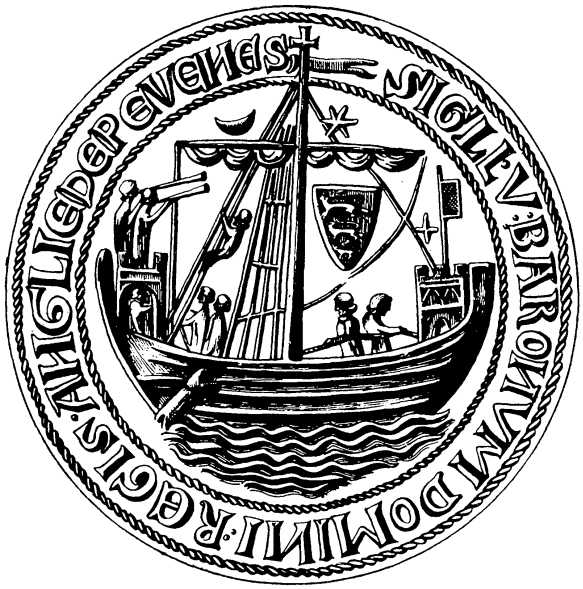


3 CRUSADERS' SHIPS AND COGS: 1000-1250

After the Viking attacks and the breakdown of government in the ninth and tenth centuries, political authority in western Europe tended to devolve on more local authorities. Though the evolution was different in France, in England, in Scandinavia and in the Empire the result in the years after 1000 was towards more effective if still largely localised government. The consolidation of authority, be it by kings, regional heads or local nobles, and the institutionalisation of conflict led to a decline in violence or at least channelled the violence so that it became more regularised, more predictable and less severe. The Church combined with royal governments to promote some stability, a stability based on the at least tacit agreement of landowners. To achieve that stability kings needed and got troops and money from the towns. Those products of the rising volume of commerce were for the most part directly subject to the kings and became a major source of royal power. The result of political evolution by the thirteenth century was the monarchy of the high middle ages, probably best represented by France under King Louis IX, St Louis.

In the Mediterranean politics followed a different course. The Iberian

Illustration above: English warship with castles of keel type, Pevensey, oldest town seal, thirteenth century.

kingdoms formed in the reconquest of the peninsula from the Moors closely followed the northern pattern of consolidation. In Italy, on the other hand, towns enjoyed virtual independence. Efforts by the Holy Roman Emperors, especially Frederic I Barbarossa and Frederic II, to bring these towns under Imperial control led to long wars but to no change in their political status. The economic expansion of the period and the rising total income of townspeople added to feelings of self-confidence and commitment to independence growing out of the wars. The crusades constituted another reason for the political strength of Italian city-states. Pilgrimages to the Holy Land as well as attacks on Muslim ports and shipping were already popular before Pope Urban II called in 1096 for an expedition to wrest control of the Holy Land from the Arab government. The difference was in the unprecedented scale of response to Urban's call. Soldiers and pilgrims filled the available ships of the Italian ports. The successful conquest of the Holy Land by 1100 and the establishment of Latin Christian principalities there created a continuing demand for transport for support of those states. The Muslim efforts to drive out the Christians led to a protracted if sporadic war placing irregular demands on Italian shipping. The Italian towns were the necessary intermediaries for the crusader states. It took only two or three years after Urban II's call for the towns to realise they might gain from giving the crusaders naval support. For their invaluable help Italians got trade concessions in the Levant. This was another reason for a rise in the volume of shipping. One of the great expeditions to reinforce the Christian states, the Fourth Crusade, was diverted and ended with the conquest of Constantinople in 1204, which further weakened an already struggling Byzantine Empire. The crusades were important to the Mediterranean for both economic and political reasons. The major crusades meant a large and sudden demand for shipping services, over long distances. The involvement of Italian city-states in the fighting drew them both politically and commercially further east. In the end the contest between Christian and Muslim, between the Byzantine and Fatimid Empires, was replaced by competition among the new naval and economic powers in the Mediterranean, Venice, Pisa and Genoa.

Italian towns enjoyed unquestionable commercial success from the tenth to the thirteenth centuries. That success coincided with the ever more general adoption of skeleton-building. By no means was the new approach to shipbuilding the sole reason for commercial growth in the Mediterranean during the high middle ages. Skeleton-building was known in all parts of the Mediterranean from the eleventh century on

yet not all regions and ports enjoyed the same pace or scope of commercial success. Some Italian towns, especially those with the greatest degree of political independence, were better able to exploit the new possibilities. The towns of southern Italy, united under Norman rule, while still prosperous and playing a significant role in Mediterranean shipping, did not fare as well as their counterparts in the northern part of the peninsula. There was a shift in the commercial balance from the eastern to the central Mediterranean in the period and yet there is no evidence of Italian ships being superior, more advanced in design than those of the Greeks or the Muslims. The surviving written evidence refers largely to ships used by crusaders, however. Those ships constituted a special case. They give an impression rather than a precise picture of vessels used in regular cargo and passenger services. Moreover, the information is concentrated in the towns of Venice and Genoa, the two primary ports of debarkation for crusaders, so it leaves out the trading towns in central and southern Italy and in Catalonia in Spain. Despite the problems with the evidence, it is clear that the major breakthrough to the use of skeletal building of frames and hulls on ships can only be part of the explanation for the rise of Latin Christian traders to a position of dominance in the Mediterranean. It is possible that, over the long term, access to stands of tall hardwoods, especially oak, may have offered a comparative advantage to northern Italians and Catalans because such trees were needed to make the heavier ribs typical of the new system of building. Throughout the Mediterranean, after the adoption of skeleton-building, there was typically just elaboration and extension of existing designs rather than significant breaks with past practice.

From 1000 to 1250 galleys were built as before. There was little or no improvement over the tenth-century larger version with castles. These vessels still showed their ancestry in the Roman light galley. By the thirteenth century there was a standard galley rig with two masts, the forward mast raked forward. The second mast was stepped just astern of the middle of the ship. On some galleys there was a third mast. Each had a single lateen sail. A second set of smaller yards and sails was carried for strong winds. With a good breeze dead aft the galley would rig a square sail; it was the awning for protecting the rowers hung from the longest yard. So Mediterranean sailors knew about the square sail. They preferred the lateen because of its versatility. On galleys there was plenty of manpower to handle it, so the labour requirement was no constraint. The abundance of manpower was expensive. The oars, each manned by one rower, were still the principal

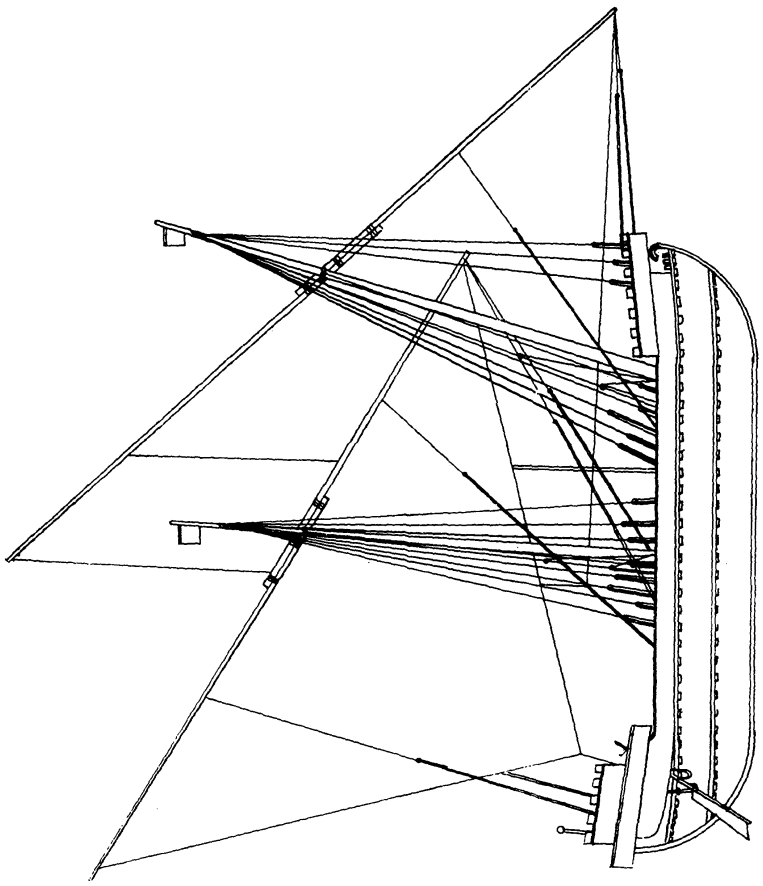
form of propulsion. Hulls were long relative to the beam, setting such galleys apart from the round ships which relied exclusively on sails for power. Lengths of such ships ran from about 12 to 25 metres. They carried 20 to 30 oars but longer galleys had as many as 60 or even 80. No matter the length, they were never more than 2 metres high. Control of the galley came from two side rudders at the stern. The hull was carvel-built and rode low in the water.[a] The cargo space was, of necessity, small by almost any standard. Galleys were fast, cost less to build and were more easily defended than cargo ships. They were the carriers for short haul of relatively light goods and long haul of highly valuable goods. They served for the distribution within the western Mediterranean and the Adriatic of goods brought from the East. They also carried the wealthiest crusaders and pilgrims to the Holy Land, people who could afford to pay a premium for speed. Over-all they were more comfortable and safer and there was less chance of sickness than with sailing ships.[1] The galleys were also warships. They were ideal for attacking pirates or competitors at sea. All the Italian towns had their collection of galleys for trading and for defending their interests. They found, as did the Byzantines and the Arabs before them, that the galley had to be used for naval activity in the Mediterranean with its relatively calm waters and light and variable summer winds.

Pressure for design change was clearer in the case of round cargo ships. All together the changes in demand led to an increase in the number and size of sailing ships. Crusaders needed large ships since they went to the Holy Land with retainers, equipment and horses. They also generated highly concentrated demand for transport. Though some crusaders made the voyage to Syria each year, expeditions were typically great events mobilising large numbers of soldiers who all had to be moved in one season. Along with the sudden demands of soldiers there was the sustained and growing demand for the carriage of bulk goods. Oriental goods came across the Indian Ocean along the route used by Romans in the third century AD. They also came by caravan through Mesopotamia and by land across Central Asia to ports on the Black Sea. There were also many goods called spices, goods requiring some care in shipment, relatively rare and of high price for their bulk, which could be and were produced along the shores of the Mediterranean. Used principally for seasoning food and for medicinal purposes, they were the logical items to be added to the budgets of people with rising incomes. Such goods could be moved in larger quantities as demand rose and that too raised the number of ships in commerce. Those ships still had to face pirates. There was no single dominant

naval power to stop piratical attacks and, though Venice deployed the most powerful naval force in the eastern Mediterranean, she did not use that force to defend peaceful trade. She, like other contending states in attacks on their enemies, acted much like pirates. The Venetians particularly took the opportunity to plunder the Byzantine Empire. Pirate fleets were made up of professionals of any nationality willing to sell their collective services to anyone offering them personal gain.[2] The belligerence which was the normal condition between Christian and Muslim, despite government truces and thriving trade across religious lines, increased the possibility for loss due to hostile action. The pirates did benefit from having more to steal. There were more ships sailing, carrying larger and more valuable cargoes.

Round ships, the carriers of bulk cargoes, were not defenceless. They still carried soldiers, often men specifically hired to protect the ship, who, of course, imposed an extra charge on the cargo. With sailing ships this could make the difference whether or not it would pay to ship a certain cargo. These ships moved along the coasts, rarely venturing into open waters. A through cargo which would fill the ship for a long-distance voyage was exceptional: one of the few through cargoes was the carriage of pilgrims and crusaders going to the Holy Land. In general round ships called at ports along the coast looking for a market for goods they had and for other cargoes to move to the next port. As time passed, these routes and trading relationships became more settled. Transportation became more regularised.[3] A commercial network or rather a series of such networks developed for the maritime republics. The Levant, Byzantium, all of Muslim Africa were integrated into Italian trading relations. These ships were slow because they stopped at each port and would wait for a favourable breeze before leaving. At sea they were slower than galleys because of the shape of the hull.

Design of Mediterranean cargo ships had changed from that of the seventh-century Byzantine coaster, but the similarities outweighed the differences. The use of lateen sails and the extreme reliance on internal frames for support of the hull were the two most obvious changes. Some data have survived for the exceptional cargo ships supplied to crusaders, and especially for those intended for the Ninth Crusade led by King Louis IX of France. He planned to attack Tunis and ordered ships from Genoa and Venice. The most impressive thing about the ships was their size. One of the vessels built at Genoa had four ship's boats, one of them equipped with 52 oars. The largest ship carried 100 horses, crusaders and their attendants. Vessels of that size could carry up to 1,000 pilgrims on a regular voyage. A capacity of 600 tons with a



11: Two-masted Genoese Sailing Ship Built for the Crusade of King Louis IX of France

crew of up to 100 men seems to have been the upper limit of mid-thirteenth-century Italian round ships. One Venetian ship was 36 metres long, without the overhanging castles. The keel was only 23 metres, the maximum breadth was 13.3 metres and the height 12.85 metres. It was among the 120 special ships for carrying horses ordered by Louis IX but, other than the addition of ports below the water-line to make loading and unloading easy, the vessel was designed like other big cargo ships. The waterline was probably at about the level of the first deck. Two decks were common on such ships but not necessary for lesser cargo ships carrying up to 50 horses. Vessels built at Genoa for the same purpose were similar and, if anything, slightly less beamy.[b] The length-to-breadth ratio was between 3:1 and 4:1 for all these ships.[4] These were special vessels but their rigging and sails seem to have been the same as for all round ships, no matter the size. The length-to-breadth ratio was higher, however.

On the largest ships there were three masts, but this was rare; the usual number was two. The mainmast was raked forward as with the galley rig. The masts were stepped in the keelson, the heavy timber on top of the keel. The mainmast would be about the same length as the ship itself, impressive in a vessel the typical 20 to 30 metres long. The yard for the mast, made of two spars fished together, was longer than the ship by as much as 30 per cent. The after- or mizzenmast and its spar were smaller but the spar was still longer than the ship. An extra spar was carried on board for each yard in case one broke. The ship also carried from four to seven sails, the surplus as reserve or for changing with a change in the weather.[5] While the orders of crusaders did lead to the construction of large lateen-rigged cargo ships, they appear to have been nothing more than imitations of earlier designs done to a larger scale. Certainly some adjustments had to be made to construct such large vessels but they were apparently minor, and Mediterranean shipwrights had no problem with the larger size. The crusaders' ships proved seaworthy. In fact the construction of the largest of crusaders' ships coincided precisely with the period when lateen-rigged cargo ships in the Mediterranean reached their maximum size, that is in the second half of the thirteenth century.

A smaller version of the round ship, the *tarida* as it was called in Genoa, had oars as well as sails which were, incidentally, large for the size of the vessel. It was obviously a compromise design, an effort to gain the best from the galley as well as the round-ship design. Such vessels owed more to the design of the cargo ship, the oars acting to supplement power – crucial for moving quickly in or out of port. The

tarida was used for the same types of jobs as other round ships. The larger the ship the greater the danger of loss each time it made port. For the frequent coastal trade the *tarida* was better suited. The use, and therefore the construction, of very large sailing ships depended on ports with relatively easy access existing at the ends of a route along which large cargoes could be carried at a profit. The use of larger ships also depended on the rise in bulk cargoes handled by Mediterranean shippers in the eleventh, twelfth and thirteenth centuries. The distances might not be great but a larger total volume of necessities such as salt, grain and olive oil was moved in the thirteenth century, and in larger ships. By that time the Venetian government expected sailing cargo ships to be of about 95-470 tons.[6]

Control on all round ships came from two side rudders at the stern which could be raised when in port. A second pair of steering oars might also be fitted, presumably larger and designed to be used in strong winds in the open sea. The hull was built with edge-to-edge planking. The posts were curved and the entire hull was rounded. Cargo was typically loaded and unloaded through the large openings, hatches, in the main deck. By the thirteenth century a third deck was sometimes added on larger vessels. At either end there were superstructures, castles, to accommodate passengers. For crusaders the number and size of these enclosed spaces were increased to house noble travellers. For merchants and crew a cabin or covered space at each end of the ship was usually enough. The addition of decks increased the volume of carrying capacity but the weight of capacity did not rise proportionally. Heavy cargoes could only be carried below. The main deck was kept clear when the ship was at sea for reasons of safety, thus placing a limitation on merchants, since to get the maximum out of the multiple-deck ships they had to get a mix of heavy cargoes for the hold and lighter cargoes for the space between the decks.

The frames and beams of these Mediterranean cargo ships were lighter and more numerous than on contemporary northern vessels, implying a need for more external protection. Heavy planks running the length of the ship, wales, were common. They were not to be found just at the load waterline, but were spaced evenly from the keel all the way to the gunwale. Stringers ran along inside the wales. In one thirteenth-century Italian ship the stringers were the only part of the vessel not of oak. At the bow the ends of one of the beams projected through the hull, apparently to hold the anchor and not to act as a bumper like the projecting beam-ends of northern ships. On larger ships, however, rows of projecting beam-ends ran along the sides. The beams may have

been secured to the tops of the ribs and served to keep them in place, thus reinforcing the skeleton. The beams also supported decks.[c] Travel on such a vessel could not have been comfortable with so many people on board. Yet there were surprisingly few complaints from pilgrims or from the knights going on the crusades, people who were not used to sea travel.

The greater volume of trade handled by cargo ships meant that they could expand their activities and increasingly replace galleys in the movement of all goods including luxuries. Galleys were thus left to function as warships. Certainly galleys were not completely displaced in the carriage of goods but the largest proportion of goods in volume and probably also in value went in round ships. That shift was aided more by the increase in the number and the frequency of sailings of round ships than by the increase in maximum size. By the thirteenth century the size of a ship was being measured in terms of the number of wine casks it could carry. There was a variety of different measures adopted, each port with its own variation, but the approach was usually the same. The reported figures can often create more confusion than clarification. Barrels had completely replaced jars for carrying bulk goods. The regular use of such a measure shows that round ships were carriers worthy of consideration. The measure was meaningless for galleys.[7]

The establishment of Fatimid power in North Africa and Egypt in the late tenth century contributed to the commercial expansion in Muslim lands which preceded that in Christian Europe. Tunisia was originally the centre of Fatimid power but the region declined when the capital was moved to Cairo and when the size of ships grew to the point where they could make continuous through voyages from prosperous Spain to the Levant without having to stop on the way. Attacks by Berbers from the interior from the 1050s on guaranteed the economic decline of Tunisia and a shift in the interests of both Muslim and Christian traders to possibilities further east. The Ayyubids replaced the Fatimids in the 1170s and ruled Egypt and Syria until the mid-thirteenth century. While they continued their predecessors' interest in naval affairs, they had as little success against Christian naval forces. By the end of the twelfth century those forces dominated the Mediterranean in the East as well as in the West. Even so the sea was still the main avenue for moving goods. Going overland was expensive, especially since it took so long compared to travelling by sea and river. While, throughout much of the middle ages, there was no strict distinction between vessels capable of sailing the high seas and those which could

be used on rivers, Muslim builders did produce types with some degree of specialisation. Seagoing ships could go from the Mediterranean to Cairo but typical practice was to take off goods and passengers in, for example, Alexandria and travel up the Nile by some riverboat such as *jurum* which were barges each equipped with one sail. There were seagoing barges, *qarib*, which carried heavy loads over long distances and were propelled by oars. The typical vessel for the Mediterranean, though, was the *qunbar* which appears to have been much the same as Byzantine and Italian cargo ships. In the largest version they carried three masts and as many as 800 men. Muslims operated galleys as well, though, as with Christian shipping, they seem to have been only infrequently used for carrying cargo. Indeed, distinction was made between merchant ships and warships at least in written records. By the mid-eleventh century the cargo ships could already carry up to 400 passengers. Even though these must have been large ships, it was still the practice to take them out of the water for repairs during the winter, a season when they never sailed.[8]

Political instability in North Africa, the establishment of first the Almoravid and then the Almohad states, acted to deter trade because of the intolerance shown by both religious sects to non-members and also the wars and piracy which were part of their growth and decline. There was only sporadic success in their establishment of naval forces. By the mid-thirteenth century almost all of Spain and the Balearic islands had been conquered by Christians and all aspects of North African commercial life had been gradually infiltrated by Italians and Catalans. Muslim ships became a rarity in the western Mediterranean. At the same time the new Christian kingdoms of Iberia expanded their naval forces and merchant marines, often with the help of Italian experts.

Shipwrights had more chances than before to change the design of Mediterranean ships but the changes they made were limited, which is even more surprising since they were exposed to a number of options in the form of designs from other parts of the Continent. Shipbuilders in the western Mediterranean throughout the eleventh and twelfth centuries may have borrowed some features of Greek ships but the changes, which had begun in the tenth century, were few. Despite the ties of the Vikings with the Black Sea, despite the activity of Scandinavians in the Mediterranean, and despite the presence of ships from northwest Europe bringing crusaders to the Holy Land, southern shipbuilders did not adopt any of those northern types nor seemingly any features from them. There can be no question but that shipbuilders in the South saw

northern vessels. The Norman state established in southern Italy and Sicily in the eleventh century relied to some degree on naval power. The Normans started using typical northern types but abandoned them, after a defeat in 1081, for dromons like those of the Byzantine navy. In the First Crusade a fleet from Norway sailed to the Holy Land. The ships then went to southern Greece and ran to Constantinople under full sail, probably to show off the decoration and colour of the sails.[9] Other northern types appeared in the Mediterranean. Pirates from the Low Countries were already in the South at the start of the First Crusade. The increase in the number of pilgrims going to the Holy Land after that campaign brought more northern ships. Successive crusades meant the formation of fleets in the North, 190 ships in all for the Second Crusade in 1147, which then sailed to Syria. These fleets followed the coasts of Spain and Portugal to get to the Mediterranean and often stopped to help fellow Christians in the fight against Iberian Muslims. By the thirteenth century the ships used included cogs, but now significantly changed from the coastal trader of the tenth century. Northern ships proved that they were better in rough seas than Mediterranean galleys with low freeboard. There must have been other advantages which southerners noticed. If nothing else, northerners learned how to sail to Iberia and in the Mediterranean.[10] They moved from port to port as did all sailors in the Mediterranean, thus giving maximum exposure for the designs. It is not known if Mediterranean shipwrights ever tried to build ships like the northern ones. Some Scandinavian designs were taken over on the north coast of Spain but influence stopped there. It is certainly true that the presence of those types did not lead to any immediate or great change in the design of southern European ships. One explanation may be that northern ships could get into, but not out of, the Mediterranean. The prevailing winds and strong current in the Strait of Gibraltar make it hard for any sailing ship to go from east to west. For ships of northern European design before the fourteenth century it was apparently impossible.[11] The traffic then was entirely one way and the advantages of designs with such a serious limitation led Mediterranean builders to take an interest in improving the capabilities of oared vessels for voyages to the Atlantic rather than adopting northern types.

All in all, modification and extension of designs dating from Roman times were sufficient to meet rising demand in the Mediterranean. The methods familiar to builders there proved adequate. It took some time to develop facility with skeleton construction and even by 1250 the full implications of that approach had not been explored. Shipbuilding yards

did not have trouble with finding labour. Population was growing and urban populations were growing even faster. Shippers faced the same conditions so they could get the sizeable crews needed to defend their ships and handle the lateen sails. Since the yards were long and heavy, the job took a good deal of muscle power; this was true not only for bringing the sail around to the other tack but also for the lowering and changing of yards and sails which were done with changes in the weather. Supplies of timber and other raw materials were plentiful for Italian and Iberian shipbuilders. The reforestation of those areas and of the south of France and Dalmatia from the fourth to the tenth century – a result of the shrinking of arable – gave builders more than enough wood for their needs. Only by the twelfth century was deforestation evident and then only on the island of Sicily. Byzantium enjoyed plentiful supplies of raw materials, especially in southern Greece.[12] There was, then, no single pressing problem for shipbuilders. Labour, raw materials, equipment were all available and earlier success with their ships made it reasonable to continue to pursue the same or slightly modified designs. The unique talents of Italian shipbuilders were widely recognised. They were brought to Iberia, for example, to help establish a navy for the kingdom of Castile and also for the kingdom of Portugal. It was obvious that in Italy men could and did produce vessels well suited to contemporary demands. On the other hand, it was not a simple matter to adopt northern designs. Northern ships had not been developed to their full potential. They required modification to fit the weather and tidal conditions in the Mediterranean. So there was an initial sizeable effort needed before northern types could be produced in the South. This threshold was high enough to keep southern builders from crossing it in the thirteenth century. At that point there was no pressing need to change. They were already passing on savings to shippers in the form of larger round ships.

There had been some improvements in navigation by 1250. Some progress had been made with the compass. Vikings may have used a magnetised needle. Such a needle floating freely in a bowl was apparently widely used by European mariners by the twelfth century. The needle was no compass, however. Sailors used it only to indicate direction. Only when it was calibrated, that is combined with a card, and fixed on a dry pivot and used along with a chart did the compass become an effective navigational tool. Up to about 1250 the compass was used in place of stars or the sun to determine direction when the sky was overcast.[13] With a floating needle skippers were still limited to following the coast and to staying in port in the winter to avoid storms

and cloudy skies. The limited sailing season disappeared in the century after 1250 with the improvement of navigational tools but up to that date there was, as yet, no imbalance between ship design and navigation which might force builders to change their vessels.

The commercial and naval power of the Byzantine Empire continued to decline. The process which began with the abandonment of Mediterranean trade to non-Greek merchants and shippers was accelerated as the Empire was forced to make further concessions to foreigners. The Byzantine navy and merchant marine did not collapse overnight. The decline of the merchant marine ensured the decline in naval strength, however, no matter the acts of successive governments. Meanwhile the Italian towns, the competitors of Byzantium, pressed their commercial advantage, using it in support of their navies and using their naval strength to improve their trading position. In part the Byzantine decline came from success. The naval victories over the Russians in the first half of the eleventh century along with the capture of Muslim pirate nests in south Italy ensured a measure of security. Then the Constantinople government allowed the navy to decline, especially the coastal defence forces. It was also a logical concomitant of the changing character of piracy. By the 1060s with the Turks advancing in Asia Minor and the Normans threatening the western provinces of the Empire, there was no effective Byzantine fleet to hold back the two enemies. A combination of commercial decline, short-sighted reform of the navy and attack from two strong adversaries at the two ends of the Empire put Byzantium in an impossible position. The only solution was to find allies and the Italian towns were the logical choice, especially the old Byzantine port at the head of the Adriatic, Venice.

Venice, in exchange for naval support against the Normans, insisted on further trade concessions which allowed Venetians to increase their share not only of the external trade of Byzantium but of the internal trade as well. This sequence was repeated each time the Normans of south Italy and Sicily posed a threat to Byzantine interests in the West. The Empire committed itself to the defence of Asia Minor and to Crete and Cyprus and so had to leave the West to allies. The concessions meant a lowering of tax income destined for the navy and heavier charges on Byzantines living along the coast, a combination which could lead only to disaster in the long run. The Byzantine naval revival of the twelfth century was temporary. The Empire was too dependent on foreign merchants and foreign naval strength to pursue the old policy of dominance at sea. Byzantine naval troubles were matched by a contraction of fleets in Muslim states in Africa and Spain. The vacuum of

the eleventh century gave western naval forces an opportunity which they seized. They did not have everything their own way. Byzantium still deployed some naval forces as did the Fatimid Caliphate. But certainly after the First Crusade, with Norman states at either end of the Byzantine Empire and with Italian merchants and shippers enjoying new privileges in the Levant, the balance of strength had been irretrievably tipped in favour of Italian shipping.[14] The final result of the expansion of Italian shipping, the decline of the Byzantine merchant marine, and the breakdown of government in Byzantium was the conquest of Constantinople in 1204 by western knights in the Fourth Crusade. The Latin Empire which they established relied on Venetian support just as did the original conquest. At that point fighting was reduced to a contest between Venice and Genoa over which town was to have the greater trading advantages in the lands of the Empire.

By the middle of the thirteenth century the Byzantine Empire, long a source of new developments in ship design, especially in the design of warships, had a much diminished shipbuilding industry. There was no sign of improvement in the technology of shipbuilding. Byzantines throughout the eleventh and twelfth centuries used the same types of merchant ships as did the Italians except that those of the Byzantines were on average smaller since demand for shipping services had not risen as much in the eastern as in the western Mediterranean.[d] The Greeks did not even make marginal design improvements as did the Italians. Governments only sporadically devoted themselves to the construction of war fleets, let alone the improvement of them. Greek shippers and merchants were less effective in using commercial vessels than were their Italian competitors because they were burdened with higher duties. They also had to suffer from piratical attacks which the government could not prevent. Many of those attacks, not incidentally, were by Italians. To relieve domestic shipping of piracy the Byzantine government had to make further trade concessions to Italian towns, thus leading to even less efficient use of ships by Greek traders. Under the general circumstances of a self-reinforcing downturn in commerce and political instability, the stagnation and, if anything, retrogression in Byzantine ship design was not unexpected.

The pattern in northern Europe from 1000 to 1250 was the opposite of that in the South. Rather than marginal improvement in established designs there were major changes in certain types, extension in the capabilities of existing types and, through borrowing of features, an increase in the variety of ship types available. Indeed, the pace of change in the North had long been faster than that in the Mediterranean

and the disparity grew after 1000. By Mediterranean standards northern ships in 600 had been primitive. But by 1250 the gap had been all but obliterated. The northern economy remained far behind that of the South, however. In the volume and in the value of goods traded, in the total production of the region, in population, in every indicator of economic prosperity the regions along the Atlantic, North Sea and Baltic coasts could not compare with those in the Mediterranean basin. Certainly the volume of trade in the North increased to 1250, perhaps even more rapidly than in the South, though starting from a smaller base. Lengths of trading voyages remained typically short. The exception was the carriage of crusaders to the Holy Land. Only in the thirteenth century did northern merchants find goods and routes to give them the same kind of trade that Italian merchants enjoyed in the long haul of luxury goods from the Levant to the Adriatic and Tyrrhenian Seas. The volume of bulk goods shipped rose in the North, as in the South. But in the North it was not a deviation from past practice. The proportion of bulk goods in trade may actually have fallen and not risen. Builders in the North, to meet the consistent demand for bulk carriage, produced vessels suited to the task. In fact they appear to have overshot the mark. They developed ships which could do more than was necessary, a common problem with technical change since it is always difficult to predict the final result of any innovation. In the process shipbuilders created entirely new trading opportunities.

Scandinavian ship types continued a pattern of improvement based on the breakthrough with Viking ships. The leading figures in the Scandinavian kingdoms insisted that builders construct the largest possible warships. In the process they became longships. Size was reported by the number of rooms, the space between two ribs for two oarsmen, one on each side. *Karvs* of some 6 to 16 pairs of oars were too small to be measured by rooms. Longships were of 15 rooms or more. Above 30 rooms they were called dragonships. Even with .70 metres for each room, .30 metres less than on the Gokstad ship, the typical longship was 24 metres long and the largest more than 30 metres long. These ships were, like the larger Skuldelev warship, a longer version of the Gokstad ship. The length-to-beam ratio was extremely high. They were still fast rowed vessels. Rig was the same with a single square sail. The method of fighting did not change. The function of the ship was to get the men to the scene using the sail, and then with oars and careful steering to bring the vessels into position and then to grapple with the enemy. The advantage with longships was their high freeboard, 5.6 metres in one thirteenth-century dragonship. The freeboard on the

Gokstad ship was only about 1 metre. The use of oarholes made it possible to build up the sides without changing the angle at which oars entered the water. The longship, then, was a high platform for shooting down on the enemy. The majority of battle fleets still consisted of smaller vessels, few of which were of over 25 rooms, so in battle the giant dragonships were a class apart. The first of the dragonships was built about 1000. Their number was never large. For Norway only 16 are reported from 995 to 1263. Longships had another advantage in battle. They could carry a large number of men, about eight per room. The greatest longships were not highly seaworthy but they were very expensive. So vessels of over 30 rooms were generally built just for kings trying to assert their dominant position. The optimal size of a longship was 20 to 25 rooms with some ten men per room. These longships retained some of the manoeuvrability of the smaller *karvs*. The last of the big longships was built in the mid-thirteenth century.[15] For most operations the smaller vessel had already proved itself superior. The ships built for the expedition of William the Conqueror against England in 1066 were little bigger than *karvs*. These ships showed improvements in the rig with ropes stretched to give better control of the sail.[e] They probably eliminated the need for the *beitiass*. In general, though, the Norman ships were just Scandinavian warships.

With the dragonship Scandinavian builders had reached the design limits of the Viking warship. It was technically impossible to extend the length. Longer vessels tended to hog, the bow and stern being lower than the keel amidships. In heavy weather the ship could break in two. Building the ship broader to counteract the problem and in general to increase seaworthiness meant changing the character of the design. The technical limit of length was also one of manpower since rowers could only sit so close together. Having tested the limit builders and their customers agreed, except in rare cases, on the optimal size and design. The result was an efficient fighting ship and one which dominated northern European waters through the eleventh and into the twelfth century. These warships apparently borrowed the nailing of frames to the planking from cargo ships, a practice which gave them the added strength necessary if they were being made longer. Warships were significantly different from cargo ships and the difference, already clear in the ninth century, was accentuated. That is not to say that warships were never used to carry goods or that cargo ships were never used in battle. Warships could not be and never were used in any regular trade. When they were not on expeditions or guarding the coast warships were laid up in protected dugouts along the beach.

Scandinavian governments, to supply defence, to exploit the warship design and to establish control over the rather independent landowners along the coasts, set up a system of recruiting such ships for royal fleets. By the thirteenth century there was an extensive system for the construction, maintenance and manning of a navy which could be called out by the king. Local fleets, based on districts, were combined with a central fleet built by and for the monarchy. The *ledung* ships supplied locally were typically of 20 to 25 rooms and under 30 metres in length. The full muster for Norway was 310 ships but it was never called out. A fleet of 200 ships was the maximum until the thirteenth century when the total rose to over 350. For Denmark the fleet in theory was 1,100 ships. Sweden had a similar system. The fleets were to be not only offensive weapons in the hand of the king, but also a type of police force to stop piracy and protect trade.[16] Though they did not eradicate piracy completely, these fleets did introduce a stability which further channelled interest away from the freebooting of the Viking period towards peaceful trade. The type of ship, the style of naval warfare and the geography of a large number of ports contributed to the development of this form of naval organisation. It was the most extensive system for generating forces at sea in northern Europe in the middle ages.

The increase in trade along established routes in the Baltic and North Seas generated pressure on shipbuilders also to improve cargo ships. The impetus was more diffuse than with warships where demand was concentrated among an ever smaller number of buyers. The process was similar, however, with the builders refining the design of the Viking ship. The principal change, beginning even before 1000, was in the cross-section of the cargo ship. The cross-pieces resting on the frames, the *bites*, were moved down. Indeed the whole system of cross-timbers seemed to move downward on to the frames and the frames themselves became flatter. More cross-beams had to be added above. These ran between heavy planks on the sides. Hanging knees were added above them to hold higher planking. By the twelfth century the *bites* were so far down that they had all but disappeared, not even reaching the ends of the frames. By the mid-thirteenth century there was nothing left of the *bites* and the frames were floor timbers. But there could be as many as three levels of cross-beams above the floor timbers.[f] Strength came from having the floor timbers close together, about .5 metres apart. The change simplified construction and increased the quantity of heavy timber needed. It made the ship sturdier and not incidentally increased cargo space in the centre of the ship. It is almost possible to date finds

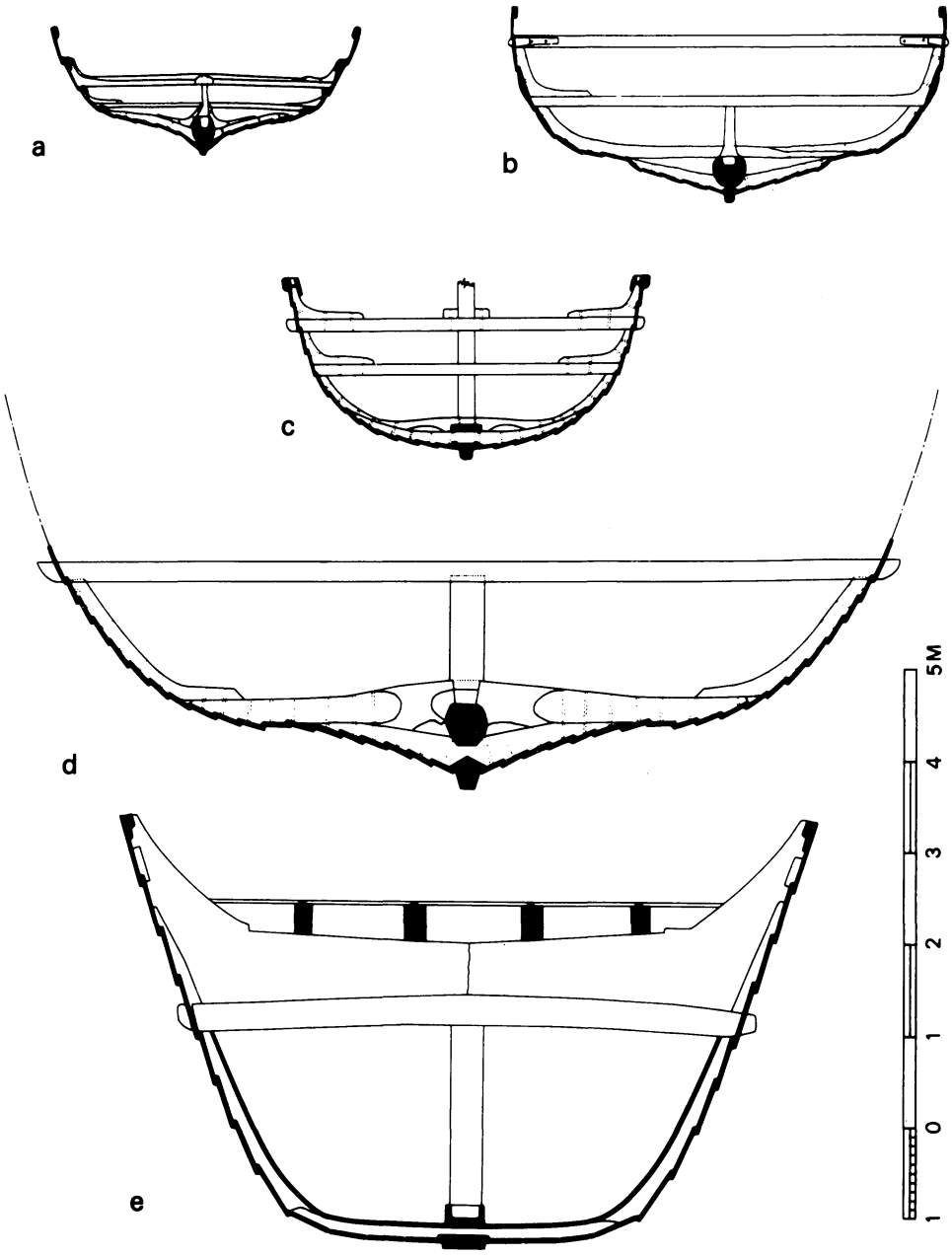
of cargo ships by the degree to which the *bites* were moved down. The same may be said for the distance between the ribs or floor timbers which decreased throughout the middle ages.[17] Apparently cargo ships followed the trend towards greater size. They never reached the dimensions of dragonships but lengths of 25 metres must have been common. Breadth would be about 9 metres giving a ratio to the length well below that for warships. The rig was the same, with sails broader than on warships. The side rudder remained throughout the twelfth century. The result was a vessel capable of handling bulk cargoes. It was used to move grain from England to Norway in the thirteenth century and to carry dried fish back in exchange. Whale oil and luxuries from the North like falcons, hawks and furs filled out the cargoes.

While cargo ships always had a lower length-to-breadth ratio than warships, another noticeable feature, especially after 1000, was a lower length-to-depth ratio for cargo ships. It was not so much through being broader that cargo ships increased capacity, though there was a fall in length-to-breadth ratios, as by becoming deeper – a characteristic which was well suited to bulk carriage and made beaching the ship more difficult, though harbour improvements were making the latter point less relevant. The shift to relatively straight and in general more upright posts at the bow and stern was made for the same reasons.[18]

The knarr was mentioned less often after 1000 though it was certainly still in use in voyages to Greenland. Other names for cargo ships, such as *buza* and *byrding*, became more common. The written evidence is not complete enough to be able to identify the distinguishing features of these types. The buss was used throughout the North and Baltic Seas. Such vessels were even mentioned as part of crusader and pilgrim fleets, so they were known in the Mediterranean. They were also mentioned as fishing boats as early as the tenth century. Though it may have begun as a type of warship, by the eleventh century the buss was a cargo ship. By the end of the thirteenth century the name was a generic term for Scandinavian cargo ships. The *byrding* seems to have been more suited to coastal trade than the buss although it too was used on ocean voyages to Iceland and to England.[19] By the thirteenth century the buss had presumably dropped the auxiliary oars at either end of the ship, though they may have been retained on smaller vessels.[g] Relying exclusively on sail, the crew size could be reduced, another advantage for the buss in bulk trades.

Despite the clear improvements in the Scandinavian cargo ship, it still was not able to compete as a bulk carrier with the improved cog. A buss might be as long as a contemporary cog but there is no evidence

12: Cross-sections of Northern European Ship Finds: (a) Viking Baltic Cargo Ship, 1000; (b) Seagoing Knarr, 1000; (c) Galtabäck Boat, 1100; (d) Buss from Bergen, 1300; (e) Bremen Cog, 1380



that it could match that cog in total carrying capacity. Moreover, the Scandinavian merchants and shippers who used busses worked at a disadvantage relative to the Germans who used cogs. The latter were closer to sources of cargo and to larger populations. They also appear to have enjoyed a more effective organisation of their trade. If the cog was not overwhelmingly superior in design to the buss, it was at least enough of an improvement to lead Scandinavians to acquire the new type of vessel, as early as the second half of the twelfth century.[20] The keel, the English type derived from the Scandinavian warship, was also superseded. Whether the improved buss or the cog was the reason for its gradual disappearance is impossible to say. By the mid-thirteenth century bulk cargo, especially over longer distances, was typically carried in northern Europe by cogs. The change in the cog which made this possible was the most important improvement in the design of northern European ships in the years from 1000 to 1250.

The new cog was no longer a coastal trader for use among sandbanks but a true deep-sea trader. The change was so great as to create an almost entirely new ship type and one with a much greater range of possibilities. Essentially the change was to add a keel to the simple long narrow cog. This was probably tried for the first time in the early eleventh century, perhaps because of the example of Viking ships. Otherwise the cog retained most of the features of the earlier version. The bottom was almost flat with planks placed edge to edge. There was a sharp angle at the sides where the vessel turned up. There was also the characteristic sharp angle of the posts to the keel. Over time the flat bottom became smaller and the turn of the sides became less sharp. The heavy keelson added amidships served in part, as on Viking ships, to hold the mast in place. On cogs the mast was stepped a bit forward, more efficient in running before the wind. The posts rose higher than the planks and the stempost was typically higher than the sternpost. The reverse clinkering, with the bottom plank overlapping the next one higher, continued and appears in the oldest town seal which is certainly an illustration of a cog, that of Lübeck of 1226.[h] High freeboard was kept as well. The rib framework was presumably attached directly to the planking.[21] The sharp straight stempost of the cog and its deeper draught made it go through the water better than the smoothly curved knarr or the keel. The cog was stronger, a better sailer, as versatile and with larger carrying capacity for each metre of length than the contemporary keel, knarr or older keelless cog.

The cog, by the end of the twelfth century, could be and was used in long-distance trade both along the coasts and across the open sea. By

the second decade of the eleventh century traders from Saxony were sailing to England and to Iceland. Frisian sailors apparently made such trips as soon as they had the improved cog, since the older version was not capable of such voyages on the high seas. Frisians also increased their voyages to Norway, not possible before the improvement in ship design.[22] The new design had another advantage: the type could be built bigger. Small cogs remained in use but throughout the eleventh and twelfth centuries shipbuilders progressively tried to build larger cogs. The hull shape of the original cog with a flat or nearly flat bottom and sharp angle to the sides gave a spacious container. Increasing shipments of grain in northern Europe, along with a rise in transport to the Holy Land, gave shipbuilders a ready market for larger bulk carriers. Pilgrims and crusaders making the trip entirely by sea had to carry extensive provisions, not to mention equipment, so space was important. By the thirteenth century the use of the word 'cog' meant, if nothing else, that a ship was large. It is impossible to estimate an average size for cogs up to 1250. Cogs would have been as much as 30 metres long. Breadth did not exceed 9.5 metres and draught would have been between 3 and 4 metres. This certainly was not the technical maximum. The length-to-breadth ratio of about 3:1 made it a tubby vessel. Port charges from the eleventh century suggest that the buss and cog were not much different in size. By 1250, however, the cog had grown so much that, compared to typical Viking ships of 1000, there had been at least a fivefold increase in potential carrying capacity. In fact thirteenth-century ships were not much smaller than those of the sixteenth. The cog was not as fast as a Viking ship but the sacrifice in speed was small. The number of trading voyages per year, especially within the North Sea, was probably about the same with both types. What was affected was the return on investment. The volume of goods shipped rose sharply. The original outlay for each ton of capacity declined since one ship could be built where four or five were needed before. The size of the crew did not grow proportionally with the increase in size. A knarr of 50 tons had a crew of 12 or 14 while the crew of a 200-ton cog was 18 to 20.[23] There can be no question, then, but that the adoption of the new cog and the increase in its size represented significant savings, especially in the movement of bulk goods.

The high freeboard of the cog increased with over-all size, making it more defensible. If that was not enough, superstructures were added fore and aft. These castles, perhaps borrowed from the Mediterranean where small decks were often fitted above the main deck at the bow and stern, were unquestionably for defence. From these platforms

archers and other soldiers were well above water level and would usually have a height advantage over any attacker. A small platform or fighting top was added for the same purpose at the top of the mast on larger ships. Cogs were unlikely to fall prey to pirates. With castles added, the cog was superior to any Scandinavian warship. Even the longest of dragonships with castles were still no match for the high cogs. Scandinavian monarchs abandoned their muster fleets and in Denmark the requirement was changed from the supply of longships to the supply of cogs.[24] Cogs in case of war could carry large numbers of men. On the other hand, they were not fast enough or manoeuvrable enough to make them strong offensive weapons, and here may lie the reason for the survival of warships similar to earlier Scandinavian vessels in thirteenth-century England. The Cinque Ports along the Channel coast were required to supply the crown with a specific number of ships for a fixed period. Contemporary seals show long, low clinker-built boats with a single square sail, a single side rudder, no oars and small castles added at the bow and stern.[i] In wartime they were equipped with a wide variety of devices to hurl projectiles at the enemy. For patrol work in the Channel, for amphibious operations in the British Isles and for attacks on the French coast, this type was clearly superior to the cog. Calls on the Cinque Ports decreased as time went on and English kings came to rely more and more on rented cogs for their naval forces.[25]

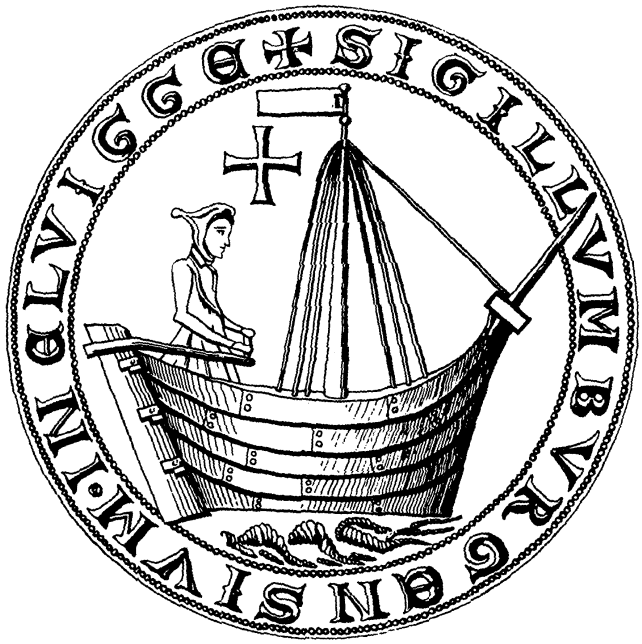
The tubby design with a low length-to-beam ratio made the cog slow by contemporary standards. For bulk carriage, of course, this was of little importance. The proportions seem to have been much the same no matter the size of the cog. The clinkering of the hull was also the same. Construction even for the largest of cogs was still of shell type. The ends of some of the cross-beams projected out through the hull. Ribs were heavy and they were close together, sitting on and attached to the flat and still relatively broad keel. There were at least two small decks at either end of the cog and on the larger ones there was at least one through deck.[26] The result was strong, massive and solid construction, which made for a heavy ship but also a sturdy one.

Moving the cog presented problems but builders retained the simple rig of a single square sail on a single mast. The mast was held in place by one large forestay running from the stempost and two backstays. There was one addition to the rigging – a bowsprit.[j] This small yard at the bow was probably to stretch lines from the lower edges of the sail. They would keep the leading edge taut when going to windward. The extension gave better leverage than was obtained just by attaching the

lines to the stempost. The bowsprit appeared in the thirteenth century and was added also to other types of ship. The collection of mast, spar and bowsprit made up the total rigging for the cog. There were lines to control the sail but these by 1250 were certainly no improvement on Scandinavian practice. Sail area was probably between 82 and 175 square metres depending on the size of the vessel. Though compared to earlier vessels the cog sail was large, the sail area per ton was much lower, one-tenth or less of ninth-century Viking ships. The sail could not get much larger since it was already hard to handle the heavy yard. At the stern there was typically a windlass used to raise the sail and also to haul the anchor. Sail could be increased by the addition of bonnets, strips of cloth which were sewn to the bottom of the main sail. If wind freshened they could be easily removed. That simple arrangement, clearly in use by the thirteenth century, meant that a much larger sail could be rigged, up to a total of 335 square metres, but without the problem of hoisting all the heavy cloth. Sail could also be shortened by using reef-points.[k] These short pieces of rope going through the sail in rows were for tying up the rolled sail.[27] Reef-points could not compare in efficiency with the brails used by Romans but they served a similar purpose. With bonnets or reef-points the cog sail had a wide range of variation. Still, the vessel was probably no better going to windward than was the Viking ship. The sail was heavy and less plastic than its predecessor, so it was not easy to handle.

The system of control changed much more dramatically. The balanced side rudder was adequate for the cog until the late twelfth century. Then builders began to fix rudders on the sternposts of cogs – an easy operation thanks to the straightness of the sternpost. The tiller was usually passed over the top of the post.[1] That, combined with the deeper hull with a keel and the bowsprit and bowlines for the sail, made it possible at least to handle the now much larger cog. The size of the sternpost rudder, as long as the post, made it heavy and hard to move. It may have been first used on riverboats in the Low Countries where the advantages clearly outweighed the disadvantages. It was then transferred to the bigger seagoing cog. Side rudders were abandoned not because they were inefficient but rather because on such a tall ship with such high freeboard they had to be made extremely long. With the ship heeled over to port a rudder on the starboard side had to extend a long way to reach the water. The bigger the side rudder the harder it was to build in one piece and the harder it was to fix properly to keep it attached and still minimise friction in turning. For a large ship with a keel, like the cog, the sternpost rudder, then, was a positive improve-

13: Sternpost Rudders: Elbing Seal, 1242 (top) and Ship on the Font in Winchester Cathedral, from the Low Countries, 1180 (bottom)



ment, especially in going to windward. It was particularly valuable in long reaches, for example going around Cape Skagen, the northern tip of Jutland, getting in and out of the Baltic. The voyage was a difficult one and involved going through the Great Belt or the Sound. The Danish coast was not marked or charted so, until the thirteenth century, routes through Lymfjord in north Jutland or the overland route to Hedeby or later to Lübeck were preferred. By the mid-thirteenth century, in part as a result of the building of the new bigger cog with its sternpost rudder, merchants from western Europe were appearing in markets in southern Sweden, presumably sailing directly through the Kattegat.[28] So the combination of improvements embodied in the cog not only expanded the volume of transport but also opened new trade routes and forced adjustment in old ones.

Building the new type of cog probably required less labour, especially skilled labour. The nature of the improved design decreased labour requirements while the increase in the size of the vessel lowered labour costs for each ton built. Moving the now larger main pieces of the ship, posts, ribs and so on, meant that more muscle power had to be deployed on the shipbuilding wharf, but skilled workers were not affected. The tendency was to concentrate the orders for new cogs in the hands of a smaller number of yards. The total number of ships built grew more slowly than the total tonnage, so certain builders, highly skilled men able to deal with the new design, found themselves with an increasing proportion of the orders. The same process led to the concentration of orders in a smaller number of places, locations with the skilled and unskilled manpower for building these ships and with a market for them.

Builders apparently moved to the use of the frame saw to cut wood. By 1250 the typical method of preparing planks in the Low Countries and in Germany was by sawing and not by splitting logs. More and heavier ribs and the increased piecing of the hull with scarfed planks meant that hull planks did not have to be as strong or as pliable as with Viking ships. The frame saw, a blade in the middle of an open rectangular frame, was used in the Mediterranean basin throughout the middle ages.[m] In the North, however, even by the mid-thirteenth century the coversion to saws from axes and adzes for preparing ships' timbers was not complete. It took less time to saw a log than to split it and the saw was more accurate than the axe and adze. The greater precision compensated in part for the loss in strength of the wood. The final consideration was the sharp decrease in waste when the saw was used. Much less wood had to be thrown away. Wood was always expensive in terms of

time and effort needed to gather in the right types and shapes, so the economic reason sealed the decision. In addition to the saw, the ship carpenter by 1250 had an improved auger for drilling holes in planks and ribs. Builders always had a wide variety of augers but from the eleventh century they added the specialised breast auger to that collection. With a pad on the top the carpenter could put his full weight behind the force of the biting edge.[n] Turning power was separated from direct pressure on the wood, thus making it a more powerful tool, which was also easier to use in cramped spaces, of which there were many in the hull of a ship.[29] These augers were added to the broad range of axes, adzes, planes and handsaws already used by ship carpenters. They contributed to the productivity of the shipbuilder and also increased the difference between the skilled ship carpenter and the unskilled worker on the shipbuilding wharf.

The cog took over an ever-increasing portion of seagoing carriage but the hulk was not driven from northern European waters. It was still better than the cog at riding in estuaries or in moving along rivers. Hulks grew in size but not as dramatically as cogs. The hulk retained its crescent shape. The strong curved boards came together at the ends but there was still no actual stempost or sternpost. The hulk kept the side rudder longer than the cog, perhaps because it was typically smaller. The rig was the same with a single square sail on a single mast, and there was a bowsprit. There were castles at the bow and stern. The distinctive feature was the construction of the bow. Without a post the bow was held together, among other methods, by ropes wrapped around the stem. With that type of bow the hull must have been smoothly rounded and without a keel.[o] The planks, though originally placed edge to edge and then held in place by heavy external pieces, were by the thirteenth century clinkered, as was the practice with the cog. The older method placed an intolerable limit on size.[30] Though it could carry bulk goods such as wine from the western Low Countries and presumably from France to England, the hulk was still relegated to a position of lesser importance than the cog. In a sense the earlier situation was reversed and the hulk was the more specialised vessel suited to specific conditions while the cog was a general-purpose vessel.

Documents from the twelfth and thirteenth centuries show that cogs and hulks were not the only sizeable sailing ships in northern waters. The English keel, for example, still appeared in contemporary records.[p] So did the buss, the bark, the ewer and many more.[31] The problem is that illustrations and archaeological finds are not sufficient to fix design features to all those names. It is always possible that two names were

14: A Ship of the Cinque Ports, the Seal of Winchelsea, Thirteenth Century (left), and a Hulk, the Seal of New Shoreham, Second Half of the Thirteenth Century (right)

used for the same type. It is also possible that the increase in surviving names of northern ships is a result of the increasing volume of surviving documents rather than any profusion of designs. Nevertheless, the unavoidable impression is that there was a greater variety in the design of northern European sailing ships in the thirteenth century than ever before. The expansion in the volume of trade was one reason. More important, though, was the growth of trade in certain specific items along fixed routes which made it possible to build ships suited for a specific task. Moreover, competition for the carriage of goods increased. Merchants and skippers from throughout the Low Countries and not just from Frisia were involved in moving goods by sea. Shippers appeared from England, Scandinavia, German towns, and Slavic settlements along the south coast of the Baltic. For the movement of luxuries specialised design was of little importance; the only need was speed to move the goods as quickly as possible without allowing shipping costs to become extremely high. The form of the container and indeed its size beyond a low threshold were of little significance. For bulk goods, however, the situation was different. Those goods came in various forms and degrees of lumpiness. Most could be broken down into smaller units but there was a gain to be made from keeping the units as large as possible. Larger wine barrels, for example, meant savings in space on board and in handling. So for bulk goods shipwrights found themselves increasingly working on building vessels which would better serve a specific need. By the mid-thirteenth century they had only begun since the opportunity and the demand for such development was relatively new. The trend towards specialised designs became clearer over time.

To handle these goods more ports were equipped with quays. By 1250 most significant ports had at least one. The older form of landing was not abandoned. A beach or shore was usually kept open at major ports so that Scandinavian warships and related cargo ships like the keel could be beached. Inland and coastal vessels were the primary users of such shores while the seagoing ships turned to the quays. The change was not a result of the increasing use of the cog; it was rather the result of the rise in the quantity of goods handled by ports, the greater efficiency to be had from quays, and the increasing size of ships which made working at the beach more difficult. It was simpler to roll wine casks off the deck onto a quay along a short gangplank than up or down a gangplank at a steep angle. The quays were simple and rarely of stone; wood was the usual material. The economies derived from these quays led shippers to seek out ports equipped with them, thus contributing to the centralisation of trade in certain towns. The deeper draught

of the cog also gave an advantage to ports closer to the sea, especially those at the mouths of rivers. These ports enjoyed a position as a transshipment point. All these factors contributed to the centralisation of shipbuilding in certain towns. Especially in Germany, shipbuilders were no longer just living along the shore, operating from a farmstead. That kind of building did continue but more typical as time passed was the professional shipwright who lived in a port town and worked on a specified piece of ground set aside for shipbuilding by the town government. The shipbuilding yard in town was still little more than a stretch of shoreline sloped so that ships could be let down or hauled out. The rise in output from such yards made them more permanent. In the growing port towns all the necessary materials and equipment and the market for the ships were easily accessible.

The quays also dictated a feature of design. Northern European ships, with the exception of eighth- and ninth-century hulks, did not have wales. The sides of ships did not have or need protection. Builders were much more worried about the bottom, which suffered abrasion when the ship was landed. With the widespread use of quays the ships needed some protection against the buffeting which the planks would take as vessels rode by the quay. The problem was not as acute as in the Mediterranean since northern clinker-built hulls could take more punishment. One solution was simply lightering the cargo, off-loading it into small vessels to move it to the market in the port or upstream to other towns. But, in case the cog had to lie at a quay, builders equipped it with bumpers in the form of projecting beam-ends.[32] Certainly, this method was not as good as the Mediterranean solution of using wales. There may have been some gain in strength, the beams serving to keep the sides of the vessels from losing shape. In the Mediterranean it was the ribs which were held by the beams but in the North the beam-ends held the hull planking itself. On the other hand, there was a sacrifice in the strength of the hull, as it was pierced along its length so the beams could pass through.[q] The sacrifice was necessary, however, if quays were to be exploited.

The changes in ship design in northern and southern Europe from 1000 to 1250 promoted social and economic developments already under way in the tenth century. Turnaround time for cargo ships continued to fall. Specialisation in production and production for export, for sale beyond individual regions, increased. There was a true international commerce in, for example, textiles stretching from the Baltic to the eastern Mediterranean, involving farmers producing the raw materials, artisans making the cloth and merchants and shippers distributing it.

The tendency towards urbanisation was even more marked. The changes were more noticeable in northern than in southern Europe. The northern region started from a lower level; but also there the technical changes in ships were greater. The widespread use of quays was combined with more economical ships, especially the cog. The process of specialisation of production by region may in fact have gone further in the North than in the South. The similarity in climate in the Mediterranean basin mitigated against specialisation in agriculture but the lack of a bulk carrier with the potential of the cog contributed to the failure there to concentrate production to the same degree. The faster pace of specialisation in the North made for a clearer division between industry and agriculture, a division which was, of course, by no means complete by 1250. With the migration of handicraft industry to towns there was a sharper as well as greater distinction between town and country. The lower costs of transport, especially between towns, fed that trend towards the separation of both personal and geographic functions.

The increased productivity of ships meant that shipbuilders were more productive. It gave them a social status not usually accorded men who worked with their hands. For example, shipbuilders were now and again mentioned by name in Norse sagas. Fewer shipbuilders spent their summers as farmers. They specialised in their trade rather than working part-time, another indication of their increasing economic value. These men, the master builders, became responsible for the entire operation of building the ship. They were directors of a complex operation employing workers of various levels of skill and buying a wide range of materials. Buyers deferred to shipbuilders' expertise in planning, expenditures and the execution of the job.[33]

Oddly enough, the augmented importance of shipbuilders was not shared by seamen. Certainly skippers, with their knowledge of navigation and handling larger ships, could expect to see their increased responsibility reflected in a higher relative income. But ordinary seamen, the workers on board, seem to have experienced a decrease in their value, especially in the North. At least in southern Europe, crewmen on round ships were called on to handle the sail, to raise and take down the yards with changes of weather. Their large numbers on each ship – that is, the high number of seamen per ton – may have kept the average wage of seamen low. In the North, men working a cog had to supply little more than muscle power for raising the yard and for loading and unloading cargo. Handling the simple sail was an easy matter. Adding bonnets or taking in sail with reef-points could not compare in complexity or skill with handling a lateen sail. In the North, accord-

ing to the law, a ship had only two types of men, the skipper and seamen. On Mediterranean vessels, on the other hand, there was a number of grades of skilled workers. In any case, seamen were still consulted on what action was to be taken, especially when the question was whether or not to sail out of port. The risk was still great enough, despite design improvements, to make voyages dangerous, and the stake of the seamen was recognised in their shared authority on major decisions. Their stake included not only their lives but also the small quantity of cargo, usually carried on deck, which each sailor was allowed to bring along and trade on his own. In northern Europe, even in the thirteenth century, the costs of ships were still low enough for some seamen to own part of the vessel they worked. This was not the case in southern Europe. Though families might still own and operate smaller coasters, the typical organisation of shipping there was for the ship to be owned by a group of investors, with wealthy merchants as the principal shareholders. Not all of those merchants would take an active part in the operation of the vessel. In fact, there was an increasing tendency towards passive investment where any individual with some money, even a relatively small amount, would buy a share in a ship without any intention of using it for trade. The only interest of the investor was a return from the successful operation of the ship.

Ships in both northern and southern Europe were made more defensible and also more reliable in the two-and-a-half centuries to 1250. The decreased risk of total loss promoted that kind of passive investment even more. The potential for high returns had a similar result.[34] The rise in the total investment in ships over those years, along with the rise in the volume of commerce, meant more employment at sea as well as in shipbuilding yards. The growth and increased investment presumably affected fishing and coastal and local shipping as well. By 1250, then, more people, absolutely and relatively, were directly or indirectly involved in waterborne commerce than at any time since the later Roman Empire. Undoubtedly, the numbers of people involved in land transport grew too, but the pace and sustained nature of growth in employment probably did not match that in shipping. There were improvements in wagons and carriages and in harness which certainly meant significant savings in moving goods by road. The technical changes were sporadic, however, and did not demonstrate the continuing and general development which was common with ships throughout Europe. Even though workers in shipping still formed only a small percentage of the total population, their numbers probably grew faster than the numbers of workers in any other sector.

Technical change in Mediterranean ships was not as great from 1000 to 1250 as in the years before or after those dates. The growth of commerce, the commercial revolution beginning in the tenth century and going on to the thirteenth, though it had its basis in better ships, was rather a product of other forces. Long-term growth in total output in agriculture and in handicraft industries, technical change in agriculture and in trades other than shipbuilding, improvement in climate, population increase, all contributed more effectively to the dynamic growth.[35] Technical change was most rapid not in ship design but in methods of doing business. Invention came from Italy and further development of methods and diffusion of established Italian practice fed commercial growth. By 1250 technical advance in business methods had moved well ahead of that dealing with the physical problems of moving goods. There was an expanding potential in commerce, more fully recognised as the talents of Italian merchants were diffused throughout the Mediterranean basin. To exploit those possibilities, however, more efficient methods of shipping were needed. That imbalance created, from the thirteenth century, a new pressure on shipbuilders to improve their product.

Changes in warships, like those in cargo ships, were limited from 1000 to 1250 but the social and political effects of the changes were more obvious and more dramatic. Throughout the eleventh century warships were built to move men to the sight of battle, as quickly as possible; they served merely to mobilise manpower. Divisibility of units was desirable. The muster system, evolved in Scandinavia in the tenth and eleventh centuries, was the most extensive example of that approach to warships. In 1066, when William the Conqueror wanted to attack England, he gathered shipwrights together, had his transports built in a short time and then used them to move his men to a landing across the English Channel. The cog changed naval operations. These vessels could serve as warships, and could dominate fighting because they were so high out of the water and because they could carry many more men for each metre of length than could any other type. Governments could not ignore the naval superiority of the cog. They were still transports for getting infantrymen to the scene of battle, be it on land or on the decks of the cogs. The use of cogs presented problems, however. Governments could not just order a fleet of cogs at short notice. The amount of wood involved, the larger shipyards needed, the larger number of workers, all meant that it took some time to construct a war fleet. Governments realised that they had such fleets already available in the hands of native and foreign merchants. Few, if any, changes

were needed in these ships in order to use them for naval purposes. Cogs owned by foreigners could be seized in case of war, but, as such an action might lead to retaliation, a safer course was to get cogs from domestic merchants. The logical choice was to rent the ships, crew and all, for the period of the fighting. The government meanwhile could and did build cogs for naval action and then in peacetime rented them to merchants for trade.[36] This made for a different type of naval organisation. A general levy of ships and men along the coast was less important than having cash and men to distribute it in time of war. Naval strength was more a product of the number and availability of merchants' vessels in a country or region. The change in navies began by the thirteenth century and was more noticeable over the following 200 years. The new situation pressured northern governments and those in Iberia to take a greater interest in shipping and shipbuilding – an interest in those operations not just as a potential source of tax income but for strategic purposes as well. The connection between strength and prosperity and the prosperity of shipping and shipbuilding had already been noted in Italian towns.

In Italy the residual knowledge of Byzantine policy and understanding of sea power had made an impression. The point was also made by the Italian pirates of the tenth and eleventh centuries who used their skills to gain capital and trading connections. The need for an active government interest in shipping was made more dramatic by the crusades. Transport for the large numbers of soldiers was arranged between kings and noblemen on one side and the town governments on the other. Private individuals, shippers and shipbuilders, were not in a position, either socially or in terms of resources at their disposal, to deal with orders of that scale from those men. The demand, its size and form led municipal governments in the western Mediterranean into direct involvement in shipping and in turn in shipbuilding. Their involvement increased as resident merchants urged their governments to try to expand their share of the crusader markets. There was also a large market to capture in the pilgrim trade. Once governments were committed to efforts to control shipping, the degree of involvement and their concomitant interest in shipbuilding depended on ship design. Town governments established regulations on the numbers of people who could travel aboard ships. They fixed load limits. They had to develop rules for measuring the capacity of ships first for pilgrims and then for general cargo. They required certain practices be followed. For example, scribes had to be carried on board to record all transactions.[37] The rules, originally to improve safety and reliability, forced governments

into increased involvement in shipping and, over time, it led them to define demand, in fact to direct technical change.

The galley became less important in the carriage of goods in the Mediterranean. The rise in bulk shipment, including the crusaders and their horses and armament, made galleys relatively less valuable in moving goods. The value of the galley as a warship did not decrease, however. As warships, galleys were the responsibility of the state, built, maintained, fitted out largely by the town governments. It was becoming more difficult simply to enlist merchant galleys. To guarantee a force the state had to take an interest in the construction and maintenance of its own ships. Commercial galleys were subject to increasingly stiff competition from land transport. While improvements in wagons might be sporadic, they did still serve to lower costs and, together with better roadways, made moving luxuries by land a viable alternative. Galley traffic was the most likely victim of the success of road carriers. People tended to prefer travelling by road to going by river or along the coast, so the increasing movement of people, with the exception of pilgrims for the Holy Land, did little to help galleys maintain their position as cargo ships.[38] The naval contests between Italian towns for control of trading areas, on the other hand, made galleys as crucial as ever to those towns. The strength of a city-state depended on the ability to deploy galleys and the ability to man them. The rowers were citizens paid to do the job. So the number of men available at short notice to work in a battle fleet was an indication of the strength of a city-state. Since men were recruited from the general public, then, sheer population became a measure of power. The interest in numbers, the tendency towards numerisation in public as well as private affairs which was clear in Italian towns, was promoted by the type of fighting ship.

The ability to move goods economically over greater distances affected the relative economic importance, the share of total income and of total wealth, of regions and of groups of people. In the Mediterranean the Italian towns which served as trans-shipment points between central and western Europe and the Orient, towns like Venice and Genoa, fared better than other ports. The relative reliance on trade in luxuries in the South made the change less extreme than in the North. Moreover, in the Mediterranean, political and naval power was used without compunction to direct those economic forces. In the North, the economies of the various districts and regions were still different enough in character for the introduction of more efficient bulk carriers to bring more producers into the exchange of goods. The cog, but also the hulk and

Table 3.1: Principal Dimensions of Early Medieval Ship Finds

AD	Ship	L	B	L/B	D	F	R	T
200	*Bruges	14.5	3.5	4.1	1.35	–	–	–
400	Nydam	23.7	3.75	6.3	1.2	0.5	1-1.1	–
600	Sutton Hoo	27	4.2	6.4	1.4	0.6	1.02	–
700	Kvalsund	18	3.2	5.6	0.9	0.35	1.05	–
800	*Utrecht	17.8	4.0	4.4	1.3	0.8	–	(23)
800	*Äskekärr	c. 14	3.7	1.8	–	–	–	–
800	Oseberg	21.4	5.1	4.2	1.4	0.75	1-1.1	–
875	Tune	c. 20	4.3	4.6	–	–	–	–
900	Gokstad	23.4	5.2	4.5	1.9	0.85	0.9-1.05	32
950	Ladby	20.6	2.9	7.2	0.7	0.25	0.91	–
1000	Skuldelev 5	c. 18	2.6	7.0	1.1	0.5-0.6	–	–
1000	Skuldelev 2	c. 32	4.2	7.6	–	–	–	–
1000	*Skuldelev 3	13.3	3.3	4	1.4	1	0.94	(9)
1000	*Skuldelev 1	16.5	4.6	3.6	2	1.5	0.9	(30)
1100(?)	*Eltang	17.5	3.9	4.4	1.9	–	0.9	(20)
1100	*Galtabäck	14	4.0	3.5	1.9	–	0.48-0.63	(15)
1100	*Falsterbo	13.5	4.5	3	2.7	–	–	(40)

*Ships designed principally to carry cargo.

AD, approximate date; L, length over-all; B, breadth; F, draught; D depth in hold; R, distance between frames; T, carrying capacity in tons. All other measures in metres except L/B. ( ) indicates estimated tonnage where there is not enough precise information.

Sources: *FHMN*, pp. 256-7; Sibylla Haasum, *Vikingatidens Segling och Navigation*, pp. 23-4, and others.

buss, increased the potential market for these producers. In the majority of cases this meant an increase in the value of their output. The ships might bring in goods which would effectively compete with some locally produced item. But there would be a net gain in lower costs of imported items and in improved markets for goods most efficiently produced in the region. By the mid-thirteenth century, agricultural producers, thanks to the lower cost of bulk carriage, had become more efficient. Not only farmers and landowners were affected. Fishing and forestry also increased output and revenue as a result of the wider market and lower transport costs for their products. The extension of trading connections in the years from 750 to 1000 was certainly more impressive and based on more obvious technical change than that in the following 250 years. But in the latter period the ship-design improve-

ment generated greater total savings because more people were affected by it. The mundane improvement of the tubby and slow-moving cog led to a greater integration of the economies of the regions of northern Europe. At the same time, the lower costs of transport contributed to the integration of the whole European economy. In the following 150 years the pace of integration increased as did the pace of technical change in ship design.

NOTES

1. Eugene H. Byrne, *Genoese Shipping in the Twelfth and Thirteenth Centuries* (The Mediaeval Academy of America, Cambridge, 1930), pp. 5-6. Lionel Casson, *Illustrated History of Ships and Boats*, pp. 70, 76. Charles-Emmanuel Dufourcq, *La Vie Quotidienne dans les Ports Méditerranéens au Moyen Age* (Hachette, Paris, 1975), pp. 59-60.

2. Hélène Ahrweiler, *Byzance et la Mer*, pp. 192, 269-70. Jean Aubin, 'Y a-t-il eu interruption du commerce par mer entre le Golfe Persique et l'Inde du XI^{e} siècle?', *TCHM*, VI, pp. 169-71. F. C. Lane, *Venice* (Johns Hopkins University Press, Baltimore, 1973), pp. 33-5. Charles-Emmanuel Dufourcq, *La Vie Quotidienne*, pp. 125-7, and *L'Espagne Catalane et Le Maghrib aux XIII^{e} et XIV^{e} Siècles* (Presses Universitaires du France, Paris, 1966), pp. 428-30.

3. For example, Hilmar C. Krueger, 'The Routine of Commerce between Genoa and North-West Africa during the late Twelfth Century', *MM*, XIX (1973), pp. 419-20, 425-30, 438.

4. Romola and R. C. Anderson, *The Sailing-Ship*, pp. 108-9. Eugene H. Byrne, *Genoese Shipping in the Twelfth and Thirteenth Centuries*, pp. 9-11, 26. John E. Dotson, 'Jal's *Nef X* and Genoese Naval Architecture in the Thirteenth Century', *MM*, LIX (1973), pp. 162-5. He offers a valuable correction to the figures given by earlier writers which are inaccurate for Genoese vessels because of conversion errors.

5. Marco Bonino, 'Lateen-rigged medieval ships', *IJNA*, VII (1978), pp. 9-15. Romola and R. C. Anderson, *The Sailing-Ship*, pp. 104-6. Eugene H. Byrne, *Genoese Shipping in the Twelfth and Thirteenth Centuries*, pp. 5-8. John E. Dotson, 'Jal's *Nef X* and Genoese Naval Architecture in the Thirteenth Century', pp. 167-8. Bernhard Hagedorn, *Die Entwicklung der wichtigsten Schiffstypen bis ins 19. Jahrhundert* (Verlag von Karl Curtis, Berlin, 1914), pp. 38-9.

6. Anthony Bryer, 'Shipping in the Empire of Trebizond', *MM*, LII (1966), pp. 6-7. Antonia de Capmany, *Memorias Historicas sobre la marina commercio y artes de la antigua ciudad de Barcelona* (D. Antonio de Sancha, Madrid, 1779-92), vol. I, pp. 32-3. Gino Luzzatto, *An Economic History of Italy* (Routledge and Kegan Paul, London, 1961), pp. 87-9, 113-14.

7. F. C. Lane, 'Note: Stowage Factors in the Maritime Statutes of Venice', *MM*, LXIII (1977), pp. 293-4. R. H. Dolley, 'The "Nef" Ships of the Ravenna Mosaics', *MM*, XXXVIII (1952), pp. 317-18. John E. Dotson, 'Jal's *Nef X* and Genoese Naval Architecture in the Thirteenth Century', p. 166. F. C. Lane, 'Tonnages, Medieval and Modern', pp. 218-20, 229-30. G. B. Rubin de Cervin, ' "Nefs" or "Corbitae" ', *MM*, XL (1954), p. 184.

8. S. D. Goitein, *A Mediterranean Society*, vol. I, *Economic Foundations* (University of California Press, Berkeley, 1967), pp. 30-9, 278-80, 295-307,

477 n13, and *Studies in Islamic History and Institutions* (E. J. Brill, Leiden, 1966), pp. 301-10. F.W. Brooks, *The English Naval Forces 1199-1272* University of Manchester Press, Manchester, 1932), p. 2.

9. G. La Roërie and J. Vivielle, *Navires et Marins*, p. 91. Archibald R. Lewis, *Naval Power and Trade in the Mediterranean*, pp. 234-6. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, p. 169. Legend has it that King Sigurd, the Jerusalem traveller as he was known, gave up his ships in Constantinople as a gift. By that time they had probably been so infested with shipworm that they were of little use except as firewood.

10. G. Asaert, *Westeuropese scheepvaart in de middeleeuwen*, pp. 25, 33-5. W. A. Engelbrecht, *Schets der Historische Betrekkingen Portugal-Nederland* (Martinus Nijhoff, The Hague, 1940), pp. 1-5. Bernhard Hagedorn, *Die Entwicklung der wichtigsten Schiffstypen*, pp. 25, 36-7. Walther Vogel, *Geschichte der Deutschen Seeschiffahrt*, pp. 124-32, 138-45. Bailey W. Diffie, *Prelude to Empire*, pp. 12-27.

11. José L. Casado Soto, 'Arquitectura naval en el Cantabrico durante el siglo XIII', *Altamira* (Santander, 1975), pp. 23-56. I am indebted to P.T. van der Merwe of the National Maritime Museum, Greenwich, UK, for supplying me with a translation of this article. Archibald R. Lewis, 'Northern European Sea Power and the Straits of Gibraltar, 1031-1350 A.D.', in William C. Jordan *et al.* (eds), *Order and Innovation in the Middle Ages: Essays in Honor of Joseph R. Strayer* (Princeton University Press, Princeton, 1976), pp. 140-54.

12. Maurice Lombard, 'Arsenaux et bois de marine dans la Méditerranée musulmane', pp. 74-80. Hélène Antoniadis-Bibicou, *Etudes d'histoire maritime de Byzance*, p. 23.

13. F. C. Lane, 'The Economic Meaning of the Invention of the Compass', *American Historical Review*, LXVIII (1963), pp. 607-8. E. G. R. Taylor, *The Haven-Finding Art*, pp. 94-8. Heinrich Winter, 'Who Invented the Compass?', *MM*, XXIII (1937), pp. 95-102. Barbara M. Kreutz, 'Mediterranean Contributions to the Medieval Mariner's Compass', *Technology and Culture*, XIV (1973), pp. 367-72. W. E. May, *A History of Marine Navigation* (G. T. Foulis and Co. Ltd, Henley-on-Thames, 1973), pp. 45-6.

14. Hélène Ahrweiler, *Byzance et la Mer*, pp. 185-97, 229-30. Hélène Antoniadis-Bibicou, *Etudes d'histoire maritime de Byzance*, pp. 116-17. She sees the decline of the navy in the eleventh century as a symptom of the general breakdown of the Byzantine polity. That is true but begs the question. Archibald R. Lewis, *Naval Power and Trade in the Mediterranean*, pp. 194-201, 217, 225-46.

15. R. C. Anderson, 'The Oars of Northern Long-Ships', *MM*, XXIX (1943), pp. 191-5. Romola and R. C. Anderson, *The Sailing-Ship*, pp. 77-80. The claim of 90 metres' length for the largest of King Canute's ships is impossible as R. C. Anderson argued elsewhere. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, pp. 126-9, 136-59, 172-3. The measures come from an Icelandic source and may exaggerate the lengths. There appears to have been some experimenting in the thirteenth century with two decks of oars but that was highly abnormal. Ole Crumlin-Pedersen, *Traeskibet. Fra Langskib til Fregat* (Traebranchens Oplysningsrad, Copenhagen, 1968), pp. 4, 24. There are reports of longships of 40 pairs, 45 pairs and 60 pairs of oars but these seem exaggerated. The largest was probably of 37 rooms.

16. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, pp. 162, 175-6. Archibald R. Lewis, *The Northern Seas*, pp. 448-9. Tradition dates the beginning of the Norwegian system of mustersships at about 950. He suggests it may have been copied from the methods of Alfred the Great in England. Adolf Schück, 'Ledung och Konunghamn', *Sjöhistorisk Årsbok* (1950), pp. 97-128. G. P. Harbitz

et al., *Den Norske Leidangen* (Sjøforsvarets Overkommando, Oslo, 1951), pp. 11-160. Edvard Bull, *Leding* (Steenske Forlag, Oslo, 1920).

17. Ole Crumlin-Pedersen, *Das Haithabusschiff Berichte über die Ausgrabungen in Haithabu*, Schleswig-Holsteinisches Landesmuseum für Vor- und Frühgeschichte, Bericht 3 (Karl Wachholtz Verlag, Neumünster, 1969), pp. 29-32. *HSUA*, p. 186. *FHMN*, p. 47. Olaf Olsen and Ole Crumlin-Pedersen, 'The Skuldelev Ships', pp. 170-2.

18. *AB*, pp. 250-2. Harald Åkerlund, 'Skeppsfyndet vid Falsterbo 1932', *Sjöhistorisk Årsbok* (1950), pp. 93-100. The vessel is dated about 1300 with an over-all length of 13.5 metres and a capacity of about 40 tons. The Galtabäck boat from Sweden, dated about 1100, was about 13.1 metres long and with similar proportions. It showed the same change in internal frames as did the Eltang ship of about 20 tons from the twelfth century found in Denmark. Sigvard Skov, 'Et Middelalderligt Skibsfund fra Eltang vig', *Sætryk af Kuml, Årbog for Arkaeologisk Selskab* (1952), pp. 71, 82-3. Knut Helle, 'Trade and Shipping between Norway and England in the Reign of Håkon Håkonsson (1217-63)', *Sjøfartshistorisk Årbok* (1967), pp. 24-6. Archibald R. Lewis, *The Northern Seas*, pp. 483-4. Carl V. Sølver, 'The Rebaek Rudder', *MM*, XXXII (1946), p. 117. Gerhard Timmerman, 'Schiffbauprobleme zur Hansezeit', *Handels- og Søfartsmuseet På Kronborg, Årbog* (1966), pp. 288-92.

19. Harald Åkerlund, *Fartygsfynden i den Forna Hamnen i Kalmar* (Almquist and Wiksells Boktryckeri AB, Uppsala, 1951), p. 157. He believes that Kalmar Find I may have been a *buza*. Narve Bjørgo, 'Skipstyper i norrøne sam tidssoger', *Sjøfartshistorisk Årbok* (1965), pp. 9-14, 20. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, pp. 154, 179-80. Paul Heinsius, *Das Schiff der Hansischen Frühzeit*, pp. 207-8. G. J. Marcus, 'The Evolution of the Knörr', p. 122.

20. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, pp. 181-2. *HSUA*, p. 190. Knut Helle, 'Trade and Shipping between Norway and England', pp. 8-14, 18-29. *AB*, pp. 259-69.

21. Harald Åkerlund, *Fartygsfynden i den Forna Hamnen i Kalmar*, pp. 151-2. Ole Crumlin-Pedersen, 'Cog-Kogge-Kaag', pp. 129-34. *HSUA*, p. 187. Wreck Q75, found in the polder land of the former Zuider Zee, dated from the twelfth century, shows all the features of the earlier cog and has a keel. The Eltang ship (see note 20) was a cog as well. *FHMN*, pp. 64, 69-71, 74-6, 120. Paul Heinsius, *Das Schiff der Hansischen Frühzeit*, pp. 104-12.

22. *FHMN*, pp. 238-47. Paul Heinsius, *Das Schiff der Hansischen Frühzeit*, pp. 73-6. The word cog to describe a large deep-sea trading vessel was not used until about 1200 in either the Baltic or North Sea. The delay of over a century is not unexpected given the nature of written records, the fact that they were in Latin and the kinds of people who kept them.

23. Roger Degryse, 'De maritieme aspecten van de keure van Nieuwpoort van 1163', *MAB*, XX (1968), p. 68. Paul Heinsius, 'Dimensions et Caractéristiques des "Koggen" Hanséatiques dans le Commerce Baltique', *TCHM*, III, pp. 9-11, and *Das Schiff der Hansischen Frühzeit*, pp. 89-102. Walther Vogel, *Geschichte der Deutschen Seeschiffahrt*, vol. I, pp. 126-8. F. W. Brooks, *The English Naval Forces*, p. 17. *FHMN*, p. 259.

24. Romola and R. C. Anderson, *The Sailing-Ship*, pp. 82-3. F. W. Brooks, 'Naval Armament in the Thirteenth Century', pp. 121-30. *HSUA*, pp. 190-1. The change to cogs from longships came in Denmark in 1304. The island of Sealand was required to supply 120 longships but after the change the requirement was five to ten cogs, reflecting the greater size and expense of the bigger ships. Adolf Schück, 'Ledung och Konunghamn', p. 128. The change from supplying longships led to a change in taxation. Governments were more interested in cash payments to build, equip and maintain cogs than in the labour of local farmers and

fishermen to build, maintain and man longships.

25. F.W. Brooks, *The English Naval Forces*, pp. 8-16, 54-68, 79-110, 168-94, and 'William de Wrotham and the Office of Keeper of the King's Ports and Galleys', *English Historical Review*, XL (1925), pp. 570-9.

26. Harald Åkerlund, *Fartygsfynden i den Forna Hamnen i Kalmar*, p. 152. Paul Heinsius, *Das Schiff der Hansischen Frühzeit*, pp. 109-14, 128-9. His argument that cogs were of skeleton construction based on the inverse clinkering and the methods of house building in Germany in the twelfth century is not convincing. J. H. Parry, *Discovery of the Sea*, pp. 20-2.

27. G. Asaert, *Westeuropese scheepvaart in de middeleeuwen*, pp. 93-5. H. H. Brindley, 'Mediaeval Ships', VII, *MM*, III (1913), pp. 14-16, and VIII, *MM*, IV (1914), pp. 110-11. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, p. 182. Paul Heinsius, *Das Schiff der Hansischen Frühzeit*, pp. 134-9, 145.

28. Romola and R. C. Anderson, *The Sailing-Ship*, pp. 85-90. *HSUA*, pp. 189-90. Paul Heinsius, *Das Schiff der Hansischen Frühzeit*, pp. 119-26. H. S. Vaughan, 'The Whipstaff', I, *MM*, III (1913), pp. 231-2, and II, *MM*, IV (1914), pp. 135-7.

29. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, pp. 164-5. W. L. Goodman, *The History of Woodworking Tools*, pp. 116-19, 125-32, 165-72. Henry C. Mercer, *Ancient Carpenters' Tools*, pp. 17-21, 179-80. Paul Heinsius, *Das Schiff der Hansischen Frühzeit*, pp. 127-8. The breast auger improved the efficiency of the youngest and least skilled carpenters since they were the ones given the job of boring holes for the treenails: J. T. Tinniswood, 'English Galleys, 1272-1377', *MM*, XXXV (1949), p. 280.

30. H.H. Brindley, 'Mediaeval Ships', V, *MM*, II (1912), pp. 44-52, VII, *MM*, III (1913), pp. 337-40, and VIII, *MM*, IV (1914), pp. 112, 130-3. *FHMN*, pp. 60, 120. Bernhard Hagedorn, *Die Entwicklung der wichtigsten Schiffstypen*, pp. 214-18, 222-4.

31. *FHMN*, pp. 57-9. Paul Heinsius, *Das Schiff der Hansischen Frühzeit*, pp. 201-10.

32. G. Asaert, *Westeuropese scheepvaart in de middeleeuwen*, pp. 133-5. Nantes, not an insignificant port, did not have a stone quay until 1492 so the process of adopting quays was a slow one. *FHMN*, pp. 159-64, 170-4. Bernhard Hagedorn, *Die Entwicklung der wichtigsten Schiffstypen*, pp. 22-3.

33. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, p. 162. Eugene H. Byrne, *Genoese Shipping in the Twelfth and Thirteenth Centuries*, pp. 25-6. Paul Heinsius, *Das Schiff der Hansischen Frühzeit*, pp. 150-1. Arne Emil Christensen, *Scheepveart van de Vikingen* (DeBoer Maritiem, Bussum, 1977), pp. 53-7.

34. G. Asaert, *Westeuropese scheepvaart in de middeleeuwen*, pp. 125-8. Eugene H. Byrne, *Genoese Shipping in the Twelfth and Thirteenth Centuries*, pp. 12-15, 22-4. Karl-Friedrich Krieger, *Ursprung und Wurzeln der Rôles D'Oléron* (Böhlau Verlag, Cologne, 1970), pp. 17-23, 71-6.

35. F. C. Lane, 'Progrès technologiques et productivité dans les transports maritimes de la fin du Moyen Age au début des Temps modernes', p. 277. He is right to say that no precise measure is possible of the contribution of technical change in shipbuilding to European growth. The necessary quantitative data do not exist. Data do not exist for any other possible explanatory factors, population being only a partial exception, so each must be weighed and estimates made based on non-numerical information.

36. M. Oppenheim, *A History of the Administration of the Royal Navy and of Merchant Shipping in Relation to the Navy* (John Lane the Bodley Head, London, 1896), pp. 4-6. Michael Lewis, *The History of the British Navy* (Penguin Books, Harmondsworth, 1957), pp. 13-18.

37. B. W. Bathe, *Seven Centuries of Sea Travel from the Crusaders to the*

Cruises (Barrie and Jenkins, London, 1972), p. 18. Eugene H. Byrne, *Genoese Shipping in the Twelfth and Thirteenth Centuries*, pp. 59-61. Paul Gille, 'Jauge et Tonnage des Navires', *TCHM*, I, pp. 92-3. F. C. Lane, 'Tonnages, Medieval and Modern', p. 221.

38. Land transport also benefited from low charges in taxes and fees for road use. Over all, road transport continued to be highly flexible. R. S. Lopez, 'The Evolution of Land Transport in the Middle Ages', *Past and Present*, 9 (1956), pp. 17-29. F. M. Stenton, 'The Road System of Medieval England', *Economic History Review*, VII (1936), pp. 19-20.

NOTES TO ILLUSTRATIONS

a. Anthony Bryer, 'Shipping in the Empire of Trebizond', *MM*, LII (1966), p. 10, figure 7. Lionel Casson, *Illustrated History of Ships and Boats*, no. 51.

b. John E. Dotson, 'Jal's *Nef X* and Genoese Naval Architecture in the Thirteenth Century', *MM*, LIX (1973), p. 164. *HSUA*, p. 213. Marco Bonino, 'Lateen-rigged medieval ships', *IJNA*, VII (1978), p. 11. Björn Landström, *The Ship*, nos. 211, 214, 219, 230.

c. Romola and R. C. Anderson, *The Sailing-Ship*, p. 105. Lionel Casson, *Illustrated History of Ships and Boats*, nos. 96-7. R. H. Dolley, 'The "Nef" Ships of the Ravenna Mosaics', *MM*, XXXVIII (1952), opposite p. 318. Bernhard Hagedorn, *Die Entwicklung der wichtigsten Schiffstypen*, p. 38. Paul Heinsius, *Das Schiff der Hansischen Frühzeit*, p. 36. G.B. Rubin de Cervin, ' "Nefs" or "Corbitae" ', *MM*, XL (1954), p. 184. Björn Landström, *The Ship*, nos. 225-9, 231.

d. Hélène Antoniadis-Bibicou, *Etudes d'histoire maritime de Byzance*, between p. 24 and 25, plate IV.

e. G. Asaert, *Westeuropese scheepvaart in de middeleeuwen* (Unieboek, Bussum, 1974), p. 48. Romola and R. C. Anderson, *The Sailing-Ship*, pp. 79-80. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, pp. 164-5. Lionel Casson, *Illustrated History of Ships and Boats*, nos. 77-8. Bernhard Hagedorn, *Die Entwicklung der wichtigsten Schiffstypen*, plate II. Claude Farrère, *Histoire de la Marine Française*, pp. 8-11. G. S. Laird Clowes, *Sailing Ships*, part I, p. 45. Björn Landström, *The Ship*, nos. 160, 161, 163. G. La Roërie and J. Vivielle, *Navires et Marins*, vol. I, pp. 177, 184-5, 187-8.

f. Harald Åkerlund, 'Galtabäcksbatens, ålder och härstamning. II', *Sjöhistorisk Årsbok* (1948), p. 80, and 'Skeppsfyndet vid Falsterbo 1932), *Sjöhistorisk Årsbok* (1950), pp. 96, 99, 103. Paul Heinsius, *Das Schiff der Hansischen Frühzeit*, p. 52. *FHMN*, pp. 37-8, 40-2. Björn Landström, *The Ship*, nos. 189-91. Olaf Olsen and Ole Crumlin-Pedersen, 'The Skuldelev Ships (II)', p. 173. Gerhard Timmermann, 'Schiffbauprobleme zur Hansezeit', *Handels- og Søfartsmuseet på Kronborg, Årbog* (1966), p. 291.

g. *AB*, no. 164. Siegfried Fliedner, ' "Kogge" und "Hulk" ', nos. 56, 63. Paul Heinsius, *Das Schiff der Hansischen Frühzeit*, p. 51.

h. G. Asaert, *Westeuropese scheepvaart in de middeleeuwen*, p. 25. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, p. 181. *FHMN*, p. 65. Siegfried Fliedner, ' "Kogge" und "Hulk" ', nos. 43-6, 49-55, 76-7. Bernhard Hagedorn, *Die Entwicklung der wichtigsten Schiffstypen*, plates V, VI. Paul Heinsius, *Das Schiff der Hansischen Frühzeit*, p. 65, plate IX, nos. 19-20. Björn Landström, *The Ship*, no. 169.

i. G. Asaert, *Westeuropese scheepvaart in de middeleeuwen*, pp. 40, 91-2.

FHMN, p. 44. Siegfried Fliedner, ' "Kogge" und "Hulk" ', nos. 78, 80, 81. Björn Landström, *The Ship*, nos. 164, 165, 167, 168. *AB*, no. 165. *HSUA*, p. 196.

j. G. Asaert, *Westeuropese scheepvaart in de middeleeuwen*, p. 94. H. H. Brindley, 'Early Reefs', *MM*, VI (1920), opposite p. 65. Siegfried Fliedner, ' "Kogge" und "Hulk" ', nos. 81, 85. Paul Heinsius, *Das Schiff der Hansischen Frühzeit*, pp. 4, 41, plate II, no. 3. Björn Landström, *Sailing Ships*, nos. 162, 166. *HSUA*, p. 196.

k. G. Asaert, *Westeuropese scheepvaart in de middeleeuwen*, opposite p. 32, p. 92. H. H. Brindley, 'Early Reefs', p. 79, opposite p. 80, and 'Mediaeval Ships', *MM*, II (1912), p. 131, opposite pp. 132, 133 and 166, p. 167, opposite p. 239, p. 241, III (1913), opposite p. 14. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, p. 181. Björn Landström, *Sailing Ships*, no. 163, and *The Ship*, no. 170. Paul Heinsius, *Das Schiff der Hansischen Frühzeit*, plate VI, no. 13. G. La Roërie and J. Vivielle, *Navires et Marins*, vol. I, pp. 196-7.

l. *AB*, no. 40. G. Asaert, *Westeuropese scheepvaart in de middeleeuwen*, pp. 94, 105-6. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, p. 183. Romola and R. C. Anderson, *The Sailing-Ship*, plate III. Siegfried Fliedner, ' "Kogge" und "Hulk" ', nos. 6-7, 98. Bernhard Hagedorn, *Die Entwicklung der wichtigsten Schiffstypen*, plate V. Paul Heinsius, *Das Schiff der Hansischen Frühzeit*, p. 48, plate X, no. 21. G. La Roërie and J. Vivielle, *Navires et Marins*, vol. I, p. 193. Björn Landström, *The Ship*, nos. 174-7.

m. Henry C. Mercer, *Ancient Carpenters' Tools*, p. 24.

n. A. W. Brøgger and Haakon Shetelig, *The Viking Ships*, pp. 168-9. *HSUA*, pp. 196-7. Claude Farrère, *Histoire de la Marine Française*, pp. 7, 25. Henry C. Mercer, *Ancient Carpenters' Tools*, p. 179. Paul Heinsius, *Das Schiff der Hansischen Frühzeit*, p. 110. Olaf Olsen and Ole Crumlin-Pedersen, 'The Skuldelev Ships (II)', pp. 154-5.

o. G. Asaert, *Westeuropese scheepvaart in de middeleeuwen*, opposite pp. 16, 107. H. H. Brindley, 'Mediaeval Ships', *MM*, I (1911), p. 44, II (1912), pp. 3, 47, IV (1914), p. 132. *HSUA*, p. 199. *FHMN*, p. 55. Siegfried Fliedner, ' "Kogge" und "Hulk" ', nos. 1, 8-9. Paul Heinsius, *Das Schiff der Hansischen Frühzeit*, p. 215. *AB*, nos. 39, 201, 202.

p. Romola and R. C. Anderson, *The Sailing-Ship*, p. 81. Lionel Casson, *Illustrated History of Ships and Boats*, nos. 79-83. G. S. Laird Clowes, *Sailing Ships*, part I, p. 47. G. Asaert, *Westeuropese scheepvaart in de middeleeuwen*, opposite p. 17, p. 90. *FHMN*, p. 44. Paul Heinsius, *Das Schiff der Hansischen Frühzeit*, pp. 40, 44-5, 47-8, plate III, nos. 7-8, plate VII, no. 15. Siegfried Fliedner, ' "Kogge" und "Hulk" ', nos. 42, 82-4. G. La Roërie and J. Vivielle, *Navires et Marins*, vol. I, p. 191, plate VIII, nos. 1, 3, p. 202. Bernhard Hagedorn, *Die Entwicklung der wichtigsten Schiffstypen*, p. 31. Björn Landström, *The Ship*, no. 166.

q. G. Asaert, *Westeuropese scheepvaart in de middeleeuwen*, p. 90. Richard Lebaron Bowen, Jr, 'The origins of fore-and-aft rigs', p. 281. Siegfried Fliedner, ' "Kogge" und "Hulk" ', nos. 79, 89. Bernhard Hagedorn, *Die Entwicklung der wichtigsten Schiffstypen*, plate IV, XIV. Björn Landström, *The Ship*, no. 179. G. La Roërie and J. Vivielle, *Navires et Marins*, vol. I, plate IX, no. 1, p. 203.