A Chapter on Maritime History: Shipping and Nautical Technology of Trade and Warfare in the Medieval Mediterranean, 11th–16th Century*

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I. Methodological introduction

This paper discusses the Mediterranean, ships, ships' design[1] as well as shipping between the eleventh to the sixteenth century AD, while addressing the following questions: was ship design the product of mere technological invention or the result of economic or political environments that induced technological solutions? How did nautical technology contribute to seafaring capabilities and to spatial and horizon shrinkage in the Mediterranean and beyond? Did nautical technology affect strategy and tactics of control of marine space? In what way did evolvement in nautical technology impact the status of various professionals involved in the industry, if at all?

At face value, the title sounds somewhat technical, especially to historians that all too frequently believe the entire field of maritime history to be a highly specialized discipline focused only on underwater archaeology and the technical aspects of seafaring and ships. Such an attitude, however, is misguided and born from the generally denied but all too prevalent tendency to compartmentalize fields of study and periods of history. Dealing with the maritime aspects of history does indeed require specific skills, such as knowledge of oceanography (in order to study currents, land-sea relationships etc.), naval architecture and the marine engineering of ports. These, however, are merely tools to enable

*) I would like to thank the Konstanzer Arbeitskreis für Mittelalterliche Geschichte for the invitation to the Reichenau and for the generous hospitality – The idea to the methodological introduction was born out of the discussions made during the conference.

1) For definition of designing methods, see: Seán McGrail, How were Vessels designed before the Late-Medieval Period?, in: Boats, Ships and Shipyards. Proceedings of the Ninth International Symposium on Boat and Ship Archaeology, ed. by Carlo Beltrame, Oxford 2003, pp. 124–131, here p. 125; Eric Rieth, Mediterranean Ship Design in the Middle Ages, in: The Oxford Handbook of Maritime Archaeology, ed. by Alexis Catsambis/Ben Ford/Donny L. Hamilton, Oxford 2011, pp. 406–425, here p. 406 f.; David McGee, The Shipbuilding Text of Michael of Rhodes, in: The Book of Michael of Rhodes. A Fifteenth-Century Maritime Manuscript, ed. by Pamela O. Long/David McGee/Alan M. Stahl, 3 Vols., Cambridge, Mass.-London 2009, here vol. III, pp. 211–241.

the scholar to understand and interpret the artefacts and historical documents that reveal the vast and varying roles of the sea in daily life, for the sea affected politics, economics and trade, warfare and logistics, the marine and coastal environment, cultural interactions, and so forth[2]. Of course every field of study requires particular skills; what is essential, then, is the scholar's ability to and extend these skills from the narrow limits of a single specialised discipline to other areas of research and to use them not only in a multidisciplinary but also in a interdisciplinary way – a distinction not recognized by all scholars – in order to display a comprehensive picture of a specific period. With respect to the Mediterranean, there are two instructive monographs to make the point clear: John Pryor's groundbreaking study from 1988 on maritime history in the Mediterranean and a recent book on the Byzantine Navy in the early and high Middle Ages[3]. Pryor is indeed unique in his approach – among other things he builds models and uses them experimentally, in order to fully understand the written documents on ships' performances maritime logistics, warfare etc[4]. Only few medieval maritime historians, the present writer included, display a similar approach combining archival documents and traditional text based studies with field work, in this case underwater and coastal archaeology, oceanography, sailing etc.

That being said, one should note the difference between the methodology of scholars dealing with the economy of the ancient and early medieval period on the one hand, who are generally more prone to interdisciplinary work, and medievalists and early modernists on the other[5]. As much as scholars claim to employ multidisciplinary approach, one cannot ignore the gaps in communication between the various fields of studies. To some degree, archaeologists justly blame historians that they use archaeology just as an auxil-

2) See the detailed methodological introduction in Ruthy Gertwagen, The Concept of Medieval Ports in the Medieval Eastern Mediterranean: Construction and Maintenance. The Case on Crete to the End of the 15th Century, in: International Journal of Maritime History 12/1 (2000), pp. 63–133, here pp. 63–66.

3) John J. Pryor, Geography, Technology and War. Studies in the Maritime History of the Mediterranean, Cambridge 1988; Id./Elizabeth M. Jeffreys, The Age of the ΔΡΟΜΩΝ. The Byzantine Navy ca. 500–1204 (The Medieval Mediterranean 62), Leiden-Boston 2006.

4) Ruthy Gertwagen/Elizabeth Jeffreys, John Pryor: A Tribute, in: Shipping, Trade and Crusade in the Medieval Mediterranean, ed. by Ead., Ashgate 2011, pp. XV–XIX.

5) Whereas in many respects the monograph of Richard W. Unger, The Ship in the Medieval Economy 600–1600, London 1980 still needs follow-ups as well as corrections and reviews based on more recent archaeological discoveries, historians of Mediterranean economy dealing with the ancient period show a more promising approach. Michael McCormick's magnum opus (Michael McCormick, Origins of the European Economy, Communications and Commerce, A. D. 300–900, Cambridge 2011) is instructive in many ways. Two impressive volumes: Maritime Archaeology and Ancient Trade, ed. by Damian Robinson/Andrew Wilson, Oxford 2011, and Maritime Technology in the Ancient Economy: Ship Design and Navigation, ed. by William V. Harris/Kristine Iara (Journal of Roman Archaeology. Supplementary series 84), Portsmouth 2011 are stimulating examples. The fact that the archaeologists' contributions still outnumber the historians' emphasizes the above-mentioned reservations of historians to maritime history.

iary discipline, while ignoring the importance of technical evidence and its impact on trade and economy[6]. With regard to the study of the medieval Mediterranean, the general spirit of this criticism may be accepted. However, when archaeologists make use of written evidence, they often take them at face value, without a proper criticism of textual sources and when there is some discrepancy between material and written evidence, archaeologists tend to ignore it. For example, archaeologists seem to ignore which impact technical processes had upon economy and trade and alternatively, which impact economy, trade, politics etc. had on technical processes. Historians then reproach archaeologists for their antiquarian as well as technical use of archaeological finds, failing to make a serious attempt to make historical sense out of scientific data.

Having said that, it should be noted that not every historian writing on themes relating to the sea can be called a maritime historian, even if he or she discusses patterns of marine economy and trade, maritime warfare, cartography etc. Most studies are only descriptive, but if accompanied by relevant documents, they are a gold mine of information. Armchair historians, as much as they »dive deep into the archives«, only study documents without involving other disciplines or acquiring intimate knowledge of marine environment, and quite often misinterpret the information yielded by the documents or develop wrong ideas about controlling marine space.

Alternatively, ignoring these maritime factors leads to misinterpretation of major events that shaped the political, economic and military life of the medieval Mediterranean. The following case study that concerns the conflicts between two prominent maritime powers Venice and Genoa clearly illustrates and highlights my argument. Both Genoa and Venice thrived to be an emporium for long distance international trade between Europe and the Far East, on the one hand, and between southern Europe, the Eastern Mediterranean and the Atlantic Ocean, on the other. Scholars have indeed generally dealt with Genoa's and Venice's military and commercial fleets, including various types of vessels, but only in a descriptive manner: they have not asked how nautical qualities of various types of vessels, vis-à-vis maritime factors, shaped these maritime powers' mercantile policy and tactics to achieve superiority, with ramifications that eventually radically changed the balance of powers not only between the Italian sea powers but between the Christian and Muslim (mainly Ottoman) worlds in general, especially from the late fourteenth century onwards, and, finally, after the Ottoman conquest of Constantinople in 1453. To illustrate my argument, I will begin with Venice:

In the partition agreement of the former Byzantine Empire between the Crusaders and Enrico Dandolo of 1204, the Venetian doge, who acted on that occasion as a private person and not on behalf of Venice, demanded the Ionian Islands from Corfu in the northeast to Zakynthos in the southeast; large parts of the Peloponnese with the coastal town

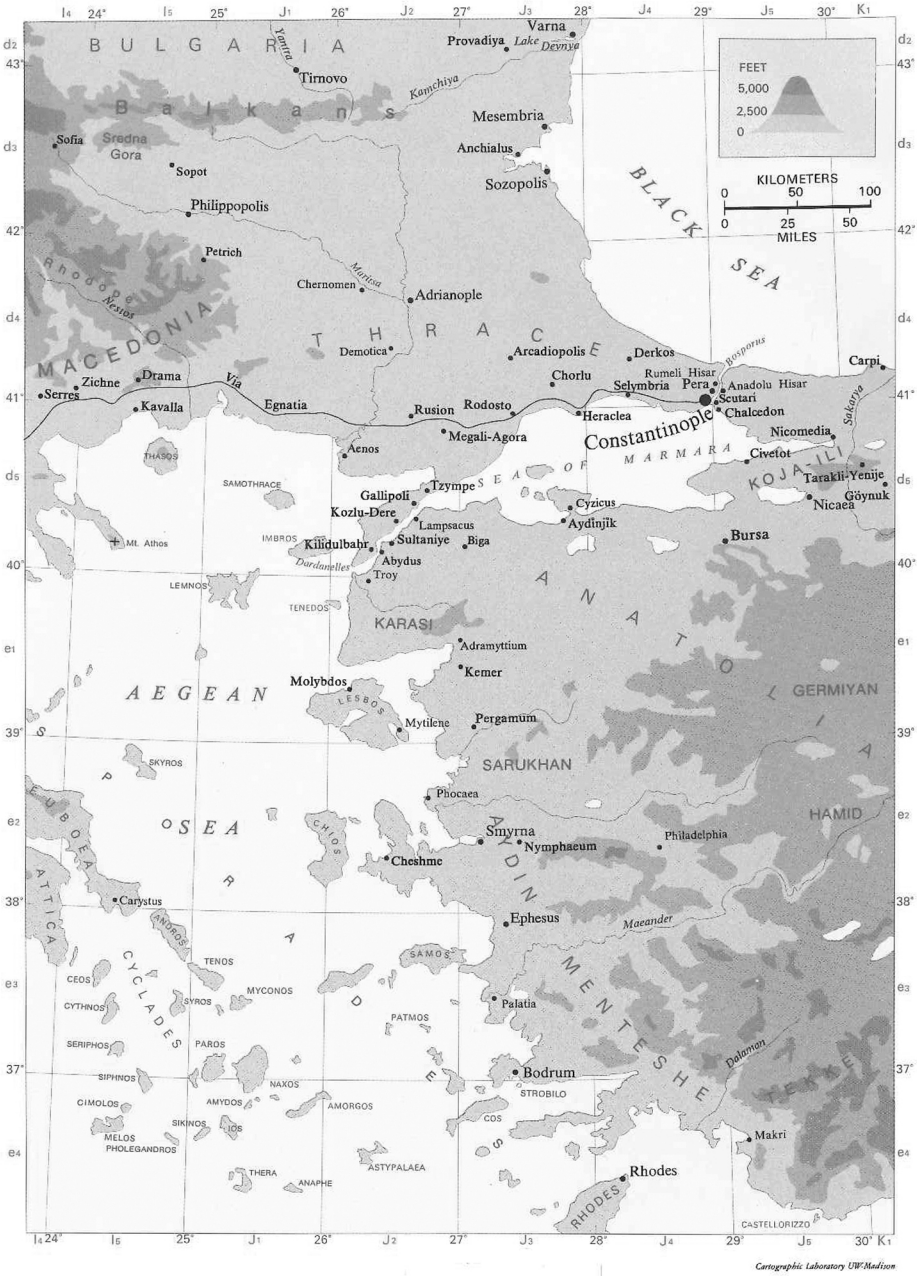
6) Patrice Pomey, Les conséquences de l'évolution des techniques de construction navale sur l'économie maritime antique: quelques exemples, in: Maritime Technology (as n. 5) 2011, pp. 39–56, here p. 39.

of Methoni; the islands of Aegina and Salamis in the Saronic Gulf; two points at both ends of the island of Evia/Eubea, medieval Negroponte, in the northern Aegean, Castro in the south, Volos in the north and the Island of Andros, at the south east of Evia (map 1). The traditional view, held by historians of economy for at least the last 60 years, emphasizes the economic and commercial aspects of Dandolo's claims, which laid the foundations for Venice's maritime empire[7]. Although all these places are islands, the maritime space was completely ignored. By chronologically unfolding the related events, from the morrow of the conquest of Constantinople in 1204, and by inspecting separately each location, one can understand that the motive behind these choices, including also the purchase of the Island of Crete, was not economic. Except for the islands of Levkas, Kefalonia and Zakynthos in the Ionian, none of these territories was agriculturally fertile in the earlier Byzantine period, prior to 1204. It was the Venetians who urged the exploiting of the agricultural and economic potential of Crete and Evia, whereas Corfu and Methoni lacked agricultural potential to start with. Rather, strategic motives lay behind Dandolo's choice of territories. Due to meteorological and sea conditions on the one hand, and shortcomings in nautical technology related to both military and commercial ships on the other, these sites were obligatory ports of call and as such aims for piracy or any other form of organized violence against the Venetians. Dandolo claimed them to root out those inimical factors and to protect Venetian, his and other merchants who may have consulted him, shipping and trade routes to and from Constantinople (not to the Crusader Levant), where he personally intended to settle after resigning from his position in Venice[8].

In the following, I am going to focus on two complexes of sites: Castro in the southwest of the Isle of Negroponte together with the Island of Andros almost opposite it to the south, as one complex, and the Island of Tenedos and the Straits of the Dardanelles in the north-east Aegean Sea as the other (maps 1, 2). Due to the limited manoeuvring abilities of both naval and commercial vessels, discussed below, and due to the difficult navigation conditions along the channel of Evia (medieval Negroponte), Karistos at the south

7) For instance: Freddy Thiriet, La Romanie vénitienne au moyen âge, le développement et l'exploitation du domaine colonial vénitien (XII^{e}–XV^{e} siècles), Paris 1975, pp. 105–108; David Jacoby, La Venezia d'oultre mare nel secondo Duecento, in: Storia di Venezia. II: L'età del comune, ed. by Giorgio Cracco/Gherardo Ortalli, Rome 1995, pp. 263–299.

8) Ruthy Gertwagen, Venice's Policy towards the Ionian and Aegean Islands in the Thirteenth to the Fifteenth Centuries, in: International Journal of Maritime History, forthcoming. The paper also refutes the traditional view that the establishment of Venice's Maritime Empire, known as Stato Da Mar, belonged to the outcomes of the Fourth Crusade (1202–1204) and to the aforementioned partition agreement of the former Byzantine empire between Enrico Dandolo and the Crusaders. Only from the late fourteenth centuries did the Venetians start to create such an empire, but due to strategic, not economic, calculations. On this subject see also: Ead., The Contribution of Venice's Colonies to its Naval Warfare in the Eastern Mediterranean in the Fifteenth Century, in: Mediterraneo in Armi (secc. XV–XVIII), ed. by Rossella Cancilla (Quaderni di Mediterranea 4), Palermo 2007, vol. I, pp. 113–173.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Petrich
Rhodope Mts.
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Adrianople
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THRACE
Demotica
Arcadiopolis
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SAMOTHRACE
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Cyzicus
Aydinjik
Kozlu-Dere
Lampsacus
Mt. Athos
IMBROS
Kilidulbahr
Sultaniye
Biga
Bursa
Dardanelles
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Troy
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Argyrokastron
Janina
Arta
Vonitsa
Ravennika
Salona
Lepanto
Patras
Vostitsa
Gulf of Corinth
Peritheorium
Corinth
Glarentsa
Pyrgos
Alpheus
Argos
Tegea
Nauplia
Megara
Athens
Thebes
Livadia
Negroponte
Oreus
Zeitounion
Halmyros
Demetrias
Verrai
Citrum
Thessalonica
Via Egnatia
Vardar
Strymon
Serres
Zichne
Drama
Kavalla
Chalcidice
Mt. Athos
Mistrà
Sparta
Navarino
Modon
Coron
Cape Matapan
Monemvasia
Cape Malea
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THASOS
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ITHACA
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east of the island enjoyed strategic importance as a port of call. Sailing up to the city of Negroponte, the vessels had to confront the prevailing northern winds, the meltemi, that reach the force of 6–7 knots, as well as northern currents that – with strong meltemi – reach force of 8.5 knots. The manoeuvring abilities of a sailing ship in such conditions were limited, to say the least. The various types of galleys could make their way by rowing, to be sure, but then they were in danger of being swamped by waves and sinking. This danger was due to their low freeboard, which prevented them from heeling too far. The galleys would have found the waves of 0.5–1 meters challenging and waves of 1.2 beyond their capabilities. Several documents show that, in spite of the increase of the dimensions of both naval and commercial ships in the late thirteenth and certainly the fourteenth centuries, both Venetian and non-Venetian ships never crossed the bridges in Negroponte to the north-east Aegean Sea towards the Dardanelles. Instead, they always returned to the southeast to Karystos (map 1). From there they proceeded to the northeast via the Doro Straits between Negroponte and the Island of Andros to the Dardanelles and thence to Constantinople and the Black Sea (maps 1,2). The difficult navigation conditions in the Doro Straits, due to strong prevailing northern winds and currents, accentuated the importance of Karystos bay and the Island of Andros as ports of call before crossing northwards and vice versa. Descriptions of various voyages in the late fourteenth and fifteenth centuries of both commercial (»naves« and big »merchant galleys«) and military (*galeae*) ships, including horse carriers, show that with the blow of moderate winds in the north east Mediterranean, it took the various vessels around six days and nights to reach the Dardanelles from south east Petalioi Channel at Negroponte. That was the reason why Dandolo required Caristos and Andros but no territory inside the city of Negroponte itself, a tactic that was changed from 1211 onwards, long after his death (1205), by the Commune of Venice that focused on the city[9].

Let us now turn to the second complex: Evia, the Island of Tenedos and the Dardanelles. By the late 1370s Venice had established a firm hold in the City of Negroponte that was the last »Venetian« port of call for Venice's commercial convoys and military fleet in the Northern Aegean. From there the Venetians sailed towards the Dardanelles, thence to Constantinople and the Black Sea, the hub for international trade between the Southern Ukraine on the one hand, the Far East and Europe on the other. Controlling the sea lanes in the north-eastern Eastern Mediterranean meant controlling this trade. This issue was at the core of violent conflicts between the Genoese and the Venetians. Between 1377 and 1379 it was the fight over the Island of Tenedos in the north east Aegean Sea (map 2) that due to navigation conditions in the area, that is meteorology and currents, was an obligatory port of call before continuing to the barren island of Imbros, thence entering the Straits. Due to the difficult navigation conditions in the Straits it was the Byzantine Emperor, Justinian I, who already in the sixth century AD ordered the build-

9) Gertwagen, Venice's Policy (as n. 8).

ing of granaries on the island for the wheat imported from Egypt, so as to shorten the stay of the *annona* ships until navigation conditions permitted them to enter and sail up the Straits. As a consequence the *annona* ships, after unloading their wheat in Tenedos, continued successively with their missions, while local vessels from Constantinople brought from Tenedos to the capital the wheat from the granaries on the island. In the late fourteenth century the island was an obligatory port of call for Venice, due to its above-mentioned geopolitical situation in the north east Aegean.

Another crucial point should be made. Provisioning with food and mainly drinking water was indispensable. During the Mediterranean summer months, the water supply dwindled away very quickly. Summer was the period of the Venetian *muda* to Romania and Constantinople. The big merchant galleys of the fourteenth and fifteenth centuries could only carry fresh water for one week and the war galleys only for between four to seven days. While one can only assume that big merchant galleys would have sacrificed the water in favour of merchandize, it is highly likely that during wartime the war galleys carried less water, since in these moments manoeuvrability was more important. Furthermore, since the rowers and mariners physical strain at least doubled during war time in peace time it was crucial for the various types of galleys of the fourteenth and fifteenth centuries to make a port of call at Tenedos before arriving, and certainly before entering the Dardanelles to re-provision with fresh drinking water.

On the other hand, for the Genoese, who held the islands of Chios, Lesvos and Imbros (map 2) since the mid-fourteenth century, although independently from the Metropolis, the Island of Tenedos was not imperative. Their islands provided them with safe anchorages prior to crossing the Dardanelles and after leaving the Straits southwards. However, by holding the island of Tenedos Genoa would have denied the Venetians strategically important anchorage, thereby achieving with »nature's help« similar results as a military block ad of the Straits. The above-mentioned nautical limitations of the various types of galleys, waves of 0.5–1 meters challenging and waves of 1.2 beyond their capabilities – prevented them from staying on sea for a long time and certainly from physically blockading straits or maritime passages. Blockading the straits therefore was brought about by holding strategic sites and anchorages around them. The failure of Genoa to achieve its goal lead the Ligurian city in 1379 to shift the war against Venice to Chioggia, Venice's front port town in the Adriatic, forming a coalition with Venice's enemies both in the Adriatic and in Venice's continental hinterland. Therefore the war was known as the War of Tenedos/Chioggia. Unfamiliar with ebb and tide in the Venetian Lagoon, the Genoese vessels were »stuck« in Chioggia's channels and eventually defeated by the Venetians. Despite Venice's victory in all battles the peace treaty signed between Venice and Genoa at Torino in 1381 obliged the Serenissima to deliver the island to a third side. The archival documents clearly expose Venice's cunning diplomatic manipulations to keep hold of the island, even on account of risking both Genoa's retaliation and sympathy for Genoa from other European Powers involved in the formulation of the peace treaty. That being said,

Venice never intended to hold the island in order to interrupt Genoese shipping, but rather to prevent the Genoese from impeding Venetian shipping. The nautical and navigation constraints show that for Venice losing the island would have meant losing the trade route to Constantinople and the Black Sea. Alternatively, to always reach those markets much later than Genoa meant to lose the European clients. In other words, Venice would have lost its status as an international emporium which would eventually have caused serious harm to the town. Venice managed to hold the island until its conquest by the Ottomans in 1453[10], who changed its name to Bozcaada and built a castle there in 1480[11]. Due to its location, the Island of Tenedos/Bozcaada continues to retain its strategic importance in the modern period. After having lost the islands to the Greeks (1912–1925) in the Balkan Wars, the Turks insisted on holding it, whereas the rest of the Dodecanese Islands along the Aegean coast of Minor Asia were delivered in 1947 by Britain to Greece, thus ending 740 years of foreign rule, despite the Turks' protests. Looking into any Atlas and modern marine chart one can see the bordered line between Greek territories – the Dodecanese Islands – and the Island of Bozcaada, that is now used as a military base to control the entrance into the Dardanelles.

It is noteworthy that even today, a modern navigation instructions book for yachts recommends to such vessels, especially to low powered ones of seven tons powered by 17 H.P diesel, but also to those with more powerful engines to carefully plan the entrance into the Dardanelles via the south east of the Straits and then to proceed northwards following the Asiatic coast in order to avoid the strong northern current in the mid-straits channel and along the European side. Meltemi or Etesian winds reach the force of 5–6 knots between November and early March and at noon times of autumn and spring. Due to the narrow width of the Straits the power of the currents is very strong. With a Meltemi of moderate force of 2–4 knots the currents in the Dardanelles reach the force of 1.5–3 knots and with a strong Meltemi of 5–6 knots, the currents reach the force of five knots. Only on the return journey a yacht can follow the European coast to take a full advantage of the northern current[12]. Not surprisingly, the Byzantines stationed a customhouse at Abydos along the Asiatic coast of the Dardanelles, right after the entrance into the Straits (map 2). With the increased maritime threats of the Arabs, the Byzantines stationed in the eleventh century a small squadron at Abydos[13]. Much later the Ottomans built there the fortress of Çimenlik (modern Çanakkale) and on the opposite European

10) Ead., The Contribution of Venice's Colonies (as n. 8); Ead., Venice, Genoa and the Fights over the Island of Tenedos (Late Fourteenth and Early Fifteenth Century) in: Venice and the Mediterranean, ed. by Ead./Jean-Claude Hocquet (Studi Veneziani 67), 2013, pp. 329–381.

11) Kâtib Çelebi, The Gift to the Great Ones on Naval Campaigns, ed. by İdris Bostan, Ankara 2008, p. 66.

12) Rod Heikell, Turkish Waters Pilot. A Yachtsman's Guide to the Aegean and Mediterranean Coasts of Turkey with the Island of Cyprus, St. Ives ^{3}1989, p. 30.

13) Pryor/Jeffreys, The Age of the ΔΡΟΜΩΝ (as n. 3), p. 88.

coast of the Dardannelles the fortress of Kilitbahi, both in the late fifteenth century. This triple fortification points to the Ottomans' marine inferiority as compared to the Christian west, which is, however, beyond the scope of this paper. Nevertheless, at the age of cannons' and firearms' predominance, a fortified Tenedos ensured a better control of the sea route from the north east Aegean and protection of the entrance into the Straits against a new combined Crusader fleet that might have returned to free Constantinople. Furthermore, sailing up the straits during prevailing northerly winds, both Gallipoli and Lapseki (map 2) provided shelter; although during strong northerlies the modern navigation guide for yachts recommends to go from Lapseki to Gallipoli, since only in that part of the Straits the force of the winds is weaker than on the Asiatic side. At Gallipoli the rate of the current is only between 1–1.5 knots[14]. In other words, entering the Dardanelles the vessels followed the Asiatic coast until Lapseki, then via Gallipoli they sailed along the Marmara Islands and along the Marmara Asiatic coast versus Constantinople. These navigation conditions explain the strategic reasons that led Enrico Dandolo to demand Lapseki and Gallipoli in the partition agreement of 1204. By holding Gallipoli from the late fourteenth century onwards the Ottomans controlled the Straits without even having a fleet of their own[15]. This long durée survey undoubtedly emphases the relationship between navigation conditions, nautical qualities of ships and policy and tactics of war and trade.

In order however, to understand the nautical capabilities of ships one has to understand their hull design, steering and propulsion systems (oarage and sails). The period covered by this paper is not accidental. From the eleventh century onwards a new hull design, discussed below, prevailed in the Mediterranean. Historically, the Mediterranean witnessed, from the 11th century onwards, evolvement of intense shipping which related to the gradual political, social, economic and urban revival of Europe, after hundreds of years of stagnation that followed the collapse of the Roman Empire. It was assumed that this led to the return of long distance maritime trade in the Mediterranean, besides the regional trafficking that prevailed throughout the Middle Ages. One however has to emphasize that enough evidence for long distance shipping already in the ninth century exists. For instance: there is the story of the smuggling of the bones of San Marco to Venice from Egypt by two Venetian merchants in 829[16], or evidence for Amalfitan merchants in Cairo later that century[17]. And, last but not least, the Geniza letters point to shipping

14) Rod Heikell, Turkish Waters Pilot, London ²1992, p. 36; The Black Sea Pilot. Hydrographic Department under the Authority of the Lords Commissioners of the Admiralty, London 1969, pp. 43, 96 f.
15) Gertwagen, Venice, Genoa (as n. 10), pp. 347 f.
16) Nelson McCleary, Note storiche ed archeologiche sul testo di Translatio Sancti Marci, in: Memorie storiche forgiuliesi 27–29 (1931–3), pp. 223–264; regarding the authenticity of its economic meanings by: McCormick, Origins of the European Economy (as n. 5), pp. 238–240.
17) Claude Cahen, Un text peu connu relative au commerce oriental d'Amalfi au Xe siècle, in: Archivio Storico per le Province Napoletane, n.s. 34 (1953–1954), pp. 3–8.

from Egypt to Southern Europe[18]. However, the commodities purchased in the East were only for those who could afford them, mainly high dignitaries in both church institutions and secular life: kings and popes, bishops and noblemen. From the eleventh century onwards, these commodities reached public markets and were purchased by whoever could afford them. In that period, Europeans could and would buy Eastern Mediterranean and Black Sea agricultural products and raw materials for their developing industries, but mainly luxurious commodities of the Far East (*havere subtile*), generally known as spices, because in the meantime they were producing more wares in demand in the East. The main arteries from the Far East to the Mediterranean were Egypt and Constantinople and for the twelfth and thirteenth centuries also the Crusader states and lesser Armenia. With improvements in navigation and commercial techniques followed by growth in shipbuilding, shipping all over the Mediterranean reached its climax in the fourteenth century, while the Black Death was only a short setback. Furthermore, from the late thirteenth century onwards, Genoese ships, followed by the Venetians in the fourteenth, sailed into the Atlantic, to England and Northern Europe[19].

Commercial and military shipping evolved simultaneously. Intense international maritime trade stirred violent competition between its European agents, the most conspicuous of which were the southern European commercial city states: Pisa, but mainly Venice and Genoa, joined later by Marseille as well as the Crown of Aragon. In addition, there were violent confrontations related to Holy Wars between the Christian and Muslim worlds as well as piracy. The major role of fleets was auxiliary – protection of commercial convoys, scouting, patrolling and pursuing enemies, transport of troops and horses as well as the siege of coastal and port towns from the sea side.

Mediterranean ships traditionally fell into two large groups. One type was long, with higher length to breadth ratio, with a low freeboard and shallow draught, fast, oared ships with auxiliary sails, mainly used for war. Another was made up of ships with high ratios of length to beam that relied on their sails whereas the oars were auxiliary, to get in and out of harbours or through difficult passages even in the face of contrary winds, used for commerce and transport. There was also a hybrid type, transport or merchant galleys that combined features of both oared and sailing ships. Despite local and regional peculiarities

18) Shlomo Dov Goitein, A Mediterranean Society. The Jewish Communities of the Arab World as portrayed in the Documents of the Cairo Geniza, vol. 1: Economic Foundations, Berkeley-Los Angeles-London 1967; Ruthy Gertwagen, Geniza Letters: Maritime Difficulties along the Alexandria-Palermo Route, in: Communication in the Jewish Diaspora. The Pre-Modern World, ed. by Sophia Menache, Leiden-New York 1996, pp. 73–90.

19) Frederic C. Lane, Venice a Maritime Republic, Baltimore 1973, pp. 137–143; Id., The Economic Meaning of the Invention of the Compass, in: Id., Venice and History: the collected Papers of Frederic C. Lane, Baltimore 1966, pp. 331–344; Eliahu Ashtor, Levant Trade in the Later Middles Ages, Princeton 1983, pp. 3–6, 16 f., 43, 56–68; Wilhelm van Heyd, Histoire du commerce du Levant au Moyen âge, Amsterdam 1959, I, p. 178; II, pp.79 f., 563–571.

and changes of some features with time, basic designs remained relatively constant and similar in the Byzantine, Muslim and Latin worlds[20].

During the four hundred years that elapsed between the eleventh and late fifteenth century, significant developments in shipbuilding and in technologies of trade and warfare took place. Until the end of the first millennium changes occurred mainly in shipbuilding design, rigging, performance and warfare technologies. From the eleventh to the late thirteenth century ships grew in size, warships evolved with a new ovarage system and the sailing ships reached their ultimate evolution prior to the appearance and influence of northern European vessels in the Mediterranean. There were also improvements in traditional warfare technologies from the Byzantine period that made the warships carriers of the precious commodities, generally known by the term »spices«. Due to the increase from the fourteenth century in size of the hybrid types of merchant galleys, they became great galleys and they took the place of the warships as carriers of the »spices«. Around the beginning of the fourteenth century, but possibly much earlier, northern European techniques were introduced and adopted in the Mediterranean, and ships once again experienced an essential evolution that ultimately launched the Age of Exploration.

II. Sources of information

Sources for ship-design vary in type and amount and include: wrecks, literary evidence and iconography. Each of these types of sources has its own limitations. The number of wreck sites discovered, excavated and analysed in scientific reports is very low. A rare thorough final report on an early eleventh century wreck found at Serçe Limanı, along the Aegean coast of Asia Minor, excavated in the 1970s, was only published in 2004[21]. Furthermore there is a discrepancy between the two basins of the Mediterranean with regard to the amount of investigated shipwrecks[22]. The tables introduced by Wilson are instructive and show the decrease in number of shipwrecks from the second century AD and, for our interest, the massive fall-off from the eleventh century onwards, with a small, very marginal, rise in 1500. The interdisciplinary analysis of the fluctuations in the numbers of shipwrecks until 1000 is indispensable, but beyond of the scope of the present

20) See the synthesis regarding all these ships types by Ruthy Gertwagen, Characteristics of Mediterranean Ships in the Late Medieval Period (13th–15th Centuries CE), in: Splendour of the Medieval Mediterranean: Art, Culture, Politics, Navigation and Commerce in the Mediterranean Maritime Cities (13th–15th Centuries), ed. by Xavier Barral i Altet/Joan Alemany, Barcelona 2004, pp. 543–561.

21) Serçe Limanı: An Eleventh Century Shipwreck, vol. 1: The Ship and its Anchorage, Crew and Passengers, ed. by George F. Bass/James W. Allan (Nautical Archaeology Series), College Station 2004.

22) For a general discussion on some of the limitations see: Rieth, Mediterranean Ship Design (as n. 1), pp. 407–409.

paper[23]. For the time span covered by the current paper, the following is important: the wrecks found mainly belong to three groups. One, that were reused, long after having been out of use, for constructing foundations. Such is the case of three wrecks found at Olbia, Sardinia, where the wrecks were reused in the thirteenth to fourteenth century as foundations for peers; although radiocarbonate dating is not exact, shipwreck 8 dates from 895–995 and wreck 9 from 985–1030[24]. The other example is two fourteenth century wrecks at San Marco de Bocclama in the Venetian Lagoon, reused for building foundations in the sixteenth century, whose origin is unknown and which still awaits a thorough investigation (fig. 1)[25]. Reusing old and out of use ships for foundations was very common in Venice and its Stato da Mar from the fourteenth century onwards, and, as it turns out, also in the Western Mediterranean[26]. Another group is of wrecks found inland such as the 34 ships excavated in the former Theodosian harbour at Yanikapi on the Marmara coast which are in process of investigation and dated to a wide range of time, the youngest to the end of the tenth or very early eleventh century. They shipwrecked during mooring, due to geological calamity, maybe an earthquake that caused a tsunami (fig. 2)[27]. The other group of shipwrecks consists of coasters/riverine also used for fishing which will be discussed in the current paper.

No wrecks of commercial vessels for long distance trade nor galleys of the line were found under water. Compared to the vast information provided by the documents, the near absence of such wrecks is conspicuous. In case of commercial vessels this dearth is however not indicative for low volumes of trade, which would contrast with the documentary evidence. How can one explain this decrease in the number of Byzantine and Medieval wrecks of commercial ships used for long distance trade? Usually wrecks are spotted underwater by unusual compounds of certain types of artefacts, such as ceramic containers for liquids, various types of fish products, various types of grains et cetera, commonly known by the name amphorae, or various types of stone objects, such as pillars, architectural components of a building/church, millstones etc. From the second century AD barrels began to replace amphorae in the western basin of the Mediterranean and in the eastern basin from the twelfth. The latest evidence so far for amphorae, not for the everyday needs of the teams on board, but for trade, were found on the above-mentioned eleventh century Serçe Limanı wreck. Wood is perishable and therefore cannot be

23) Andrew Wilson, Developments in Mediterranean Shipping and Maritime Trade from the Hellenistic Period to AD 1000, in: Maritime Archaeology and Ancient Trade (as n. 5), pp. 33–39.

24) Edoardo Riccardi, Medieval Boats from the Port of Olbia, Sardinia, Italy, in: Connected by the Sea. Proceedings of the Tenth International Symposium on Boat and Ship Archaeology, Roskilde 2003, ed. by Lucy K. Blue/Frederick Hocker/Anton Englert, Oxford 2006, pp. 312–315.

25) John McManamon/Marco D'Agostino/Stefano Medas, Excavation and Recording of the Medieval Hulls at San Marco in Boccalama (Venice), in: The INA Quarterly 30/1 (2003), pp. 22–28.

26) Gertwagen, Concept of Medieval Ports (as n. 2).

27) The ›Old Ships‹ of the ›New Gate‹/Ynikapi'nin Eski Gemileri, ed. by Ufuk Kocabaş, Istanbul 2008.

spotted, neither by divers, nor by fishermen, who with their nets also »fish« amphorae and are thus responsible – in a positive manner – for finding wrecks. One could safely argue that the sharp drop-off in shipwrecks from the eleventh/twelfth century in comparison to ancient and early Byzantine periods indicates changes in containers carried on board of ships, from ceramic to perishable barrels and sacs, baskets or cloth for dry commodities.

From another angle, the substitution of amphorae by wooden casks that substantially lowered costs of transportation had important economic ramifications, for example concerning the calculation of ships' capacities. In fact, the modern term »ton« is derived from the English labelling of wine casks as »tun« or the French label as »tonneau«[28]. Could one infer from the substitution of types of containers to changes in types of cargoes? For instance, could lack of underwater stone cargoes point to an abandonment of such loads in long-distance shipping in the medieval period, in contrast to ancient and byzantine times? One should be wary of such conclusions, since there is contradictory written evidence, such as the twelfth century dispatch from Venice to Acre of architectural components of a church dedicated to San Marco to be assembled in the Venetian quarter in Acre, or the looted architectonic artefacts transferred from Constantinople to Venice in 1204, following the fourth Crusade and that are exhibited in Piazza San Marco such as the two erected at the end of the Piazza bordering the Bacino di San Marco, or the four bronze horses put at the balcony of the Church of San Marco. Also, one could try to explain the absence of war galleys' wrecks, except for those found through inland excavations .War galleys did not carry cargo. Thus, after having been shipwrecked or discarded, the wood was rapidly consumed. But although galleys carried cannons and swivel guns from the fourteenth century onwards, finds of these weapons with war vessels are almost nonexistent. The dating of those swivel guns found, for example in Venice Lagoon, and displayed in the Naval Museum at Venice, is only estimated and there is no thorough report regarding them.

Due to the decrease in number of shipwrecks, written texts and iconographic representations form the main source of information on ship technology. Iconography that depicts types of vessels never found underwater provides details missing in shipwrecks due to their deterioration, or provides valuable and genuine evidence for a wide scope of maritime activities[29]. Nevertheless, this evidence does not cover the whole Mediterranean

28) Frederic C. Lane, Tonnage, Medieval and Modern, in: Venice and History (as n. 19), pp. 355–370.
29) Marco Bonino, Lateen-rigged Medieval Ships. New Evidence from Wrecks in the Po Delta (Italy) and Notes on Pictorial and other Documents, in: International Journal of Nautical Archaeology 7/1 (1978), pp. 9–28, here pp. 23–27; Christiane Villain-Gandossi, Illustrations of Ships: Iconography and Interpretation, in: Cogs, Caravels and Galleons. The Sailing Ship 1000–1650, ed. by Robert Gardiner/Richard Unger (Conway's History of the Ship 3), London 1994, pp. 169–174; Lillian R. Martin, The Art and Archaeology of Venetian Ships and Boats (Studies in Nautical Archaeology 5), London 2001; Pryor/Jeffreys, The Age of the ΔΡΟΜΩΝ (as n. 3), p. 639; Joe C. Flatman, The Iconographic Evidence for Mari-

or all types of watercrafts. Only few iconographic representations of Muslim ships bear any semblance of reality before the thirteenth century and the earliest depictions of Western ships, which are more than stylistic »banana boats«, are miniatures of the later twelfth century. Furthermore, medieval artists cannot always be trusted to report accurately what ships were like or how they worked, since before the seventeenth century, they were generally not sailors and vice versa. Consequently, artists often did not have the technical knowledge to understand what they were seeing. Additionally, care must always be taken due to problems of stylization, copying and error[30]. This is also valid for graffiti that, more often than not, were unrealistic and very schematic[31]. On the other hand, as is detailed below, studies have shown the genuine importance of the various types of iconographic evidence, provided it is accurately dated, for trade and warfare technologies.

Historic records that contain detailed information on shipbuilding first appeared in the late tenth century but concerned only warships. From the thirteenth century onwards the number of written sources increased, even comprising detailed information on commercial vessels. Texts on shipbuilding first appeared in an eastern Mediterranean Byzantine context; in the early medieval period byzantine shipping was the dominant force and consequently Greek terminology prevailed.

III. The Byzantine Empire and the Eastern Mediterranean

The first written evidence on shipbuilding only concerned war ships and appeared at the turn of the first millennium. It comprises three treatises on naval tactics in a Byzantine context. A thorough recent studies show that the information they contain was based on arm-chair sailoring, and that they were not written from a shipwrights' view point. Furthermore, the terminology of these texts can rarely be accepted at face value, and their testimony must always be weighed against other evidence such as artistic sources and shipwrecks[32]. The next Greek text in a Byzantine context was written in Cyprus in the second half of the thirteenth century, and it discussed two methods of determining a

time Activities in the Middle Ages »Special Section: Underwater Cultural Heritage«, in: Current Science 86/9 (2004), pp. 1276–1282; Id., The Illuminated Ark: Interrogating the Evidence from Images and Materials (BAR International series 1616), Oxford 2007.

30) John H. Pryor, From Dromōn to Galea. Mediterranean Bireme Galleys Ad 500–1500, in: The Age of the Galley. Mediterranean Oared Vessels since Pre-Classical Times, ed. by Robert Gardiner/John Morrison, London 1995, pp. 101–116, here pp. 106, 110; See Unger's discussion regarding the Crusader period: Richard W. Unger, Difficult Sources: Crusader Art and the Depiction of Ships, in: Shipping, Trade and Crusade (as n. 4), pp. 85–104; in contrast to Villain-Gandossi, Illustrations (as n. 29), p. 169.

31) Otto Meinardus, Medieval Navigation According to Akidographemata in Byzantine Churches and Monasteries, in: Δελτίον τής Χριστιανκής Άρχαιολογκής Έταιρείας, περ, Δ, 6 (1970–72), pp. 29–52, here p. 32.

32) Pryor/Jeffreys, The Age of the ΔΡΟΜΩΝ (as n. 3), pp. 175–406, 455–605, appendices 1–5.

commercial vessel's burden in baskets (*kouphia*), which stem from an earlier period, that is the sixth and ninth centuries (fig. 3). This is also the earliest text that provides a new vocabulary with regard to hull structures. Nevertheless these topics are included among other themes and thus one could classify this document as a type of hodgepodge treatise that reminds us of similar books on shipbuilding, termed *zibaldone*, common in Northern Italy and Venice from the early fifteenth century onwards. Like its later western counterparts, the Cypriot document was theoretic, comprised only for didactic purposes. Nevertheless the methods it describes were actually in use. Although the author does not indicate his sources, scholars speculate on a match between this method of assessment and the methods of designing as well as between the six-part division of the hull, manifest in the ships of Bozburun (ninth century) and Serçe Limanı (eleventh century). They also speculate that if the text reflects actual practice, the Bozburun and Serçe Limanı design-methods would enable shipwrights to estimate burden in *kouphia* prior to assembly. In other words, shipwrights may have possessed sets of moulds that designed vessels of specific capacities and, alternatively, ship owners could request a vessel of a particular capacity when contracting a shipwright[33].

Unfortunately, there are no Muslim treatises on ship types and construction. Right after their irruption into the Mediterranean in the mid-seventh century, Muslims used ships taken from or modeled upon those of the indigenous Byzantine population. With Muslim shipping emerging from the eighth and ninth centuries, terminology in Arabic for ships proliferated rapidly and widely in the Levant and thence to the west. Nevertheless, even discussions of naval warfare are few in Arabic. The material on this topic found in thirteenth and fourteenth century Muslim treatises are copies of passages from the ›Concerning of naval warfare‹ of Leo VI, translated into Arabic at an unknown date[34].

IV. Southern Europe and the Western Mediterranean

Shipbuilding is consistently recorded in writing of European provenance from the late thirteenth century onwards. By that time, European shipping dominated the Mediterranean. These documents included contracts, among others those set up by Louis IX of France with Marseilles, Genoa and Venice for the construction and lease of various sailing ships for his two Crusades of 1248–1254 and 1270, as well as those recorded in Angevin

33) Matthew Harpster/Nicholas Coureas, Palatinus Graecus, 367: A 13th-Century Method of Determining Vessel Burden?, in: Mariner's Mirror 94 (2008), pp. 8–20; Matthew Harpster, Designing the 11th-Century-AD Vessel from Serçe Limanı, Turkey, in: International Journal of Nautical Archaeology 39/1 (2010), pp. 44–55.

34) Pryor, From Dromōn to Galea (as n. 30), pp. 106–108.

registers regarding the construction of galleys under Charles I of Anjou, Louis' IX brother, king of Sicily (1269 and 1284). In contrast to the contracts regarding galleys, those concerning sailing ships lack essential details about the conceptual foundation of their design[35].

Other types of documents offering important information are thirteenth and early fourteenth century north-Italian decrees regulated by the state that mainly applied to galley construction. Occasionally the contractor did not bother to detail the shape of the required galley and only laconically limited himself to noting the length without clearly indicating its specific relevant end points, and then to its height or width, presumably of the amidships frame, a design that predicted the later Italian *partisoni*, discussed below; this is true for the *taride*, the horse carriers constructed for the fleet of Charles of Anjou in 1275. The contractor limited himself to a brief conventional formula »of the same mold« implying a model that had already been proven. Thus it was stipulated in a contract of 1275, stating that the galleys built in Brindisi for the fleet of Charles of Anjou will be according to the design of a »red galley« of Provence that had ninety six moulded frames.[36] McManamon and Hocker argue that these documents mentioning measurements and design systems laid down the prescribed basic methods from which shipwrights developed specific shipbuilding directions and evolved them further to form non-structural procedures. They claim that these documents formed the basis for the oldest surviving shipbuilding manuscripts of the early fifteenth century that were of Venetian origin, such as the Fabrica di Galere (ca. 1410) and works by Michael of Rhodes (1434–1436), Zorzi Trombetta of Modon (1444–1449) and of the Millo family (1470)[37]. This argument is reinforced by a number of clear philological parallels and verbal rules that were rooted in much earlier periods and came from different Mediterranean geographical areas[38]. Archaeologists, as we shall see below, predate the influence on Venetian manuscripts to much earlier periods.

35) For definition of designing methods, see: McGrail, How were Vessels designed (as n. 1), p. 125; Rieth, Mediterranean Ship Design (as n. 1), pp. 406 f.; McGee, The Shipbuilding Text (as n. 1), pp. 211–243.

36) John H. Pryor, The Galleys of Charles I of Anjou King of Sicily: CA 1269–84, in: Studies in Medieval and Renaissance History 14 (old series 24) (1993), pp. 33–103.

37) On a survey of all the Venetian Manuscripts, see: John M. McManamon, The »Archaeology« of Fifteenth Century Manuscripts on Shipbuilding, in: International Journal of Nautical Archaeology 28/4 (2001), pp. 17–25; On the evolvement of the shipbuilding treatises in Venetian manuscripts until the late seventeenth century see: Frederick M. Hocker/John M. McManamon, Medieval Shipbuilding in the Mediterranean, in: The Mediterranean Historical Review 21/1 (2006), pp. 1–37, here pp. 2–25.

38) John H. Pryor, The Naval Architecture of Crusader Transport Ships: A Reconstruction of some Archetypes for Round-hulled Sailing Ships, in: Mariner's Mirror 70 (1984), pp. 171–219, 275–292, 363–386; Id., The Galleys of Charles I. of Anjou (as n. 36); Ulrich Alertz, The Naval Architecture and Oar System of Medieval and Later Galleys, in: The Age of the Galley (as n. 30) pp. 142–162, here pp. 142 f.; Mauro Bondioli, Early Shipbuilding Records and the Book of Michael of Rhodes, in: The Book of Michael of

Several crucial points should, however, be made. First, the Venetian written evidence from the early fifteenth century regarding sailing vessels, light and great galleys, consists of hodgepodge books, *zibaldone*, which were not intended as shipbuilding manuals but instead meant to present an array of nautical topics, which happened to include data on the construction of a variety of contemporary vessels. The information they contain is mainly theoretical, with some practical use for the benefit of their authors, editors or owners, who could be merchants or sailors, or for didactic purposes. Second, a recent study has convincingly argued[39] that the information on shipbuilding as well as on other topics was copied and not compiled by the authors/editors. Concordances between the descriptive phrases found in Michael's of Rhodes and Giorgio Trombetta's books and a close resemblance between the texts related to the galley of Flanders, the galley of Romania, and the light galleys suggest that a single author with access to internal documents stored in an office at the Arsenal composed the original texts used in both books. Furthermore, the drawings, some of which are sloppy, were either illustrations for didactic aims or intended to give a general impression how the vessels will look at the end. They represent the ship's main dimensions in graphic forms or surveys composed after construction. They did not reflect contemporary methods for determining dimensions that were transferred to paper, nor geometrical methods for determining dimensions on paper that could be transferred to yards, and they could not be used to obtain the shapes of the construction parts; the real dimensions were determined in a different manner during the construction process. Indeed, among the many drawings in Giorgio Trombetta's book with minimal measurements and without reference texts there are two with distinctive elements, lacking in Michael's book. One is very detailed when it comes to constructional elements with proportional relations between them, yet without a text. The other reflects the intention to understand the geometrical mechanisms of narrowing the frames, the *partisoni* method, starting from the main frame amidships by narrowing the length of the floor timber and its rising. This method, employed with the device of the *mezza-luna* diagram, was fundamental to define the gradual refinement of the hull from its maximum breadth amidships towards the bow and stern. However, the sketches are small and drawn freehand. Only in the next hundred years they were developed to reach the level of large-format line drawings of engineering standards. Furthermore, the hull ends themselves were out of the scope of this *partison.* Since the stern and bow were crucial for the shape of the hull, their design and construction, which was very difficult, were kept as a professional secret by the master shipwright, on whose skills the successful accomplishment of the mission depended. He himself did not use written instructions but relied on mo-

Rhodes (as n. 1), pp. 243–280, especially pp. 261–265; Hocker/McManamon, Medieval Shipbuilding (as n. 37), pp. 3 f.

39) Bondioli, Early Shipbuilding Records (as n. 38), pp. 251, 268, 276–278; McGee, The Shipbuilding Text (as n. 1); Rieth, Mediterranean Ship Design (as n. 1), pp. 409–416.

dels, at the most, aiming at laying down simple rules which would govern the main dimensions and the form of the hull. In other words, the practical technique of shipbuilding was still handed down orally and required the close instructions of the master shipwrights, who recited them aloud. This was the practice used in the Arsenal in Venice as well as in the arsenal in Crete, the only territory of Venice's *Stato da Mar* where the construction of galleys was permitted. This acoustic method first found its way in writing, lyrical in form and based on words and numbers, in the Fabrica di Galere (1410)[40].

The master shipwrights' insistence on providing only very spared written information, keeping in secret the technical construction details of the stern and bow shows their efforts to maintain their position vis-à-vis their competitors. By the fifteenth century, education and learning was common and available to those who could afford or thrived to attain it. One can assume that many oral practices in many fields, principles in shipbuilding included, were transferred into writing at some point. This cultural process would have increased competition and undermined the status of the shipmasters, who tried to pass on as little information as possible, particularly regarding the crucial components of the shiphull.

V. Archaeological Evidence

Notwithstanding documentary information provided by historic evidence, archaeologists[41] claim that principles of shipbuilding design methods had been in use much earlier than documents record. In order to prove their point, they bring forward forth two groups of material evidence from Venetian contexts, both from the early fourteenth century. One is the Contarina I, a merchant sailer wreck, found at the Po River, and the other is a galley, found at San Marco in Boccalama, at the southern Venetian lagoon which, however, still needs to be studied thoroughly. There is other evidence from the Western Mediterranean: the Culip VI wreck (fig. 4) of a fourteenth century coaster found in Cat-

40) Alertz, The Naval Architecture (as n. 38), pp. 145–147; Id., The Venetian Merchant Galley and the System of »partisoni« – Initial Steps towards Modern Ship Design, in: Boats, Ships and Shipyards (as n. 1), pp. 212–221, here pp. 212–217; Mauro Bondioli, The Arsenal of Venice and the Art of Building Ships, in: Boats, Ships and Shipyards (as n. 1), pp. 10–13; Id., Early Shipbuilding Records (as n. 38), pp. 251, 268, 276–278; McGee, The Shipbuilding Text (as n. 1); Rieth, Mediterranean Ship Design (as n. 1), pp. 409–416; Ruthy Gertwagen, Byzantine Shipbuilding in 15th Century Venetian Crete and the Link to the Arsenal in Venice, in: Shipping, Trade and Crusade (as n. 4), pp. 115–127.

41) Bonino, Lateen-rigged Medieval Ships (as n. 29); Carlo Beltrame/Marco Bondioli, A Hypothesis on the Development of Mediterranean Ship Construction from Antiquity to the Late Middle Ages, in: Connected by the Sea (as n. 24), pp. 89–93; Marcel P. Hamelink, Catalan Shipbuilding in the Late Middle Ages, the Contribution of Maritime Archaeology: Culip VI. and Les Sorres X., in: Splendour of the Medieval Mediterranean (as n. 20), pp. 563–571; Hocker/McManamon, Medieval Shipbuilding (as n. 37), pp. 7 f.

alonia at Cape Culip near Cadaquès that most probably belonged to a merchant of the Crown of Aragon; one could also mention the Les Sorres X wreck (1350–1400), a small merchant vessel that sank in the Baix Llobregat, while conducting cabotage sailing between Barcelona and Costa de Poniente. It is believed that the shipwrights of the Contarina I (fig. 5) and Culip VI (fig. 4) wrecks used the half-moon or a similar device. (fig. 6) Marks inscribed on the frames' surface indicate that frames differed, one from the other, starting from the main one amidships.

Rudiments for this method, defined as »proto master-frame method«, had been identified in two much earlier wrecks, the afore-mentioned ninth century Bozburun vessel and the early eleventh century Serçe Limanı one, both in the Eastern Mediterranean. Each was built with the standard unit of measurement and with a tripartite division of the floor timbers that is still evident, as is the use of multiples of flat amidships to determine the dimension and layout of the craft[42].

Some archaeologists argue[43] that this evidence, along with the above-mentioned thirteenth century Byzantine Cypriot text, point to a Byzantine provenance of this method found in Southern Italy, Venice and Catalonia. Even the term *partisan* is of Greek origin, and means »to put up in a row side by side«, and the Arsenal hierarchy under a *proto-maestro* reflects the Byzantine hierarchy under a *protomaistor.* According to this theory, Byzantine shipwrights might have introduced this method into Venetian naval architecture well before the fifteenth century, although these early influences are still an enigma. Considering the Byzantine cultural legacy in Norman Sicily, Southern Italy and Venice, this argument sounds convincing. Furthermore, there is ample evidence that, in the first half of the fifteenth century, the Venetian Arsenal hired Greek shipwrights to oversee the construction of their light galleys. The Greek/Byzantine shipmasters thus worked alongside but separately from Venetian shipmasters, each responsible for his own type of vessel[44]. One could also argue for Byzantine influence via Venetian shipwrights in the Western Mediterranean. The first Florentine merchant galleys for Alexandria, for instance, were constructed in 1422 by shipwrights and sailors invited from Venice[45].

42) Ibid., pp. 7–9; Richard J. Steffy, Construction and Analysis of the Vessel, in: Serçe Limanı (as n. 21), pp. 154–158; Matthew Harpster, Geometric Rules in Early Medieval Ships: Evidence from the Bozburun and Serçe Limanı Vessels, in: Connected by the Sea (as n. 24), pp. 95–98; Rieth, Mediterranean Ship Design (as n. 1), pp. 416–418.

43) Hocker/McManamon, Medieval Shipbuilding (as n. 37), pp. 8 f., 24; Alertz, The Venetian Merchant Galley (as n. 40), pp. 215 f. On the impact of Byzantine shipbuilding in Venetian documents and hierarchy in the Arsenal, see: Ennio Concina, L'arsenale della repubblica di Venezia, Mailand 1984, pp. 14–20.

44) Beltrame/Bondioli, A Hypothesis (as n. 41), p. 93; Bondioli, Early Shipbuilding Records (as n. 38), pp. 261–266; Gertwagen, Byzantine Shipbuilding (as n. 40), pp. 120–124.

45) Michael E. Mallet, The Florentine Galleys in the Fifteenth Century, Oxford 1967, p. 26; Genoese shipwrights were also invited.

Fig. 1a

Fig. 1a and 1b: Quaderni Trimestrali Consorzio Venezia Nuova 9 n. 2/3 (2001), pp. 3–15, here pp. 4 and 7.

Fig. 2: Yanikapi 16 A galley after: The ›Old Ships‹ of the ›New Gate‹/Ynikapi'nin Eski Gemileri, ed. by Ufuk Kocabaş, Istanbul 2008, p. 177 fig. 88a.

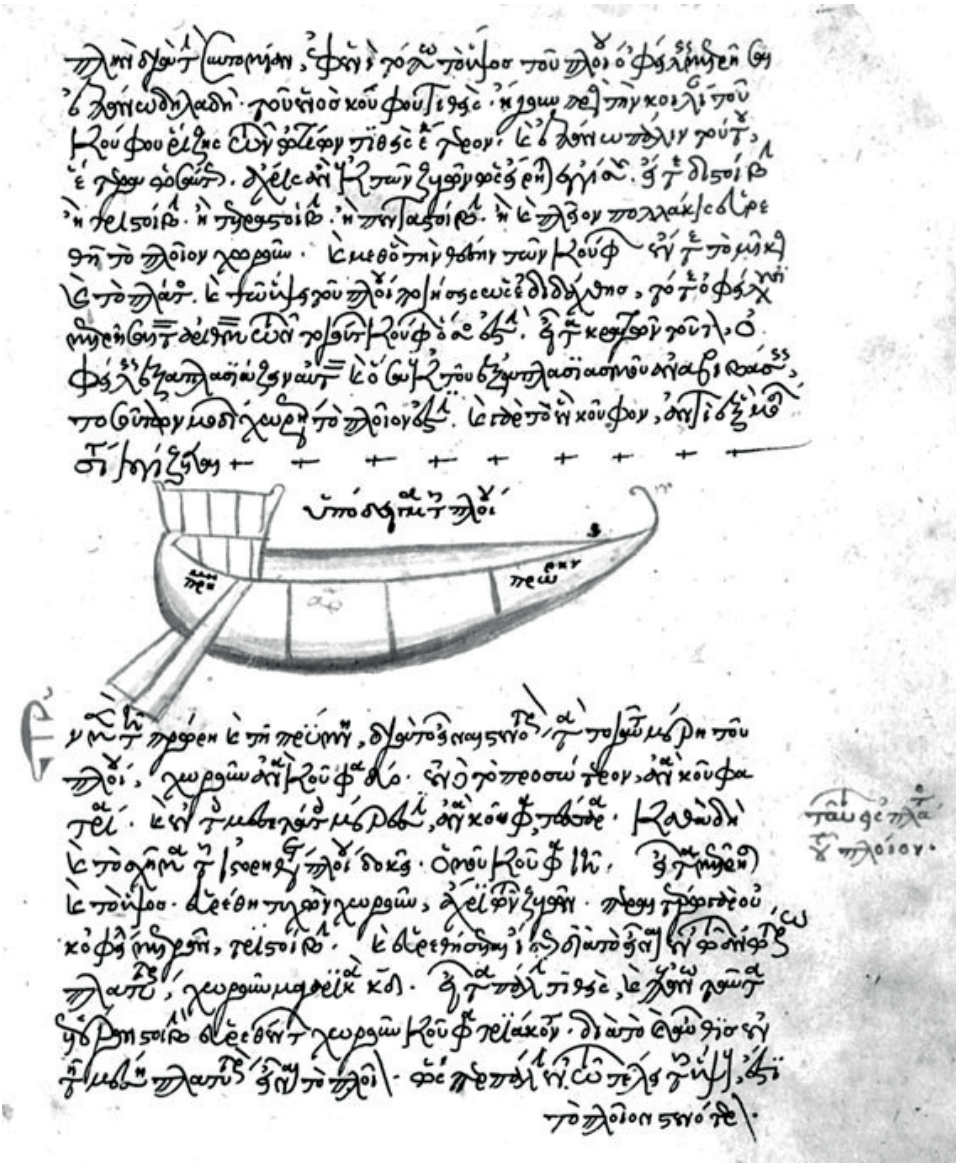

Fig 3: After: Mathew Harpster/Nicholas Coureas, Palatinus Graecus, 367: A 13th-Century Method of Determining Vessel Burden?, in: Mariner's Mirror 94 (2008), pp. 8–20, here p. 15 fig. 1.

Fig. 4: Model of Culip VI wreck after: Marcel P. Hamelink, Catalan Shipbuilding in the Late Middle Ages, the Contribution of Maritime Archaeology: Culip VI. and Les Sorres X., in: Splendour oft the Medieval Mediterranean: Art, Culture, Politics, Navigation and Commerce in the Mediterranean Maritime Cities (13th–15th Centuries), ed. by Xavier Barral i Altet/Joan Alemany, Barcelona 2004, pp. 563–571, here p. 567.

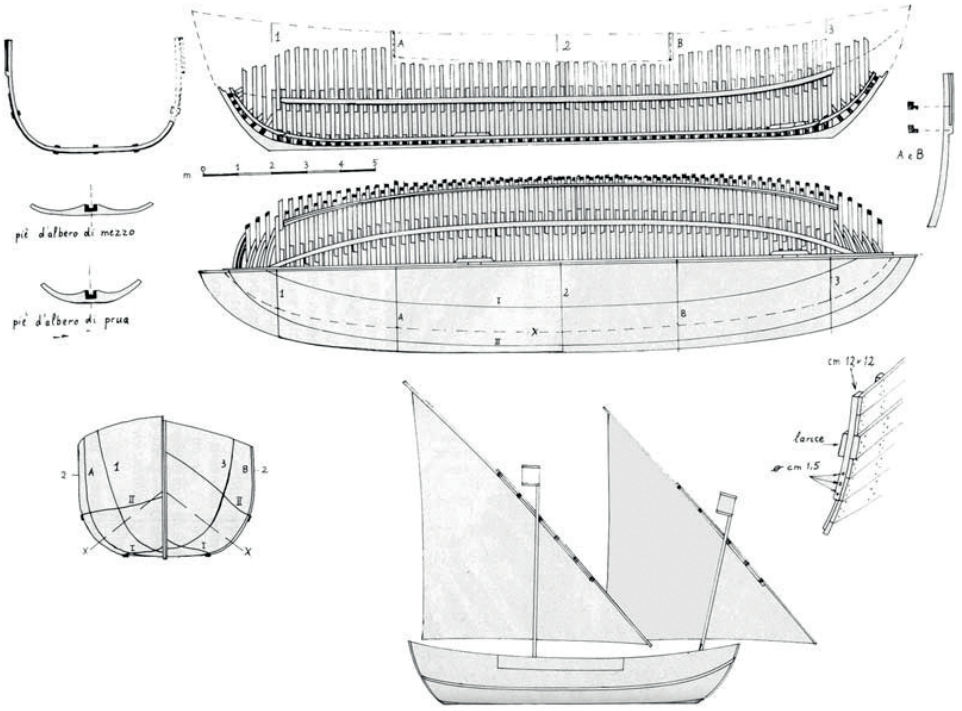

Fig. 5: Marco Bonino, Lateen-rigged Medieval Ships. New Evidence from Wrecks in the Po Delta (Italy) and Notes on Pictorial and other Documents, in: International Journal of Nautical Archaeology 7/1 (1978), pp. 9–28, here p. 14.

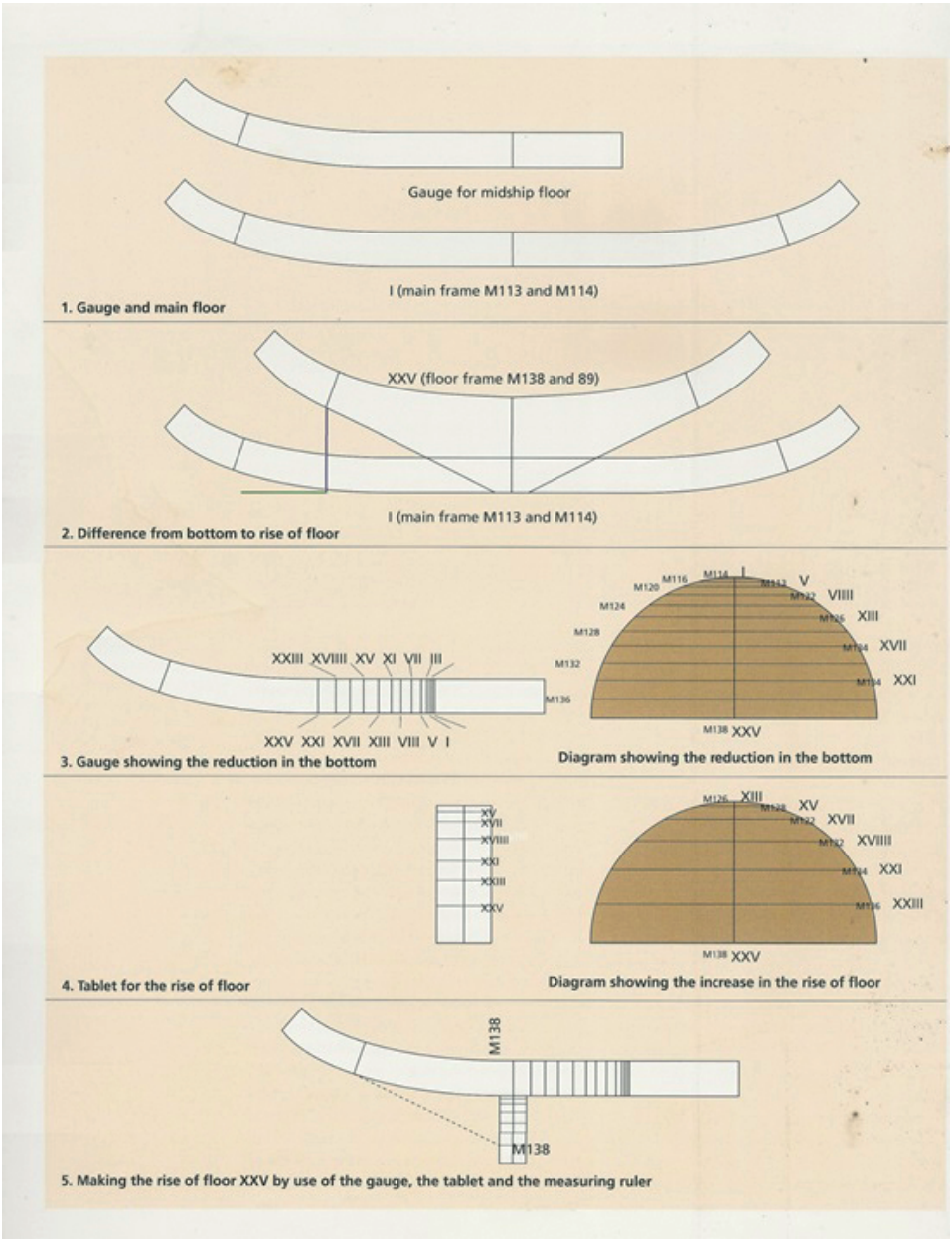

Fig. 6: Marcel P. Hamelink, Catalan Shipbuilding in the Late Middle Ages, the Contribution of Maritime Archaeology: Culip VI. and Les Sorres X., in: Splendour oft the Medieval Mediterranean: Art, Culture, Politics, Navigation and Commerce in the Mediterranean Maritime Cities (13th–15th Centuries), ed. by Xavier Barral i Altet/Joan Alemany, Barcelona 2004, pp. 563–571, here p. 569.

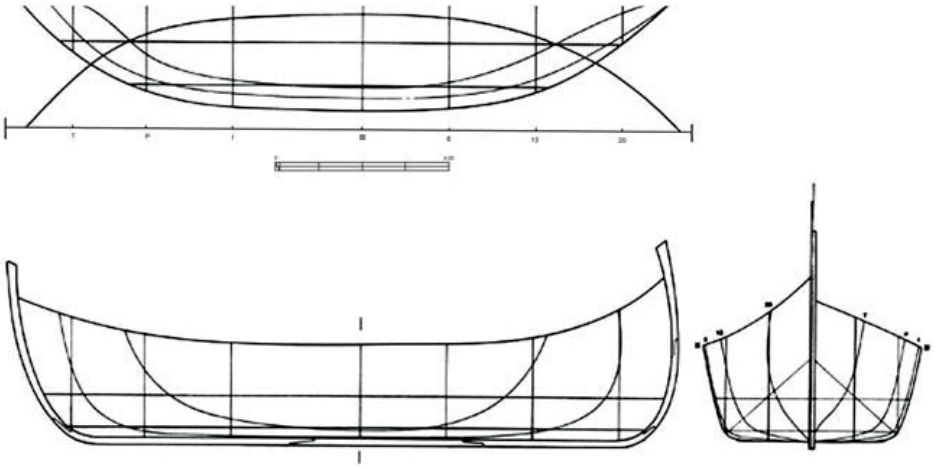

Fig. 7: Serçe Limanı wreck. Lines of the hull after: Richard J. Steffy, Construction and Analysis of the Vessel, in: Serçe Limanı: An Eleventh Century Shipwreck, vol. 1: The Ship and its Anchorage, Crew and Passengers, ed. by George F. Bass/James W. Allan (Nautical Archaeology Series), College Station 2004, pp. 154–158, here p. 166 fig. 10–11.

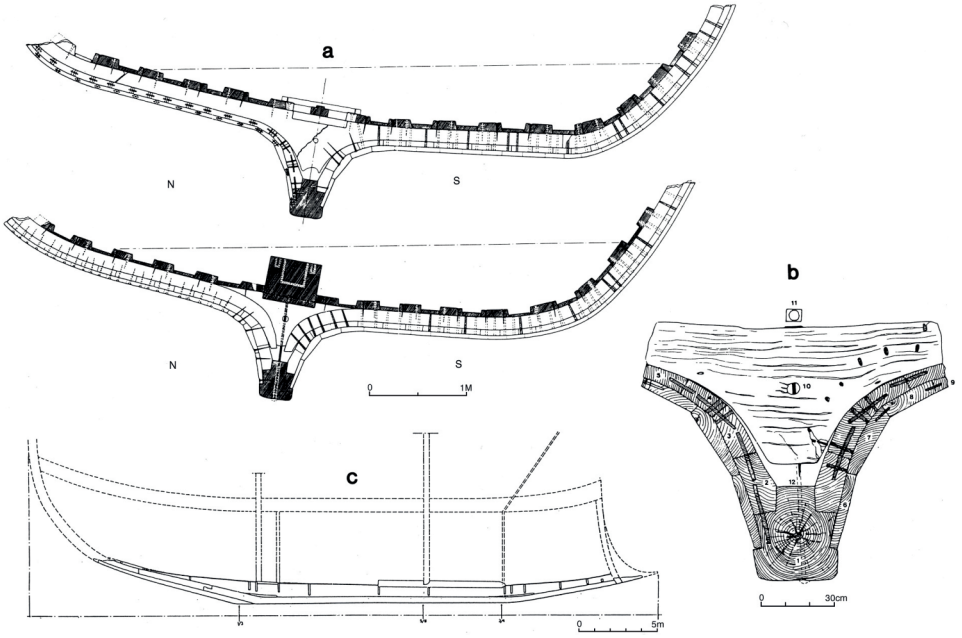

Fig. 8: Andrew Wilson, Developments in Mediterranean Shipping and Maritime Trade from the Hellenistic Period to AD 1000, in: Maritime Archaeology and Ancient Trade, ed. by Damian Robinson/Andrew Wilson, Oxford 2011, pp. 33–39, here p. 41.

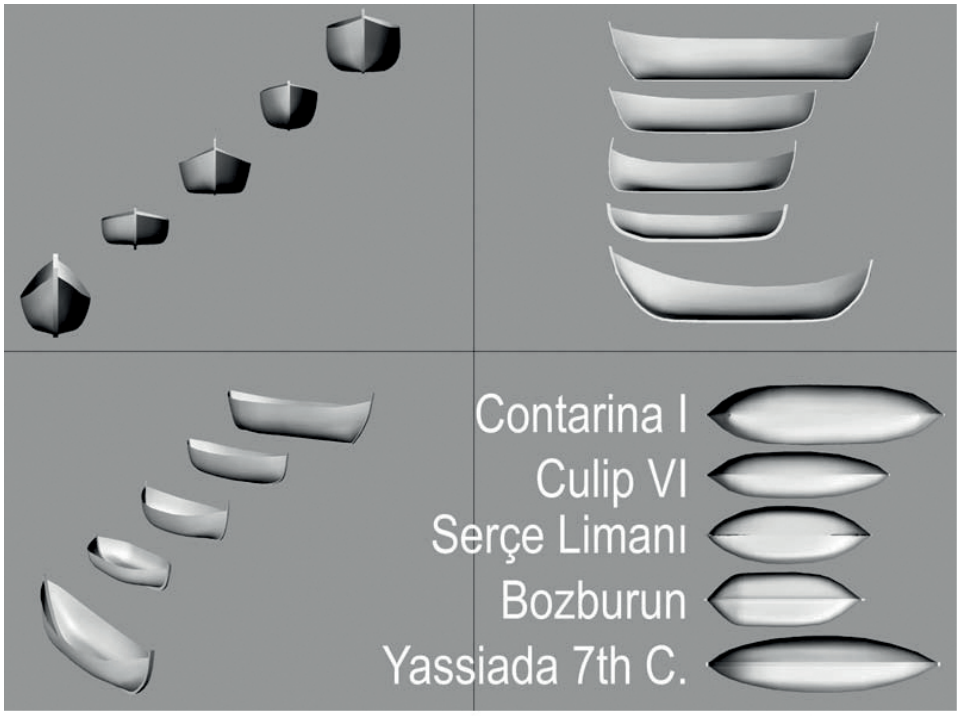

Fig. 9: F. Castro/N. Fonesca/T. Vacas/F. Ciciliot, A Quantitative Look at Mediterranean Lateen- and Square-Rigged Ships (Part 1) in: International Journal of Nautical Archaeology 37/2 (2008), p. 358 fig. 6.

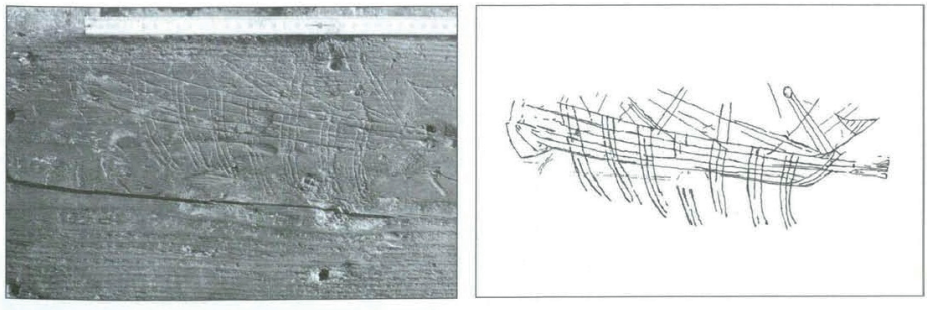

Fig. 10a and 10b: A schematic reproduction of the graffitto after: McManamon/D'Agostino/Medas, Excavation and Recording of the Medieval Hulls at San Marco in Boccalama (Venice), in: The INA Quarterly 30/1 (2003), pp. 22–28, here p. 25 fig. 6 and 7.

Bondioli and Beltrame, on the other hand, insist on Western European origins of shipping technology that arose in the context of the twelfth century »European« Renaissance. They disregard Byzantine archaeological and written evidence and adhere to the mistaken assertion of a Byzantine lack of productivity in the fields of mathematics and geometry. They try to sustain this claim by pointing to similar verbal formulas found in mid-thirteenth century Genoese notarial contracts and bills for fitting galleys, in late thirteenth century documentary corpuses of registers from the royal chancellery at Anjou, as well as in the aforementioned Venetian documents[46].

Since, however, Byzantine and Venetian shipmasters worked at the same time in the Venetian Arsenal, one can safely maintain that this industrial compound was a melting pot of both traditions, Byzantine and western European.

VI. Hull design and shipbuilding technology

The above-mentioned ship designs characterize the »frame-based« shipbuilding method, a process that assembles some of the framing prior to the exterior planking, while the transverse frames play an active part in forming the geometric shape of the hull. The sequence of construction was such that frames were first nailed to the keel, then planking was nailed to each frame by iron nails, and the seams were sealed with threads of oakum laid out in force. To give additional strength to the construction, longitudinal reinforcements, such as a keelson, central timbers et cetera are also needed[47].

The earliest wrecks of ships built with this method were found in the Dor Lagoon along the Israeli coastline and are dated to the turn of the sixth century AD: Tantura A and Dor 2001/1[48]. Data from a sequence of wrecks, from the eleventh century Serçe Limanı wreck (fig. 7) in south-western Turkey, the twelfth century Pelagos wreck in the

46) Bondioli, Early Shipbuilding Records (as n. 38), pp. 261–266.

47) On this construction method and its contrast to the earlier »shell-first«, see: Rieth, Mediterranean Ship Design (as n. 1), pp. 407–409; Patrice Pomey/Yaacov Kahanov/Eric Rieth, Transition from Shell to Skeleton in Ancient Mediterranean Ship-Construction: Analysis, Problems, and Future Research, in: International Journal of Nautical Archaeology 41/2 (2012), pp. 235–314.

48) Yaacov Kahanov/Jeffrey G. Royal/Jerome Hall, The Tantura Wrecks and Ancient Mediterranean Shipbuilding, in: The Philosophy of Shipbuilding: Conceptual Approaches to the Study of Wooden Ships, ed. by Frederick M. Hocker/Cheryl Award (Ed Rachel Foundation Nautical Archaeology), Texas 2004, pp. 113–127; Hadas Mor, The Dor 2001/1 Shipwreck: Hull Construction Report, in: Transferts technologiques en architecture navale méditerranéenne de l'antiquité aux temps modernes: identité technique et identité culturelle. Actes de la Table Ronde d'Istanbul 2007, ed. by Patrice Pomey (Varia Anatolica 20), Istanbul 2010, pp. 87–96; Hadas Mor, The Socio-economic Implications for Ship Construction, in: Shipping, Trade and Crusade (as n. 4), pp. 39–63; Pomey/Kahanov/Rieth, Transition from Shell to Skeleton (as n. 47), pp. 259–263.

Aegean[49] and the above-mentioned fourteenth century Contarina I and Culip VI wrecks (fig. 4, 5), clearly indicate, until new evidence proves otherwise, that the early eleventh century Serçe Limanı provides the *terminus ante quem* for the »frame-based« Mediterranean shipbuilding technology, the only one practiced in the Mediterranean from the second millennium AD onwards.

This shipbuilding technology was completely different from the ancient, »shell-based« one, both in concept and construction. In shell based construction the ship was viewed longitudinally, based on a shell of strakes running parallel to the keel, joined together to determine its form and structural integrity. From a constructional point of view, the maintenance of integrity was based on planks held together and connected to the keel with narrowly spaced, robust, pegged mortise-and-tenon joints. This sound connection provided water tightness without caulking. Nevertheless, pitch was applied internally and externally, penetrating into the seams, and sometimes luting was also used. Technologically and economically speaking, producing such hull designs required a great amount of time, a large amount of material, and skilled professional shipwrights and workers, since wrecks of this period, starting with the Hellenistic Kyrenia ship (late fourth century BCE) show actual carving and sculpting. A sharp bottom and prominent keel permitted the formation of hulls with a »wineglass« section that improved stability and reduced leeway, enabling the ships to hold a course closer to the wind when sailing windward. This quality was strengthened with a sternpost with a cutwater (fig. 8)[50]. Such a fact should not be dismissed off hand, since sailing capabilities depended to a large part on hull design, and not, as erroneously thought, on the geometric shape of sails[51]. On the other hand, greater emphasis was invested on the shape of the hull than on the internal space, which was necessarily limited by this building technique. These vessels were for cargo carrying with minimum crew members.

VII. Economic and social ramifications

The new frame-based hull design had substantial ramifications in various fields. The frame-based assembly system did not require as much material as the previous shell-based

49) History of Seafaring based on Underwater Archaeology, ed. by George F. Bass, New York-London 1972, p. 72.

50) Richard J. Steffy, Ancient Scantlings: The Projection and Control of Mediterranean Hull Shapes, in: Tropis 3rd International Symposium on Ship Construction in Antiquity, ed. by Harry Tzalas (Hellenic Institute for the Preservation of Nautical Tradition 3), Athens 1995, pp. 417–428; Pomey/Kahanov/Rieth, Transition from Shell to Skeleton (as n. 47), pp. 236, 294 f.; P. Arnaud, Sailing 90^0 from the Wind: Norm or Exception?, in: Maritime Technology (as n. 5), pp. 147–160.

51) Julian Whitewright, Efficiency or Economics? Sail Development in the Ancient Mediterranean, in: Maritime Technology (as n. 5), pp. 89–102.

one, and allowed for less professional manpower since the mortise-and-tenon joinery was abandoned. The entire process was much faster and cheaper, and maintenance was easier and less costly. However, the abandonment of the ancient waterproof tenon-and-mortise joinery required increased means in caulking. Thus, while the social and economic standing of the professional shipbuilding workers of the previous period decreased, that of the caulkers increased. They were required to caulk the vessel over and over again at regular intervals to overcome the solid sealing of the hull, formerly provided by the mortises and tenons, as well as the joints between the planks and between them and the keel[52].

Surprisingly, this cheaper hull design was eventually adopted all over the Mediterranean despite European economic and political revival which stimulated long distance trade between Europe and the Southern Mediterranean. The first evidence for growing ship sizes that points to an increase in trade volume is of iconographic nature and hails from the Byzantine and Muslim worlds which dominated Mediterranean shipping until the twelfth century. Three-masted Muslim ships are depicted on early-eleventh century dishes originating in the Balearic Islands and a large three-masted ship from Apulia, then under byzantine rule, is reported by the byzantine princess Anna Comnena[53]. Two observations should be made in this regard. First, merchants always looked for means to economize expenses. At that time, shipbuilders were more often than not also the owners, merchants and captains who invested all their possessions in these enterprises. One has to bear in mind that, in the eleventh century, the revival of European long distance trade was still in its infancy and rather opportunistic. There were not enough revenues yet to cover the costs of shipbuilding that must have been expensive. The situation was indeed to change during the twelfth century within the course of the Crusaders movements. By then, however, the qualities of this hull design had already been acknowledged and the shipbuilding techniques, that were until the sixteenth century merely orally transmitted, had already been deeply-seated.

VIII. Ramifications on ships' capacities

In »frame-based« hull design emphasis was put on transverse frames that played an active part in conveying a geometric shape to the hull, as demonstrated by the Serçe Limanı vessel. (fig. 7). This allowed the interior space of the hull to take precedence over the ex-

52) Unger, The Ship in the Medieval Economy (as n. 5), p. 105.
53) John H. Pryor, The Mediterranean Round Ship, in: Cogs, Caravels and Galleons (as n. 29), pp. 59–76, here p. 65.

terior shape. These hulls became round or boxlike in cross section (fig. 9), even if smaller in size than the ancient ships, and allowed for more cargo[54].

Crusading logistics and the increase in long distance trade resulting from the Crusades stimulated an increase in European ships' capacities. Pioneered by the Venetians in their expedition of 1123, sailing ships under the name *naves* (singular: *navis*) were used for transporting troops and horses on the same passage. For this purpose they had hatches to allow airing the horses[55]. These were the times that shipbuilders could »get rich« by providing many cheap vessels within a very short period of time. From the twelfth century onwards the economies of various regions of the Mediterranean, including the Byzantine and Muslim worlds, began to coalesce creating an international market. All these developments stimulated European sailing ships to reach their maximum capacity in the thirteenth century. They were able to carry animals, merchants, crusaders, pilgrims, commodities, all in one passage. Iconography of the late twelfth century, starting with a relief on the *Campanile* of Pisa, which was begun around 1183, shows ships with forecastles and sterncastles, two masts and more than one deck (in contrast to the opened Serçe Limanı ship and corresponding iconographies of the eleventh century from the *Pala d'Oro* altar screen in St. Marco in Venice as well as from a manuscript in the monastery on Mt. Athos). In the late thirteenth century two mosaics from San Marco show ships with three masts, the first depiction of such ships in the West[56].

IX. Ramifications of cruise abilities and sea routes

The round or box-like hull design, product of the frame-based concept, lost its wineglass cross section and stempost with cutwater and consequently ships made more leeway. The early eleventh century Serçe Limanı shipwreck showing such a hull, with a flat bottom and draft at full load of 1.4 meters, must have been pounded on sea in all but the calmest weather. It was indeed only apt as a coaster that could sail very shallow waters including rivers[57]. The same is true for the above-mentioned two Catalan coasters' shipwrecks of the fourteenth century, the Culip IV and the Les Sorres X.

That said, it should be noted that there were circumstances inducing ships to consciously risk high sea routes. The Geniza letters from the early eleventh and twelfth centuries point to hostile assaults of the Byzantine fleet which prevented Muslim/Jewish shipping from Egypt from following the longer route along the Levantine coast through

54) Steffy, Ancient Scantlings (as n. 50).

55) Pryor, The Naval Architecture (as n. 38); Id., Digest, in: Logistics of Warfare in the Age of the Crusades, ed. by Id., Aldershot 2006, pp. 275–292, here p. 290.

56) Id., The Mediterranean Round Ship (as n. 53), pp. 69 f.

57) Steffy, Construction and Analysis of the Vessel (as n. 42).

the Aegean to Italy and instead forced them to sail until Libya and thence to Sicily via Tunis. However, navigational skills could not save these ships, which were only apt as coasters that could sail very shallow waters, including rivers, as demonstrated by their wrecks[58]. Anticipating wreckage, merchants used to split up commodities on several ships in order to minimize losses[59].

Historical records show that sailing against prevailing winds was quite normal when returning to Europe from the southeastern Mediterranean, or when following or side winds veered, which took both sailing and great merchant galleys from the twelfth to late fifteenth century at least twice as long as with following winds. The reason for this bad upwind performance was their rounded hull configuration. There was nothing to prevent excessive leeway when beating into the winds. The same is true for the great fifteenth century Venetian pilgrim galleys, as made clear by Pietro Casola's graphic description of his experience against strong and stormy contrary winds during his home voyage in 1483[60]. It has also been argued[61] that, until the late thirteenth century, the limited capabilities of these ships caused them to avoid squally, unpredictable winter weather. Thus ships stayed in port from the end of October to the beginning of March. At Pisa, twelfth century city statutes forbade a master who brought his ship into port from leaving until the first of March. The common belief is that the real motive behind the closure of the port was fear of rain or fog that prevented astronomical navigation. This obstacle was removed with the very late thirteenth century introduction of the compass, the marine chart, navigational tables and dead reckoning[62].

Interestingly, sounding weights, already introduced in the sixth century BCE, were also adopted to overcome such obstacles[63]. From the late twelfth century onwards, however, the Genoese seem to have broken all the above »rules«. Ibn Jubayr's description of his voyage from Acre to the West on a Genoese ship in 1184 is instructive. The ship left in October, just at the beginning of the winter season. Furthermore, the captain intended to take the direct westward route on the high seas along the unfavourable southern coast of Crete. Sailing against the strong westerlies, the mast broke and the sails were torn down. The Genoese had succeeded only with difficulty in reaching the southwestern end of the island when the strong westerlies pushed the vessel out towards the sea, where they lost all sense of orientation. Eventually, the captain had to sail from northeastern Crete to

58) See, for example, the early eleventh centuries Serçe Limanı vessel.

59) Gertwagen, Geniza Letters (as n. 18).

60) Pryor, The Mediterranean Round Ship (as n. 53), pp. 73 f.; Canon Pietro Casola's Pilgrimage to Jerusalem in the Year 1494, translated by M. Newett, Manchester 1907, pp. 292, 296, 209.

61) John P. Oleson, Testing the Waters. The Role of Sounding Weights in Ancient Mediterranean Navigation, in: The Maritime World of Ancient Rome, ed. by Robert H. Hohlfelder, Michigan 2008, pp. 119–176

62) Lane, The Economic Meaning (as n. 19).

63) Oleson, Testing the Waters (as n. 61). Despite the title the topic is dealt from a long durée perspective.

the Ionian Sea and the Straits of Messina.[64] This pattern repeats itself in the descriptions of the voyages of Jacques de Vitry to Acre in late September 1216 as well as during the Crusades of 1239 and of Louis IX in 1249, where all routes lead directly south to Sicily and along the southern coast of Crete to the Levant. Although setting out with following winds, all met strong adversary easterlies that dispersed the ships and made life on board unbearable[65].

Why would pilgrims like Ibn Jubayr risk voyages in winter and why would Crusaders risk voyages on high seas instead of taking coastal sea routes? Undoubtedly, their fundamental fear of the sea induced them to reach their destination as quickly as possible. The descriptions of the ›Itinerarium Peregrinorum‹ and Ambroise, eyewitnesses for Richard the Lionheart's expedition in late twelfth century, and of Pseudo-Brocardus, eyewitness for Louis IX's expedition of 1249[66], graphically convey the poor physical and psychological condition of those aboard during heavy weather: the loss of sensibility leading to suicidal tendencies, cries for salvation causing stress and so forth. According to Pseudo-Brocardus, life aboard was unbearable for the French, who were not accustomed to sea voyaging, tasteless fat food, stinking putrid water, enclosed conditions and other things that caused illness. He advised sea voyages only for seamen and those accustomed to or not affected by tempests and perils, even suggesting making port in uninhabited havens and during heavy weather[67]. One could safely imagine that Ibn Jubayr's praise of the Genoese captain's seafaring skills in fact repeated the Genoese's advertisement of his own expertise, meant to persuade passengers to make the voyage against all odds. Jacques de Vitry's statement that the Genoese were used to crossing the sea in winter owing to their very sturdy ships of great size should be read in the same manner. His comment that »in that season the provisions aboard ship do not go bad easily nor the water putrefy as [it does] aboard ships in summer«[68] also strongly suggests persuasion to risk such a voyage in the first place. In reality, according to the same writers, people vomited or lay down and certainly did not care for food. One can safely assume that Genoese captains, more so than the Venetian, were ready to take all risks by speeding up voyages in order to achieve profits, clearly conscious of the limitations of the nautical capabilities of their ships. As seamen, such risks were part of their everyday life. One can also assume that the increase

64) The Travels of Ibn Jubayr, translated by Roland J. C. Broadhurst, London 1952, pp. 327–334.

65) Jacques de Vitry, Lettres, in: Serta mediaevalia: textus varii saeculorum X–XIII in unum collecti. Tractatus et epistulae, ed. by Robert B. C. Huygens (Corpus Christianorum Continuatio Mediaevalis 171), Turnhout 2000, pp. 560–562; Continuation de Guillaume de Tyre de 1229 a 1261 dite du manuscrit de Rothelin, in: RHC Occ, vol. 2, pp. 483–639,§ 20, p. 529; John of Joinville, Vie de saint Louis, ed. J. Monfrin, Paris 1995, §§46–8, pp. 72 f. and cf. Ruthy Gertwagen, Harbours and Port Facilities along the Sea Lanes to the Holy Land, in: Logistics of Warfare (as n. 55), pp. 95–118, here pp. 99–103.

66) The Travels of Ibn Jubayr (as n. 64), pp. 327–334.

67) Gertwagen, Harbours and Port Facilities (as n. 65), pp. 99 f. and note 21.

68) Jacques de Vitry, Lettres (as n. 65), p. 555.

in volume of maritime transportation and trade between Europe and the Crusader Levant intensified the competition between Genoa, Pisa, and especially Venice, whose sea routes naturally crossed the Ionian and Aegean Sea. The sea routes to Pisa and Genoa, in comparison, were much longer. I would also argue that they made efforts to make more than one voyage in the same year, almost hundred years before it is commonly claimed. Ibn Jubayr indeed attests the Genoese captains' intimate knowledge of various sea routes on high seas before technological innovations such as the compass, navigational charts and portolans were used. The fact that there are no prohibitions on winter navigation in Genoa as above-mentioned in Venice and Pisa makes the point clear. Furthermore, relying on Casola's eye witness description, we might question the effectiveness of the compass and charts in comparison to the practical experience of pilots[69]. One major reason for that was the inability to calculate exact time spans, apart from day light or spans of several days. In other words, distances could not be calculated, thus ships could not have located themselves on high seas. Pryor argues that was the reason why Muslim jurists prohibited sailing on high sea and instead prescribed coastal navigation[70].

The exceptional daring of the Genoese, however, is worth underscoring, since they were also pioneers in the crossing of the Straits of Gibraltar in the 1270s and in adopting new types of ships, as described later on.

X. Ramifications on warfare technology and tactics

Another by-product was the abandonment of the Greco-Roman waterline ram. Rams were specifically designed to cause frames to be dislodged from their joints with the planks, thus causing the planks to split down the middle and the attacked ships to sink. In the frame-based design, the planks were more flexible and not so susceptible to splitting, while the frame became heavier, because its timbers was more closely spaced and more integral to the construction of the hull; thus they supported the hull against outer impacts, while breaches would be more localized and more easily sealed. The Greco-Roman waterline ram ceased to be effective and was eventually replaced by a different offensive weapon, the above-water spur that was designed to ride up and over the enemy ship, smashing it and disabling its power source so that it would be rendered helpless and vulnerable to attack by mariners and archers. In contrast to the Greco-Roman rams, the spurs were not built – neither in Byzantium nor later in the West – as integral parts of the hull. In the tenth century, they were suspended by a chain or coupling from the stem post. In the twelfth and thirteenth centuries, according to Western sources, these spurs were long, oak-wooden and iron-clad in some cases. Due to the abandonment of rams, battle

69) Canon Pietro Casola's Pilgrimage (as n. 60), pp. 299, 302.

70) Pryor, Digest (as n. 55), p. 278. Therefore »blue sea« in that period meant opposite hampering.

tactics changed. Rather than manoeuvring to obtain position to ram and sink, the objective was to diminish the enemy ship's ability to resist so that it could be boarded and captured while chained to the attacking vessel. Whereas the literary sources are inconclusive as to the dating of this shift, pictorial evidence, both from the West and from Constantinople, along with the early sixth century AD wrecks Tantura A and Dor 2001/1, suggests that it had occurred as early as the sixth century. The new warfare tactics remained unchanged, even with the introduction of the firearms and cannons, until the late sixteenth century, when the days of galley warfare in the Mediterranean were over[71].

Another new warfare technology employed by medieval Mediterranean warships had nothing to do with changes in hull design, but with alchemy: the »Greek Fire«. Its original milieu was Byzantine. The »Greek Fire« was a type of combustible which was either shot from tubes, *siphōnes*, whose mechanism was an adaptation of a Greco-Roman force pump, or hurled or poured. Its components and composition were a family secret passed on over several generations and are therefore unclear. The raw material, that is petroleum, was, however, gained from wells on the east coast of the Black Sea and processed in some way before use. Its first employment is indicated in Byzantine sources and it is attributed to a certain person from Syria, who helped the Byzantines to repel the Muslim siege of Constantinople in 674 by burning the attackers' ships. The Byzantine sources do not reveal the secrets of the fuel, neither what the tubes were made of, nor its method of projection. The Muslims who captured Byzantine fire-ships also acquired the secret of the *siphōnes.* In Latin sources, the use of throwing combustible through *siphōnes* is only attributed to the Venetians in 1081. In Byzantine sources, the *siphōnes* were positioned one at the prow, below foredeck, and at least two others along the sides, rarely on the stern as well. There were also hand *siphōnes* used by men stationed on flying bridges running from the mastheads of ships. The use of this tactic, however, requires completely different objectives and in fact, when in use, annulled the above-mentioned tactic that relied on spurs. In Byzantine sources the employment of »Greek Fire« is reported until the late twelfth century, but in 1203 the Byzantine galleys for the protection of Constantinople against the Fourth Crusade, according to both Byzantine and Western Sources, were not equipped with this weapon. The reason for the falling out of use of this device is still an enigma. The traditional cold weapons, the ship hulls and the upper spurs, on the other hand, remained in use.

71) Pryor/Jeffreys, The Age of the ΔΡΟΜΩΝ (as n. 3), pp. 134–146 and p. 146, fig. 10, pp. 152, 384; on pp. 378–382 the authors discuss the various types of weapons on Byzantine warships, their use according to different objectives and their parallels, or not, in the Muslim and the Western Latin worlds. Mor, The Socio-economic Implications (as n. 48).

XI. Steering, manoeuvrability and propulsions

Until the early fourteenth century, both sailing ships and the various types of galleys carried stern quarter steering oars (*timoni*) that originated in the ancient period. Furthermore, both were propelled by a lateen-settee rig, whose origin in the Mediterranean dated back to pre-Christian small merchant crafts (fig. 4). The Lateen sail was finally adopted at the turn of the sixth century. It has been persuasively demonstrated[72] that the lateen/settee sail possessed comparable sailing performances to the square sail. The adoption of the lateen/settee was due to reasons of cost reduction, because it required less financial means to build and maintain than did square sail. Indeed, the lateen sail allowed economising construction and maintenance, because it had fewer rigging components than the square sail, such as: brails, brail rings and bowlines. Its widest adoption resulted from changes in Mediterranean society and from the declined economy that characterized the early Middle Ages[73]. Not accidentally, it was readopted parallel to the introduction of the frame-based hull design. Iconographic evidence points to continuity in its technology and practical application from late-antiquity until at least the late eleventh century AD. Literary descriptions of Venetian ships from the late eleventh century point to changes that took place in the masthead structure that produced a barrelled cross-nest. This change had several impacts. First it required a stronger mast and standing rigging; second, a handling of the sail that resulted in »dipping« of the yard behind the mast, while going about the front, rather than being taken around, as was hitherto the case. And finally, it increased the scouting as well as military capacity of the vessel, by positioning extra fighting structures on the vessel[74]. Only from the early fourteenth century onwards did the square sail regain its predominant role in the Mediterranean, but only on sailers, as discussed below.

XII. Evolvements in war crafts

By the tenth century the ordinary warship was the *bireme*, termed *dromōn* by the texts, with 100–108 oars on deck. This oarage system enabled the *dromōn* to be faster with greater manoeuvrability, than the monoreme. In the late eleventh century Italo-Norman chronicles use a new term, *galea*, which points to a Byzantine provenance of the ship in question. However, considering the absence of records of construction, it is impossible to know if these were *monoremes* or *biremes.* All that is known about them is that they had

72) Pryor, The Mediterranean Round Ship (as n. 53).

73) Whitewright, Efficiency or Economics? (as n. 51), pp. 89–102; Id., Technological Continuity and Changes: The Lateen Sail of the Medieval Mediterranean, in: Al-Masaq: Islam and the Medieval Mediterranean 24/1 (2012), pp. 1–19.

74) Pryor, The Mediterranean Round Ship (as n. 53), pp. 59–76.

fine lines and were fast. To judge by three miniatures in the early twelfth century ›Annales Ianuenses‹, they resembled the Byzantine bireme *dromōn.* However, iconographic evidence of the 1060s or 1070s reveals a change in the oarage system of the *bireme galeae* in the Latin West (or at least in Sicily and South Italy)[75] that caused the *dromōn* to decline as a battle ship. From then on it was used merely for transport before disappearing entirely. In the new oarage system, called *alla zenzile*, two oarsmen each rowed single oars from the same bench above deck, while using a stand-and-sit stroke as opposed to the fully-seated stroke of classical and Byzantine galleys. The stand-and-sit stroke permitted more power to be applied to the oars, increasing the speed and resulting in greater endurance on the part of the oarsmen. It is argued that this system (that involved other changes) must have also produced greater carrying capacity and increasing cruising range, because the holds were freed for spare gear, armaments and especially provisions and water supplies. Furthermore, these *bireme* galleys gave the Latin West technological superiority over the Byzantine and Muslim worlds, whose merchant marines and navies declined and which, in the twelfth century, adopted the Latin *galea* (known in the Byzantine sources as *katergon* and *taretes*)[76].

From the late thirteenth century the *alla zenzile* system was applied to a *trireme:* A third rower was added to the existing two, each one of them holding an oar on the same bench. The system evolved first in Barcelona. Frederic Lane argues[77] that the increased speed of voyages (attributed to the use of the compass and the marine chart in the late thirteenth century) as well as the economic growth that created a demand for more voyages influenced the introduction of these vessels which were using oars and did not solely depend on wind. However, due to limitation of muscle energy rowing could be done for only very short distances and mainly for entering or leaving ports. Merchant galleys of all sorts mainly were sailors, unless also in combat necessities. There was indeed an economic reason for ›invention‹ of this type of galley. One has to bear in mind that shipbuilding industry was private practice, even in Venice until the fourteenth century. With the increase of frequent naval confrontations between the Venetians and the Genoese in the eastern Mediterranean merchants, captains and ship owners looked for a nautical technology solution that would provide safety, mainly for the luxurious eastern commodities, and minimize protection costs caused by employing galleys to escort the merchant ships. Such a solution was essential for Venice with the permission to sail in winter and the increase in number of convoys to the eastern Mediterranean. The loss of one convoy or part of it could have caused to sever damage. From the 1290s onwards, their hull was enlarged

75) Anticipating the traditional dating of its introduction by nearly a century.

76) Pryor/Jeffreys, The Age of the ΔΡΟΜΩΝ (as n. 3), pp. 128–134, 430–437.

77) Frederick C. Lane, Venetian Ships and Shipbuilders of the Renaissance, Baltimore 1992. I, however, disagree with Lane's argument regarding the increased speed of voyages (attributed to the use of the compass and the marine chart in the late thirteenth century). As above-said, the speed of voyages had already increased in late twelfth century.

accordingly, a feat made possible by setting the benches at an angle and adjusting the outrigger. These vessels had the lines of galleys but they were longer, wider, and deeper, thus accommodating sizable cargoes. From the 1320s onwards, they could carry about 150 tons with an average crew of 150, meaning a decrease of more than 70 per cent in labor costs alone. Armed like galleys, they carried precious far-eastern and Levantine commodities at much lower costs than sailing ships escorted by galleys. In the early fourteenth century, Genoa became the last to adapt the *trireme* system, which became ubiquitous in galleys by 1350[78)].

In mid-fifteenth century Venice the increase in merchant galleys' sizes in practice turned them into three-masted sailing ships, ships of the line for pilgrim voyages. Although their superstructures and, more faintly, their proportions preserved the memory of their origin as oared ships, they were longer, wider and deeper, thus providing more room for sizeable amounts of cargo as well as provisions and water, which allowed them to stay at sea for longer. The merchant galleys had a higher, yet less sharp prow than the light galleys (though with a spiron or a beak) and used both lateen sails and oars; these, however, arranged *alla zenzile* like on light galleys, were only auxiliary[79)].

The introduction of the *alla zenzille* system in the late twelfth century West contributed to the development of a new type of oared vessel, namely galleys for horse transport, known as the *uscerius/uxerius* (from the Arabic *'ushārī*) and, by the thirteenth century, under the name *tarida.* The freeing up of the holds by removing oarsmen from below deck must have given Western vessels a greater carrying capacity (thirty to forty horses) than Byzantine ones, which could carry only twelve. Like the Byzantine horse transporters, they had ports, sealed when at sea, and ramps at the stern for embarking and disembarking horses. They represented an improved version over previous horse carriers, not only in terms of hold capacity but also in terms of airing the much larger number of animals, either by enabling the quarter ports to be opened when beaching en route, or by some form of forced ventilation into the holds. From the time of the Third Crusade onwards, this innovation contributed to the revolution in the transportation of Crusaders and their horses over the long distances from Europe to the Levant[80)].

78) Federico Foerster Laures, The Warships of the Kings of Aragón and their Fighting Tactics during the 13th and 14th Centuries in: International Journal of Nautical Archaeology 16/1 (1987), pp. 19–29; Laurence V. Mott, Ships of the Thirteenth Century Catalan Navy, in: International Journal of Nautical Archaeology 19/2 (1990), pp. 101–112 and fig. 13; Michel Balard, La Romanie génoise (XIIe–début du XVe siècle), Genova 1978, vol. 2, pp. 547 f., 550 f.; Pryor, From Dromōn to Galea (as n. 30), pp. 101–116; Frederick C. Lane, Venetian Ships (as n. 77), pp. 9 f.

79) Ibid., p. 16.

80) Pryor, From Dromōn to Galea, (as n. 30), pp. 125 f.; Id., Digest (as n. 55), pp. 289 f.

XIII. The North-European influence on mediterranean technology

The next phase in innovative shipbuilding technology took place in the fourteenth century and affected merchant sailers, with the introduction of a new type of ship into the Mediterranean, the *cocha*, derived from the northern *cog.* Unger, however, argues that by the fourteenth century the term *cog* was not specific, but simply implied a large, single-masted, square-rigged vessel. Unlike the northern cogs, their southern counterparts were built with the »frame- based« Mediterranean shipbuilding technology, while adopting the original stem and stern posts with castles, the capacious hull with flat bottom and the northern steering and propulsion mechanisms. The cog's features were not simultaneously adapted in the whole Mediterranean. The northern *cogs* appeared for the first time with the northern Crusaders fleets in 1217 and then in 1270[81]. The Genoese notarial acts of 1286 and 1292 are the first to mention *choche*, which came from Bayonne in the Biscay. They transported alum from Phocea in Asia Minor out of the Mediterranean. *Coche* also appear in early fourteenth century Genoa as transporters of other bulky low valued merchandise from the Aegean to Flanders. This evidence predates the traditional view discussed, among others, by Balard, Hocquet and Friel that the first reference to the *cocha's* actual use in the Mediterranean dates to 1302 or 1312, or that it goes back to the invasion of pirates and their *coche* from Biscay, mentioned in 1304. After 1340, the Genoese replaced all their great merchant galleys going to Flanders and England with *coche.* A decade earlier, the *coche* replaced the Genoese *buzius navis* in the Mediterranean. In Catalonia, the *cog* replaced the *nau* towards 1380, then it disappeared for sixty years, before it became very common until the end of the sixteenth century. In Venice, although first introduced in 1310, the *cocha* only became dominant from the last quarter of the fourteenth century onwards[82].

It is hard to explain why the cocha's adaption in the Mediterranean was not concurrent. It is easier to explain why the Genoese were the first to do so, as they had to cross the English Channel and to face the Biscayan pirates on their way from the Mediterranean to England and Flanders from the 1270s onwards. The Venetians established a regular shipping line to the North Sea only in the second decade of the fourteenth century and only for a short time. Furthermore, Venice was more conservative with regard to the introduction of the cog, and even if built by private owners, the Senate took means to con-

81) Richard Unger, The Northern Crusaders: The Logistics of English and other Northern Crusader Fleets, in: Logistics of Warfare (as n. 55), pp. 251–274, here pp. 267 f.

82) Balard, La Romanie génoise, vol. 2 (as n. 78), pp. 555–557; Jean-Claude Hocquet, Le sel et le fortune de Venise 2: voilliers et commerce en Méditeranée, 1200–1650, Lille 1979, pp. 194–197; Ian Friel, The Carrack: the Advent of the Full Rigged Ship, in: Cogs, Caravels and Galleons (as n. 29), pp. 77–90, here p. 78.

trol their building[83]. The hull configuration of the vessel with strait sternpost enabled cutwater that reduced leeway considerably, allowing sailing upwind to Northern Europe and while crossing the Channel to England. The high sides of the *cocha* presented difficulties to climbing attackers from any sorts of galley. Thus, this structure protected the *coche's* defenders and alternatively their attacking crews, facilitating downhill throwing of projectiles toward the lower galleys. As late as the fourteenth century more than a dozen Venetian galleys overhauled a large Genoese *cocha* but were unable to take it until another Venetian *cocha* arrived to match the Geneose height[84]. The *coche's* high fore and aft castles provided battle platforms and allowed the crossbowmen, the professionals that handled the main weapon able to penetrate armor, time to aim and fire. Archers could also be stationed in the crow's nest crowning the mast.

The main steering and propulsion characteristics of the original northern *cog* copied by Mediterranean sailers during the fourteenth century were the stern rudder and squaire sail together with reef pints and bowline. The stern rudder was easier to use than the traditional two sided rudders in the Mediterranean *naves*, which became heavier and harder to handle with the increase of the ships' size. The stern rudder was also less vulnerable to collision and gave better overall control of the vessels by a bar attached to the tiller at 90° angle. The helmsman handling the bar was able to stand higher and watch the action of the ship[85]. In case the tiller was too long, as is the case with the fifteenth century authentic Catalan model made by a professional for ex-voto purposes, the helmsman could not see the direction in which he steered and had to rely on commands that were called to him from the quarter deck[86].

The one square sail served for all kinds of weather, the expanse of canvas being enlarged or decreased at need by the use of bonnets. Lifts were added, easing the hoisting of the sails. A more complex system of ropes allowed better control of the sail. A bowline was used to prevent the forward edge of the sail from curling away from the wind[87]. In lateen rigged ships, the sails had to be changed according to the wind force and their handling on large ships could require a greater number of sailors than the average crew of an equivalent square-rigged ship. With the increase, from the twelfth century onwards, of ship sizes, the yards of the sails could weigh up to 6.5 metric tonnes, by the thirteenth century could be carried on two big masts, as in the case of the ships promised by Genoa

83) Hocquet, Le sel et le fortune de Venise (as n. 82), pp. 194–197; Id., Productivity, Gains and Technology Changes. Venetian Naval Architecture at the End of the Middle Ages, in: The Journal of European Economic History 24/3 (1995), pp. 537–556.

84) John Dotson, Ship Types and Fleet Composition at Genoa and Venice in the Early Thirteenth Century, in: Logistics of Warfare (as n. 55), p. 67.

85) Hocquet, Le sel et le fortune de Venise (as n. 82), pp. 104–109; Friel, The Carrack (as n. 82), pp. 78 f.

86) Sjoerd de Meer, The Coca of Mataró: A Medieval Ship Model, in: Splendour of the Medieval Mediterranean (as n. 20), pp. 573–579, here p. 578.

87) Ibid.; Unger, The Ship in the Medieval Economy (as n. 5), p. 86; Friel, The Carrack (as n. 82), p. 78.

to King Louis IX in 1246. Indeed, the replacement of the three-masted lateens by a single main square sail reduced the crew numbers responsible for managing the ship by 50 %: one man per ten tons, as compared to one man per 5 tons employed on the lateeners. In Venice, calculated productivity gain rose by 3,5 points from 1229 to 1400[88]. This made the *cocha* economical. However, the *cocha* was also economic in terms of shipbuilding costs. Since it was tubbier than the contemporary Mediterranean cargo, less wood was needed to build the hull[89]. The timing of the replacement – not the introduction – of the *naves* by the *coche* all over the Mediterranean is not accidental. It followed the Black Death in the 1340s, as a result of which there was a substantial reduction in both population and ultimately in working hands on board. With the quick recovery after the Black Death, many mariners found themselves without work due to the adoption of the *cocha.* Many had to look for hard labour on merchant galleys[90] and may have turned to piracy that flourished in this intensive period of long distance trade within the Mediterranean as well as between the Mediterranean and Northern Europe.

That being said, it should be noted that the square, in comparison with the lateen sail, only allowed the better weathering of astern storms. The single square sail, moreover, was effective only when carrying winds prevailed; to improve the *cochas* maneuverability, a lateen mizzen, whose purpose was to improve bite on the helm and steering, was introduced close to the stern. It was rarely handled at the same time as the mainsail, so there was no increase in crew numbers. This improvement enabled the *cocha* to make round trips between the Mediterranenan, the Atlantic and northern Europe[91]. The first evidence for two-masted *cocha* in the Mediterranean is a Catalan contract of 1353[92].

Similar economic calculations caused the introduction to the Mediterranean, more specifically to Barcelona, of another type of northern vessel in circa 1350, namely the *keel*, which was common in England and Biscay. A mid-fourteenth century *keel* graffito in Barcelona shows a conglomerate of both northern and Mediterranean elements. It showed a longer and narrower vessel than the *cog*, with stem and stern posts which curve upwards until they are nearly vertical. Its hull configuration, the square-rigged main mast and the stern mounted rudders are northern whereas the reticulated sails and the presence

88) Hocquet, Productivity, Gains and Technology Changes (as n. 83).

89) Unger, The Ship in the Medieval Economy (as n. 5), p. 185.

90) Frederick C. Lane, Venetian Seamen in the Nautical Revolution of the Middle Ages, in: Id., Studies in Venetian Social and Economic History, ed. by Benjamin G. Kohl/Reiner C. Mueller (Variorum Collected Studies Series 254), London 1987, pp. 413–415.

91) Unger, The Ship in the Medieval Economy (as n. 5), p. 186; Id., The Northern Crusaders (as n. 81), p. 270.

92) Friel, The Carrack (as n. 82), p. 80.

of a mizzen mast, probably together with a lateen sail, are of Mediterranean origin. This graffito represents the earliest square-rigged medieval ship with a mizzen[93].

The wrecks of the two above-mentioned fourteenth century Catalan ships, the Culip IV and the Les Sorres X, prove both the persistence of older traditions as well as the creation of hybrid types in such coasters. The Culip IV carried two lateen masts and stern quarter steering oars. The Les Sorres X carried one lateen mast but stern quarter steering oars with stern post rudders[94]. Used for local, coastal and riverine shipping, in contrast to long distance trade, these vessels may reflect a phase of trial and error in the handling of new inventions.

It has to be remembered that for all types of galleys, war and merchant, whose crew numbers remained constant due to defensive requirements and rowing, adopting the square sail was not economical. Even when, in Venice, these vessels grew in size and became great galley sailers for pilgrims, they even carried three lateen masts, while the sail on the main mast was in some cases replaced by a square one. It has been suggested that these improvements enabled them to claw off the great trunk routes along the coasts[95]. Another proof for this practice is the re-appearance of the chain bilge pump. This device, introduced by 100 BCE, was intended for collecting sea water that seeped through the seams to the bilge, the lowest point in the hull. Bilge pumps were only found in big ships over 150 tons and certainly in the grain ships that could ride out storms. They were almost identical to the pumps of eighteenth century ships and vital equipment for large wooden eighteenth and nineteenth century sailing ships. Bilge pumps attest to upwind as well as year-round seafaring. No remains of bilge pumps were found on ship-wrecks from the afore-mentioned sixth century Dor Lagoon. Wilson convincingly argues that the decline of shipwrecks found impairs statistics and concludes that the lack of literary evidence was due to decreases in ship sizes, because smaller ships did not use bilge pumps[96]. The Jewish/Muslim shipping from Egypt to Sicily documented by the Geniza letters attests to bailing water by hand. No bilge pumps were mentioned by Ibn Jubair or Jacques de Vitry in the aforementioned sturdy Genoese ships that rode the high sea upwind. They do appear, however, in fifteenth century descriptions. For instance in Pietro Casolas pilgrimage: »Down below, in the place where the pilgrims live, is the well for bilge water […] and this well does not contain human filth, but all the water which visibility and invisibility enters the galley filters through and collects in that well […]. The well has to be pumped out once in every day, but in rough weather has to be drawn out of it without cessa-

93) Laurence V. Mott, Medieval Ship Graffito in the Palau Reial Major at Barcelona, in: Mariner's Mirror 76 (1990), pp. 13–22.

94) Hamelink, Catalan Shipbuilding (as n. 41).

95) Lane, Venetian Ships and Shipbuilders of the Renaissance (as n. 77), pp. 10 f., 35 f.

96) William W. Wilson, The Economic Influence on Developments in Maritime Technology in Antiquity, in: Maritime Technology (as n. 5), pp. 211–234, here p. 222; decrease in ship size was well before the seventh centuries AD, as claimed by Wilson.

tion«[97]. Nevertheless, one could assume that the Genoese vessels leaving the Mediterranean for England and Northern Europe from the 1270s onwards, as well as those of the Venetians who followed them for a short time in the first half of the fourteenth century, were equipped with such pumps. Scholars have not mentioned it yet, either because it was obvious, or, which is more plausible, because such a technical subject matter was not of interest to historians, so they ignored it completely. Having said that and returning to the great Venetian galleys of the fifteenth century, their above-mentioned round hull design encouraged considerable leeway while sailing windward. Bilge pumps were crucial, because of the need to heel when biting into the wind.

The great galleys also adopted the stern rudder without, however, straightening the stern. Instead, a special stern rudder was developed to suit the curved stern posts. Whereas on Genoese galleys the stern rudders were fitted, like on the *coche* and *carracks*, with a tiller, on Venetian galleys the rudder shaft ended simply in a circular or a spherical knob. Most probably the Venetian galleys had rudder tillers which were removed when not needed. One still has to await the results of the research on the graffito found at the internal part of the bow of the above-mentioned fourteenth century galley found on the Island of San Marco of Boccalama in the Venice Lagoon, which represents a trireme with a stern rudder (fig.10). The Mediterranean galley shipbuilders, however, remained loyal to the traditional two side rudders as opposed to the stern rudder. Having said that, an iconographical representation of a late medieval Byzantine galley shows only a stern rudder on a straight stern[98].

From the second half of the fourteenth century onwards, a new type of ship, the *carrack*, appeared in the Mediterranean, which, in the second decade of the fifteenth century, became the *navis* in the West, but was only used in small numbers in the Byzantine and Muslim worlds of the Eastern Mediterranean. Friel claims that The Venetian Pizigani's portolan chart of 1366[99] marks the first evidence for this new type of vessel which retained several main characteristics from the fourteenth century until the first half of the sixteenth: a large, wide, deep and imposing hull by the standards of the time, with two to three decks, ideal for bulk cargoes, a flat floor at least amidships as a legacy from the *cocha*, a curved stem with a marked rake and castles fore and aft, the fore castle usually substantially higher than the after castle, and, last but not least, a mounted rudder on a vertical sternpost. The gradual disappearance from iconography of this profile in the sixteenth century is one of the signs of the *carrack's* gradual transformation into another type of large ships[100]. The *carrack* introduced propulsion innovations by the adoption of

97) Canon Pietro Casola's Pilgrimage (as n. 60), pp. 325 f.

98) Gertwagen, Characteristics of Mediterranean Ships (as n. 20), no. 46, p. 559; McManamon/D'Agostino/Medas, Excavation and Recording of the Medieval Hulls (as n. 25). The authors wrongly interpreted the upper spur as a ram.

99) Friel, The Carrack (as n. 82), pp. 77–83.

100) Ibid.

the foremast. An ink drawing dated to 1409 from a manuscript of a compilation of ordinances for Barcelona shows a foremast with a square sail. Mott reasonably argues that this evolution took place at the end of the fourteenth century, parallel to the growth in ship sizes that required the necessary technology to balance out the sail plan for handling these vessels[101]. It is thus the earliest evidence for the full-rigged ship with the essential design elements of the Age of Exploration, predating the customary dating of the evolution by almost a hundred years. The other major improvements took place in the 1460s with the introduction of a topsail on the main mast, which contributed significantly to the drive-section of the ship's sail plan without greatly impeding its handling. By the late 1470s, a lateen rig, »bonnaventura«, enabled a course at 80° to the wind and consequently to claw off the lee shore. This addition brought to completion the full-rigged ship of the Ocean discoveries[102], and was adopted by the Iberian *caravel*, the ships that Christopher Columbus set out on for his expedition in 1492.

XIV. End notes

The current study has addressed various aspects of history via a discussion of shipbuilding technology: political, economic, military and cultural phenomena of various Mediterranean political entities from the Byzantine period until the sixteenth century, while also considering correlations and interdependencies between all factors. By doing so, the paper emphasizes the important role the sea played for civilizations around the Mediterranean coasts, where people had intimate knowledge of maritime space and life, Venice and Genoa being a prominent example, as well as for those living on terrestrial parts of the European continent. For instance, the north European and central European crusaders learned quickly the advantages of marine transportation as compared to arduous terrestrial travel. Dedication to a religious cause induced them to risk their physical and mental health when boarding a vessel. They, together with other pilgrims, were pardoned for their sins before reaching the Holy Land. On the other hand failures in successfully crossing the sea endangered the accomplishment of their goals on land. The Crusade of 1239 that left from Marseille was hit by an easterly storm two days from Acre and scattered. The crusaders eventually reached Acre later in September, where »they rested themselves for a time because of the great distress and the great fear and great peril that they had had on the sea«[103]. Louis IX lost the momentum of surprise in 1249 because his

101) Laurence V. Mott, A Three-Masted Ship Depiction from 1409, in: International Journal of Nautical Archaeology 23/1 (1994), pp. 39 f.
102) Ibid.
103) Continuation de Guillaume de Tyre (as n. 65), pp. 483–639, here p. 529; Gertwagen, Harbours and Port Facilities (as n. 65), pp. 100 f., note 26.

fleet encountered storms sailing from Cyprus to Damietta, where the Mamlukes ultimately succeeded in capturing him and his army[104].

The consciousness of risking lives allowed the evolvement of cults of maritime saints that had ramifications on politics and economy. This subject matter deserves a thorough discussion beyond the scope of this paper. Only one telling example is the cult of St. Nicholas of Myra, an important port of call in southwest Asia Minor due to the difficult navigation conditions in the area and, as such, a thriving Roman/Byzantine port town. Realizing the importance of this cult, the people of Bari claimed his bones, early on in the eleventh century, for their home town and built a church for him. Bari thereby aimed to become the main port of call for pilgrims going to the Holy Land. Building a shrine for a maritime saint, thus promising his protection, was a smart move. Venice who thrived to be the only port of call in the Adriatic to the Holy Land also claimed to bring those bones from Myra, while returning from the Holy Land in the early twelfth century. The Venetians built a shrine on the Lido Island for St. Nicholas, a cultural and peaceful strategy to gain economic and political superiority. As is well known, the cult of St. Nicholas was expanded by mariners, merchants and pilgrims to the Western Mediterranean and beyond.

Ship design depended on two main variables: Human skill and the constraints that induce human skill to find solutions, usually economic and logistic. Discussing human skills, the paper has illuminated, via the use of marine archaeological data, the highly developed and specialized art of hull design and related efforts of shipwrights to preserve their position in times when practical knowledge started to be transferred into writing from the late twelfth century onwards.

Economic constraints following the gradual collapse of the Roman Empire that led to shrinkage in Mediterranean maritime commerce caused to changes of shipbuilding technology of hull designs, because the Hellenistic/Roman hull was expensive, since its elaboration required, among others, great amount of wood and time. As long as shipbuilding skills were orally obtained through apprenticeship and practice, shipmasters proceeded with the traditional ›cheap‹ practice, even after the period of economic recovery from the eleventh century onward. In fact, the Byzantine and medieval shipmasters did not have any means to compare their technology of hull designs to that elaborated of the Hellenistic/Roman period. On the other hand, the ›cheap‹ practice enabled the medieval shipmasters who quite often were the ship-owners, to build more ships than in the previous period, thus increasing their profits. In fact, all that mattered were such economic considerations. Indeed, in retrospective, the ›cheaper‹ hull design did not prevent seafarers from using the same sea routes as their Hellenistic/Roman predecessors, albeit the risks involved. Furthermore, economic constraints vis-à-vis security calculations induced

104) Ibid., p. 101.

searching for nautical technology solutions such as the adaption of an hybrid type of galley, merchant galleys for the most expensive commodities.

Economic variables also had effects on social conditions. For instance, mobility affected the status of personnel working in the shipbuilding industry: caulkers, who stood at the low end of the professional ladder in shell-based design of the Hellenistic and Roman period, were upgraded with the establishment of the frame-based design. The replacement of the *naves* by the *coche* had other implications, in that this process economized expenses for ship owners, merchants and captains, increasing their profits as well as unemployment among simple sailors. Since the sea was their only livelihood, failing to find employment on other types of vessels, that is merchant galleys, they turned to piracy, thus contributing to a phenomena that in itself evolved rapidly with increasing maritime trade.

Another interesting social aspect discussed by this paper is the difference in attitude to life on sea between two of the main medieval and early modern Mediterranean sea powers, Genoa and Venice. The Genoese captains, despite their intimate knowledge of the qualities, or better, limitations, of their ships' hull designs, risked taking to sea in winter and speeded transport of sailing by choosing the shorter sea routes biting into strong winds, instead of using the long safer coastal routes. One could safely presume that their motive was purely economic, namely not for passengers, either merchants, pilgrims, or troops with or without their horses. The Venetians displayed a more conservative and moderate attitude, permitting winter sailing only in the early fourteenth century, allegedly due to evolutions in nautical navigation, a theory which, as discussed above, is overestimated. More probably Venice could not allow itself to be too far behind Genoa.

Last but not least, a crucial message the current paper highlights is the importance of technological issues for the discipline of history, quite separately from the history of technology that stands by its own merits as an independent field of study. In other words, technological aspects are essential tools for any historian, who wishes to address history issues analytically and not only descriptively, and for anyone interested in tackling questions starting with »why« and not merely with »how« and »what«. In our case, the current paper has emphasized the importance of nautical technology within the field of maritime history.

Summary: Shipping and Nautical Technology of Trade and Warfare

The current study examines various aspects of history via a discussion of Mediterranean shipbuilding technology and ships' design as well as shipping between the eleventh and the sixteenth century AD. The paper addresses the following questions: was ship design the product of mere technological invention or the result of economic or political environments that induced technological solutions? How did nautical technology contribute

to seafaring capabilities and to spatial and horizon shrinkage in the Mediterranean and beyond? Did nautical technology affect the strategy and tactics for the control of marine space? In what way did the evolution of nautical technology impact the status of various professionals involved in the industry, if at all.

Political, economic, military and cultural phenomena of various Mediterranean political entities from the Byzantine period until the sixteenth century are discussed, while also considering correlations and interdependencies between all factors. By so doing, the paper emphasizes the important role the sea played for civilizations around the Mediterranean coasts, where people had intimate knowledge of maritime space and life. The paper highlights a crucial message regarding the importance of technological issues for the discipline of history, quite separately from the history of technology that stands by its own merits as an independent field of study. In other words, technological aspects are essential tools for any historian who wishes to address historical issues analytically and not only descriptively, and for anyone interested in tackling questions starting with »why« and not merely with »how« and »what«. In our case, the current paper has emphasized the importance of nautical technology within the field of maritime history.