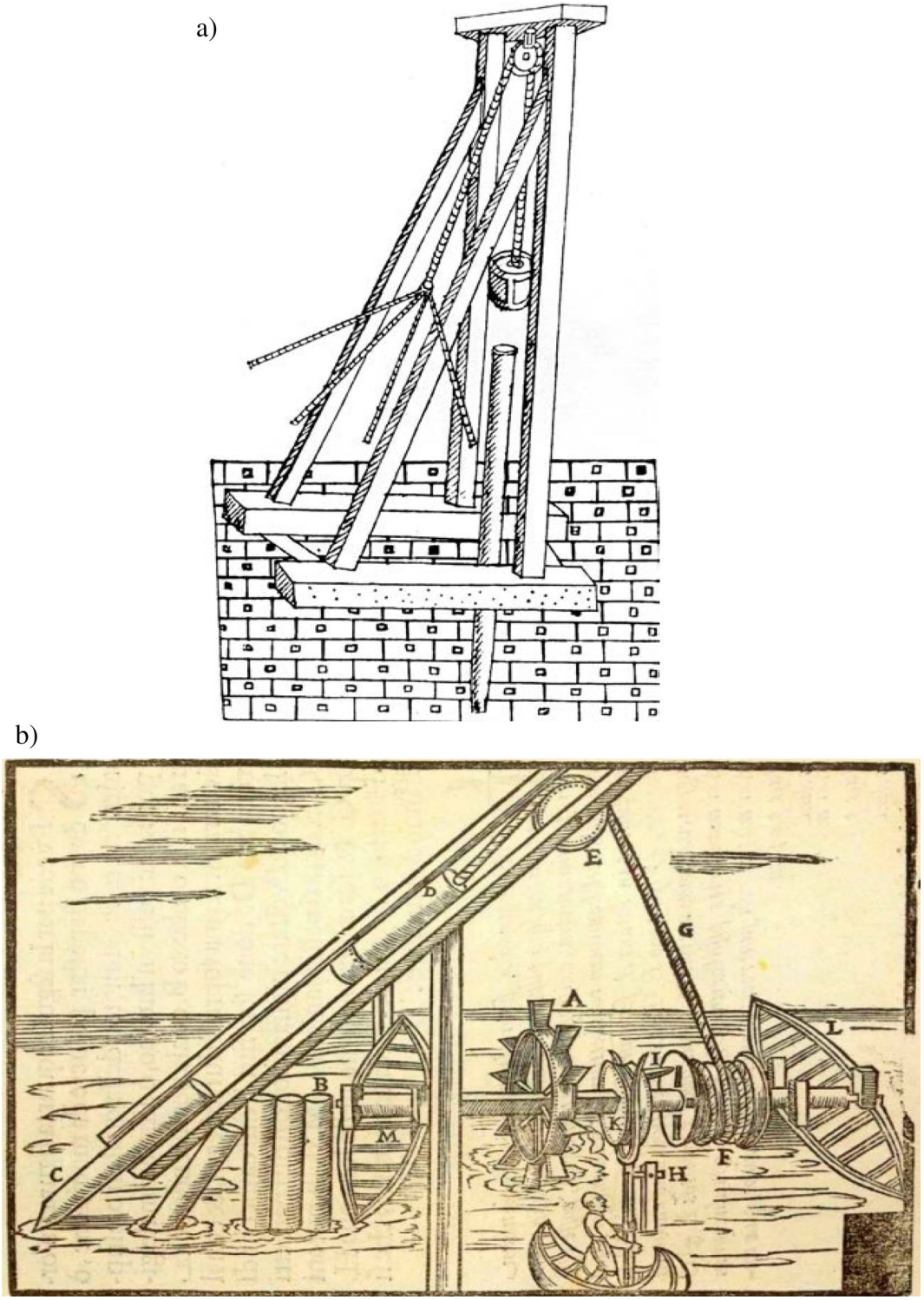

Fig. 13 **a** Pile driving machine and plan view of the arrangement of ashlars with holes passed through them. **b** Pile driving machine driven by a hydraulic wheel with a skewer clutch, (Ramos 1985; Rojas 2005)

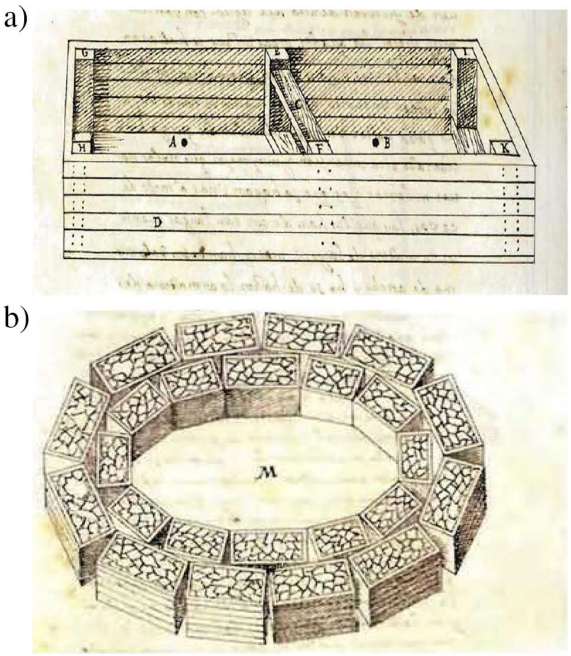

Fig. 14 **a** Enclosure of sheet piles to be founded in the water, **b** Spanish cajon from the sixteenth century, **c** Arrangement of a set of moored caissons, **d** Frame of a caisson to be founded in the water, (Turriano 1996)

for smaller loads and short distances, with radial wheels, they were less resistant, but faster, (Cabrera Cruz et al. 1992).

Constructive processes

This is one of the richest sections of Cartagena's colonial construction, where the influence of southern Spain is very evident. Almost always the masonry is based on brick, ashlar stone, coral stone with irregular edges or rubble. With these materials it can be built the high walls that give intimacy and freshness to the courtyards built with the "mixed masonry" system, executed in the Arab way with bricks, stones and mortar with lime and stone, (Fig. 11).

The construction of the last segment of the wall, on the La Marina sector and the construction of the Vaults of Santa Clara or Cuartel de las Bóvedas, gave an end point to the enclosure of the walled perimeter based on the plans of Arévalo from 1800 (Fig. 12).

According to the cartography found and the historical data, initially the fortifications of the city were made in a primitive way by means of stakes with wood that were found in the area such as the mangrove. Later, in a second stage, cannons were placed on low walls at strategic points, which served during the first pirate attacks on the city.

In a third stage of construction, stone walls were built without embankments, only the escarpment. Later the counter wall is made and filled with an embankment, these primitive walls were made by building the escarpment at the edge of the body of water, as a defensive strategy and the counter escarpment was built on land, (Fig. 6b). Over time these military constructions were built entirely on land.

One of the most serious problems faced by the city's defense structures was the absence of load bearing (solid) soils on the surface. This was especially present in sectors annexed to the suburb of Getsemaní. While in some sectors of the curtain, the surface level contained sludge of decomposing organic matter. There was, therefore, a marked difference between these and the soils of other sectors where their consistency was due to the excellent quality snail, added to the high-quality sand that only required a good foundation.

The solution to this inconvenience had deep roots since ancient times, since the Romans applied effective methods, especially when building their bridges over rivers. It involved building a mangrove sheet piling taking care to drive the piles very close to each other, or failing that, a planking with some piles and reinforcing stirrups. This is how a first stage was developed, in order to avoid collapses in the ground, as the excavation progressed, as a protection measure for the workers. Therefore, piles were driven very close to each other, joining their centers to produce a grid.

This part of the work was done with manual machines on a rail on which a small mass slid and hit the head of the pile until it sank to the desired depth. Generally, the bearing substrate was sought with the tips of the piles. Same as the system implemented today, after driving the piles, the foundation was built, a strong grid was built in thick wood of good quality and carefully assembled. Then the interstices of the grid were filled with a high resistance rockfill and mortar with hydraulic characteristics. Successively, the semi-cut stones were chosen and locked one by one, glued with lime mortar, installing layer by layer until the foundation was obtained, (Lucuze 1772).

This deep foundation system transmitted the loads not to the surface soil, but to the soil at a greater depth, which in general terms has a greater capacity to support the weight, (Ramos 1985). The walled cordon and the fortifications of Cartagena de Indias are founded on piles, as shown in the old plans drawn up by the military engineers who participated in its erection, (Ramos 1985), (Fig. 13a). When it came to foundations under water, to solve the two major difficulties, inaccuracy in driving and the impossibility of driving inclined piles, it was necessary to resort to more complex systems. In these cases, the hammer that hit the head of the pile no longer fell

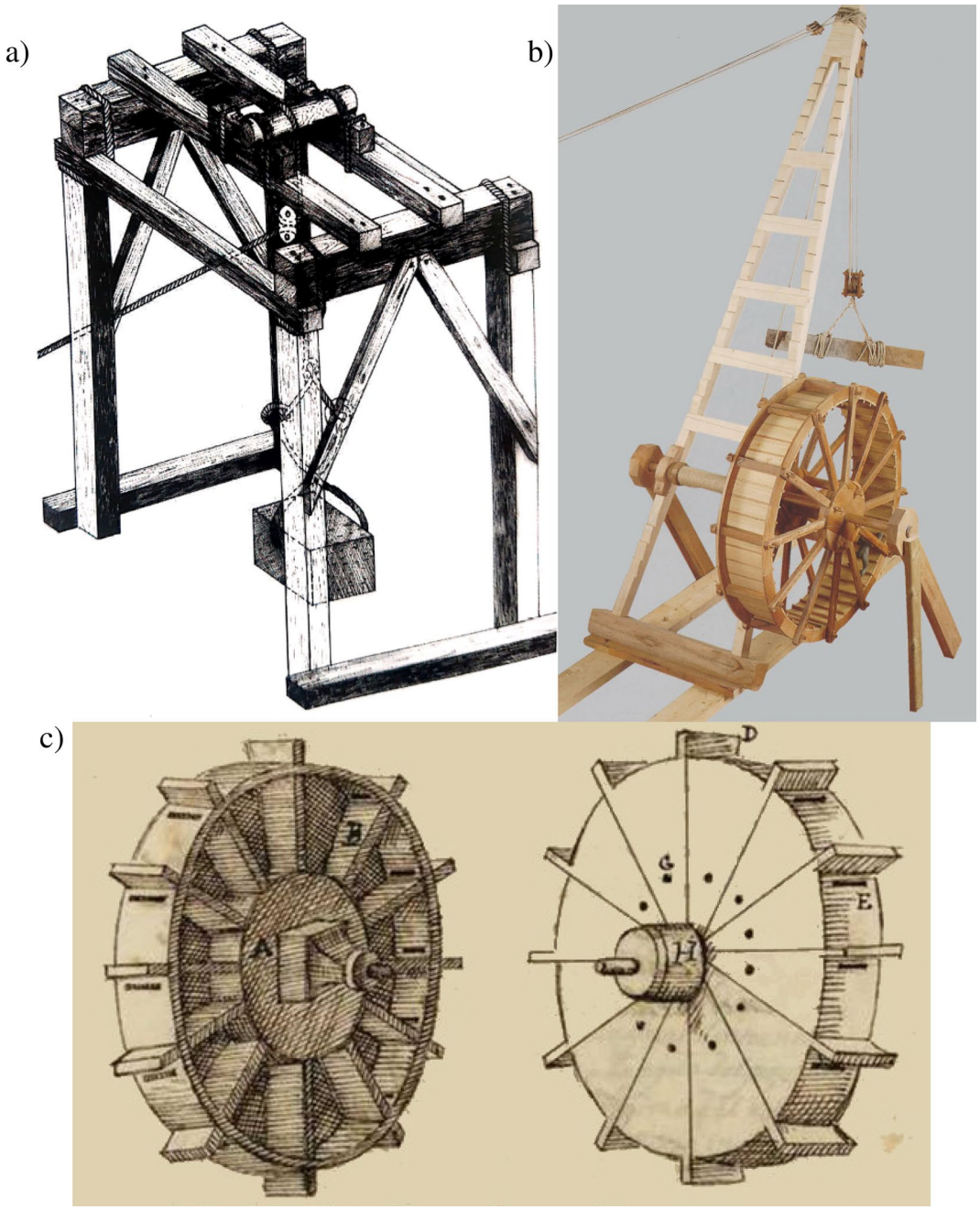

Fig. 15 **a** Hoists, taken from (Cabrera Cruz et al. 2019), **b**Treadmill-driven crane used in Spain, (Turriano 1996), model taken from (Multimedia Laboratory of the Istituto e Museo di Storia della Scienza in Florence 1999). **c** Wheel to raise water Tongs for crane (Ramos 1985; Turriano 1996)

freely, but rather was guided, so as to achieve great precision in the impact, and allow the guides to be tilted and the piles to be driven into the desired position (Turriano 1996).

Another underwater pilotage system is the one shown by the Fig. 13b, where a hydraulic wheel-driven piling machine with a skewer clutch is observed, (Turriano 1996; Vitruvio Polión 1582).

In both cases, the way of proceeding is analogous, being necessary to build either with piles or with sheet piles a double palisade, driving the piles to the butt and the sheet piles at a certain distance, but always at the

same separation. The gap between the two palisades is filled with compacted clay to obtain a sufficiently impermeable enclosure, (Fig. 14).

On the other hand, cranes in the ancient world formed a whole set of devices, which have historically been used to lift and move loads. Figure 15 shows different types of cranes used in the construction processes of the walled cordon of Cartagena de Indias, (Ramos 1985). Few differences can be found with the Renaissance construction tools. Thus, for example, the crane designed by Juan de Herrera to be used in the works of the Monastery of El Escorial, Spain. It is an ingenuity that multiplies force by means of tread wheels, the same as most of the Renaissance construction wheels, commonly used in the construction of the fortification of Cartagena de Indias (Fig. 15), (Turriano 1996).

Conclusions

This research focused on the characterization, diagnosis, assessment and enhancement of the heritage and cultural landscape of the fortification system of Cartagena de Indias through a historical documentary review. It is a work of extreme importance, partly unpublished and interdisciplinary. The purpose of this research is to contribute to the knowledge of these fortifications from a historical and technical point of view to provide a better understanding of how they were conceived and erected, in order to provide tools to guarantee their conservation in the future. One of the most important conclusions of this work is that we can collect, order and explain a large series of historical, military and technical events about the city of Cartagena de Indias.

This excursion made it possible to identify all the fortifications built in the city during the presence of Spain in New Granada. The constructive panorama of the citadel of Cartagena de Indias is shown, which was undoubtedly extensive and very convulsive. These fortifications and the city, in their long history, were exposed to about eleven shots that left a sad legacy of destruction on the fortresses and civil, religious, and institutional buildings.

The authors consider this inventory a fundamental step forward in the knowledge of the Cartagena's historical heritage. Government and local authorities have now valid basis to design and realize proper conservation plans. They should ponder the teachings of past infrastructure weaknesses, comprehending the vision to overcome the challenges of the future, such as rising sea levels and extreme weather events that are ever more powerful and frequent.

According to this study and the experience of the authors, it is observed that water bodies are still considered as a geographical "accidents" by the authorities, as it was in the past. However, channels and swamps of the city should be included as part of the fortified citadel and recognized within the monumental complex. They should be a key for an inclusive protection plan to avoid the loss of heritage and incalculable economic damage to the local and national economy.

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Author contributions

MS was a major contributor in writing the manuscript. JLAC and ARCC analyzed and interpreted data found in the literature. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests

The authors declare that they have no competing interests.

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