MEDIEVAL SEAMANSHIP UNDER SAIL

by

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ABSTRACT

Voyages of discovery could not be entertained until the advent of three-masted ships. Single-sailed ships were effective for voyages of short duration, undertaken with favourable winds. Ships with two masts could make long coastal voyages in the summer. Both these types had more or less severe limitations to sailing to windward. To sail any ship successfully in this mode it is necessary to be able to balance the sail plan accurately. This method of keeping course could not reach its full developemnt until more than two sails were available for manipulation. Rudders never were adequate to hold ships to windward courses. Ships with three or more masts could be sailed in all weather with very little dependence on the power of the rudder and the freedom from this limitation made it possible to build ships large enough to carry sizable crews, their stores and spare gear over ocean crossings.

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CHAPTER I

THE SAIL: A SHEET TO THE WIND.

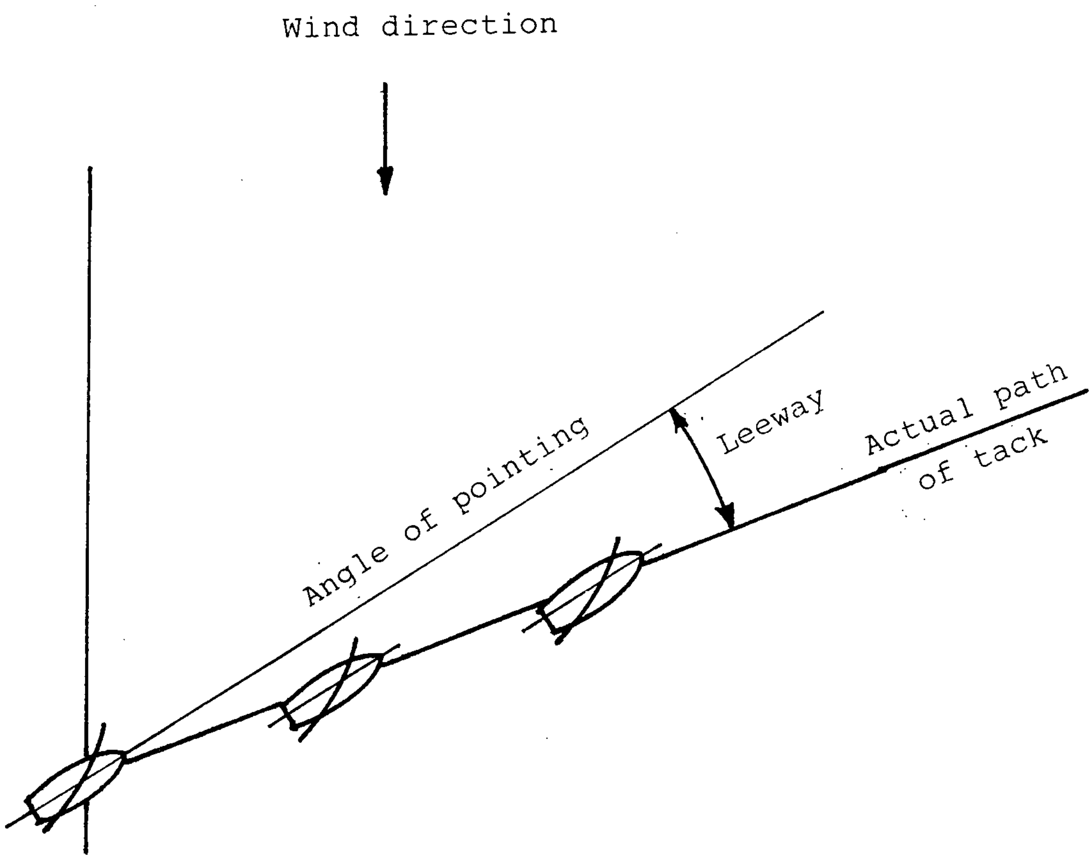
The ocean was first conquered in 1492 by Columbus, and within 27 years the whole world was girded. By Magellan's time navigational aids relative to the scope of ocean-going endeavours were still extremely rudimentary or non-existant. That was true of charts and astronomical instruments, including time-keeping devices. Determining longitudes at sea was impossible. Navigation as a science was unknown and consisted wholly of the process of dead-reckoning, supplemented by environmental observations, such as visual sightings and the examination of bottom samples brought up by the lead-line. It was possible though to determine one's latitude, probably within 30 or 40 nautical miles under ideal conditions. Dead-reckoning navigators, therefore, only required two tools -- compass and lead line -- and one fundamental skill -- seamanship -- to ensure that their ships would follow the desired courses as closely as possible, within very narrow margins of safety. The development of the technology required to control ships of increasingly large size for the length of time necessary to cover great distances following a practical path between two points, is the medieval lesson in sea-faring. Sailors advanced from handling ships that could only be sailed in favourable weather for the duration of short voyages, to the manipulation of ships with complex sail plans, capable of long, uninterrupted coastal voyages that encompassed the Atlantic shores of Europe and voyages over all the seas of the world, in all weather.

Early medieval ships, with a single square sail and one side-rudder, and even with a sternpost rudder, were difficult to control, but compatible with voyages of short duration. They could only leave harbour with favourable winds. Two-masted ships offered a measure of direction control that was adequate in fair weather, but was prone to fail under conditions of reduced sail area. The advent of the tri- and multi-masted ship changed that. A study of the steps in the development of sailing methods, based on available documents, some of which contain extensive statistical data, and of the shipboard practices accompanying this evolution, will provide information about the sea-going capabilities available and necessary for winter sailing and, ultimately, for the undertaking of deliberate voyages of discovery across oceans. The evidence of this study is intended to support the thesis that such activities could not have been carried out prior to the introduction of multiple masts. Very long voyages required large crews, to make up for losses due to disease and accidents, and large stores in the form of food and spare gear, all of which meant a need for ships of large displacement. Displacement translates itself to momentum, that is to say resistance to abrupt changes of direction. This resistance had to be overcome in emergencies and in day-to-day maneuvering in ever-changing circumstances. Owing to the size of these ships the demands could not be met by the sailing mariner except by his being able to use the power of the wind for steering.

There has been no time in the history of sailing when the requirements for overcoming momentum were adequately met by the available steering gear. Therefore it has been essential for sailors to learn to follow their courses by balancing the sail plan of their craft and to execute changes of course by altering it. This art could not reach a complete measure of success until the introduction of the multi-masted ship.[1] The contribution of the rudder to keeping a course was minimal. Going about and changing tacks was accomplished by re-setting the sails in the required order. The rudder was at best useful for this purpose, but not essential.

One major difficulty in assessing the sailing capabilities of early medieval sailing vessels is the dearth of descriptions of everyday medieval seamanship. Archaeological finds and graphic descriptions still provide the best clues as to how vessels were constructed and rigged. Too many variables affect the results of tests, on full-size replicas or on models in test-tanks and wind-tunnels, for us to be able to arrive at self-evident conclusions as to how the vessels were in fact sailed[2]. The tradition of sailing single-masted square-sailed boats has practically died out in Europe and such folk-sailors that still cling to this practice, in the Shetland Islands for instance, do so in hulls of quite recent design, with the help of fairly sophisticated gear that is equally modern. Therefore no valid experience can be gained from these sources.

There is little difficulty with understanding the early method of downwind sailing, as all that was required for this purpose was a sail of any shape, hoisted and balloning over the forepart of the ship. The same sail, if too crudely cut and thoughtlessly rigged, was not able to take the ship upwind. In order to entertain the idea of travelling to windward it is necessary first of all to have a ship that can be pointed that way and even when this is possible it does not necessarily follow that the resulting trajectory will actually see the ship reaching any point upwind of her point of departure. As a ship pointing to windward must sail at some angle to the wind, the wind pressure on the exposed side of the hull and the sails will push her downwind to some extent. Sailors call 'leeway' the difference between the direction in which the ship is pointed and the direction of the path actually sailed (Figure 1, p. 6). Various elements affect this angle in different ways, up to the point of making it so large as to deny the sailor any practical gains. Among these elements 'windage' was the least understood: windage is the amount of wind caught by all the surfaces that do not contribute to sailing, necessary as they may be to other functions. Castles were the most notorious sources of windage on medieval craft. As long as the only method of warfare at sea was boarding, large and tall "castles" were necessary to provide offensive and defensive advantages to the fighters and were the most prominent superstructures of medieval ships. As sailing technology progressed and ships became able to hold reliably courses to windward, bigger castles were built. The advantages of improved sail plans were again lost to the necessities of warfare and the performance of ships to windward improved very little. In the first half of the sixteenth century ships with four masts and topsails could not sail appreciably closer to the wind than the basic three-masted ships of the previous century. At that time the concept of sea-battles consisting of artillery duels at a distance occur-



Leeway

Figure 1

red to Hawkins, while serving as the comptroller of the English navy, prior to the Armada episode. His ships did not require castles to the same extent and consequently were more weatherly than those of his opponents.

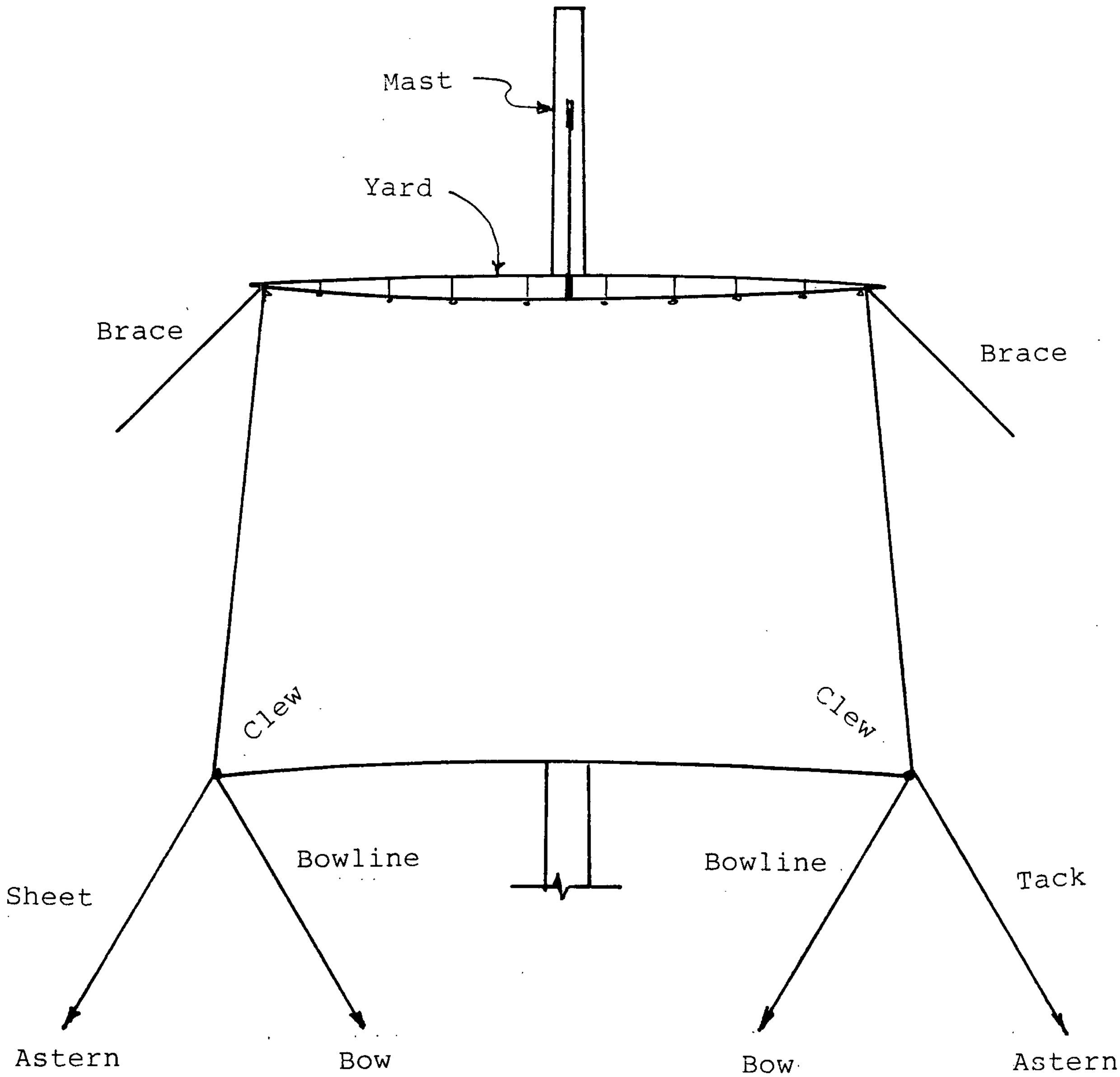
In order to point a ship to windward the following elements are essential (Figure 2, p. 8):

First, a sail that is taller than it is wide or is at least square, or a group of sails arranged on the mast in a similar configuration.

Second, some means of adjusting the position of the centre of the sail on a fore-and-aft line according to the necessities of sailing with the wind or against it, and these include the bowline.

Third, a braced yard. The brace is a rope (or a tackle for bigger sails) going from the tip of the yard to the stern of the ship. The brace prevents the yard from being accidentally flipped around the mast when the ship is pointed too close to the wind.

Fourth, a keel, leeboard or at least a rudder so shaped as to counteract leeway.



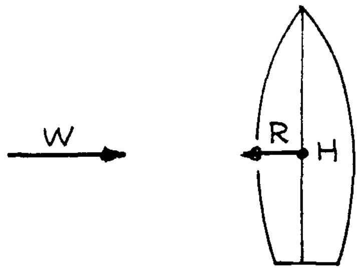
Sheet and tack are two different names for the same rope.
The sheet controls the windward clew.

The square sail
Figure 2

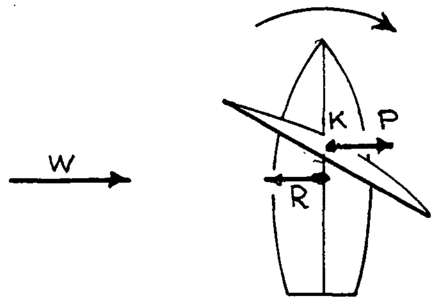
It has not been determined by archaeologists whether early single-sailed ships had braced yards. For this reason it is not clear how those ships were handled in certain sailing conditions. "The invention of the brace was a vital step away from the dependence on oar for getting to windward", according to Owain Roberts, an historian with the National Maritime Museum of Greenwich and a specialist in rigging and ship-handling[3]. The necessity for a braced yard is not self-evident, unless one carries out experiments trying to sail with a square sail to windward. This necessity became obvious to Roberts in the course of witnessing a number of experiments carried out in Denmark and Sweden with replicas of Viking boats with gear typical of the Vikings. To sail at all, in any direction but straight downwind, the sail must be constrained by the bowline, a rope going from the clew to the bow. It follows that the bowline represents the first sail control devised in the earliest attempts to sail with winds anywhere forward of the beam. As a matter of speculation it can be said that the etymology of the equivalent words in many Mediterranean languages would indicate a northern origin for it (It. bolina; Fr. bouline; Sp. bolina; etc.). These southern words are mere sounds that are imitative of that of the northern word, with no roots or local meaning in these languages.

Ordinarily a sail will have the effect of creating a marked tendency for the ship to rotate away from the wind or into the wind. A sail that is rigged too far forward will cause the ship to turn downwind. A sail set too far back will have the opposite effect (Figure 3, p. 11). In minute amounts these tendencies can be used by the sailor to advantage, but, in the general case, rotation creates large forces and a rudder will counteract these effects with only limited success and with no success for sustained periods of navigation. The problem of controlling rotation hinges therefore on the setting of the sail in the broadest sense. The rudder is effective only minimally in this respect, its principal function being that of controlling accidental minor deviations from the course that corresponds to a certain setting of the sail. These deviations, called by sailors 'yaw', are normally random effects of waves striking the bow or the stern, or caused by pitching.

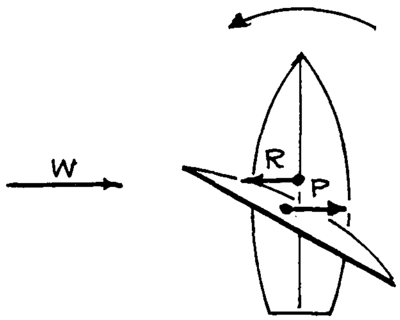
The shape of a sail varies with the angle at which it is struck by the wind and it is never symmetrical, a fact that is obvious even to an untrained eye. The shape varies over time, as well, with the stretching and shrinking of the sailcloth and ropes, as they respond to stresses and wetting. Therefore, the problem of placing and keeping the



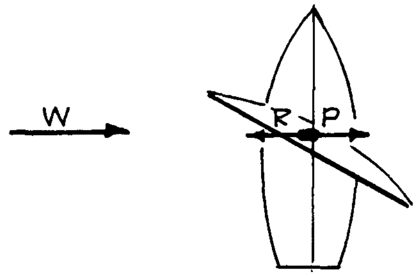
A. The wind W causes the ship to drift. A resistance to drift (R), centered in H, is developed by the hull.



B. A sail set too far forward. The lateral effect of the wind (P) on the sail is centered in K. The result is a rotation downwind.



C. A sail set too far back. The result is a rotation to windward.



D. A sail set neutral. No rotation.

Control of rotation with the single sail

Figure 3

centre of wind pressure anywhere near the centre of resistance to drift is a practical one that requires constant attention to fine tuning and was particularly pronounced when the sail and rigging were wool and hemp. At the same time the sail will cause the ship to heel, that is to lean over downwind, regardless of the mode of sailing, except when the ship is sailed straight downwind. The amount of heeling allowed in sailing oared ships was severly limited by the low freeboard of such vessels. Viking longships are a good example. Leeway, as well, is always present to some extent, regardless of the mode of sailing, except when going straight downwind. Everything else being equal, its intensity is a function of the angle at which the ship is sailed in relation to the wind direction and increases as the ship is brought closer to the wind. Oared ships required shallow hulls and keels and under sail made unacceptable amounts of leeway. Within these parameters the medieval sailor had to learn his professional craft, changing from being a rower to becoming a handler of sails.

Notes to Chapter I.

1. J. H. Parry, an historian with an interest in overseas expansion, has examined the problems of the single square sail in other craft, world-wide, besides medieval ships. He has also studied the various devices used when attempting to overcome its basic disadvantages to windward. These subjects are discussed in the chapter "A Reliable Ship", in The Discovery of the Sea, (The Dial Press, New York, 1974), p. 16-17.

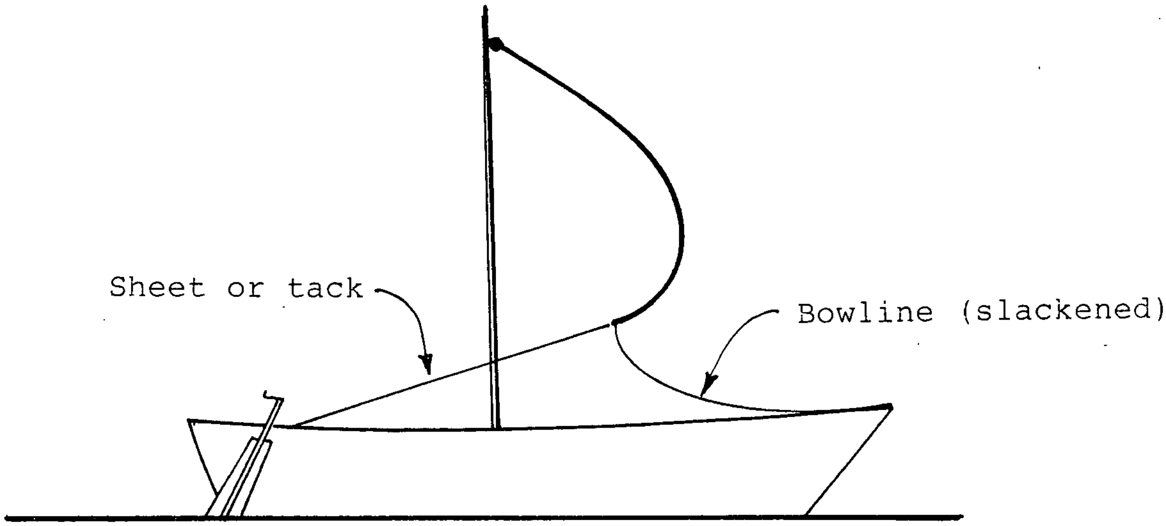
2. Owain Roberts, "Viking Sailing Performance", in Aspects of Maritime Archaelogy and Ethnography, Ed. Sean McGrail, (Wandle Press, London, 1984), pp. 123-151.

3. *Ibid.*, p. 131.

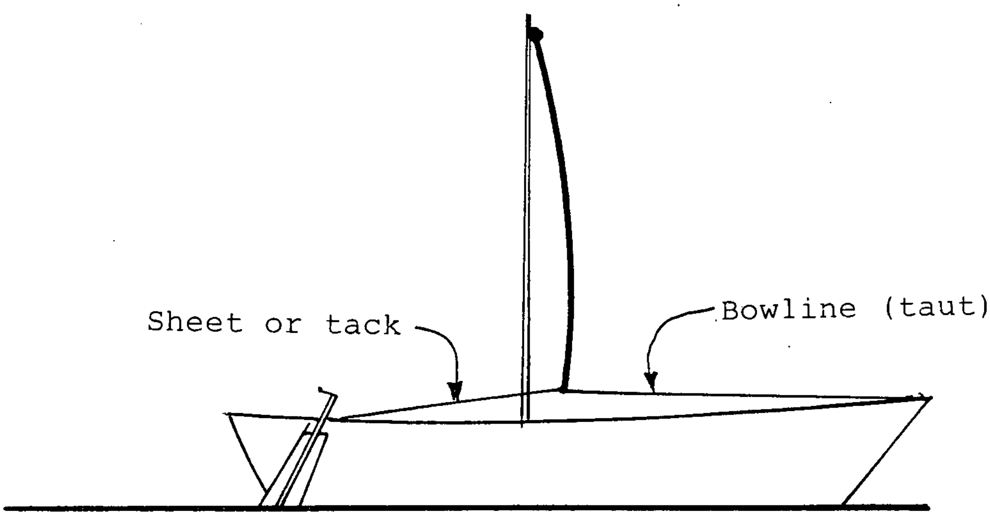
CHAPTER II

SINGLE-MASTED SHIPS

The problems inherent in sailing a single-masted, squared-rigged craft both downwind and anywhere close to the wind are formidable, if the play of the sail is the only device available to the sailor to enable him to control rotation. Such play must have involved the introduction of the bowline, first, in order to flatten the sail while the sheets kept it close to the mast (Figure 4, p. 15), and eventually that of the yard brace to prevent the wrong side of the sail from catching the wind. Also, as a square sail will not keep its shape steadily on a broad reach (Figure 5, p. 17), a system of multiple sheets was used, as had already been done in Roman ships, and the whole crew had to participate in the effort, each man holding one of the sheets. The experiments with imitation Viking gear, mentioned above, included a trial of this method of sail control. The boat was sailed successfully on various downwind courses, with the foot of the sail being kept adjusted as required[1]. On un-oared ships this solution was impractical, for lack of manpower. The problem of controlling a large, balloning sail



Downwind



Upwind

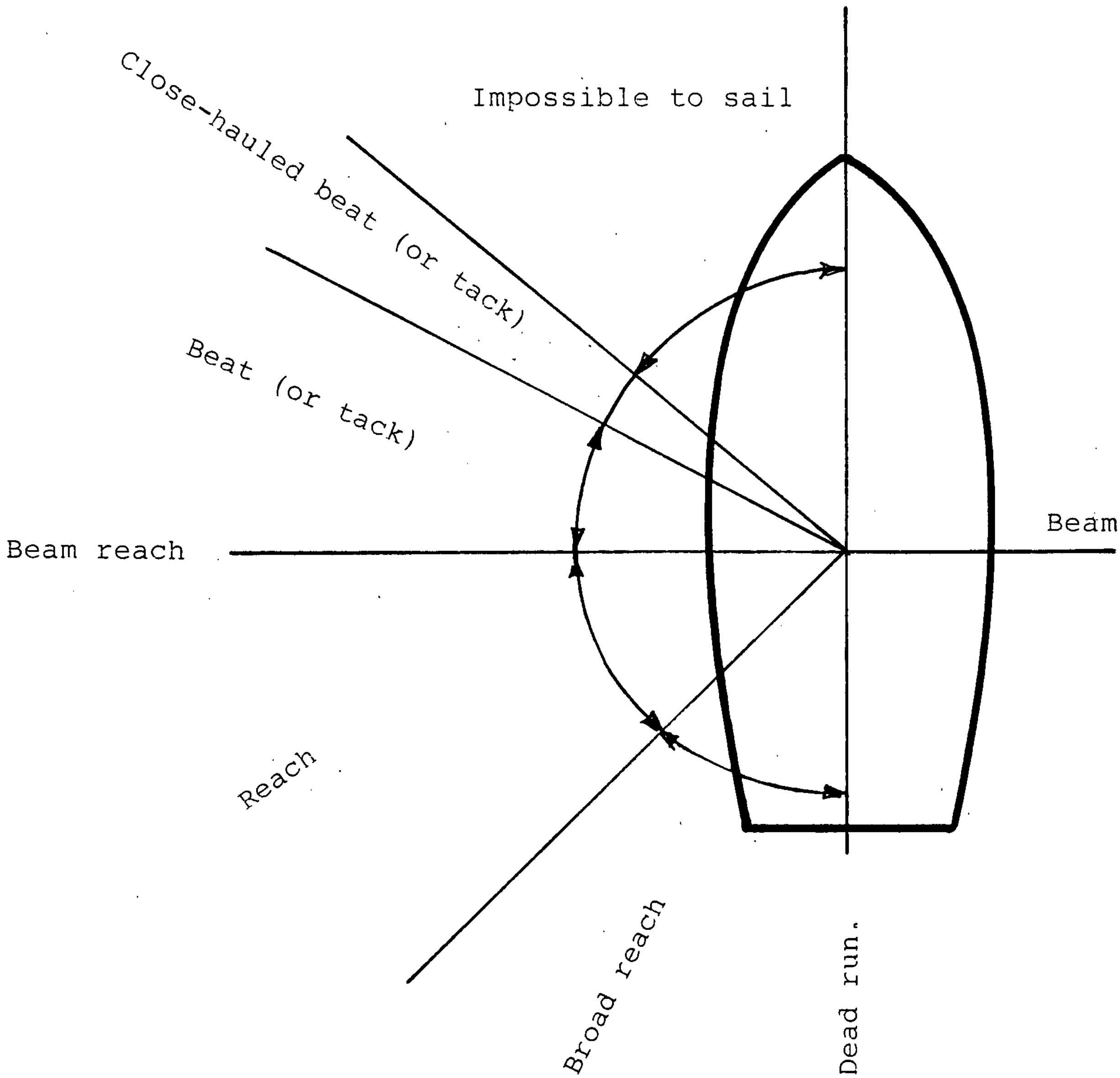
The function of the bowline in sail-setting

Figure 4

was never satisfactorily solved until divided sail plans that included topsails were introduced in the fifteenth century. However, some sort of whisker pole, used in conjunction with sheet and bowline would give the best possible results at stabilizing the sail on a run or on a broad reach.[2]

The control of rotation, it seems, was still quite marginal in single-masted, squared-sailed ships, except in fair weather, when great forces are not encountered. The amount the sail had be moved fore-and-aft to ensure stable sustained sailing in any direction, day and night, to compensate for the stretching and shrinking of gear could hardly be achieved by the coarse manipulation of the sail alone with sheets, bowlines and whisker-poles. But if it was possible to alter measurably the angle of rake of the mast, then there are reasons for accepting the idea that boats with adequate height of freeboard and at least a moderate depth of keel would indeed have been capable of sailing downwind and also close to the wind, and also, to some measure, holding a course. This requirement could be plausibly fulfilled by a stern windlass or a simple system of toggles or dead- eyes on the backstay[3].

Windlasses in <u>knörrs</u>, the Vikings' cargo boats, are mentioned in sagas even in the twelfth century[4] and in

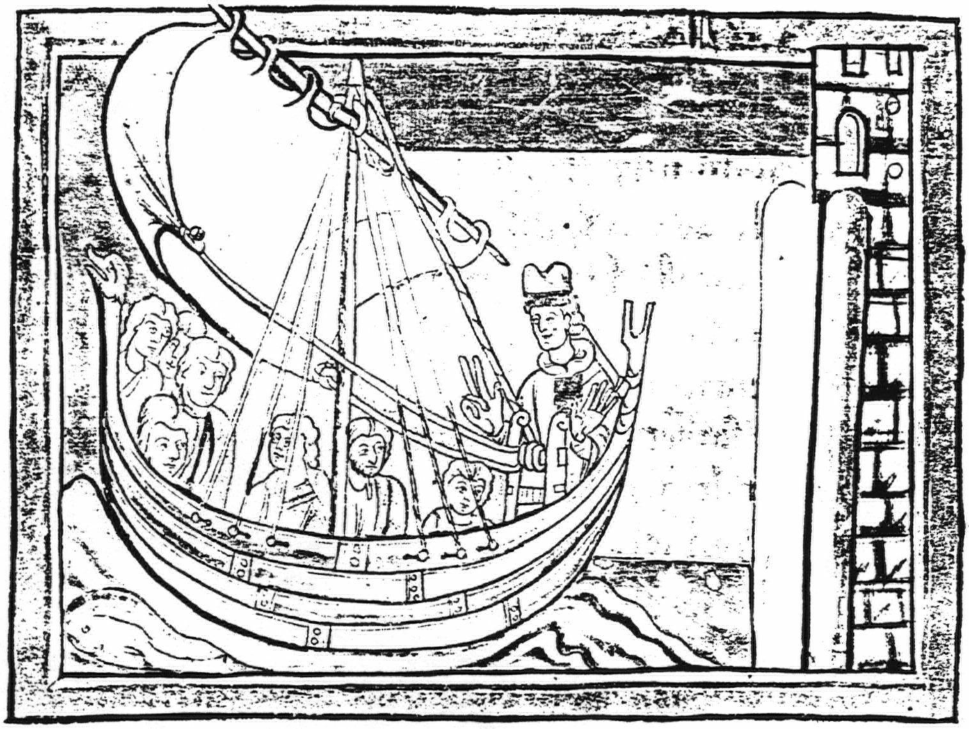


Modes of sailing

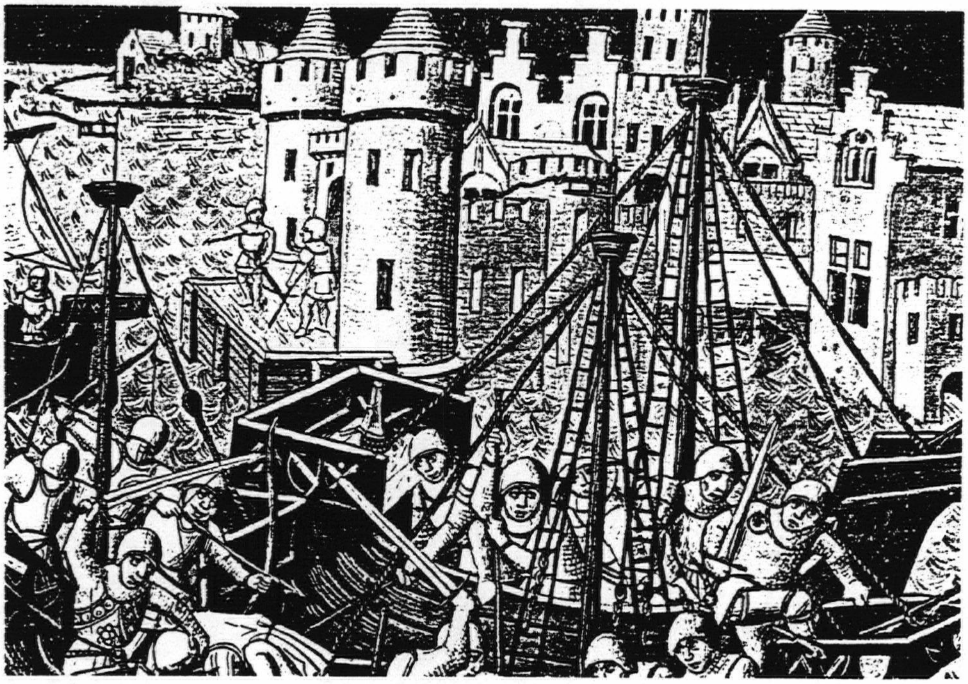
Figure 5

his ideal reconstruction of a knörr, from a number of reproductions, Björn Landström, an authoritative illustrator of the development of ships and the author of many books on this subject, shows the backstay of that type of boat attached to a stern windlass[5]. An inventory of the gear found in the Cog John after she foundered in 1414 includes an apparatus for the mast[6]. Cogs, too, had a windlass or a capstan on the stern castle[7], which would be used for handling cargo and to weigh the anchors. However, if these were to be its only purposes, this winch would have obviously been installed somewhere nearer to the mast and the forecastle, as was common in later, multi-masted ships. The conclusion is almost inevitable that the location of the winch on the very stern had the purpose of adjusting the rake of the mast according to the different necessities of sailing downwind or close-hauled (Figure 6, p. 19).

Warships had to keep their maneuvrability under oars pre-eminent, a fact that would make their sailing capabilities rather indifferent, as, later, was the case with single-masted galleys. Therefore experiments with reconstructed warships are not likely to provide evidence of the best sailing performance possible at the time. For merchant vessels the presence of a large number of rowers in them would have increased operating costs and therefore



A. A windlass. A miniature in Gregorii Dialogi. Royal Library, Brussels. (From G. Asaert, Westeuropese scheepvaart in de middeleeuwen, 1974, Plate facing p. 33).



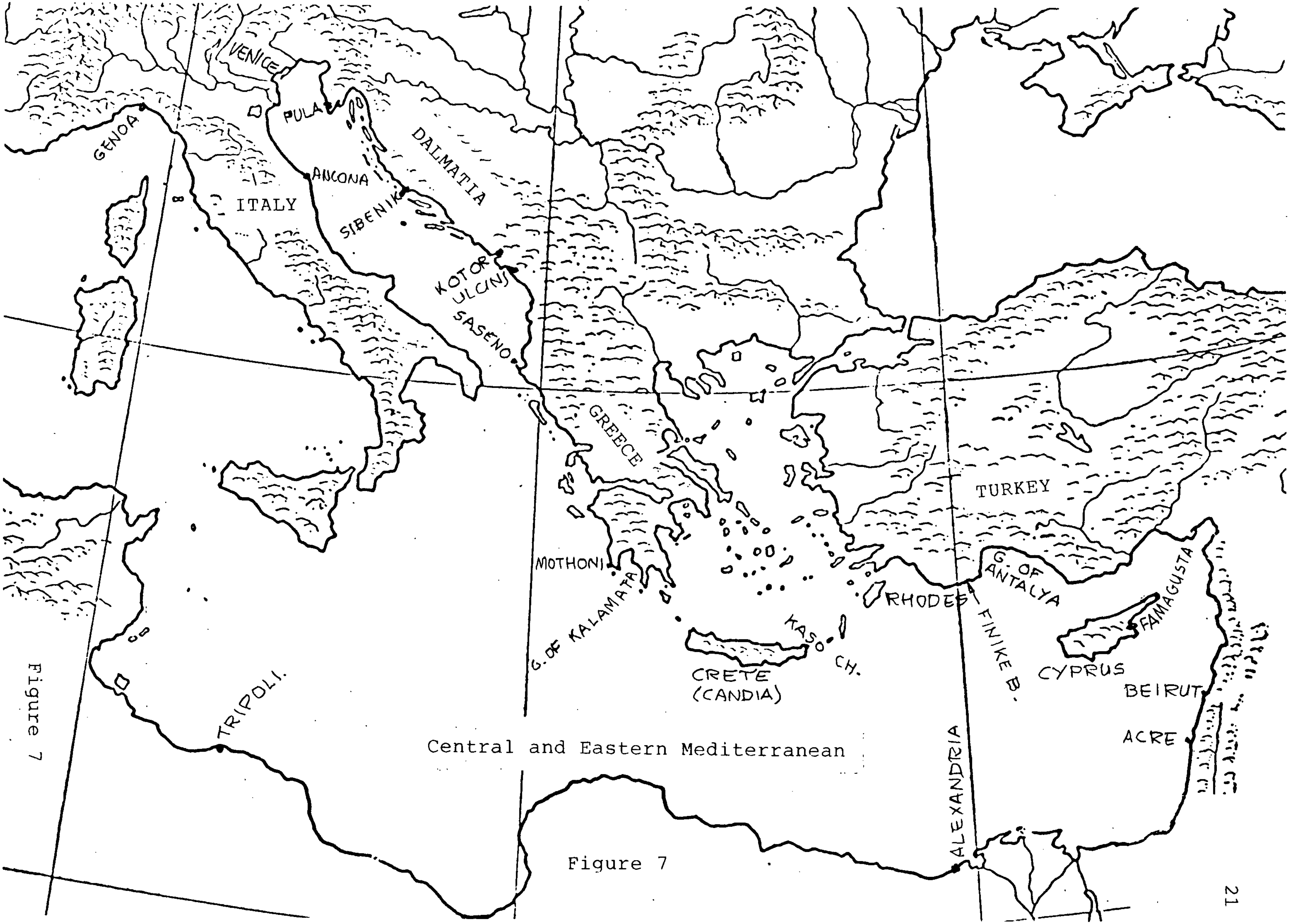
B. A capstan. Detail from a miniature in La Premiere Guerre Punique, ca. 1460. Royal Library Brussels. From G. Asaert, Westeuropese scheepvaart in de middeleeuwen, 1974, Plate facing p. 81).

Devices on the stern

Figure 6

it was mandatory that such vessels performed best under sail. G. F. Marcus, a specialist in Scandinavian seamanship, in a study on the evolution of the knörr based on sagas, points out that the warship or langskip could not be trusted for passages even as short as the run from Norway to the Faeroe Islands, nor could the langskip make the crossing from Norway to Iceland[8].

The ultimate defensive position of a single-masted ship in a storm was running before the wind, eventually even up a beach, as Norse sailors would do if it was the only way to save lives[9]. Running before a wind would have very costly consequences even for a cog[10] of later times, simply in distance and time lost. Additional time would be spent calling at some nearby harbour, re-supplying stores that were depleted during the run. A vivid account of such a voyage on a cog in the summer of 1385 was written by the Florentine Lionardo di Niccolò Frescobaldi, a politician and a military leader, on the occasion of his pilgrimage to the Holy Land. He had left Italy late in the spring of 1384, and had a fairly uneventful trip to the Levant, since in that season the winds are mostly from the westerly quadrants in that part of the Mediterranean. The same winds would have been unfavourable for travelling from Beirut to Venice in May, the following year, as Frescobaldi found.



Central and Eastern Mediterranean

Figure 7

> "We made sail [from Beirut] at the beginning of May, having always favourable winds as far as the Gulf of Satalla [Antalya]; there a sudden blow caught us, with such a storm and such a stress of wind that it blew the bonnets of the sail and wrapped the sail around the mast and it pushed us all the way to Barbary, with the water coming many, many times over the deck, and thus it brought us close to land, perhaps half a mile from it. By the grace of God it started to lessen, as we had cast into the sea some relics, of a kind suitable for such a storm. And we found that we had travelled about eight hundred [Venetian] miles before the storm ..."[11].

Allowing for a Venetian mile of 0.6 nautical miles they would have lost four hundred and eighty nautical miles.[12] This is in fact, as a round figure, the correct distance between the Gulf of Antalya and the coast of Egypt. However, this was not their only loss of time. Frescobaldi relates further on:

> "... we had been fourteen days without seeing anything but air and water, and in great fear for our lives. And thus, backtracking on our course, and leaving the Island of Cipri [Cyprus] on our right-hand side, we went on land to take new provisions of water and food, of which we were in very great need, because of the great thirst that we had suffered in that cog, having had to eat in the manner of a salad all the leaves of certain oranges that the master had in some barrels, that he was transporting from Baruti [Beirut] to Vinegia [Venice]"[13].

Fra' Niccolo da Poggibonsi, a Tuscan friar known only for the voluminous diary of his travels, tells of a worse experience, during his return to Venice from a pilgrimage to the Holy Land.

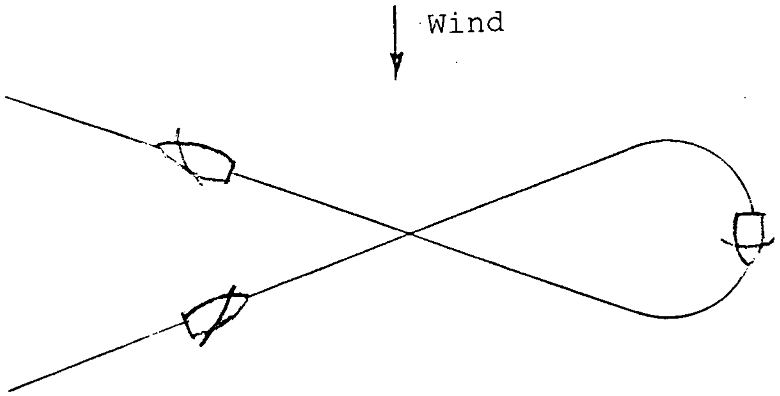
> "On the 7th of August [1346] ... I went to the harbour of Famagosta [in Cyprus] and I entered the sea on a very large Venetian cog; and in the name of God we set sail towards the West: and we had good weather, so that we went out of the Gulf of Cipri. Then the wind gherbino [South-West] came up, contrary to us, and it gave us so much trouble that it brought us to the Sea of Setalia [Gulf of Antalya] and we found ourselves upon Turkey Major, in a country that is called Achillidon [Cape Khelidonia (Greek) or Taslik (Turkish)], at the harbour of Caccovo [Kekova]"[14].

The two last mentioned localities are in Finike Bay (South-West Turkey), some 120 nautical miles from the course intended for the cog. They anchored in that bay to wait for better weather and when they thought it had come they set off again. Then, Niccolo relates,

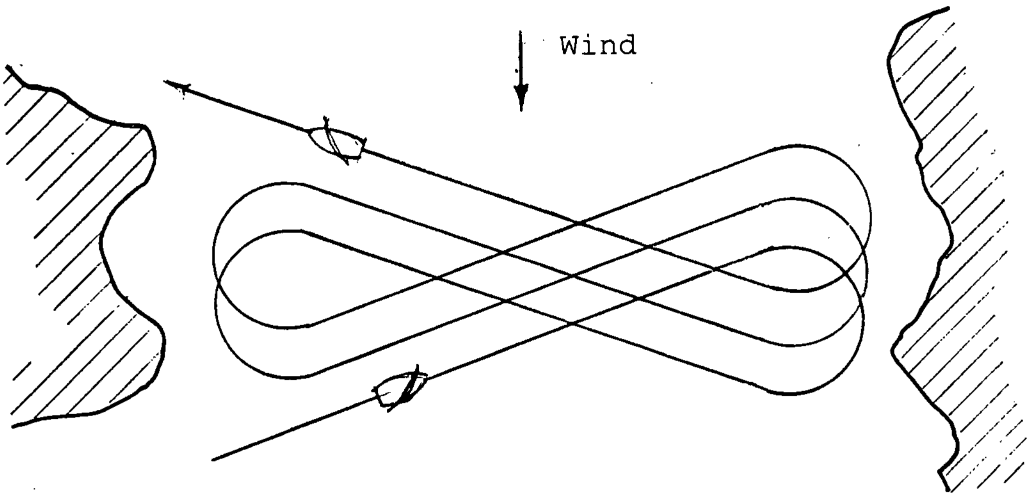
> "when we were out at sea, where it is open, lo! a storm came up contrary to us and it took us, against our wishes, to Barbary and thus we approached the harbour of Tripoli; and do not misunderstand it for Tripoli in Soria, but Tripoli of Barbary [Libya]"[15].

The distance between Finike Bay and Tripoli is about 700 nautical miles. From there the cog had to go to Mothoni (Greece), a distance of about 480 miles. Thus, a planned voyage of about 685 miles (Famagusta-Mothoni) required sailing 1400 miles to complete. A more relevant indication of the narrowness of the limitations of a cog is the fact that the course that the cog should have followed to enter the Kaso Channel from Finike to Mothoni (285 degrees) and the course it followed to go to Tripoli (265 degrees) only differ from one another by 20 degrees.

Mediterranean cogs of the time already carried bonnets, sail extensions that could be added at the foot of the sail in fair weather. Bonnets were responsible for an improved sail configuration. To reduce sail the bonnets were removed and the remaining sail still had the desired cut. Sails with reefing point had to be trussed in bad weather and the resulting shape was far from ideal. The benefits of the square sail with bonnets for most modes of sailing are obvious, but the basic disadvantage of the single square sail to windward still remained, because a close-hauled sail with bonnets was impossible to maintain and the remaining sail was not tall enough to produce the desired results. So the reasons for such astonishingly long runs of single-sailed ships as those reported by Frescobaldi and Poggibonsi are not difficult to explain. All medieval sails, regardless of cut, were rigged before the mast and therefore required taking the wind on the stern in order to change tacks (Figure 7, p. 25). This maneuver -- called 'wearing ship' -- consists of a turn that is always greater than 180 degress (about 220 degrees on medieval vessels). On single-masted ships this meant starting the turn with the rudder while the sail was



A. Changing tacks (wearing ship)



B. Multiple tacks in a narrows

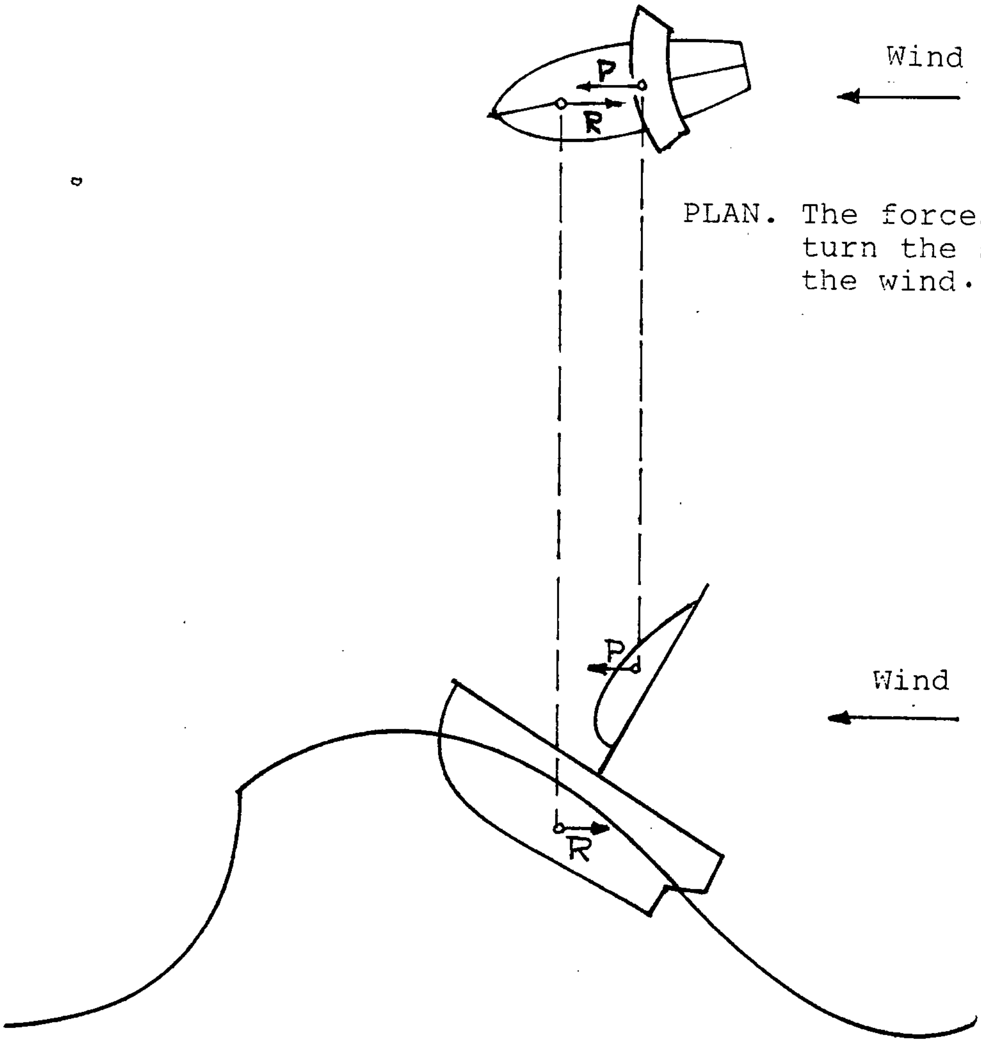
Making tacks with medieval sails

Figure 8

slackened and the yard was slowly swung around to suit the incoming tack. Neither sail, nor rudder were quite capable by themselves of producing a drastic turn on short notice in a tight space. Together, they were adequate, but as the ship approached the point of the turn where she was receiving the wind dead astern, she accelerated and lost most of the ground gained on the previous tack. In the case of short tacks in narrow channels she was likely to loose ground. In this case she would be incapable of sailing the channel and, being in an open sea, she would have to start running. It is very doubtful that zig-zagging to windward was a worthwhile exercise in any case, except for the necessity of working the ship off a lee shore. In a strong wind making continuous tacks was not possible at all, and this explains why a master would avoid entering a channel between two islands -- thus having shores on both sides -- even at the cost of a financially disastrous run. Severe storms would require running even if the ship had plenty of sea-room, as single-sailed ship could not hold a course to windward in rough waters.

A ship running freely before a following sea will pitch wildly, a fact that alters the position of the centre of pressure of the sail in relation to the hull: when the ship nears the windward side of the crest of a wave she will find herself stern-down, with the tip of the mast pointing somewhat astern (Figure 9, p. 28). If this condition brings the centre of pressure of the sail too far back , the ship will irresistibly turn toward the wind and the next wave will find her across the weather. This type of accident is called 'broaching' and is almost always fatal. When running in emergencies such as those described above, the master would want his only mast and sail as far forward as possible, so as to reduce the risk of broaching to a minimum. This could be prevented only by raking the single mast drastically forward. Of course, a reduced and lowered sail would greatly contribute to the same effect.

Under conditions of normal navigation hemp shrouds had to be re-adjusted at every change of tack, by means of tackles. A ship sailing to windward heels noticeably and her sail is thereby off centre. This causes a strong tendency for the ship to turn into the wind. This tendency was practically impossible to correct beyond a certain point when sailing with a single sail, even by great exertions on the rudder. As long as the rudder could cope with that condition, the pressure of the wind on the sail would be physically transferred from the sail to the hull through the rigging, sometimes to the point where the strain on the shrouds could exceed the strength of the



PLAN. The forces R and P will turn the ship across the wind.

ELEVATION

A running ship on the windward side of a crest of a wave.

Figure 9

material. Dismasting was a normal consequence.[16] Whenever the helm could not cope in any manner with this phenomenon, sailors knew that they had too much wind for their rig and they had to run or risk dismasting. For this reason, reinforcing the mast and the yard with extra rigging in the event of heavy weather was a common practice in the Middle Ages, according to Roberto da Sanseverino[17], a fifteenth century condottiere and a diplomat, and the author of an interesting diary of sea voyaging on galleys and round ships.

Of course, shrouds and stays also had to be tended to periodically, particularly in the initial hours of sailing, until most of the stretching had occurred. Sail trimming was the most essential part of controlling the ship in order to run a desired course, the helm having only the minor function of checking yaw. The importance of proper sail-trimming as a determining factor in running a safe course was clearly recognized in medieval legal prescriptions. The Black Book of the Admiralty, a collection of ancient maritime statutes in use in England and elsewhere in Europe from the early Middle Ages and used in the Court of the Admiralty for settling judicial cases arising from the practices of the sea, is clear in this respect. The earliest parts of this book are believed to have been collected in 1422, but the chronologies of the various parts of this document are a matter of discussion among paleographers. Some of the statutes collected at that time are believed to have existed in 1068 and may have even earlier origins. The earliest part of the collection are the "Rules of Oléron", from a sea-port on the island of the same name. In these rules the master's responsibilities for sailing proper courses, courses which would prevent cargo damage due to excessive motion of the ship, were defined in terms of sail-trimming:

> "A shyp being laden at Brest or elswher, and hoyseth its sayle to go with its wynes, and the mayster and his maryners trymme not theyr sayl as they shulde, and bad wether taketh them at sea in suche manner, that the shyp's casks roll, and stave in pipe or tonne, and the shyp arrives in saufte at its ryght discharge. The marchaunt says to the mayster that his wyne has been lost by fault of the shyp's casks ...", etc.[18]

The validity of this ruling found recognition elsewhere. It was incorporated, almost verbatim, in the Blacke Booke of the Admiralty: "A ship being charged at Burdews or elsewhere, ... and the maister and his mariners trymmeth not theyr sayl as it shulde, ...", etc.[19] The principle was that damage to the cargo caused by the ship being improperly sailed was a result of the sail not being trimmed as it should.

With the sail properly set and the ship on course only one side-rudder would suffice for the general purposes of sustained navigation: the sail would have to be trimmed slightly astern of neutral for sailing with the wind on the port side and slightly forward of it for sailing with the wind on the starboard side. In either case the boat would be left with a minimal tendency to rotate to port and the job of the helmsman would then simply consist of trailing his oar reasonably deeply in the water, fairly well vertical (but not necessarily so), with the blade in a feathered position, that is to say with the blade almost vertical, with its leading edge slightly inward, so that it would have a negative dip. That is all that would be required to create enough drag to counteract the rotation of the ship to port and to create an effective lateral force that would counteract leeway to some extent[20]. Increasing the amount of negative dip would increase the drag and bring the ship to starboard. Decreasing it would allow the ship to rotate spontaneously to port. Any gondolier would find this exercise familiar and convenient, as each stroke imparts the gondola a push to port, while the amount of dip of the oar-blade at the end of the stroke controls whether the gondola will go straight or turn to port or to starboard. The gondola, one the few craft to have survived unmodified since the Middle Ages, is unique in that it can only be rowed and steered from the starboard side. A similar stroke is used by expert canoe paddlers who can keep a straight course without having to resort to paddling on both sides. No theoretical knowledge is required of a sailor to produce this result on any sort of boat, but under sail the capability of fine-tuning the only sail is essential to this effect, particularly so because the best of ropes and sails stretch under strain, altering the balance.

In all the above cases the peculiar method of steering from the side with an oar, paddle or rudder is required because a side-rudder has positive action only towards the side of the boat on which it is physically applied. The boat must turn towards the other side of its own accord, under the pressure of the propelling oar or of the sail. The sail was progressively set to give direction with small adjustments being made, depending on whether the wind was blowing from the port or the starboard side of the ship, in order to allow for a minimum of rotation to port. A sailor could produce these results more easily than it sounds, however, because the progress of the adjustments was reflected in the reduction of the effort required for steering. The ability of the rudder to work effortlessy, or even to work at all, depended essentially on these adjustments being made correctly. Depending on the symptoms reported by the helmsman[21] sheets, bowlines, shrouds and probably stays had to be shortened or lengthened, as taught by experience, until the rudder could cope with the circumstances. It is not difficult to see why sail-setting was considered such an essential part of seamanship.

Steering a cog with a side rudder was not much different, in principle, than steering a knörr, except that the higher sides would require a very long rudder or the rudder would have to be kept closer to the vertical. Of course, this would require an inordinate amount of physical effort, as the tendency for the rudder would be to trail astern. A simple line, or, for heavier craft, a tackle going from the neck of the rudder (or through a hole in the blade) forward to the side of the ship would do the job of holding the rudder in the correct position. Then a line going astern could be used to lift the rudder completely out of the water when not in use in tidal harbours, or for beaching. A fifteenth century ship with this kind of arrangement is depicted on the tomb of St. Peter the Martyr in the Church of St. Eustorgio at Milan.[22] With this gear and a minimum of care from the helmsman, the rudder could be kept vertically close to the hull almost all the time and one would not require a great deal of experimenting to discover that a rudder in such a position would counteract leeway more effectively, as well.

Trying to beat against a wind blowing from the starboard side of the boat (a 'starboard tack'), with the rudder partly out of the water because of the direction of heel, would result in a very precarious condition of equilibrium in any sort of chop, short of moderate, with the rudder blade coming out of the water at every trough between waves and during severe rolling. If boats with a single side-rudder were capable of making tacks to windward on both sides, these tacks would be very unequal. At any rate, the problem of controlling and counter-acting rotation by the means of a side-rudder was a difficult one to solve. Beyond a certain size of hull it was impossible with any kind of rudder. These difficulties led sailors to experiment adopting at least four different types of rudders. Romola and R. C. Anderson, the authors of a fundamental book on the history of ships, argue that different levels of efficiency of four dissimilar kinds of rudders in steering boats of varying sizes were recognizable in the thirteenth century, thus causing some northern port authorities to levy different dues on ships, according to the type of rudder employed. These authors have found that Flemish, Dutch and German documents name four different kinds of steering gear: the ordinary stern-rudder ('hangroeder'), the steering-oar ('hantroeder'), the side-rudder ('sleeproeder') and a fourth kind ('kuelroeder'), that passed through a hole in the hull. It is not clear whether it was part of the rudder itself or only the tiller that was inboard. Ships with the hangroeder, also called "rudder astern", paid more.[23]

The problem of steering with equal ease on either tack had been solved in ancient times in the Mediterranean, and in other parts of the world, with the adoption of two side-rudders. In the North this idea never found application. There is no explanation for this fact. The northern solution to making equal tacks was the introduction of the central rudder (Figure 10, p. 36). The problem of sail-setting with a central rudder or with twin side-rudders was a great deal simpler than with a single side-rudder, as each rudder had positive action on its side. Ships would then use the same sail setting on both tacks, regardless of the side from which the wind blew, thus making it easier for systematic zig-zagging when beating a long way to windward. Adjustments were required only when a change of course would bring a running ship to beat, or viceversa. The earliest illustration of a Mediterranean ship with sternpost rudder is at Pisa, and it is of the fourteenth century. In the Mediterranean the introduction of the sternpost rudder did not lead to the immediate obsolescence of the twin side-rudders, and even ships with three rudders were seen more than one century later.[24]

A. Elbing Seal.

B. Ship on the Font in Winchester Cathedral, from the Low Countries, 1180.

The sternpost rudder. (Both figures from R. W. Unger, <u>The Ship in the Medieval Economy, 600-1600</u>, p. 142).

Figure 10

The reasons for the general acceptance of the sternpost rudder are obvious. The effect of a side-rudder of any type varies with the depth of immersion of the blade. This caused a great deal of unnecessary work for the helmsman in any sort of sea, and keeping a steady course was difficult. But the most essential benefit of the sternpost rudder was that greater angles of heel became acceptable, and with this the capability of sailing closer to the wind was enhanced.

All medieval ships could do little better than hold their ground in the face of contrary winds in an open sea. They could not work their way out of harbours with peculiar channels in adverse conditions without resorting to rowing or towing. Leaving an open anchorage was another matter again. The wind had to be blowing from the shore and a great deal of sea-room had to be available downwind, as the ship, laying head to the wind, had to be turned around by sail alone, until she was sailing in a fairly broad reach, so as to acquire enough speed to be steerable. A poem in a manuscript preserved at Trinity College, Cambridge (probably composed earlier than the fifteenth century) describes how it was done on a single-masted ship[25]:

....
Anone the mastyr commandeth fast
To all his shypmen in all the hast
To dress hem sone about the mast
   Theyr takeling to make.

The first order given by the master is for the sailors to come at the mast for making sail.

....
With howe issa then they cry
What howe mate thou stondyst to ny
Thy fellow may not hale the by
   Thus they begin to crake.

The sailors cry "Ho! Hoist!". Someone is told that while pulling the halyard he is standing too close to his mate, who has no room to do his hauling. It appears that they are working together, pulling by hand.

A boy or tweyn anone up styen
And overwhart the sayleyerd lyen
Yhow talya the remenaunt cryen
   And pull with all theyr myght.

A boy or two immediately go up and lay over the yard (and thus are hauled up with it) while the rest cry "Ho! Tallyho!" (Ho! Haul, Ho!) and keep on pulling with all their might. This boat, evidently, had no ratlines, that is the rope rungs stretched across the shrouds. So the boys had to go aloft with the yard, in order to unfurl the sail as soon as it was up. Once they had their job of unfurling done, they would descend along the boltrope, that is the rope sewn to the edging of the sail, down to one of the clews and then continue hand over hand along the sheets until their feet touched the deck. This was neither an unusual practice, nor a particularly dangerous one. Sailors would always shun the ratlines for descending, since this process entails looking down to find one's footing, an uncertain undertaking on a rolling ship, whereas while coming down along a rope they would always have had a grip between their ankles. Once the sail was drawing wind they would go aloft by the same route, if needed. The poem does not describe the unfurling of the sail.

> Hale the bowlyne now vere the shete
> Coke make redy anone our mete
> Our pilgrims have no lust to ete
>   I pray God geve hem rest.

This is the voice of the master. The sheet controlled the downwind clew of the sail. Hauling the bowline and veering, or slacking off, the sheet would have caused the sail to go way forward, thus causing the ship, still drifting astern and falling off the wind, to go about by herself. There was no one at the helm yet, because the helm was not necessary nor usable at this stage. The cook is ordered to make a meal readily available to the pilgrim passengers, as they seem to have already lost their stomach for food.

> Go to the helm what howe no nere
> ....

They are now under way and the master orders someone to go the helm and steer, so as to prevent the ship from heaving any closer to the wind than she already is doing.

> Yhowe trussa hale in the brayles
> Thow halyst nat be good thow fayles
> O se howe well owre good ship sayles
> And thus they say among.

There is too much wind and the sailors are ordered to gather, or truss, the sail up by hauling in the brails. This could be very well the effect of the apparent wind[26] being properly felt as the ship accelerates towards her cruising speed, after she is finally trimmed. The master berates a shirker and then has words of admiration for the behaviour of his ship under the press of wind. Without question, they are having a very fine sail. As the ship gathers more speed the apparent wind seems to shift farther forward and this will require further trimming, so as to sail closer to the wind.

> Hale in the wartack hit shall be done
> ......

"Haul in the tack!" "It shall be done". The sail is not taut enough for the kind of beat they are now making. The tack controlled the windward clew of the sail. Hauling the tack in without slacking the bowline tightened the sail and brought the foot closer to the mast, at the same time, as required so as to sail closer. This is the effect of the increased apparent wind, as the ship reaches her cruising speed.

The problem of having to turn the ship around with one single sail upon leaving, during the phase in which the craft did not have enough speed to respond to the action of the helm, was by itself a challenging one. The same problem existed also when entering a cramped harbour or when having to anchor close to shore at an open beach. With a light wind a master would simply come in under minimum sail, choose his spot for anchoring, drop the sail and the first anchor, and let momentum and wind do the rest. It was quite a different story if he had a strong stern wind: if he came in at too high a speed he would need to turn the ship into the wind before (or while) letting down his anchors, and in doing so he would have to depend on the stoutness of the hawsers and on the holding quality of the bottom in order to check the considerable momentum. Also, while coming around, the ship would have to expose her side perpendicular to wind and waves. The seriousness of such a predictament was considered on board

Sanseverino's ship on the night of the 20th of December 1458 while they were driven under bare poles before a storm, towards the beach of Ancona.

> "... They were afraid that the fury of the wind would throw them onto the shore at night, breaking the ship to pieces on some place where there was no chance of escape whatsoever, particularly because of it being night-time; or else, if they had wanted to cast the anchors and lay to, that the fury of the wind and the very powerful and very horrible storm that they were having were such as to prevent them from stopping and anchoring; or that while [the anchors] were taking hold and swinging the ship around, the wind and the waves of the sea would have caused the ship to heel over to the point of making her to turn turtle."[27]

The master carried out the maneuver in this way:

> "In the end Our Lord God and Our Lady of Loreto ... caused the wind to abate to some extent, so that, as they kept on sounding all the time and having found twenty-four fathoms of water a short time after midnight, the master ordered two very heavy anchors to be cast, each anchor being secured with two very thick and very long new hawsers tied to one another. And while casting the said anchors he ordered the helm to be put down to turn the ship and, Deo Gratia, the wind having dropped somewhat at that time, the aforesaid anchors took hold well. The ship did not run into any danger while coming around, which was a marvellous thing and beyond the expectation of the master and of as many officers and sailors as there were there"[28].

All told, the episode describes a remarkable feat of semanship in accelerating the rotation of the ship, so as to reduce the time the side of the ship was exposed to a minimum, that is before the anchors started to grab. The helm being put over started the ship turning of its own accord, as otherwise the sudden pull of the anchors, with the ship still across the wind, would have caused her to heel over. Meanwhile the hawsers were paid off running around a bitt, so as to have the necessary friction for stopping them and making them fast when the anchors would take hold. The presence of these lengths of cable running from the bows would have had the same effect as a sea-anchor, creating an additional turning force that would see the ship facing the wind before the anchors touched bottom. This, ultimately, explains the reason for electing to anchor at great depth, using two very long hawsers, as this combination of factors would buy the ship the extra time necessary for turning around completely while still free of the bottom. Maneuvers such as this would be attempted only if a greater risk was impending, such as that of being run onto a lee shore. Otherwise a master would wait for the weather to abate, riding out the bad weather offshore, and Sanseverino's diary reports several instances of this kind.

To enter a harbour with no wind at all, or with a contrary wind, or an ebbing tide meant using a tug, in the form of a tow-boat powered by strong backs pulling the oars. The "Rolls of Oleron" provided some rules dealing with these circumstances: "Likewise, a shyp cometh to any place and wuld enter into a port or haven, and it sets an ensign to have either a pilot or a boat to tow it within bycause the wind or the tyde is contrary ..." etc.[29]. This, of course, would occur quite frequently and masters were allowed to set their own crews at towing in other vessels, for a financial consideration, when no other help was available. This labour was considered ordinary ship duty, according to the customs that bound the sailors to the master. The Good Customs of the Sea, the section of the Black Book of the Admiralty that dealt with the arrangements between masters, shippers, traders and crews, decreed: "Further, a mariner is bound to go and tow a ship or a vessel in order that it may enter a port, if the mate orders him to do so ..." etc.[30]. The earliest origins of the Good Customs are unknown. They were received in England in a version called "La Chartre d'Oleroun des Juggementz de la Meer" during the reign of Edward II (1284-1327).[31]

Nothing is known about the reasons that caused a competitor to the square sail of northern fashion to appear in the Mediterranean, nor it is certain how the lateen sail re-acquired relevance in that area. Not even the etymology of its name is altogether clear. According to Landström the earliest illustrations are from Greek manuscripts of the ninth century and they depict small craft with two rudders[32]. The classicist Lionel Casson hypothesizes a Mediterranean origin for this sail, because ancient sailors there had learned a method of changing the square sail -- used as such on reaches and runs -- into a triangular one for sailing to windward.[33] Casson found evidence for this in the work of several writers of antiquity.[34] Ancient Mediterranan sailors had devised a complex system of brails, which they used for adjusting the shape and size of the sail according to the strength of the wind. The brails were ropes that went from the deck over the yard, to the foot of the sail. Pulling them would shorten the sail, slackening them would allow the sail to balloon over the fore part of the ship. Unmodified ancient square sails could be used for dead runs or broad reaches. When going to windward the sailors would modify the sail by brailing it in a triangular shape. This modification was achieved by pulling the brails more on one side than on the other. "A square sail brailed up in this particular fashion and set aslant is in shape not unlike a lateen, and may possibly have sparked the invention of that all-important sail".[35]

In the Middle Ages the lateen sail spread from the Mediterranean Sea to all the countries of Europe and played a major part in the development of multi-masted ships. The importance of this cut of sail consists in its allowing a ship to point to windward at closer angles than the single square sail. Under such conditions it behaves almost like a fore-and-aft rig. Medieval sailors, in fact, considered it as such[36] and so do many modern scholars, although it differs from a pure fore-and-aft rig in two essential manners: it is rigged before the mast and it requires wearing the ship, that is turning before the wind, in order to change tacks, like a square sail, while a pure fore-and-aft rig, being rigged aft of the mast, allows tacking, that is turning into the wind. This is, of course, a matter of semantics, and it can be said that the lateen sail embodied most of the advantages of the fore-and-aft rig to windward and most of those of the square sail downwind[37]. The rigging of the lateen sail forward of the shrouds is strongly indicative of its origin as a downwind sail and using it to windward involved a fairly complicated maneuver with the yard and shrouds. To facilitate this maneuver the masts were raked forward. The lateen sail yard was set asymmetrically to the mast, so the portions of sail area on the two sides of the mast were unequal. Setting the sail for different modes of sailing consisted in varying the angle of the yard with respect to the mast by the means of tackles and then hauling the sheet in until the ship ran true with a minimum of help from the helm. When on a windward course the sheet would then cause the sail to curve along the downwind side of the ship. Reasons of geometry of sail and yard required that the downwind shrouds be removed and the windward ones be re-tightened at every change of tack. This maneuver shifted the position of the centre of wind pressure as needed, depending on the course sailed. The yard was obviously amenable to receiving varying sizes of sail, to suit different ranges of wind velocity, and, while the practice of changing sails according to the weather is documented for fifteenth century ships[38], nothing is known about the manner of sailing early medieval single-masted lateen-rigged craft. Single lateen sails were the normal means of propulsion for all Mediterranean merchant ships as early as the seventh century and large oared warships of the Eastern Mediterranean used them as sources of auxiliary power as early as the tenth century. The usage of lateen sails on galleys lasted as long as galleys remained practical ships of warfare.

Notes to Chapter II.

1. Owain Roberts, "Viking Sailing Performance", in *Aspects of Maritime Archaelogy and Ethnography*, Ed. Sean McGrail, (Wandle Press, London, 1984). See the Section 'Future Experiments with Sails', pp. 128-131.

2. This is simply a speculation, as there is no documentation for this use of the *beitiass*, but then there is no documentations as to how it would be used in any manner. The Danish *Immer Sleipner* replica, built in 1981, used the *beitiass* successfully in this manner. See Ole Crumlin-Petersen, "Experimental Boat Archaeology", in *Aspects of Maritime Archaeology and Ethnography*, Ed. Sean MacGrail, (Wandle Press, London, 1984), Fig. 5.15, p. 121.

3. If this conjecture is correct it could offer an explanation for the fact that an odd number of pairs of fittings were found at Gokstad. See O. Roberts, *Op. Cit.*, p.132. For the quantities of finds Roberts quotes A. E. Christensen, 1979, *Viking Age Rigging, a survey of sources and theories*, in McGrail, S (Ed.), 1979, pp. 183-193.

4. G. F. Marcus, "The Evolution of the *Knorr*", *The Mariner's Mirror*, 41, 1955 (Cambridge University Press, Cambridge, 1955), p. 118.

5. Björn Landström, *The Ship*, (Allen and Unwin, London, 1961), pp. 62-63.

6. Ian Friel, "Documentary Sources and the Medieval Ship", in *The International Journal of Nautical Archaeology and Underwater Exploration*, 12.1, 1983, Table 3, p. 46. Friel assumed this *apparatus* to be the yard parral, although the word *tyre* is used for this device elsewhere (Gear from the wreck at Grainthorpe, 1353, *Op. Cit.*, Table 6, p. 59).

7. Richard W. Unger, *The Ship in the Medieval Economy, 600-1600*, (Croom Helm, London, 1980), p. 141. Also, Romola & R. C. Anderson, *The Sailing-Ship, Six Thousand Years of History* (George G. Harrap and Co. Ltd., London, 1926), p. 166.

8. G. F. Marcus, *Op. Cit.*, p. 121.

9. G. F. Marcus, "A Note on Norse Seamanship: Sigla Til Brots", Mariner's Mirror, 41, 1955 (Cambridge University Press, Cambridge, 1955), pp. 61-62.

10. This name was applied to a number of large Northern trading ships and did not become specific until the twelfth century. In the Mediterranean they are mentioned in the fourteenth century (It. cocca, Fr. cocque).

11. Lionardo di N. Frescobaldi, "Viaggio in Terrasanta", Viaggi in Terrasanta, Ed. Cesare Angelini (Felice Le Monnier, Firenze, 1944), p. 166. The translation of this and all the quotes from this work are by Tullio Vidoni.

12. A comparison between the distances given by medieval authors and actual distances expressed in modern nautical miles has been made by T. Vidoni. Sanseverino offers the greatest data. The Venetian mile was equal to 0.63 nautical miles, or 1167 metres. Distances in the text are in nautical miles and speeds are in knots (nautical miles per hour). Distances in quotations from medieval texts are in Venetian miles and the modifier '[Venetian]' is always used in these occasions.

13. L. Frescobaldi, Op. Cit., pp. 166-67.

14. Fra' Niccolò da Poggibonsi, Libro d'Oltramare, Ed. Alberto Bachi Della Lega, 2 vol., (Commissione per i Testi di Lingue, Bologna, 1968), Vol. 2, pp. 216-17. The translation of this and all the quotes from this work are by T. Vidoni.

15. Ibid., p. 217.

16. Dismasting in heavy weather on a ship where all the gear is properly maintained can only occur when sailing to windward. In other modes of sailing in a storm the ship will capsize instead. To avoid capsizing a master had the option of cutting stays, shrouds and mast and loosing all the gear overboard. "Hewing the mast", chopping it with an ax, was probably not a rare event, and the statutes of all port cities defined the ensuing financial liabilities in great detail. Among the collection of sea-laws in Sir Travers Twiss Ed., The Black Book of the Admiralty the financial problems deriving from "hewing the mast" are discussed in the following statutes: "The Judg-

ments of the Sea" (Vol. III, p. 15), "The Gotland Sea-laws" (Vol. IV, p. 77), "The Purple Book of Bruges" (Vol. IV, p. 313), "The Dantzic Sea-laws" (Vol. IV, p. 341), "The Maritime Laws of the Osterlings" (Vol. IV, p. 373) and "The Sea-laws of Flanders" (Vol. IV, p. 427). The invariable legal approach was that of considering this action as a form of jettison, like any other 'act of man'.

17. "Their fears were not ill-founded, because the master and the other officers and sailors, expecting a storm, started to reinforce the mast, the yard, and to take all the other measures that are usually taken when a storm is expected." R. Sanseverino, Op. Cit., Diary of 27th October 1458, pp. 208.

18. Sir Travers Twiss Ed., "Rolle of Olayron", The Black Book of the Admiralty, 4 Vol. (1871; Professional Books Limited, Abingdon, Oxon, 1985), Vol. 2, p. 445.

19. Sir Travers Twiss Ed., "The Blacke Booke of the Admiralty", The Black Book of the Admiralty, 4 Vol. (1871; Professional Books Limited, Abingdon, Oxon, 1985), Vol. 1, p. 103.

20. This conclusion can be reached intuitively. However, model tests reported by O. Roberts (Op. Cit., p. 138) confirmed this fact. Only the setting for one tack was tried and a modest angle of "about 5 degrees, lee helm" was found to be sufficient. Leeway was estimated at 10 degrees. Total elimination of leeway is impossible.

21. The jargon used by Venetian sailors to report the state of steering is often used by Sanseverino. A ship was said to be orziera when it was difficult for the helmsman to counteract the tendency of the ship to turn to windward. She was said to be pozera in the opposite case. A whole vocabulary existed to describe similar conditions (i.e., Sanseverino: Orza stricta = Close-hauled).

22. B. Landström, Op. Cit, p. 88.

23. Romola and R. C. Anderson, The Sailing-Ship, Six Thousand Years of History, (George Harrap and Company Ltd., London, 1926), pp. 89-90.

24. One such ship is depicted in a 1486 illustration of the anchorage of Mothoni in von Breydenbach's relation of his pilgrimage to the Holy Land. Bernard von

Breidenbach's entourage during that voyage included a draftsman and his Peregrinatio in Terram Sanctam is the earliest known illustrated travelog.

25. The version used in this paper is that transcribed by R. and R. C. Anderson in Op. Cit., pp. 91-93. Unfortunately this book does not have a list of sources and the authors identify the manuscript thus: "A poem that has been preserved in a manuscript at Trinity College, Cambridge. The actual manuscript belongs to the fifteenth century, but the poem seems to be rather earlier." The poem has no title and begins with the following lines:

    Men may leve all gamys
    That saylen to Seynt Jamys
    For many a man hit gramis
       When they begin to saile.

26. A person on a motorship that is travelling in calm air feels a wind blowing from the bow toward the stern. This wind is called 'apparent'. If a 'real' wind blows across the path of the moving ship, the apparent wind will be felt blowing diagonally, from somewhere between the bow and the beam. A ship travelling at 15 knots in a cross-wind blowing also at 15 knots will experience an apparent wind coming from a direction of 45 degrees from the bow. This wind will be stronger, by a factor of 1.4 in this case, according to rules of vectorial mathematics. On a sailing ship, propelled by the real wind, the sails are set according to the apparent wind. The direction of the apparent wind and its strength are affected by the speed of the ship, thus the sails must be retrimmed at short intervals of time while the ship is accelerating, until she reaches cruising speed. It is normal for a ship getting under way with a beam wind to find herself beating into a stronger apparent wind by the time she reaches cruising speed.

27. R. Sanseverino, Op. Cit., p. 280-281.

28. Ibid., p. 281-82.

29. Sir Traver Twiss Ed, "Rolle of Olayron", Op. Cit., p. 465.

30. Sir Traver Twiss Ed., "The Good Customs of the Sea", The Black Book of the Admiralty, 4 Vol. (1871; Professional Books Limited, Abingdon, Oxon, 1985), Vol. 3, p. 223.

31. _Ibid._, pp. xii-xiii.

32. B. Landström, _Op. Cit._, pp. 80-83.

33. Lionel Casson, _Ships and Seamanship in the Ancient World_, (Princeton University Press, Princeton, N. J., 1971), pp. 243-45 and 273-76. Latineers probably existed in the fifth century B.C.. See _Op. Cit._, pp. 268-69.

34. Aristotle, Aristophanes and Tatius. Aristotle knew that the rudder alone was not adequate to hold a ship on a windward course. See L. Casson, _Op. Cit._, p. 276n.

35. L. Casson, _Op. Cit._, p. 277.

36. "... at about midday three fore-and-aft sails appeared ... [some] guessed that they were the galleys ... from Alexandria". R. Sanseverino. _Op. Cit._, p. 260.

37. Although not much is known about the use of the single lateen sail, it can be deduced from drawings that it would be best at any mode between a close beat to a broad reach. On this subject see also J. H. Parry, _Op. Cit._, pp. 17-19.

38. R. Sanseverino, _Op. Cit._, p. 39 and _passim_. F. C. Lane mentions the square _cochina_ and the triangular _pappaficho_ as storm sails used by the Venetians in the fifteenth century. See Frederic. C. Lane, _Navires et Constructeurs à Venise pendant la Renaissance_, (S.E.V.P.E.N., Paris, 1965), pp. 17-20.

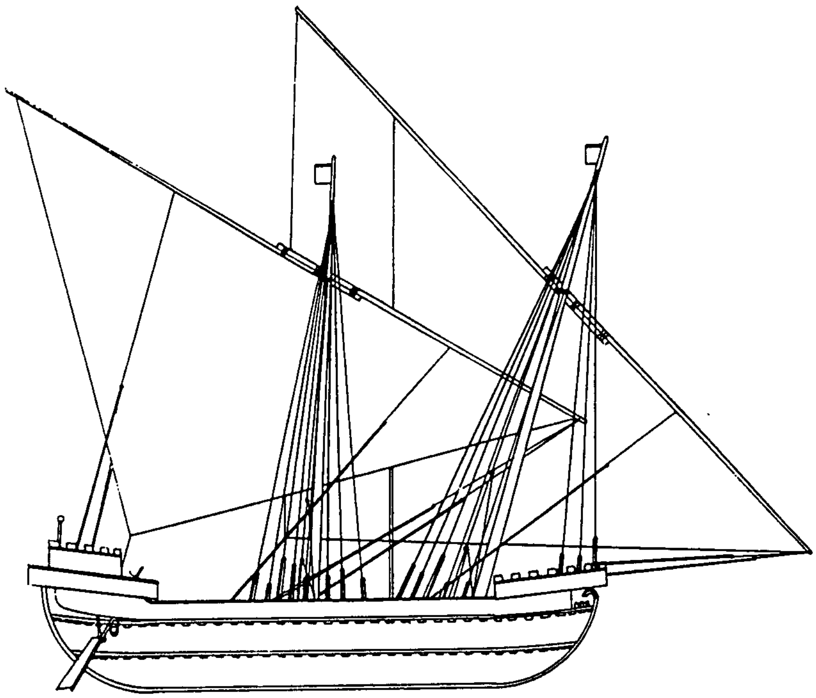
CHAPTER III

TWO-MASTED SHIPS

Pictures of the fourteenth century indicate that by then square-rigged ships in the Mediterranean were quite similar to the single-masted square-rigged ships of the North. The difficulties inherent in trying to control ships with this type of rig dictated the maximum size of the ships. The concentration of power in one sail and one mast alone limited the amount of sail area that a crew could handle safely. In the twelfth and thirteenth centuries demands for bottoms started to soar in proportion to the crusading zeal of kings and the opportunities for large profits in shipping were not lost on the maritime cities of the Mediterranean. Whole armies of soldiers, knights and horses had to be shipped to the Holy Land, together with all their weapons and gear. This volume of shipping demanded more capacious hulls, beyond the size that could be managed with the existing rigs. Mediterranean shipbuilding met this demand by adopting a divided sail plan.

The reasons for the adoption of the double-masted, double-sailed type of rig are obvious. The resulting craft was undoubtely much easier to handle than any previous type. The main requirement in handling a sailing ship -- control of rotation -- was easily achieved by regulating the amount of wind carried by the individual sails, depending on how hard they were sheeted. Thus it became possible to perform drastic changes of course, with shortened turning radii, in a manner that was wholly independent of the effects of the rudders. This was an essential advantage while going about at the end of each tack, where some ground is always lost during the time that the ship labours her way around. In certain weather conditions this factor alone would be decisive in allowing a master to enter a narrows between two islands or his having to circumnavigate one of the islands. Thus a tiny, but important gain towards a technology of all-weather navigation was made. The splitting of the sail plan allowed the same size crew to handle a larger sail area. Sails only needed to be hoisted or reduced one at a time.

The basic two-masted ship of the twelfth and thirtenth centuries was the type of craft built for King Louis IX of France for his Crusade of 1250[1], rigged with a lateen mainsail deployed from a main-mast that was stepped somewhat forward of amidships, and a lateen mizzensail astern, which had the basic function of keeping the ship on course (Figure 11, p. 55). This solution provided a measure of stability in holding windward courses that was



Two-masted Genoese sailing ship built for the Crusade of King Louis IX of France. (From: R. W. Unger The Ship in the Medieval Economy, 600-1600, p. 124).

Figure 11

unknown to earlier sailors, with plenty of safety for downwind runs, as well. The mainmast carried the larger sail and was so located that its sail, alone, would make the ship 'pay off', that is cause her to rotate downwind whenever necessary, and certainly in very heavy weather. To counteract this effect when closer sailing was required, the mizzen, carefully set, would push the stern downwind to the point where a balance of the sail plan was acquired. In spite of her greater size, such a ship could be held on a windward course in fair weather quite steadily by the simple means of adjusting the mizzen to suit the circumstances. However, even the best balanced sailing ship creates some difficulties for the helmsman when she pitches in heavy seas. The cyclical variations of the position of the centre of wind pressure as the ship climbs wave after wave, create variable rotational forces that result in a marked tendency for the ship to yaw to port and starboard alternately. To counteract this tendency in a two-masted ship required a great deal of labour and attention to mizzen sheet and rudder. The most relevant and most undesirable by-product of this phenomenon on any sort of craft is the lengthened trajectory of the ship during a given tack, caused by zig-zagging about the intended course. This phenomenon was plainly understood by sailors at least in the fifteenth century and it is often mentioned by Sanseverino in his diary as the principal cause of ships loosing ground in adverse winds. On medieval ships, only capable of very wide tacks, that is greater than 80 degrees off the wind, this effect reduced drastically their practical capability of making real gains to windward in any sorts of sea but flat ones.

Beating with a two-masted ship had its own kinds of perils. It was quite possible that too much of a downwind yaw would create enough wind pressure on the mizzen to send the ship rebounding too far into the wind, with results that could be little short of catastrophic. In other words, the advent of the second sail made it possible to manage bigger ships in higher winds but the problem of the control of rotation was still far from being fully solved. Niccolò da Poggibonsi's relation of a voyage on a ship rigged in this manner clearly demonstrates that this kind of vessel could not take severe adverse weather much better than a cog. Ultimately, like a cog, she had to seek a haven or make a costly run for it.

> "On the day six of April of the year 1346 of Our Lord, in the morning, we crossed ourselves and embarked on a ship with two masts and two crowsnests, and in the name of the Lord we made sail: thus we travelled several days. Then we had a contrary wind, thus we went making tacks over the sea, now towards here, now towards there; and after the third day [of making tacks] we had a favourable wind, and we made a good distance with a strong wind astern; and then for some days we had a contrary gale, so that we took refuge in Ischiavonia [Istra] at a city that is called Puola [Pula]. We remained there a few days ..."[2]

The distance between Venice and Pula is 68 miles, and this is all they had to show for perhaps eight or more days of sailing. Obviously the rig was very poor at holding its ground when making tacks, and it would loose a great deal more than it was capable of making. To this loss they had to add the stay in Pula for a few days, waiting for a favourable wind. Eventually they left, on Good Friday, and met with further troubles:

> "We were a short time at sea and lo! a contrary wind came up, that was pushing us toward destruction onto the shore; and us dropping the sail, the wind was so strong that it made it fall in the water."[3]

In order not to drop the sail in the water the ship had to be swung into the wind while the sail came down, a necessary practice with a lateen or any kind of triangular sail, since such sails cannot be furled upwards. After the sail fell in the water the ship would become un-manageable and drift out of control. Poggibonsi describes a scene of utter panic, as the ship was rapidly closing on the shore, until it was about "two arbalest-shots from it" and he was making himself ready to jump for it[4]. At that point they had a break:

> "While we were thus going toward destruction onto the shore, the wind eased and the sailors, with very great effort, took the sail in, completely soaked; and immediately this was understood to be a [good] omen, and they cast the an-

> chors into the sea, but not soon enough that the ship would avoid coming close to the rock[s]. It happened that one of the rudders was damaged and to repair it we stayed ... in the said city [of Pula] ten days."[5]

In due course they reached Mothoni (Greece) and they left this harbour on the first of May, early in the morning. They went some way towards their destination, but by evening they were battling a storm that in the end sank nine other ships[6]. Poggibonsi's ship was new and stout and survived, but not without paying a heavy price in damaged cargo, as well as in distance lost: "And this storm took us back one hundred and fifty [Venetian] miles and put us back in the Gulf of Venice [the Adriatic Sea] in one single day and night"[7]. In a day of good wind that ship could cover 180 nautical miles[8], turning out an average speed of 7.5 knots. She was obviously a very good sailer at reaching and running, but next to useless at going to windward over rough seas. The reasons for this kind of performance are not difficult to see. The castles, typical of this type of craft, caused an inordinate amount of windage, and consequently leeway. It is impossible to say whether the potential degree of weatherliness of this ship, owed to her lateen sails, could have compensated for this flaw at all, even under a manageable force of wind. Under heavy stress, when she could have been sent by the mizzen to rebound into the wind, prudence required that she sail wider tacks, so as to allow for a greater margin of safety for the mansail. When sailing wider tacks she obviously could not hold her ground. Under those circumstances the mainsail was the only source of propulsion, the mizzen providing the precarious balance to windward and the ratio of progress versus leeway would have favoured the latter.[9]

Another type of two-masted ship was the early carrack, known to have existed from the late fourteenth century, rigged with a square main and a lateen mizzen, the mainmast being stepped forward of amidships. The earliest known illustration of a ship of this type is in the Pizzigani Atlas of 1367[10]. The origins of this rig are unknown. Probably it was the result of adding a triangular mizzen to stabilize a square-sailed ship. Landstrom speculates that the larger single-masted square-sailed vessels would have been next to impossible to keep on course in certain circumstances and that Mediterranean sailors voyaging beyond the Pillars of Hercules were responsible for adding the lateen mizzen to such ships[11]. A well-known model of a two-masted carrack is the so-called Mataró Ship of the Maritiem Museum Prins Hendrik in Rotterdam. Originally this model was kept in the Church of Mataró, near Barcelona. Landstrom's speculation is based on the fact that the hull and the rigging of the mainmast of this model are similar to those to be seen in many illustrations of single-masted ships of the time. No details about the performance of two-masted carracks are known. The fact of having a square sail as the main source of propulsion would not make this craft a better candidate for successful windward sailing than the two-masted ship with two lateen sails. Theoretically at least, it could have been the better downwind sailer.

Notes to Chapter III.

1. On the occasion of the Seventh Crusade King Louis IX ordered a fleet of 120 transports to be built at Genoa and Venice. According to E. Angelucci and A. Cucari these ships had the following dimensions: overall length 84 feet; length at the waterline 57 feet; beam 20 feet; height of the sides 20 1/2 feet. See E. Angelucci & A. Cucari, Ships, (McGraw-Hill Book Company, New York, 1977), p. 52.

2. N. Poggibonsi, Op. Cit., pp. 8-9.

3. Ibid., pp. 9-10.

4. Ibid., p. 10.

5. Ibid., p. 11.

6. The waters around Mothoni always had a high concentration of traffic, as it was a compulsory port of call for all home-bound Venetian ships, in order to report to the authorities sightings of pirate ships. Outbound masters would call there in order to decide whether to proceed alone or in convoy, depending on the information received. Poggibonsi's ship had called at Mothoni for this reason.

7. N. Poggibonsi, Op. Cit., pp. 11-12.

8. Ibid., p. 18.

9. As the wind increases so do the waves. A beating ship will begin to yaw and, as a matter of prudence, a master will ease the ship and point her on wider tacks. With the increased wind the ship will travel faster, but only up to a certain percentage of her hull speed. At the same time the effects of windage on superstructures such as the castles increase more rapidly (in a certain proportion to the square of the wind velocity) and leeway increases accordingly. Fourteenth-century sailors were concerned with fighting off pirates, and would sacrifice performance to defence. Pirate ships had castles, as well, and therefore the compromise in performance was not very critical. Sanseverino describes an encounter with a Genoese pirate ship within sight of the city of Rhodes. The first concern of the master of Sanseverino's galley was then to gain sea-room to windward on his adversary and made a tack all the way to Turkey.

The pirate could not sail as close to the wind as the galley and lost his quarry. The galley wasted one day as a result of this encounter. The presence of pirates affected the economics of shipping well beyond the immediate cost represented by the material losses due to captures and sinkings. The necessity for castles diminished the overall economy of ship performance to an extent that is not calculable. Further time was lost forming convoys. Ships traveling alone had to go to ports from where convoys sailed. Squadrons of escort galleys were kept by the Venetians at Mothoni and Koroni (Greece).

10. B. Landström, Op. Cit., p. 91.

11. Ibid., p. 92.

CHAPTER IV

MULTI-MASTED SHIPS

The most relevant factor that made the three-masted ship an all-weather craft and a versatile fighter, was her capability, in most situations, of being quickly and simply turned about by altering the balance of the sail plan, to meet all circumstances. It was just as easy to bring her about again, when the emergency was over, and resume the proper course.

The most severe flaw of the mizzensail in a two-masted craft was that it was liable to send a beating ship farther into the wind that was intended, at the worst possible moment, at the surging of a gust of wind. A small foremast with a little foresail would offset this tendency effectively, and so the three-masted ship was born. Three-masted ships existed in Venice and Genoa, and possibly elsewhere, at the beginning of the fifteenth century.[1] The earliest illustration of a three-masted ship is in a Spanish bowl, believed to be of the early fourteenth century, kept in the Victoria and Albert Museum in London. The seal of Louis de Bourbon is the earliest dated illustration (1466).[2] In the spring of 1458 Sanseverino voyaged on a three-masted galley and in the winter of

1458-1459 on a three-masted ship. Handling these vessels was already common practice, and their masters and crews were experienced and seasoned at their trade.

Tree-masted vessels could be balanced to point in any direction within the physical limits set by the geometry of shrouds and yards. Sailing such a ship on a steady course was a matter of adjusting the mizzen and foresail sheets to minimize the work of the rudder and its ensuing drag. Drastic changes of course to windward would be made by reducing the amount of wind carried by the foresail, as a first measure, and then by resetting the remaining sails, until a new balance was acquired. Similarly, a change downwind would be started by decreasing the effort of the mizzensail. Sanseverino never mentions the rudder or the tiller when describing changes of course, and only once or twice on other occasions throughout his diary, but he invariably repeats "they reset their sails", in all the instances where a change of course is reported.

When on a dead run such a ship would be almost self-steering. With the mizzen furled, or reduced, the principal press of wind was on the main. The foresail would be shielded by the main and do no work, unless the ship strayed off course and then this sail would become exposed to the wind, with the effect of sending the ship back back downwind, onto her course. This technique would make broaching impossible. It was a very ancient method, having been practiced by the downwind sailors of antiquity, who used an artemon on the bow for this very reason. Sanseverino describes a free run under similar conditions on a dark night, on the 6th of December. 1458: " .. at about the fifth hour of the night the Levante and Scirocco [East-South-East] wind started to blow very fresh, whereupon the master and the sailors reset the sails, took very gladly the said wind on the stern and sailed very successfully and gladly for the rest of that night ...; and ... they lowered the mizzensail as far as they could for their safety."[3]

On a reach, after balancing the fore and the mizzen she was pure pleasure, according to Sanseverino. He describes a similar occurrence on a three-masted galley on May 21st. 1458 in the vicinity of Sibenik (Dalmatia), with these words:

> "At that time [4 p.m.] the wind called Maestro [North-West] started to blow, from astern of the galley and the master ordered all three sails to be reset and with the said wind they were making seven or eight [Venetian] miles per hour. And because until that time they never had had any stern winds, everybody was cheerful and joyous, not just the pilgrims, but even the sailors. Because of their gladness a number of them, young and fit of body, gathered together around one of

> them standing near a cable which the sailors call the mainstay and it is the cable that holds the mainmast of the galley, and climbed the said cable, some reaching the crowsnest and some the main yard and they climbed on each others' shoulders so that they were touching the crowsnest ... Besides this, they were climbing up and down the ropes and the sail with ... agility ..."[4]

Obviously the ship required very little attention from the crew while on this course. This vessel was rigged with three lateen sails and therefore her most efficient mode of sailing was a broad reach. This explains why, having a stern wind, the master ordered the sails reset. A wind on the stern quarter would make all three sail provide power. By balancing the fore and the mizzen the course would be kept almost automatically. The sailors stopped frolicking as soon as the wind shifted:

> "They could have performed many other feats if that wind had continued, but it died after about two hours and a contrary one sprang up, requiring that they pay attention to the trimming of the ship."[5]

Travelling to windward was still difficult. Three-masted ships could make modest gains against a wind, but leeway was still a very severe problem. In heavy weather a three-masted galley, or a ship, would make some headway or loose ground almost indifferently. Pitching would cause yaw, with the inherent loss of ground, so that it appears that these vessels could make gains only over a fairly smooth sea. Sanseverino's diary of November 11, 1458 records: "... since the sea was not very rough, with all this making tacks they advanced enough to see the rock of Sapientia."[6] On the following night "the same Provenza [Westerly wind] prevailed and they had to make tacks continuously, but, as the sea was calm, they nevertheless made some gains."[7] Similar comments are to be found sprinkled throughout the book.

A rare wealth of statistical data on the general performance of fifteenth century three-masted vessels, in all possible conditions of sailing, can be found in Sanseverino's diary of his pilgrimage to the Holy Land. His outbound voyage was made on a galley and his data regarding the windward tacks made by this vessel provide some of the most accurate information available for a realistic determination of the level of performance attainable with fifteenth century rigging and gear. She was an excellent sailer, capable of doing at least 140 nautical miles in a good day, as she did on June 4th, 1458, under ideal conditions[8], turning out a speed of 5.8 knots, a respectable rate for a hull designed to be rowed. On the other hand, when sailing to windward, her performance was poor. On the 24th of May, 1458, as they were approaching a harbour making tacks: "being five miles off Ragusa, ... because of the contrary wind called Levante [East] it took six hours to do what in good weather would have taken but one".[9] The indication is that this galley was capable of making tacks at a ratio of 1 to 6 to the direct course, or, at an angle of 80 degrees to the wind.

On the 28th of May, in the vicinity of Kotor (Dalmatia) : "In the morning the wind started to blow from Scirocco [South-East], which was contrary to them, and caused the sea to be turbulent. ... However ..., they kept sailing close-hauled and beating to windward as close as they could, day and night, [and] .... the next morning they found that they had made good about fifteen [Venetian] miles" (about 9 nautical miles) [10] These tacks were even wider, at about 87 degrees.

On the 29th of May, in front of the castle of Ulcinj (Dalmatia): "The seas [started] to become bigger than ever, [as] the contrary Scirocco [South-East] wind was still persevering, so that they stayed in the same position almost the whole day ... and so, they re-mained all day making tacks in sight of the said castle ..."[11] Since they did not move, the results of the total effort for the day is equal to tacks of 90 degrees. Throughout the diary of the outbound leg of the voyage similar results are reported regularly, as are records of net losses, for tacks greater than 90 degrees.

Similar data are available for the three-masted ship on which Sanseverino travelled from Acre to Ancona in the winter of 1458-59. This ship was a fast sailer. For example on the 26th of October she ran from sunset to "some time past midnight" a distance of 60 nautical miles under bare pole before a storm.[12] On November 7, on a broad reach, she made 180 nautical miles in twenty-four hours, which gives an average speed of 7.5 knots, very likely the hull speed of that craft.[13] Running before a very severe storm under bare poles during the night 19/20 December she was travelling at speeds between 6 and 7 knots[14]. However, when beating, her performance, like that of the galley, was rather indifferent.

On the 16th of October, five days out of Acre, in the Eastern Mediterranean: "... a very fresh wind from Maestro [North-West] came up, which caused them to make tacks all night, at times towards Barbary, at times towards Turkey, without gaining any headway."[15].

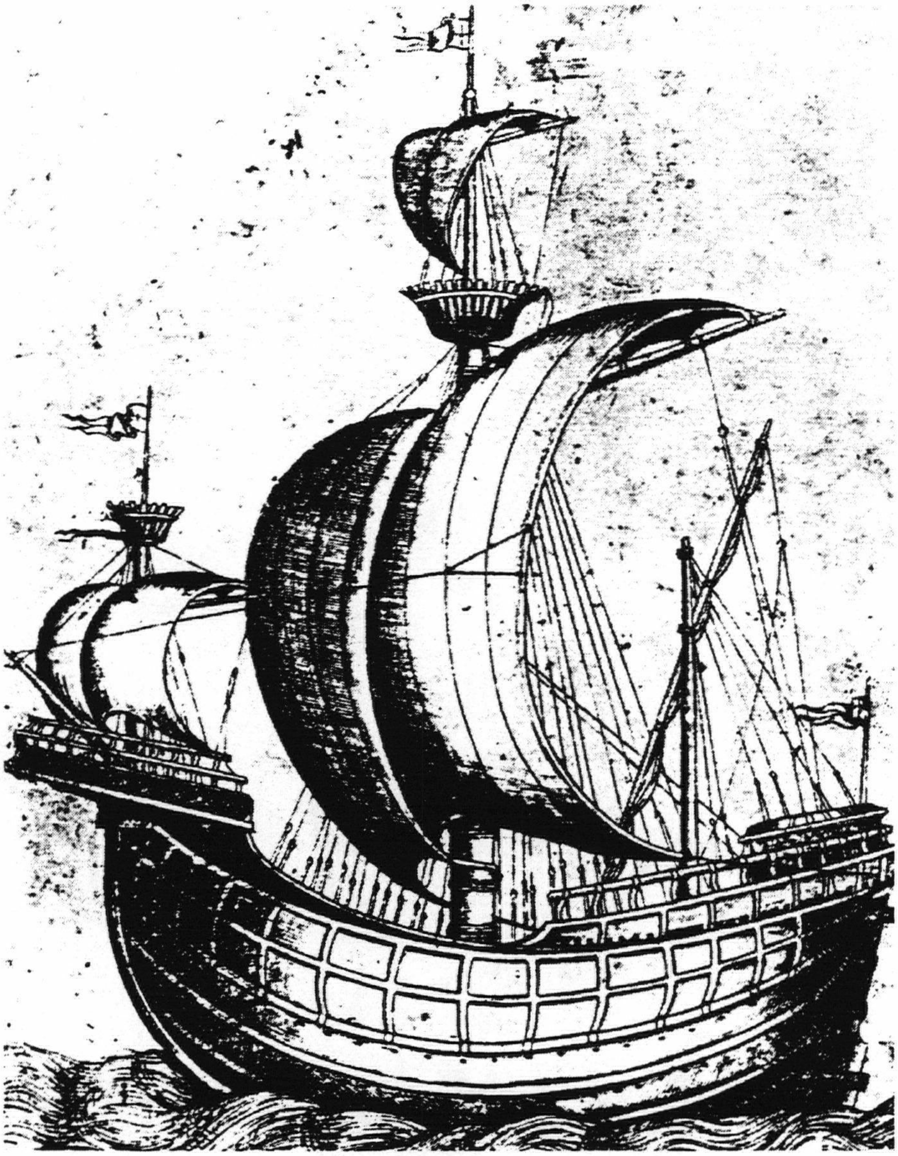
It took three days in variable winds for this ship to double Cape Matapan, on the Mani Peninsula (Greece), which they had approached on November 8th: "they sighted Cape of Mayno [Mani] ... but during the night [the winds] changed to *Garbino* [South-West], sometimes to ... *Provenza* [West], sometimes to *Maestro* [North-West], all contrary winds, so that they gained little or nothing on their travel."[16] On November 9th "... in the morning they found themselves near and upon the same Cape of Mayno, but, nevertheless, as the *Ponente* [West] wind was freshening, they kept on making tacks all day, without ever being able to double it and without making any progress, to the great chagrin and trouble of all."[17] On November 10th, "... in the morning they found that they had drifted downwind during the night, rather than having made good any distance, because they were still abeam of the said Cape of Mayno, but out at sea and more than thirty miles from it; and as it began to blow a little *Greco* [North-East] and a little *Tramontana* [North] and sometimes there was a contrary wind, still they kept at it long enough, so that at about midday they doubled the said Cape of Mayno".[18] This particular voyage from the Levant to Venice, being made in the winter, was dogged by contrary winds, as was to be expected in that season in that part of the Mediterranean. It is not surprising that Sanseverino reports many similar difficulties.

Although these records are indicative of an indifferent ability to windward, this ship would loose very little ground, overall. The master could keep on trying as long as needed, until he made the next point of land. Under more severe weather conditions, twice he resorted to running before the wind, but the runs were relatively short. It appears that he would elect to do so when big seas started to break over the gunwales at night and began to toss his deck cargo around. It is difficult to know whether his decisions were born of prudence or dire necessity. During the day he could assess the size and the power of each wave as it came, and ease his ship over the worst ones as he saw fit. It was simply a matter of loosening the mizzen sheet when the bow started to lift, and the ship would turn to take the wave on the stern quarter. In the dark he was likely to misjudge some of these waves, and running would be the best part of valour. A third run, nearly disastrous, was made out of extreme necessity on the night of December 19, the rudder having proved inadequate to hold the ship on course under a single reduced sail, after the fore and mizzen had to be dropped.

There is no question that by the fifteenth century sailors were fully capable of handling their ships by sails alone and Sanseverino describes a dramatic event where this type of maneuver was called for to save the ship from being run aground in the Gulf of Kalamata (Greece).

> "Sunday, the 12th of November, with the Provenza [West] wind still prevailing, but very light, and the sea being almost calm, they kept on making tacks as usual until midnight, still gaining some small distance. It was about midnight and the ship on a tack towards the land and not far from it, when the said Provenza died, so that the ship had no motion and almost every man was asleep. And while everything was like that, all of a sudden the Levante and Scirocco (East-South-East] wind rose, strong and forceful, which was very favourable to their voyage, except it caught the said ship so pointed [towards the land, as the wind had died during an inshore tack] and so close to the land that it almost threw her aground and they found themselves in a very great danger. But the master, the officers and the other sailors were immediately on their feet and ... immediately reset the sails and took her farther out to sea."[19].

It must be noted that the ship was totally becalmed, so there was no steering available. The shore had become suddenly a lee one, so they had to turn the ship quickly and sail her off. Only a great deal of familiarity with this type of manoeuver would have allowed them to succeed. This style of seamanship was inherited from a long line of generations struggling with the earlier, less sophisticated rigs. It was that experience which made possible handling heavier ships by dividing the sail plan among an increasing number of sails (Figure 12, p. 74). Seamanship was rapidly evolving towards the mastery of craft big enough to carry relatively large crews and all their gear across the vastness of the oceans, and to bring them back consistently[20].

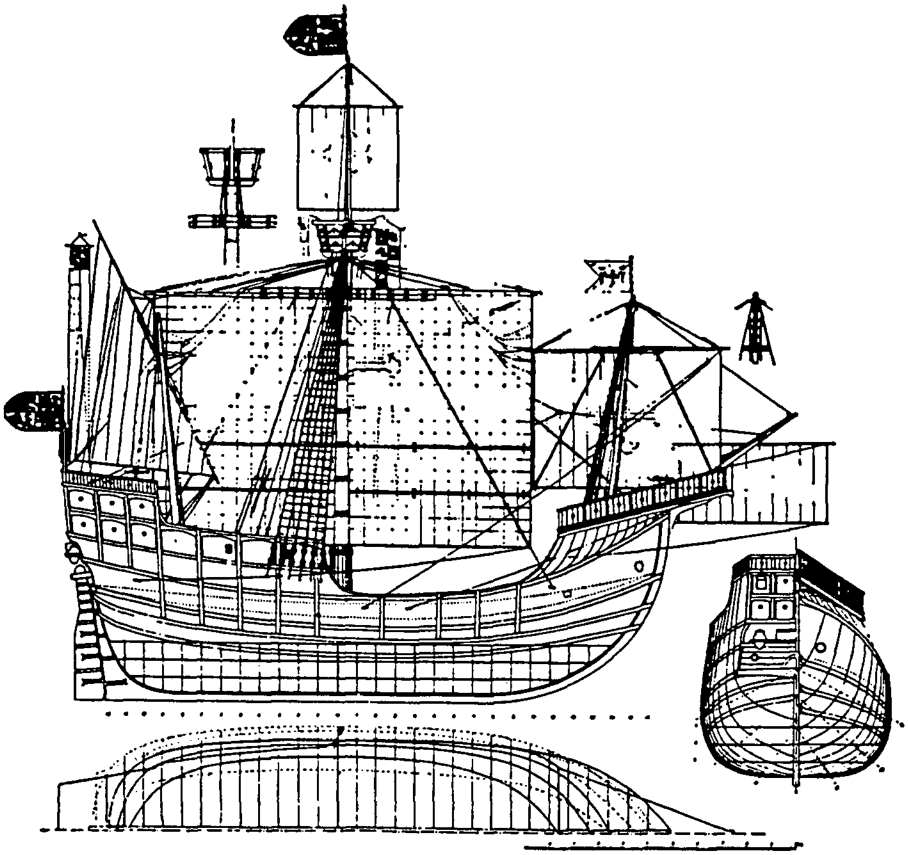


Italian full-rigged ship of 1470-88. (From R. W. Unger, The Ship in the Medieval Economy, 660-1600, 1980). p. 218

Figure 12

Already by the beginning of the fifteenth century ships were making the first deliberate forays far from land in the Atlantic, west and south of Europe. These ships were capable of being sailed in operations of discovery, and eventually of commerce and war, in areas of the world where secondary bases that could be reached in case of bad weather or shortages did not exist. The early caravels[21] employed in the expeditions that led to the discovery of Madeira, the West Coast of Africa and of the route to India were round ships, about sixty feet long, had small superstructures so as to reduce windage and had two masts rigged with lateen sails. This type of caravel developed into a three-masted lateeneer, called _caravela latina_, favoured for exploration because of her weatherliness, which allowed her greater manoeuverability when working along unknown shores. Variant rigs and hulls were associated with them all over Europe and multiple square sails could be rigged on them, obtaining a sail plan that was specific of _caravelas redondas_ or _naos_. Navigators understood the benefits of this type of rig for long voyages over oceans in regions where the winds were known to blow from constant directions. Columbus' _Santa Maria_, a _nao_, had a complex sail plan, consisting of a square mainsail that could be augmented with two bonnets, a main topsail and a square foresail. In addition to these sails she was provided with a spritsail for downwind course-control and with a small lateen sail that could be hoisted on the mizzen for balance on windward courses (Figure 13, p.77). On a reach with gentle winds all these sails, and more, could be used at the same time.[22]

The size of these ships entailed very large rotational momentums so that steering them was too heavy and dangerous an operation to permit the use of the tiller directily, even to control yaw. The whipstaff, already known in the thirteenth century, became mandatory. The construction of this device was an application of the principle of the lever. "... the rudder, instead of just passing over the sternpost, went through an opening in the stern. There was a bar attached to the tiller at a 90° angle. The helmsman handling the bar could stand higher and see the action of the ship. For larger ships a fulcrum had to be added above the point where the tiller met the bar so that the helmsman could move the heavy rudder. Moving it in one direction made the rudder move in the other ... Builders added the fulcrum which made the mechanism effective some time in the fourteenth century"[23]. Like all levers, the whipstaff reduced the total amount of movement of the tiller, probably to little more than what was required for the ordinary operation of counteracting yaw. By the fifteenth century ships were controlled in a manner that can be defined as modern,



The nao Santa Maria. An ideal reconstruction.
(From: J. M. Hidalgo-Martinez, Columbus' Ships, 1966) p. 50

Figure 13

insofar as large changes in direction were effected by smooth, but drastic changes in the balance of the sail plan, a basic method that was not to be altered even by the appearance of the modern steering wheel.

The final development of this principle was the addition of a fourth mast, the bonaventure, and of a square sail flying from the bowsprit. This sail plan, found to be indispensable on larger ships, made its appearance towards the end of the fifteenth century or, rather, it was by this time common enough to be depicted in illustrations. The process had been hastened by the discovery that the fore and mizzen sails, indispensable for course-keeping, did not have to be as small as had been previously thought necessary. The carrack with a large square foresail was one of the early results. This ship was held on a windward course by a lateen mizzen and she was in all certainty not more efficient in this mode than Sanseverino's three-masted ships, until a topsail was added to the mainmast, the combination resulting in the tall rig indispensable for positive and sustained performance to windward. This performance could be enhanced by a larger mizzen and all three sails could be used for driving the ship. As the amount of sail adjustment required for setting a ship on a course is very small, large mizzens and large foresails proved to be too unwieldy for this type of work. Thus the bonaventure mast with a small sail, called the 'bonaventure sail', was rigged aft of the mizzen for adjustments to windward. The square spritsail on the bowsprit was used for downwind runs. The mainmast carried a topsail, as well. The Venetian carrack of about 1500 was typical of this kind craft, together with the nao and the galleon, that could be sailed to windward as a matter of choice, rather than as a matter of necessity. Unquestionably, the best tacks that these ships could make were closer than 80 degrees.

Three- and four-masted ships heralded a new age in the economy of navigation. A more demanding, daring and efficient style of ship management ensued. With some luck in the weather ships could be sailed non-stop over great distances, for example from the Mediterranean to the North Sea, all year round. Having to make tacks in contrary winds still reduced ranges dramatically, due mainly to stores spoilage and to shortages of vital needs. Sanseverino's 1458-59 voyage from Acre to Venice was planned by the master of the ship as a bold, direct, non-stop run. He was so sure of the performance of his craft, as to speed and weatherliness, that he refused to go to Beirut to join a convoy that was being formed there to protect the Beirut galleys, about to return from their Fall run, from pirates. For the purpose of enhancing speed he also took in only as much ballast as he deemed strictly necessary. This decision gave his ship higher freeboard when beating and reduced draft and resistance. This gamble did not pay off as well as he had hoped. Contrary winds slowed his progress to the point that he ran out of food at about one third of the way and had to stop at Melos, an island in the Greek Archipelago, where provision turned out to be scarce. He did manage to add several boatloads of rocks and gravel to his ballast, however. The next stage brought him as far as Mothoni, about two-thirds of the way, and from there, in what was supposed to be the final leg of the voyage, he had to make a stop in Ancona, less than one hundred miles from Porec, where he would have taken the pilot for entering the harbour of Venice.

Stoppages of this kind depended on the luck of the winter weather but, otherwise, multi-masted ships could be relied on to reach their destinations all year round, regardless of their type and size. The great number and variety of ships Sanseverino met in a single winter trip are evidence of that. All seemed to be affected by the weather more or less to the same extent. Among the ships reported by Sanseverino was a very large galleass, so big as to be comparable, in his opinion, to a palace in a city, and a light galley of the Knights of Rhodes that was escorting her. The galleass was a large oared vessel rigged like a ship, with a square main and two lateen sails for steering her; the light galley had three lateen sails, and was as maneuverable as the caravel with similar rigging. These two ships travelled together and sought refuge at Melos at the same time as Sanseverino's ship. Another Venetian ship of some three-hundred botti[24], also arrived at this harbour, battered by the storm.[25] All these vessels left on the same day and, while beating their way out of Melos, they met a galley that was making tacks and later, during the same stage of the voyage, a second one, loaded with malmsey wine, also beating on her way home. Both were returning from a recent military expedition at Euboea. Finally, a pirate was also out in the same weather, attracted by the heavy traffic, and gave them an unsuccessful chase. All the above ships, including the pirate's, arrived a few days later at Mothoni, within a few hours of one another. There they were joined by another ship, and by two other galleys, not better defined. Later during that stay, and at the height of a very severe storm, five light galleys arrived at the same harbour, apparently quite unruffled. A cargo boat from Ragusa did not manage to enter that haven and was lost with all hands. A few days later another light galley joined the first five, coming from Crete and having on her stern the same weather that was preventing Sanseverino's ship from setting out. These six galleys were supposed to replenish their stores at Mothoni while waiting to provide escort to the Beirut and the Alexandria galleys of the Fall run, due to arrive in a short time. Another galley loaded with sugar was also expected from Cyprus to join the same convoy.[26] Later in the voyage, Sanseverino's ship was overtaken by three of the above large galleys which were proceeding under oars on a calm day. Further still they met a Candiot caravel, coming from Venice and on the same day they were overtaken by a fast ship. loaded with an unusally large and expensive cargo of spices, forty days out of Alexandria.[27] In the harbour of Ancona they encountered ten more ships that had arrived on different days, seeking refuge from a long-lasting storm[28]. All these events occurred between October 12th, 1458 and January 11th, 1459.

These records make possible a preliminary comparison of the economics of winter and summer sailing with multi-masted ships. Sanseverino places the encounter with the fast ship at a point of land called Capocesto, five miles South of Sibenik (Dalmatia). At that point she had made good, beating or otherwise, 1100 nautical miles in forty days, an average speed of 27.5 miles per day. At the same point Sanseverino's ship had made good 1250 nautical miles in sixty-two days, an average speed of 20.2 miles a day. These times and averages include the stopovers made necessary by the long periods of contrary winds and the ensuing shortages on board. In favourable weather these ships would make 82 nautical miles on an average day. During the outbound part of Sanseverino's voyage his vessel was at sea for a total of 23 days, during which it travelled about 1900 nautical miles. The least daily run was 0, in contrary winds, the largest 138. In this particular case the stopovers were not included in the calculations, as they were made for the purpose of sight-seeing and for the comfort of an unusual group of passengers that incuded a cousin of the King of England. Ordinary merchant vessels were making that run non-stop. It appears that winter weather would require three to four times the number of days necessary for an equivalent summer voyage. There is no doubt, however, from the number of ships plying the waters, that the outcome was still economically viable. Some stopovers, although forced, could be made productive to some extent, if the opportunity arose. The master of Sanseverino's ship managed to sell part of his cargo of cotton in Mothoni, while contrary storms prevented him from leaving that harbour. Part of the weight that he had unloaded was replaced with ballast. In the end he made some profit and was ready to leave with a ship that had greater freeboard and increased stability. In the total economy of any voyage the manner of carrying on business in relation to the capabilities of one's craft was a matter of judgement and experience in seamanship. This matter included the dilemma of overloading (summer) versus underloading (winter), and the problem of juggling the sum of the weights carried, in relation to their specific gravity, so as to ensure maximum stability. A tender ship is compelled to sail wider tacks in order to avoid swamping, and this may result in extra days or even weeks of sailing. A competent master would have to keep an eye on all these details, particularly critical during the winter season, so as to maximize per diem returns. Sanseverino's diary is very eloquent in this respect. The most relevant aspect of voyaging in the winter involved all the problems of sailing to windward in heavy weather and sailors of the second half of the fifteenth century were able to cope with them, if by the smallest of margins.

However, the new breed of multi-masted ships needed smaller crews, in proportion to their size, and were able to make shorter times than their single and double-masted predecessors, and, being capable of sailing all year round, they could provide greater revenues to their owners. In the case of the ordinary cog, with a single square sail, it had been difficult to keep her sail plan balanced while on a beat in high winds over a rough sea and ultimately she had no alternative to running before the wind when she could no longer be sailed. Runs of a day or two before a wind meant some hundreds of miles lost, miles to be made up. Two-masted ships were unsafe when pointed to windward in anything but summer weather and even in that season they were liable to loose a great deal of time running and recovering from a run. Big ships with axial rudder, three masts and bowsprit could beat much closer to the wind, provide greater safety for their cargo, and, although they would make truly effective gains to windward with great difficulty, they could at least hold their ground or loose only a little. When they could no longer fight to windward their three sails could be trimmed so that they would heave-to. This was a delicate operation, resorted to only in extreme weather conditions, and it is not known when the technique was first developed, but fifteenth century sailors were already familiar with it.[29] Heaving-to is the ultimate defensive position of a multi-masted ship, before having to make a run. It consists of orienting the foresail and the mizzensail in such a manner as to cause the ship to yaw in an arc of some 20 to 30 degrees, each sail catching and spilling the wind alternately, while the bow is always kept off the wind. The mainsail, drastically reduced, is set so as to provide no more power than is required to ensure that the ship does not make sternway. A ship in this condition of sailing makes very negligible progress through the water, only enough to prevent the rudder from being pressed backwards and damaged. Her speed is so low that she never plunges into oncoming seas and she cannot, nor needs, to be steered. Meanwhile she drifts uncontrollably along a wholly unpredictable trajectory that will eventually result in a measurable loss of ground over long periods of time. This loss is always much less than the one she would suffer on a run. Thus a ship caught by a storm in an ocean can be kept in this mode for days on end, and she would be in very little danger. Only after this posture became impossible to maintain, only when three sails could no longer be kept set because of the press of wind, would a ship have resorted to running. Besides, the ease with which a three-masted vessel could be turned about would make the alternating of postures between beating and running an intermittent affair during periods of marginal weather.

Long-range navigation prompted the development of navigational aids, such as the compass with rotating windrose and nautical publications in the form of charts, tables and rutters, to supplement the age-old leadline and sandglass. While improved navigational aids were bound to contribute to the general performance of ships, their specific benefits to winter navigation are less clear and more difficult to prove, as a ship that is not inherently strong and properly designed and rigged to withstand the rigours of winter storms will receive no conceivable advantage by possessing navigational aids, in any age. Owing to the level of technology then available, medieval ships fought for their lives more than once on any given voyage, as witnessed by Frescobaldi, Poggibonsi and Sanseverino, and seamanship alone, born of traditional experience, had to see them through.

For the purpose of coastal navigation data from navigational aids are meanigless unless one's position is known with very great accuracy, as a course to any point on a chart can only be plotted from a point that is known. This kind of accuracy was not available to medieval masters, because medieval charts were drawn on a square grid. Their designers "took no account of the sphericity of the earth; the area covered was treated as a plane surface".[30] As a consequence medieval charts favoured accuracy of distances over accuracy of angles. The medieval navigator "did not work his dead reckoning, as a modern navigator does, by actually drawing on the chart; he calculated the distances made good along his chosen course, measured with his dividers the appropriate length on the distance scale, and marked his position by pricking the parchment with the point of the dividers. He used his written portolano for coastwise pilotage and the chart for passages on the open sea."[31] Navigating under sail does not require plotting a course, as the odds of a sailing ship being able to sail a plotted course are very small. Under sail no two voyages could be the same, as one would only mark on the charts daily fixes, trying to stay with whatever winds happened to give the best daily runs, and one might have had to switch courses in mid-run if the wind shifted[32], so it was sail and rig changes and not changes in navigational aids that were important.

Under stress of weather the man in charge of steering had to keep an eye on the sails, watch how easily his ship would keep her angle of heel and be sensitive to the amount of weather that he felt on the tiller[33]. As the pressure on the tiller varied he had to adjust the fore or the mizzen, with a consequent shift of course. Where he was going was then immaterial, as the total safety of the ship depended on his alertness in responding to these symptoms. He would consider the readings of a wildly oscillating rose, swinging in a poorly suspended compass box, of quite secondary concern. Sanseverino depicts one of many such cases that occurred in his ship: "but ... the strength of the contrary wind did not permit [the master] to arrive at his proposed goal, and it was necessary to stick it out at sea and steer by the wind".[34] Of course, a master could periodically take a look at the compass, try to average the readings, and endeavour to acquire a mental picture of where his ship might have been going, as compared to where he had intended to sail her, so as to make corrections when the weather would give him a break. Similar conditions of navigation are reported by Sanseverino during his voyages from Crete to Rhodes, from Acre to Melos Island and from Mothoni to Ancona. The final outcome of a master's navigational efforts, which is to say the degree of accuracy of his dead reckoning, depended totally on his mental picture of the location of the various lands in relation to wind directions. These were, in fact, the only points marked on most medieval compasses and so courses and bearings were not amenable to mathematical calculations. Even elementary charting problems were impossible to solve.

Any sailor can be a witness to cases of dead-reckoning errors as large as thirty or forty miles at the end of eight or nine days of winter fury in the Atlantic. Sanseverino has a humorous anecdote about five officers working separately with charts and dividers after a week in a storm and then looking out for land, where, as it turned out, they were seeing clouds[35]. A responsible master, unsure of his dead reckoning after a few days of making tacks in murky weather, would be compelled to make a landfall somewhere, to ascertain whether his hunches were correct. Such a case is reported by Sanseverino during his voyage from Mothoni to Ancona, requiring they make a landfall at the lighthouse on Saseno Island before venturing into the Adriatic[36].

When crossing a fairly large body of water out of sight of land, the practice was to sail as close to the wind as reasonable, and meet the opposite shore well to the windward of the intended point of arrival. Once the coast was sighted and some mountains or other landmarks were recognized, the master would make a reach or a run for his destination, sailing along the shoreline. This procedure was followed on Sanseverino's galley upon approaching the coast of Istra[37] and again when making the final approach to the coast of the Holy Land[38]. Perhaps the best contribution of the compass in bad weather, in this case to safety, could be that of helping a master to make up his mind as to where or how far he should try to fight his way in a storm before turning on a dead run for a specific haven. His decision would allow him at the end very little room for correcting mistakes. But even in this case he had to have a better than fair knowledge of his point of departure by ordinary, visual means[39]. Sanseverino, although his daily reports contain clearly understandable nomenclature of ship gear and extremely reliable records of wind directions and courses sailed, very rarely mentions the use of navigational instruments, and in these cases the leadline seems to be the most crucial one. He mentions charting only once.

All medieval commercial navigation was limited to voyages during which one was seldom out of sight of land for more than five or six days[40] and the navigational difficulties involved were well within the limits of the experience and traditional knowledge of the average master. When he was out of sight of land for longer periods he and his officers would be groping for clues and Sanseverino records many such instances. Seamanship was a trade, like any other, to be learned as an apprentice, the essential point of it being the skill of handling a ship so as to prevent her from being overcome by the weather. Next came the skill of using the wind for propulsion and steering so as to be able to go toward a destination. At last the apprentice became proficient at navigation simply by being on board a ship and becoming familiar with sights and landfalls.[41]

Notes to Chapter IV.

1. J. H. Parry, Op. Cit., pp. 27-28.

2. B. Landström, Op. Cit., p. 96.

3. R. Sanseverino, Op. Cit., p. 267.

4. Ibid, pp. 27-28.

5. Ibid, p. 28.

6. Ibid, p. 230.

7. Ibid, p. 231.

8. Ibid, p. 48.

9. Ibid, p. 31.

10. Ibid, pp. 37-38.

11. Ibid, p. 39.

12. Ibid, p. 210.

13. R. Sansverino, Op. Cit., p. 228. 'Hull speed' is the ultimate speed that a displacement hull can develop under the best circumstances. No amount of power will be able to push that hull through the water any faster. This is the fundamental reason for having to reduce sail when running before very high winds: the excessive power produced by the sails would have destructive results, as the hull, having reached its maximum speed, will produce infinite resistance to further acceleration. The hull speed of any vessel is related to its underwater length, longer hulls having the potential for higher speeds. Planing hulls do not have this limitation.

14. R. Sanseverino, Op. Cit., p. 278.

15. Ibid, p. 204.

16. Ibid, p. 228

17. Ibid, p. 229.

18. Ibid, p. 230.

19. Ibid, p. 231-232.

20. The manoueverability and reliability of multi-masted ships altered the methods of warfare, as well. Sea-battles in open seas, rather than in quiet bays, became common. See Archibald R. Lewis and Timothy J. Runyan, European Naval and Maritime History, 300-1500, (Indiana University Press, Bloomington, 1958), pp. 144-169.

21. The origins of the caravel are not known and some authors associate the name with that of a type of hull construction (carvel), typical of Mediterranean shipbuilding. Two-masted caravels existed and Landstrom suggests that an influence in their development can be recognized in the rig of the Venetian galie sottili, which in the thirteenth century travelled as far as England (Op. Cit., p. 128). The caravel associated with the early voyages of discovery was rigged with two or three lateen sails, although variants existed everywhere. So, it is often necessary to mention caravels by the local name, such as the Portuguese caravela redonda or the Italian sciabecco. Sanseverino, for instance, mentions a "caravella candiota", meaning a vessel rigged in the Candiot (Cretan) manner. A more drastic change in rigging, to square sails, would transform a large caravel into a nao. Two of Columbus' caravels underwent this change. See Jose Maria Martinez-Hidalgo, Columbus' Ships, Howard I. Chapelle Ed., (Barre Publishers, Barre, Mass., 1966).

22 "[The wind] began to blow very gently. I then raised all the sails of my ship, the mainsail and two bonnets, and the foresail and the spritsail, the mizzen, the main topsail and the sail of the boat on the poop." See Frey Bartolome de las Casas, Primer Viaje de Cristóbal Colón segun su Diario de a Bordo, (Ramon Sopena, Barcelona, 1972), p. 38. All the translations from this book are by T. Vidoni.

23. Richard W. Unger, Op. Cit., p. 168 and 195n.

24. The botte was a unit of cargo capacity. Studies by F.C. Lane indicate that the botte originally used in Venice was about 750 litres. In 1432 the smaller botte of Candia (Crete) was adopted as the standard unit for pricing cargo and its use became general. This botte candiota, calculated by Lane on the basis of other current volumetric units, had a capacity of

605 litres and would then weigh about 0.6 metric tons, or 0.6 tons deadweight, as the two are almost identical. In modern terms a ship of three hundred botti would have a deadweight of 180 tons. At the turn of the fifteenth century smaller botti, of about half a ton or less, became standard in various ports of Europe, including Venice. See F.C. Lane, Op. Cit, pp. 236-243 and p.43n.

25. R. Sanseverino, Op. Cit., p. 215-217.

26. Ibid, p. 233-252.

27. Ibid, p. 260-272.

28. Ibid, p. 292.

29. Ibid, p. 38.

30. J. H. Parry, Op. Cit, p. 41.

31. J. H. Parry, Op. Cit, p. 42. Pedro de Medina, the librarian of the future admiral of the Armada, the Duke of Medina Sidonia, wrote an Arte de Navegación, a Suma de Cosmografia and is best known as the author of the Regimiento de Navegación, written in 1563. In the first chapter of the first part of the Regimiento he describes the uses of the marine chart: "A marine chart (provided that it is true and accurate) shows six things useful for navigation, viz.: ... The location and the lay of lands and islands, ... the winds that are favourable for going to various places, ... the distance between places, ... the latitude of the various places in degrees, ... the position of the ship according to the elevation of the sun and, finally, ... it can be used to mark on it new islands or bays not yet drawn on it". See Pedro de Medina, Regimiento de Navegación, compuesto por el Maestro Pedro de Medina (1563), Julio F. Guillen Ed.,2 volumes, (Istituto de España, Madrid, 1964), vol.1, pp. 26-27. To choose a favourable wind "look at the chart ..., find the place of departure ... and the place of destination ... and select one the thirty-two winds that are used for navigation." (Ibid., p. 27). The position by the sun at the end of the daily run, at noon, was marked as follows. "When a master ... wants to to mark his position on the chart he must take two dividers ... the first divider must be placed with one point on the place of departure and the other on the rhumb line followed [with an opening equal to the estimated distance

travelled], then he must put the other divider with a point on the the East-West line [a parallel of latitude] with an opening equal to the latitude measured ... then he must slide with gentle hand the two dividers until the points meet ..." (*Ibid.*, 29-30). The position was thus pricked on the chart. All the translations from Pedro de Medina's book are by T. Vidoni.

32. R. Sanseverino, *Op. Cit.*, p. 274-290.

33. For reasons of safety ships are never sailed with the sail plan balanced perfectly neutral. A minimal amount of tendency to turn to windward is generally left. This tendency is perceived by the helmsman as a light pressure of the tiller against his hand and is referred to as "weather helm". With a steady wind the amount of weather helm is constant. Should the wind increase suddenly because of gusts or because of the approaching of a squall the amount of weather helm felt would increase immediately, giving the helmsman a warning. The sheets will be slackened and the ship will be sailed a little more off the wind while the gust or the squall last. When they die the weather helm felt decreases. It is then time to haul the sheets in again and resume the previous course. A sudden lightness on the tiller is the only warning a helmsman will have, even in the dark, of his ship having yawed too far to windward. He will slacken the mizzen and give all the lee helm he can, hoping to sail the ship off the wind. Following doggedly a rhumb line without paying attention to these symptoms would have disastrous consequences.

34. R. Sanseverino, *Op. Cit.*, p. 42 and *passim*.

35. *Ibid*, p. 206-07.

36. *Ibid*, p. 264-65.

37. *Ibid*, p. 24-26.

38. *Ibid*, p. 65-66.

39. R. Sanseverino, *Op. Cit.*. A very precise run of this kind, from the Gulf of Quarnero to Ancona, was made by Sanseverino's ship on the night 19/20 December 1458, pp. 275-283.

40. The longest runs away from land were the stages Norway-Iceland and Greenland-Labrador sailed by the

Vikings. At 630 nautical miles the distance from Norway to Iceland is the greatest. At 5 knots, with weak winds, that distance requires about five days to cover. They probably made faster passages.

41. Local knowledge was absolutely essential to a master for making approaches to harbours. This included a memorization of the different aspects of landmarks when making landfalls from different directions. Pedro de Medina gave advice on this problem in his Regimiento de navegación. See "Aviso XVIII. De cuando el piloto conoce un puerto que ha entrado en el y después viene a el por rumbo diferente del con primero entró. Que debe hacer para lo conocer. (Advice XVIII. About the case of a master who knows a harbour in which he has previously entered and afterwards comes to it on a course that is different from the one used the first time. What he must do to recognize it.)" in Pedro de Medina, Op. Cit., pp. 150-151.

CHAPTER V

CONCLUSIONS

Leaders of expeditions of discovery required little help from navigational aids and not much was available. Compass, astrolabe and quadrant had unique importance for adding new lands to existing charts and for finding one's way home. For long ocean crossing the ability to navigate by instruments was necessary. Accuracy of navigation was less relevant, owing to the lack of shore dangers. For ocean crossings medieval instrumentation was, in this case, more than adequate: even an error of half a degree (30 nautical miles) in daily latitude fixes with an astrolabe would not impair the outcome of a crossing, as positional errors are not cumulative. Thus, it was in the field of overseas expansion that the chief impact of medieval navigational aids, such as they were, was felt.

Compasses and astrolabes were centuries old by the time of the voyages of discovery and the same can be said of the sternpost rudder. The case can be made that oceanic navigation created a demand for more accurate instruments and charts, which were not readily forthcoming. Early oceanic navigators still depended on their dead reckoning skills first and foremost. Columbus did not even bother with observations of latitude during the outbound leg of his first voyage, as he did not have a precise destination, nor a chart that he could trust west of the Azores. He crossed the Atlantic using nothing but dead reckoning. Columbus had only one chart -- reputed to be a copy of the highly fanciful 1474 Toscanelli map -- that he had to share with Martin Alonzo Pinzón, the captain of the Pinta, whenever one or the other needed it.[1] The ordinary log for measuring speed -- a very important tool for the determination of dead reckoning when out of sight of land for more than a few days -- became common only with oceanic crossings, in an endeavour to establish the westerly progress of ships, at a time when longitudes could not be calculated. So it was not lack of instruments and navigational aids that had prevented sailors from entertaining the idea of oceanic voyaging.

For a measure of the difficulties that an ocean crossing entailed one must refer to books such as the Regimiento de navegación, written by Pedro de Medina seventy years after Columbus' first voyage. The Regimiento was written specifically for ocean-going masters, having in mind the runs to and from Nueva España (America). In it the effects of drift when sailing close-hauled are described[2] and the intricacies of keeping proper dead reckoning when sailing against the wind for long periods are discussed[3]. A complicated method of retrieving one's intended position as soon as there is a favourable break in the weather is illustrated[4]. From the discussion one can gather some additional information about the angle of tack of sixteenth century ships. One problem Medina discussed was that of a ship leaving Sanlucar for Santo Domingo on a course to take her to the Canary Islands. Contrary winds take her to Cape Verde instead. Another problem he gives deals with the case of a ship leaving Barcelona for Malaga and being pushed south to Mallorca. Both the posited problems indicate that very open tacks, on the order of those described by Sanseverino, were still the norm.

However, these ships would keep on sailing. Pedro de Medina's text teaches, as an ordinary matter of fact, how new courses can be set from the new positions to the desired destinations. As soon as ships could be built that could travel thousands of miles in all weather the notion of systematic ocean crossings became realistic. Such ships could only be of the multi-masted type, with complex sail plans, as only these rigs endowed ships with the reliability required for such long-range ventures, regardless of wind direction and, to a great extent, of wind strength. There is no question that a single-sailed craft, even one of the earliest types, could have been blown by an uncommon storm across the Atlantic and survive. This could have well been the case with many a Viking boat if caught by a storm while engaged in hops from island to island while voyaging as far as the westernmost reaches of the North Atlantic. But the same boat could not be sailed again, by design, over the same route. Ordinary Atlantic weather systems carry typically changeable winds that would have unfailingly overtaxed the very limited capabilities of a single-sailed craft to windward[5]. For similar reasons it would have been impossible to sail with any probability of survival a two-masted ship across vast bodies of water. A two-masted ship with medieval sails could not be managed to windward on long rolling waves for any great length of time. As the wind increased the master would have had to compromise as to whether to the mizzen-sail for power or for steering. The equilibrium being a precarious one, soon the ship would have acquired too much weather helm and the mizzen would have had to be furled. At that point the design of the rig would have compelled him to run.

Pedro de Medina stressed that the ability to sail to windward was not a natural thing and that all-weather sailing was impossible without knowing how to manage a complex sail plan with the highest degree of artfulness:

> "There are certain things about navigation that appear natural, and one among them is when the master sails with a favourable wind, and as much so as he wishes, with which he makes his straight run without impediments of any sorts, so that it appears that this thing is a natural one and a source of great contentment as well. But when he sails with a wind that is different from the one he needs, and he travels with trouble, and labour, and worry, ... when ... [he] is sailing and cannot find a wind suitable for his progress, such as he has to make, and thus not in conformity with the course that he must follow; I say that ... then he must sail by the wind operating the sails; that is setting them in such a manner that, although the wind is not directly in conformity with his course, his endeavour must be such that the ship keeps on sailing as close as possible to her intended course. The master must know how to order this setting of the sails, furling some of them, hoisting others, and [how] to ensure that they are set in conformity with the mode with which the ship is sailing, as practice requires, and [he must know how] to modify it when it does not work as conveniently [as it should].[6]

The Pinta made her first landfall at the Grand Canary after the crew twice carried out lengthy repairs to the rudder at sea,[7] proof that a skilled master could sail a ship with three masts, although with difficulty, even without steering gear. Navigation over great distances was still a fairly primitive affair, as it was based on charts of very little substance. The state of cartography at the time of the voyages of discovery is discussed in the classic work of Admiral Antonio Barbosa, Novos Subsidios para a Historia da Ciencia Nautica da Epoca dos Descobrimientos (1948). Cartographers of that time had to resort to compromise in order to compile charts in which both wind directions and distances would correspond to reality with the same degree of accuracy. These data were more accurately expressed in words in portolans. None of the charts produced before 1568 allowed plotting courses and bearings by ruler and pen, because they were based on a square grid that made no allowance for the sphericity of the Earth. In that year the mathematician Gerard Mercator devised the cartographic projection that bears his name, to obviate this essential difficulty.[8] Charts were not a key factor for success in long voyages of discovery.

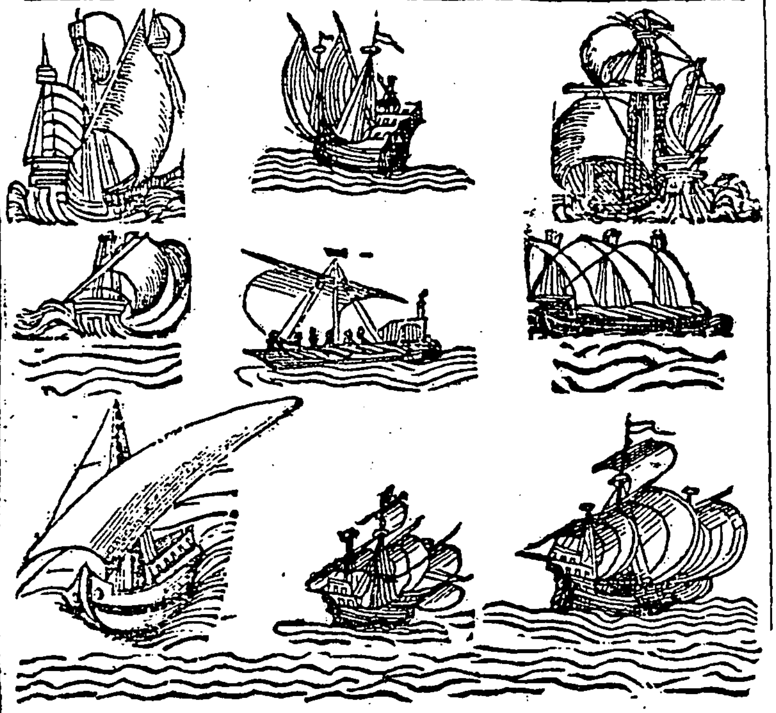
At the end of his first voyage Columbus made a perfect return landfall at the Azores -- the most crucial phase of the whole expedition, as they were out of food and water -- by dead reckoning alone. Only once had they seen the Polar Star, which "appeared quite high, as at Cape St. Vincent, but the motion of the ship would not allow them to take its altitude with the astrolabe or the quadrant."[9] Columbus made the landfall after being driven by a storm for two days. He had made no astronomical sightings.

It has often been a matter of discussion as to whether improved navigational aids or the sternpost rudder were responsible for the beginning of overseas navigation. At the core of the benefits of navigational aids is the

Auisos

que con el se hiziere. Dos cosas deuen tener los ynstru-
mentos dela nauegacion / vna que sean ciertos / y otra
que sean polidos: y muy bien hechos: y que el piloto se
precie de tenellos tales. Pues el ser ciertos le es grā pro
uecho / y ser polidos y muy bien hechos da contento.

¶ Auiso .ij. Como el piloto ha de conoscer el na-
uio en que ha de nauegar y saber las
mañas que tiene.



EN la nauegacion de la mar andan muchos na-
uios: y no todos de vna manera mas de difer-
tes hechuras y maneras: y assi vnos son de
porte y otros de otra [illegible]

Different types of three-masted ships. "Advice II. How a master must acquaint himself with the ship on which he has to voyage and understand her capabilities." (From Pedro de Medina, Regimiento de Navegaciòn, 1563, vol.1, fo. lvii).

Figure 14

marine chart. Unless a chart can be drawn according to certain mathematical principles the results of observations by instruments cannot be recorded reliably. Cartographers of the age of the discoveries did not possess the required mathematics and their knowledge of geography depended heavily on traditions and legends. Discoverers mapped the world and brought the information back to the makers of maps.

The sternpost rudder was known since at least the late twelfth century and the consequence of its appearance was an improved capability for ships to sail to windward. Greater angles of heels, deriving from closer sailing, became acceptable. Even with this benefit the existing rigs could not take full advantage of this improvement. It was impossible to set the single sail taut enough to sustain closer courses until the bowsprit, perhaps one generation later, made its appearance. Passing the bowline through a block at the end of the bowsprit produced the desired result. The effectiveness of any rudder diminishes in proportion to the size of the ship, unless some sort of power steering is available. The whipstaff increased the force available at the tiller, but reduced the arc of movement to the amount required for control of yaw. The appearance of the whipstaff is the signal that the lesson in course-keeping by balancing the sail plan was fully learned.

The single technical advantage that made possible voyages of discovery was the dependability of multi-masted ships. At the end of the fifteenth century there were many types, suitable for different sorts of endeavours, and theories and opinions on their merits were widely discussed. The subject was understood well enough that rigs were changed during stopovers, to suit prevailing meteorological conditions. Also mixed fleets of ships with lateen rigs and others with squares ones were employed for different purposes in the same expeditions.[11] The ultimate performance of these ships depended on the master's understanding of their capabilities (see Figure 14, p.103). Pedro de Medina considered it essential that masters make themselves acquainted with the type of ship of which they were to take charge[10], because much more depended on the characteristic behaviour of certain rigs than on all the other factors combined, in order to sail a ship thousands of miles out and back home.

Notes to Chapter V.

1. "Tuesday 25 September [1492]. ... The Admiral was talking [across the water] with Martin Alonso Pinzón, the captain of the other caravel, Pinta, about a chart that he had sent him on his caravel three days before, on which, it appears, the Admiral had drawn some islands [reputed to be] in that sea. Martin Alonso was saying that they were in their neighbourhood and the Admiral answered that he believed it to be so, too ...; and with this the Admiral told him to send him back the said chart. As soon as the chart was sent to him by the means of a rope, the Admiral started to chart on it together with the captain of his ship and his officers." B. de las Casas, Op. Cit., pp. 14-15.

2. Pedro de Medina, Op. Cit., v. 1, Second Part, Advice IIII, pp. 125-127.

3. Pedro de Medina, Op. Cit., v. 1, Second Part, Advice V, pp. 127-129.

4. Pedro de Medina, Op. Cit., v. 1, Second Part, Advice VI, pp. 129-130.

5. For the vicissitudes of the Viking replica that was sailed by Capt. Magnus Andersen to North America in 1895 see O. Roberts, Op. Cit., p. 139.

6. Pedro de Medina, Op. Cit., v. 1, Second Part, Advice III, pp. 123-125.

7. "The Admiral was showing great anxiety at not being able to help the said caravel [Pinta] in her predicament but says that his apprehension is diminished by the knowledge that [her captain] Martin Alonso Pinzón was a man of courage and capacity." B. de las Casas, Op. Cit.. p. 8.

8 The fact that a ship travelling on a constant compass heading does not travel on a straight line, such as the rhumb lines seen on medieval charts, had escaped the attention of medieval cartographers. A ship traveling on a constant heading crosses all the meridians with the same angle. Since the meridians radiate from the Pole, the ship travels on a spiral with its centre on the pole. This spiral is called 'loxodromy' and Mercator's merit is that of having devised a type of projection that transforms loxodromies into

straight lines, thus enabling navigators to plot them with a ruler. Prior to the introduction of Mercator's charts the only charting tools were dividers, because medieval charts were reliable only for the purpose of recording distances travelled. The rhumb lines drawn on them had some degree of accuracy only in low latitudes or over short distances.

9. B. de las Casas Op. Cit, p. 134.

10. Pedro de Medina, Op. Cit. Second Part, Advice II, vol.2, p. 122-23.

11. The compositions of Columbus' fleets after his first voyage and the choices of ships made by Cabral, Vasco da Gama and Magellan are a reflection of this division of labour among ships of different sailing characteristics. See J. H. Parry, "Technical Problems and Solutions", in The Discovery of the Sea, (The Dial Press, New York, 1974), pp. 149-170.

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