RES MARITIMAE

CYPRUS AND THE EASTERN MEDITERRANEAN FROM PREHISTORY TO LATE ANTIQUITY

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KYRENIA II: The Return from Cyprus to Greece of the Replica of a Hellenic Merchant Ship

GLAFKOS A. CARIOLOU

Captain of KYRENIA II (1986–1990)

According to information passed on by Hesiod in his Works and Days, *"there is nothing pleasant about sailing in April, in the so-called spring sailing season, and it is hard to escape coming to grief; yet still and even so, men in their shortsightedness do undertake it."*

The Hellenic Institute for the Preservation of Nautical Tradition, with a carefully prepared experiment, investigated the sailing routes of antiquity and the performance under sail of commercial sailing vessels dating to ca. 400 B.C.E.

An almost eighty percent authentic replica of an ancient merchant ship, called the KYRENIA II, sailed over 520 Nautical Miles (N.M.) via the ancient port of Paphos on Cyprus, to Rhodes, Astypalea and Syros with its final destination being the harbor at Zea (Piraeus). The dates of this voyage were April 7–26, 1987.

The results are very useful to the field of Nautical Archaeology as they include the planning of the voyage, the preparation of the ship and crew, the sailing performance of the vessel and other aspects of navigation and seamanship. They also provide an insight into the vast amount of knowledge possessed by the ancient Greek mariners and shipbuilders.

INTRODUCTION

On Saturday, the 20th of November, 1965 Andreas Cariolou, my late father, who was on a dive gathering sponges, discovered the wreck of an ancient merchant ship of the fourth century B.C.E. at a depth of 30 m off the northern coast of Cyprus. With him, I took the first black and white photographs of a small mound of amphoras, which was all that protruded from the sandy bottom. A few years later, a team of archaeologists and divers under the leadership of Michael Katzev managed to bring the finds to the surface and, with the assistance of Richard Steffy (1985, 1994), the ship's hull was reassembled in the castle of my home town of Kyrenia. I personally worked as a diver on the underwater excavation in the summers of 1967 to 1969.

Project Origin

As one may correctly assume, a deep sentimental connection drove me to become involved in the KYRENIA II project and thanks to the Hellenic Institute for the Preservation of Nautical Tradition, and the Greek Ministry of Culture, I present my findings here.

Objectives

The objectives of the return trip of KYRENIA II[1] from Cyprus to Greece were fourfold:

[1] For the first voyage of KYRENIA II in 1986 see Katzev (1990) and Tzalas (1987). See also the video tapes "The Ancient Ship of Kyrenia: Captain and Sailors Three," National Geographic Production; "Kyrenia II: Greece to Cyprus" an RVTV/Transvideo Co-Production in collaboration with the Hellenic Institute for the Preservation of the Nautical Tradition, Piraeus, Greece.

1) To investigate and test the possibility of sailing west, back to Greece in the wintertime, when the winds are most favorable and blow from the east,[2] and to determine the possible duration of the trip in antiquity.
2) To test the feasibility of sailing the vessel with only four men as crew members and of handling the vessel at night.
3) To test and investigate the performance and capabilities of the vessel in general as well as under adverse conditions.
4) To try to obtain as much information as possible in order to aid archaeological research as well as maritime studies.

Planning the Voyage

Using statistical analysis of meteorological data provided by the Cyprus Meteorological Department (Meteorological Service 1986) it was decided that the trip should commence on the 1st of April 1987 because of the high probability of strong Easterly winds during this month. These winds are the result of the so-called Atlas or Desert Depressions, usually forming over the Atlantic ocean near the Atlas mountain region and the coast of East Africa from January to May each year. These depressions pass over the desert picking up hot dry air. With the center of a cyclonic system over Egypt they usually move eastward, causing a strong easterly gradient in the area between Paphos, Cyprus and Mandraki, Rhodes.

The Optimum Route

Due to political reasons it was necessary to avoid the coast of Turkey and Turkish occupied northern Cyprus, thus sailing to the harbor of Kyrenia had to be excluded. This partially effected the authenticity of the trip. Sailing 230 Nautical Miles (N.M.) from Paphos to Rhodes became a navigational exercise that was probably not encountered by the sailors of the Kyrenia Ship in antiquity. Using a polar diagram and other records, including those of the 1986 trip from Greece to Cyprus, a probable route was formed with thirty-four alternatives. The choice of each route totally depended on the wind direction. The optimum route, i.e. that with the least number of tacks, was as follows: Limassol, Paphos, Rhodes, Nisyros, Denousa (a small island east of Naxos), Syros, Kythnos, Kea, Sounion, Phleva (a small island off Sounion), to Phaleron (Piraeus). This route gave a linear distance of 520 Nautical Miles (N.M.). We estimated a sailing time of twelve to fifteen days to cover this journey.

The Navigation Plan

The Navigation Plan of the voyage contained the port of departure, the port of arrival, the compass courses, the distance, the favorable wind direction, the wind direction limits and finally the totally unfavorable wind direction or "No sail" limits. It was calculated that wind with an "average" direction commencing at 140 degrees and ending at 067 degrees was unfavorable to sail and from 240 degrees to 330 degrees was a "No sail" situation. The plan of the voyage was submitted to and approved by the Hellenic Institute for the Preservation of Nautical Tradition.

Safety—Security—Towage—Scientific Escort

By courtesy of the Greek ship owner Mr. Latsis, the offshore tug "Ellas" (45 m L.O.A., 5 m draft, and capable of 13 knots maximum speed) was to be our escort/safety vessel. The tug was to provide towage in and out of ports as it was difficult, if not impossible, to maneuver a square-rigged vessel in and out of the small modern day harbors in this area. It also served as a base station for the accompanying researchers, scientists and archaeologists.

PREPARATION OF THE SHIP

Ship's Condition

On the 8th of February we commenced the maintenance of KYRENIA II at the Kyrenia Nautical Club, Limassol, Cyprus, inside a specially constructed building, which housed the entire ship with lowered mast. The KYRENIA II had remained after the previous trip in the moderately polluted waters of the port of Limassol for a period of forty-threedays. As a result, 11.5% (0.84 sq m) of the total keel surface that was submerged (7.28 square meters) had been superficially affected by woodworm, which had penetrated the thick outer covering of pine-resin/pitch. Upon detailed examination, 7.9% (0.42 square meters) of the first planks on both sides of the rabbet line had also been attacked by woodworm. In addition, most of the submerged hull had a thickness of 2 mm of marine growth over the pitch. The ancient ship had had a 2 mm thick plating or lead-sheathing placed on top of the pitch, which offered a degree of protection. It was decided to protect the hull with modern anti-fouling paint.

[2] For an interesting article on seasonal wind patterns in the eastern Mediterranean see Murray (1995).

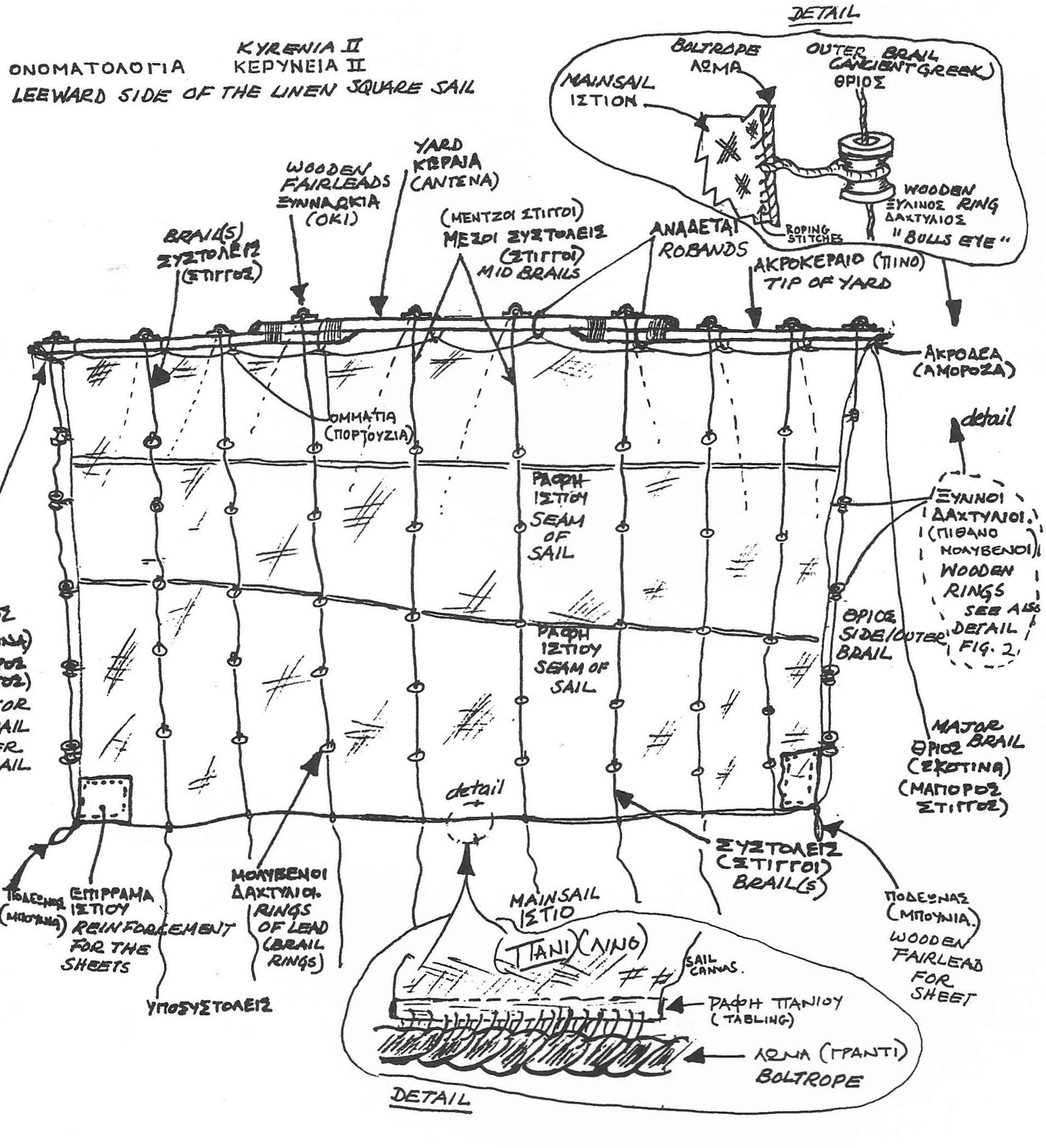

Fig.1. Leeward side of the linen square sail with details of rigging. Sketch from author's log.

Antifouling Treatment

Three coats of protective chemical were applied inside and outside the hull below the waterline, prior to applying the antifouling, in order to protect the wooden hull from worm action. Most of the hull below the waterline was painted with black (so as to follow the ancient tradition colorwise) antifouling paint. However, four areas were treated with only the ancient method of protective coating, a mixture of pine/pitch and linseed oil, in order to test and measure the different methods of protection and degrees of fouling.

Rigging—Sail—Refurbishment and Repair

The main halyard (ΥΠΕΡΑ-ΜΑΝΤΑΡΙ) and seven of the sail brails (ΣΥΣΤΟΛΕΙΣ ΙΣΤΙΟΥ) were changed, including the two major brails (ΘΡΕΙΟΣ) (fig. 1). The sail tabling (reinforcing) (ΡΑΘΗΜΑΝΙΟΥ) was checked and re-sewn on the boltrope (ΛΩΜΑ ΙΣΤΙΟΥ) where necessary (detail, fig. 1). The stitching was reinforced around the brail rings (ΔΑΚΤΥΛΙΟΙ ΜΟΛΥΒΔΟΥ)/fairleads on the sail (fig. 2 with details). The halyard block system (ΕΠΑΡΤΗΣ ΥΠΕΡΑΣ) was changed from a ratio of 1:2 to 1:3, and was tested along with the steering arm or tiller, (ΛΑΓΟΥΔΕΡΑ) (fig. 3). Two broken stanchions were replaced. The wooden rings (ΞΥΛΙΝΑ ΔΑΧΤΥΛΙΔΙΑ) of the major brail (figs. 1 and 2 details) were respliced. Finally the entire vessel, as well as all the ropes and blocks were thickly coated with linseed oil. The total area treated, below the first wale, was 64.8 square meters. To complete these refittings and all other work on the hull, we spent a total of 281.9 man-hours.

The Crew: Captain and Crew of Four

A crew of five was selected, four to be the working crew and one to act as a replacement in case of an emergency. They were:

- Nikos Mertiris, age 40, a professional seaman with trawler fishing experience both in the Atlantic and the Mediterranean.
- Kostas Agathangelou, 39, a proficient seaman from the town of Kyrenia, a quay master in Limassol port, who distinguished himself by his excellent humor and cordial character.
- Stamatis Chrisafitis, 27, an experienced sailor from the island of Hydra, student of naval architecture at the Metsovian Polytechnic, who had rowed on Tim Severins' "Argo" experiments and had been a crew member of the KYRENIA II's 1986 trip to Cyprus.
- George Pahitis, 28, a good sailor and a coastal navigator, from the town of Kyrenia, who has a degree in Hotel Administration and now proven cooking abilities under rough sea conditions.
- Glafkos A. Cariolou, 35, a marina and boat yard director, from the town of Kyrenia, with twenty-five years of sailing and navigation experience.

Each crew member, with the exception of Nikos Mertiris, had already had a minimum of fifty hours of experience and training on board KYRENIA II.

THE TRIP

KYRENIA II was relaunched on the 1st of April 1987 (fig. 5). We departed from Limassol on the 7th of April with a crew of four; calm weather and *completely* calm seas; so we had to be towed to Paphos!

With a long-range forecast for an Atlas Depression we left Paphos with *all* crew on board. There were light, westerly, unfavorable winds. We sailed on a starboard tack, in anticipation of the Easterly, on a course heading to Alexandria for approximately 50 N.M. out of Paphos. We then changed to a port tack, which headed us towards the coast of Anatolia, the ancient Tristomon, and Cape Gelidonya.

The anticipated Atlas Depression arrived, which caused gusting easterly winds of 53 knots and waves up to 3.5–4 m in height. In spite of the fearsome roar of the eastern Mediterranean, KYRENIA II, with no significant problems, successfully arrived on the 12th of April, four days after departure, in Mandraki, Rhodes.

We departed from this harbor on April 14th, after having reinforced KYRENIA II's rigging and prepared for lower temperatures as well as having waited for favorable weather. After having sailed a distance of 124 N.M. in adverse weather conditions, we ran, close hauled, into a storm near the island of Amorgos, which gusted to 55 knots (10 Beaufort). During this storm most of the lead brail rings came off the sail and one of our two quarter rudders broke on its loom and thus most of the close-haul capability of the sail was lost. In spite of the storm, however, the freeboard of the vessel (1.5 m) proved to be adequate to prevent swamping by the rough seas.

Canvas and awnings were kept stowed as we had to be able to move swiftly at night when visibility was less than 50 m. Temperatures were close to zero due to the windchill factor. Handling the sail and natural-fiber ropes at night without sailing gloves was an extremely difficult task.

After sailing to the lee of the island of Amorgos and into safer waters, we were towed southeast to Astypalea where we sought refuge in the harbor of Skala. We waited there four days before the wind force decreased to a reasonable level. Our damages were repaired in 24 hours. The loom was fixed and the new steering oar tiller was reinforced.

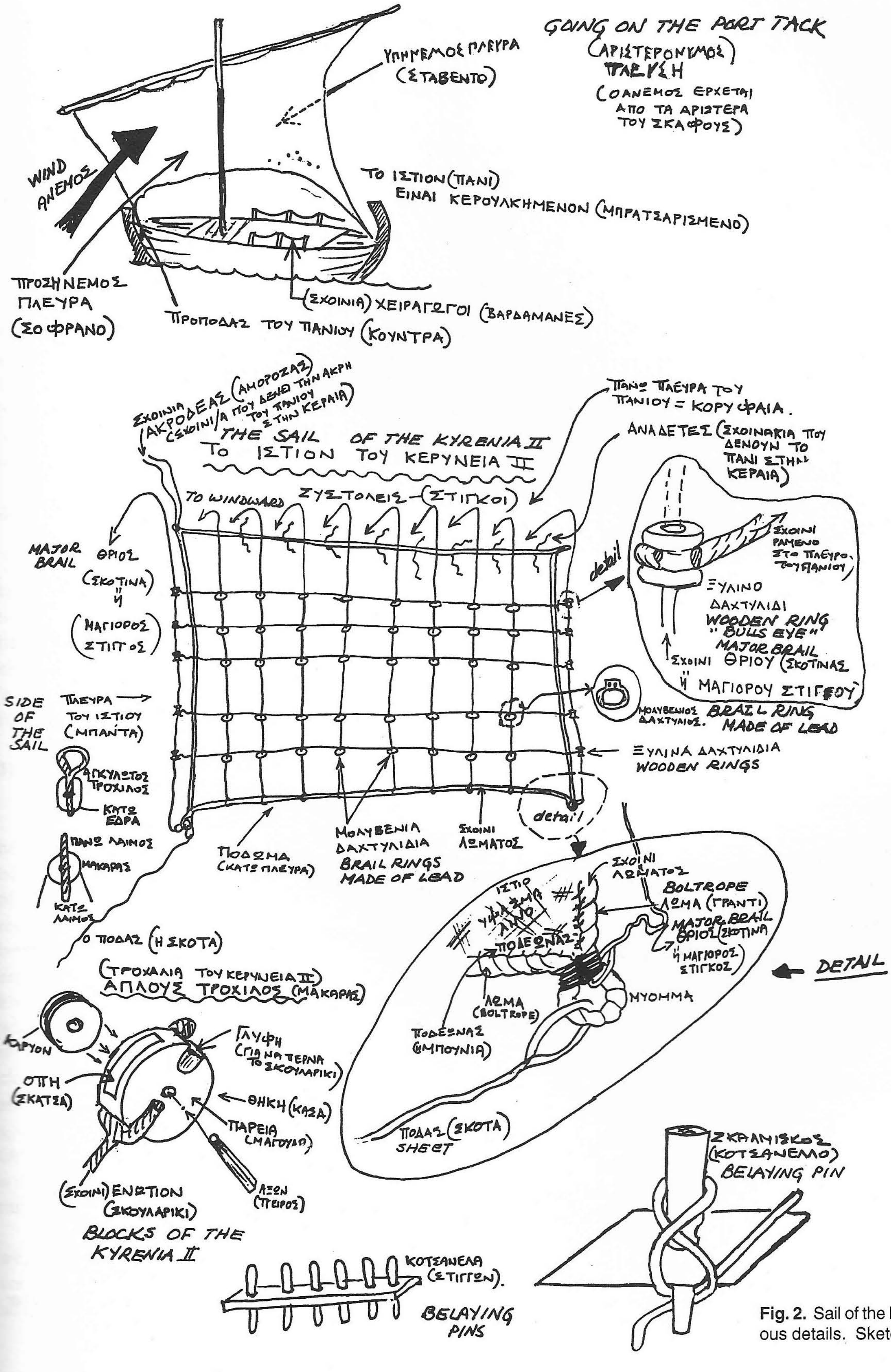

Fig. 2. Sail of the KYRENIA II with various details. Sketch from author's log.

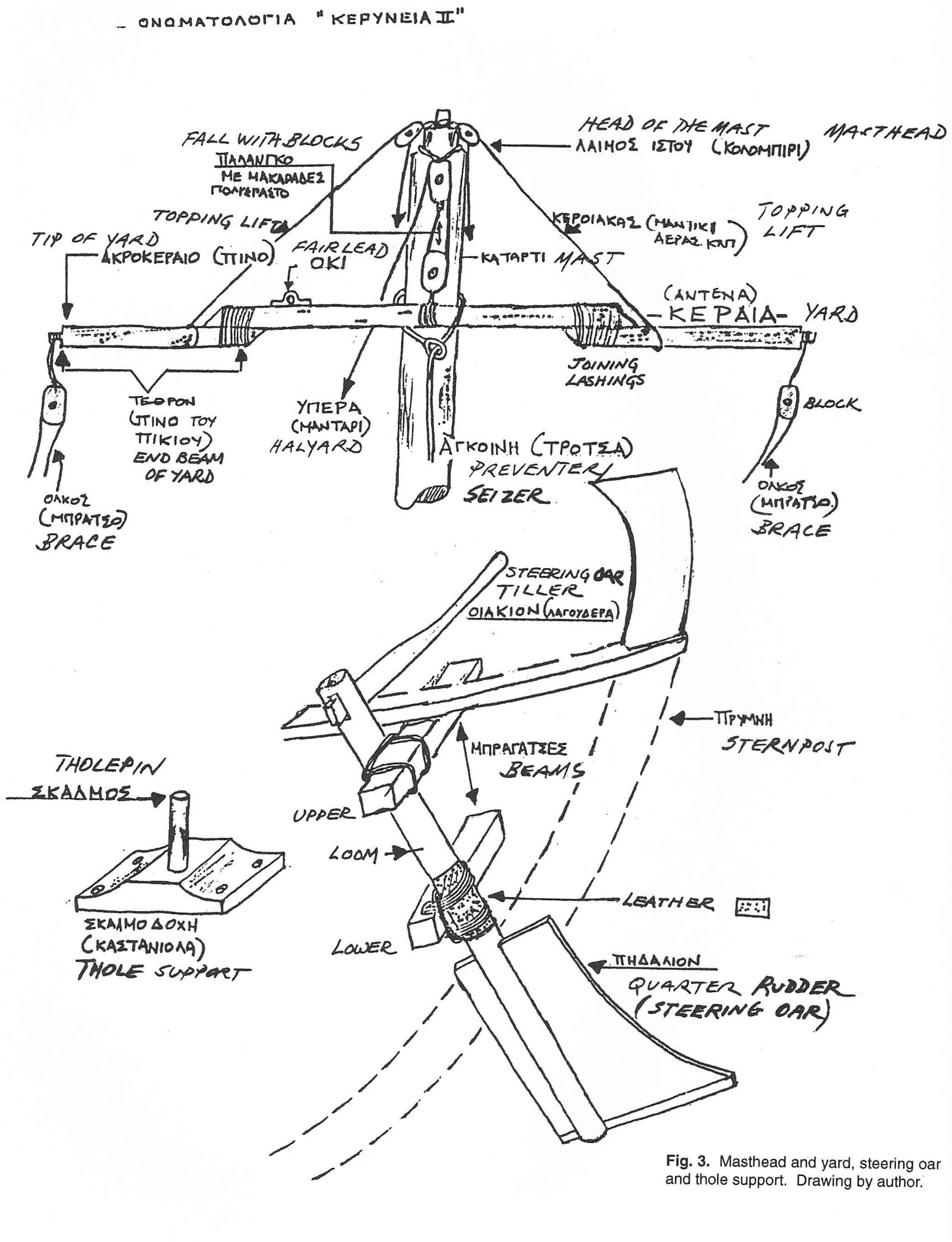

Fig. 3. Masthead and yard, steering oar and thole support. Drawing by author.

After we had departed from Astypalea on April 20th, we were forced to stop, for the third time, at the port of Syros due to encountering head winds of 40 knots, which broke one of the steering oars off the island of Delos. But we had sailed 110 N.M. non-stop.

At Syros we had the opportunity, with the assistance of the local shipyard, to overhaul KYRENIA II with a new forebeam, two totally repaired and reinforced steering oars and other minor repairs and improvements.

We departed from Syros on the 25th of April after having waited four days once again for weather conditions to improve. After sailing 10 N.M. we entered into the flat calm of an anticyclone. As we were now heavily pressed for time we decided that we had to be towed to Zea Marina at Piraeus, instead of sailing the leg from the island of Yaros (18 N.M. northwest of Syros) via Kythnos to our final destination. We arrived at Zea on the 26th of April 1987 at 02:40. The total duration of the trip had been 20 calendar days.

Actual Distances—Sailing versus Towing

From Limassol, Cyprus to Zea, Greece, we sailed a distance of 495 N.M., 70% of the total voyage, and we were towed for a distance of 212.5 N.M., 30% of the voyage. We had actually sailed for 181 hours and 15 minutes (84.5%) and we were towed for 33 hours and 15 minutes (15.5%). We were able to follow the best possible rhumb line route for approximately 75% of the trip.

Weather Conditions

From Cyprus to Rhodes we had mostly light variable head winds with temperatures up to 22 degrees C. and zero octas (0/8) cloud coverage. When we were 100 N.M. east of Rhodes, there was a sudden change. A low over Egypt, moving slowly east caused an easterly pressure gradient. It became partly cloudy, 3 octas, (3/8 cloud coverage) with drizzle and wind from 100 degrees with a force of 45–53 knots (10 Beaufort). The sea was very rough and visibility was 3 N.M. or less. From Rhodes to Astypalea conditions were mainly unfavorable with head winds and complete cloud coverage, low temperatures (10–12 degrees C) and almost continuous rain. Low clouds and fog made the voyage after the island of Kos more difficult and dangerous. Out of Amorgos we entered a violent storm of gusting head winds up to 55 knots (10 Beaufort) with very low visibility, rain and high waves.

The leg from Astypalea to Syros was sailed in fair weather with sunny, clear skies and light to moderate, favorable winds. It was only out of Delos that we experienced head winds gusting up to 40 knots (8 Beaufort).

The anticyclone encountered from Syros to Zea caused a complete calm with clear skies and comfortable temperatures.

In conclusion, we had either very light or very strong winds! We had two storms of 10 Beaufort, 53 and 55 knots from 100 degrees and 340 degrees respectively and one strong wind of 40 knots from 230 degrees.

Measuring Instruments and Services

A minimal number of instruments were carried by KYRENIA II and the tug "Ellas." On board the KYRENIA II were:

1) One wind speed indicator (cup impeller type of horizontal rotation) calibrated in knots. All of the wind speed readings represented Apparent or Relative wind speed. The anemometer was positioned on top of the stern post, away from any unwanted airflow.
2) One electromechanical Log/Speedometer that recorded the vessel's speed through the water. The impeller was towed from the stern approximately 3 m off the centerline of the vessel in order to avoid any interference with hull turbulence. The speed scale was from 0–12 knots. The same instrument was also used to record the total distance travelled.
3) One stationary steering compass used to record the ship's heading.
4) One handbearing compass that was used to determine the azimuth bearings of a) the approximate apparent wind direction, b) the leeway or the angle between heading and actual course, c) the angle of drift.
5) An improvised clinometer that had been hand-made by Stamatis Chrisafitis and was located on the bulkhead inside the stern cabin. The scale was in 5 degree increments and covered angles of heel up to 45 degrees port and starboard.
6) A traditional scale capable of weighing materials up to 300 kg *(kantari)*.
7) A tape measure for general measurements and a complete selection of tools for a wood joiner or carpenter.
8) For draft measurements, three positions were marked by a chisel on the hull to indicate the vertical distance between that point and the bottom-most point of the keel. All three points were marked on the port side of the vessel, and included: a) a stern mark with the figure 350 on the top of the rail, b) the greater depth mark with the figure 270 on the gunwale, and c) the stem mark with the figure 253 on top of the rail near the bow. These figures indicated the exact vertical distance in centimeters from the bottom of the keel to the carved point or mark. Measuring the distance between these

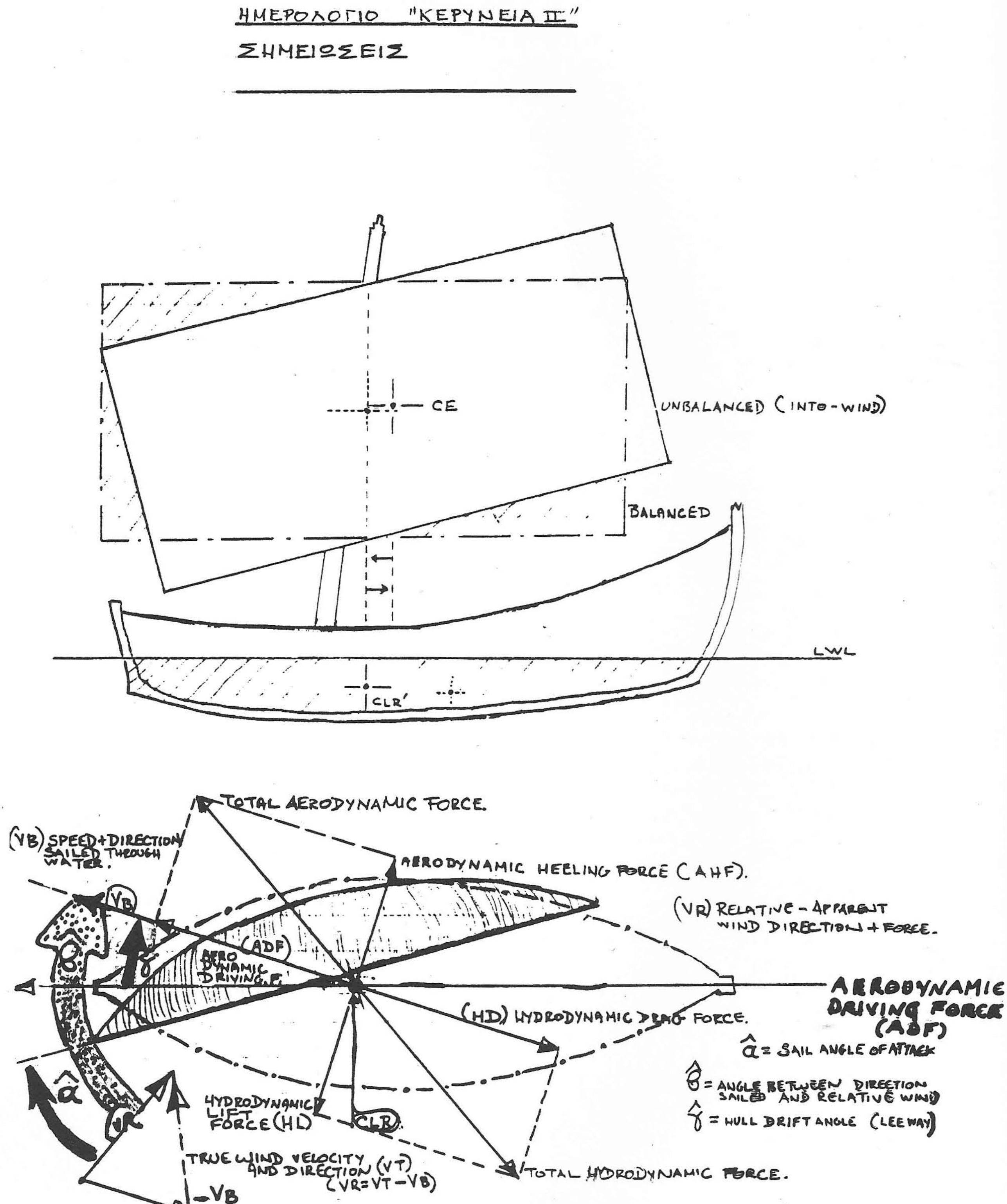

Fig. 4. Improved sailing performance. Drawing by author.

Fig. 5. Voyage of the KYRENIA II. After Katzev (1987).

points and the sea surface in the calm waters of each mooring site at a zero clinometer reading, gave us the exact draft of the vessel and the cargo loading balance, as well as a good idea of the vessel's trim.

9) Our normal electronic wristwatches and stopwatches were used for timing, noon-sights and other navigational purposes and saved us from having to use a sun-clock!

Safety Equipment and Navigation

Safety equipment carried on board consisted of one marine VHF radio with another reserve radio, fourteen life jackets, one life raft capable of holding ten people and two parachute flares.

Navigational instruments and procedures were kept to a minimum in an effort not to vary greatly from assumed authentic circumstances. We have no significant information as to what navigational instruments were used by our ancestors. For navigating we used the stationary compass of the vessel, a hand bearing compass, three sea charts, a simple plastic sextant, our wristwatches, the nautical almanac and a star chart.

From Paphos to Rhodes we used both dead reckoning and astronavigation as this is a stretch of approximately 200 N.M. with no visible land. The Sun, Venus, Arcturus, the Moon and Polaris were used extensively. From Rhodes to Sounion and Piraeus usual coastal navigation procedures were adequate during the daytime. Navigating the Aegean during daylight hours is comparatively easy as it is usual to see another island before you loose sight of your port or island of departure. However, at night with strong winds, heavy seas, fog and low cloud, without an engine or radar and very limited sailing performance capability, navigation and sailing gives one a nasty feeling, similar to that produced by playing Russian roulette!

The vessel moves at a speed of 8–12 knots without one having accurate knowledge of the distance from navigation dangers and nearby islands. When and if land is sighted under these circumstances, it would probably be impossible to avoid a crash or calamity. It was found that navigating in the open sea, far from the islands and land, was much easier during the night than the day. One always had a wide choice of stars for guidance. It was, and is, much safer to navigate amongst the islands during the daytime.

Sailing Performance

KYRENIA II has a square sail with a horizontal breadth of 11.18 m and a vertical height of 5.6 m. The sail area equals 62.6 sq m. The dry weight of the sail was 61 kg It is attached on the yardarm by 12 robands (ΑΝΑΔΕΤΕΣ). On the leeward side of the linen sail (figs. 1 and 2) there are eight vertical rows of lead brail rings facing up and down. From the boltrope on the foot of the sail we spliced eight brails (ΣΥΣΤΟΛΕΙΣ), which pass through each of the five rings attached on the sail in a vertical row (one on top of the other). The brail then passes over the yardarm (ΚΕΡΑΙΑ) on the windward side, through the wooden fairleads (ΟΚΙΑ) of the yardarm, and ends up on the after deck secured on the brail belaying pins (ΚΟΤΣΑΝΕΛΑ). On the port and starboard sides of the sail there are five wooden rings or "bulls eyes" spliced on the boltrope through which the rope of the outer buntline or outer brail or clew garnet (ΘΡΕΙΟΣ/ΜΑΓΓΙΟΡΟΣ ΣΤΙΓΓΟΣ) is passing in the same manner as through the lead rings.

The clew and tack of the sail are controlled by two long sheet ropes (ΠΟΔΑΣ) passing through two wooden fairleads (ΠΟΔΕΩΝΑΣ) giving a ratio of 1:2 to the pulling of the sheets. The rotation of the yardarm is controlled by the port and starboard braces (ΟΛΚΟΙ) (fig. 3) passing through a block giving a 2:1 purchase. On the vertical plane the movement of the yardarm is controlled by the port and starboard topping lifts (ΚΕΡΟΙΑΚΕΣ) passing through their respective blocks (fig. 3). The yardarm weighs 80 kg and has a length of 11.6 m.

Prismatic Coefficient and Metacentric Height

The prismatic coefficient of the vessel is approximately 0.627. The beam to depth ratio is 2.68. The metacentric height of the vessel was not measured but this should have been fairly high as the return or recovery to the vertical plane of the mast after wave induced inclination was very quick. It would be further improved with additional weight-cargo loaded on board. (No inclination test was done.) The approximate freeboard was 1.5 m at all times.

THE SAIL OR THE PLAN OF THE SAIL

During the storm that we encountered 100 N.M. east of Rhodes, we were able to sail with full sail area, without using the sail downhauls, at speeds up to 12 knots, at an almost dead run or open broad reach course. The superiority (compared to contemporary triangular mainsails) of the plan or form of a square sail during this storm was very clear as regards the balance of the hydro and aerodynamic forces exerted on the hull and sail. We found to our surprise that periods of up to 15–30 minutes would pass without any course adjustment being necessary when we had both steering oar tillers lashed during the storm.

In view of the low aspect ratio of the sail form, compared to contemporary sails, the usual rolling effect experienced in modern yachts when on a run was not present or it was comparatively little. In spite of waves with an approximate height of 3.5–4.5 m, we experienced no particular problems. The run was so smooth that in one case, with winds gusting up to 50 knots, it was possible to climb to the top of the mast and replace the badly worn yardarm preventer or seizer (ΤΡΟΤΣΑ/ΑΓΚΟΙΝΗ) (fig. 3).

The close-hauled ability and performance of the vessel was influenced in a negative way mainly by the following parameters:

1) Low sail aspect ratio approximately 1:5.
2) The external depth of the actual keel, which is only 21 cm. (There was no practical keel effect).
3) The C.L.R. (center of lateral resistance) of the vessel is well aft of the C.E. (center of effort).
4) The general hydrodynamics of the hull form, specifically due to the lack of a deeper keel, was regarded as not suitable for sailing close-hauled.

[Note: the L.W.L. (length at the waterline) equals 14.5 m, the L.O.A. (length over all) equals 14.8 m, the C.L.R. is estimated to be at a point approximately 7.2 m, measured from the bow, the C.E. is approximately 1.42 m forward of the C.L.R., thus giving a "negative lead of approximately 9.8%.]

Many other parameters must have affected the close-hauled sailing ability, such as the actual tailoring of the sail, the angle of the yardarm, the shape and handling of the steering oars, the trim or loading method of the vessel, and even the position of the crew. Sailing close-hauled required skill, coordination and speed, which all took us considerable time and effort to master. The best close-hauled angle was achieved off the island of Delos, south of Mykonos, where we were able to sail at a relative angle of 51 degrees between the heading of 283 degrees and the true wind direction of 232 degrees, with a true wind speed of 23.4 knots. The vessel's water speed was 6.8 knots on a port tack and at an angle of heel of approximately 20 degrees. Due to sea surface conditions it was not possible to measure the leeway. However, the estimated angle of drift was 10 degrees. (The above gave us a close-hauled ability or angle between the course and the true direction of wind equal to approximately 60 degrees.) This could reasonably be compared to contemporary yachts, which have a normal close-hauled ability from 40 to 50 degrees to the true wind direction.

The same on course stability was observed on a close-hauled tack as mentioned before. On this course there was a very slight tendency to go off the wind. Damage to the steering oars always occurred when sailing close-hauled. By aligning the steering oars on the island of Syros, I believe we at least minimized the effect of short period waves and the effect of the hydrodynamic drag. We did not, however, have much chance to investigate and test this new steering arrangement.

The following procedures for improving the sailing performance at close-haul were carried out (fig. 4):

1) To try to achieve a higher aspect ratio for the sail form, we a) lifted the yardarm higher on the mast by approximately 70–80 cm, and b) inclined the yardarm when sailing as close-hauled as possible, with the after arm or leeward arm as high as possible, thus increasing the height(s) of the sail plan form by 1.10 m, which in turn raised the aspect ratio from 1.5 to 1.7. In this case the tack of the sail was very tightly secured to the windward end of the fore-deck cross-beam.
2) To try to balance the sailing performance, we transferred the cargo forward in order to move the center of lateral resistance (C.L.R.) forward to meet the center of effort (C.E.), and inclined the mast further aft in an effort to move the C.E. aft so as to meet the C.L.R.
3) The sailing performance of the KYRENIA II was improved immensely by the introduction of downhauls (ΥΠΟΣΥΣΤΟΛΕΙΣ), in an effort to flatten the sail and to improve the close-haul ability.

Tacking (ΑΝΑΣΤΡΟΦΗ)

Tacking was found to be difficult but possible. We successfully tacked twice without using oars in winds between 2–4 Beaufort. Tacking in winds above 4 Beaufort proved difficult and very dangerous for the integrity of the sail, and therefore was not practiced.

Gybing (ΥΠΟΣΤΡΟΦΗ)

Gybing was the most frequently used method to go about, changing from a port to a starboard tack. The procedure was easy in winds up to 5 Beaufort, but above that it requires skill and perfect coordination. A gibe may be carried out in wind forces up to 10 Beaufort without serious problems. In general the sailing performance dramatically improved with the use of sail downhauls or brail hitches (ΥΠΟΣΥΣΤΟΛΕΙΣ) as mentioned above.

Rolling

Rolling was found to be less than that experienced on modern yachts under sail.

Heeling

Heeling in winds up to 30–35 knots at close-haul was approximately 25 degrees.

Yaw

The yaw was negligible in comparison to modern yachts and almost non-existent.

Hogging

No proper measurements were taken but there was no apparent hogging.

Plank Sheering

We did not detect any apparent plank sheering.

Leaking

When at zero degrees of heel the vessel did not leak. At 8–12 degrees of heel, the port side third frame from the after bulkhead (on the wale scarf) leaked considerably. This was repaired using oakum, animal fat, leather and a lead patch.

Broaching

Even with the sail reefed or "brailed" it was easy to avoid broaching, and no tendency to broach was observed. However, on two or three occasions we passed from the broaching position without any considerable problem.

Swamping

In spite of rough conditions, swamping was not experienced and we did not find it necessary to use a canvas "spray deck" when the vessel was unloaded.

Longitudinal and Transverse Strength

No measurements were taken, but I can confirm that the hull had substantial flexibility.

Twisting

None was observed. Twisting and slight hogging was noted only during split seconds when we were hit by the escorting ships "Ellas" and "Aedon" (a minesweeper) on two different occasions. During the collisions considerable flexibility of the shell-construction was conspicuous. However, there was immediate, total, recovery. No leakage was observed following the impacts.

Hull Speed

In theory, the hull speed should be approximately 9 knots. However, in practice with approximately 45–50 knots of true wind speed on a run or broad reach we averaged 11.98 knots for a period of 5.8 hours over a distance of 69.49 N.M. During this period the maximum speed must have been just over 12 knots!

Vibrations

We did not feel vibrations of any frequency on the hull or the rigging under any conditions.

Main Weakness

This was the steering oars. They had the tendency to break at speeds of above 5 knots and during close-hauled tacks. This was slightly counteracted by the realignment of the two steering oars so that their projected hydrodynamic axis was brought parallel with the center line of the vessel (fig. 4).

Moisture Effect

With high atmospheric humidity, moisture and rain, the sail and ropes often became saturated with water, with a subsequent increase in sail and rigging weight. Handling had to be slower and performed with greater care. As the result of a heavier and flatter sail, the sailing performance when close-hauled with a good wind (5 Beaufort) improved, whereas performance was adversely affected in lighter winds. A slight increase in rolling was observed as a result of the heavier sail and rigging.

Rowing Performance

This vessel was certainly not designed to be rowed over a distance! A lot of muscle, body weight and skill was required. KYRENIA II could be rowed with two or four standing oarsmen. The oars are balanced by lead weights and the four oars weigh 21.75, 30.00, 22.00, and 27.50 kg respectively. They are 6.12 m long. The oars had to be trimmed to the correct loom length so as to avoid the collision of opposing oars. Four competent oarsmen can row this 16 ton vessel (without cargo) at a speed of 0.75 knots with the yardarm raised, the sail fully reefed or brailed-up in an absolute calm. Under these conditions or with a very light breeze the ship could be accurately controlled and maneuvered inside a port. With a wind of approximately 5–7 knots (2–3 Beaufort) the vessel cannot be controlled at all by the oars only.

The Rigging

The standing rigging consisted of 30 mm diameter natural-fiber (hemp and manila) rope. It consisted of a backstay (ΠΑΡΑΤΟΝΟΣ) and two shrouds (ΕΠΙΤΟΝΟΥΣ) on each side of the mast. For the running rigging, there was an inner and outer forestay (ΕΣΩ ΠΡΟΤΟΝΟΣ—ΕΞΩ ΠΡΟΤΟΝΟΣ) used according to the sail and yard position. The inner forestay was used with strong winds when the down hauls were all released together with the outer forestay, and the sail was used like a spinnaker. The topping lift halyards (ΚΕΡΟΙΑΚΕΣ), the yardarm halyard and block system (1:3 purchase) as well as the preventer or seizer (ΑΓΚΟΙΝΗ/ΤΡΟΤΣΑ) completed the running rigging (fig. 3). We also had a bosun's chair halyard.

It was observed that both the forestay and backstay did very little work and the inner forestay could be removed for future trials. The joining lashings of the yardarm (fig. 3) allowed the two end beams of the yard to bend forward on the horizontal plane.

SAILING

Close-hauled

We installed eight sail down-hauls (ΥΠΟΣΥΣΤΟΛΕΙΣ) in order to fully utilize the square sail. The tack of the sail was tied as low as possible on the upper side of the forebeam on the windward side. Two thick ropes under tension were positioned between the inboard part of the forebeam, ending on each side of the aft part of the vessel, diagonally crossing the boat at a point just forward of the mast.

This rope served as the attaching base for the downhauls. The tension of the downhauls would start at maximum tension next to the tack and continue decreasing until the last two or three down hauls which were left either loose or with very little tension. The best sailing results were observed when a sail "groove" was achieved on the sail surface, commencing from the tack and ending on the leeward side of the yardarm.

Broad Reach—Running (ΦΟΡΟΣ—ΕΠΙΦΟΡΟΣ—ΟΥΡΙΟΔΡΟΜΙΑ)

The inboard downhauls were still used with low tension so as to try to place the foot of the sail right below the yardarm.

Tacking (ΑΝΑΣΤΡΟΦΗ)

As already stated, one of the most difficult procedures was tacking the boat. It required training, fitness, good knowledge and high coordination. It also became more difficult in a strong wind. The procedures we followed were:

1) We attempted to achieve a maximum boat speed on the particular course.
2) Both steering oars were turned, but not too much; a wide turn was necessary.
3) One person was responsible for the braces, a second crew member for the downhauls, the third for the tack of the sail and the fourth on the clew of the sail. No one was actually needed to steer as the tillers were lashed and left in a turning position.
4) The topping lifts were slackened.
5) On the fore side of sail, the luff was made tight.
6) As the vessel turned into the wind, the tension on the clew was increased by the manual force of a crew member, thus presenting a full flat sail plan form.
7) When the vessel's bow was on the eye of the wind, all downhauls were immediately released and the "braceman" slowly turned the yardarm, but stopped as soon as the yardarm was 90 degrees to the wind.
8) As soon as the yardarm rotation commenced, the clew and tack of the sail were untied. As the vessel turned, the yardarm was rotated. During the rotation the "tackman" held the sail, which lay above him, as flat and as tight as possible while the "downhaul-man" was doing exactly the same thing, as he was positioned by the mast. The forepart of the sail was tensioned, while the afterpart was flapping in the wind. The other half of the sail, from mast to leech, had to be loose to present as little surface as possible to the wind.
9) The vessel sometimes drifted astern, before turning to the required side.
10) As soon as the bow passed into the new tack, the rotation of the yardarm was continued. The previous "clewman" quickly ran to the forebeam and very tightly tied down the old clew, which now becomes the tack. The "downhaul-man" pushed the sail in front of the mast against the wind and kept the sail tightly down while the rest of it was flapping. As soon as a positive tack was established, the sail was set as in the previous tack.

DANGER! With strong winds, the sail will turn and be blown against the mast, so care must be taken so as not to break the yardarm. So, in a strong wind it is necessary to brail the after half of the sail before one commences the tack. All the crew members must stand and put their weight on the side of the turn if possible. Gybing was much easier, as has already been explained, and this is what we did most of the time, and under most weather conditions.

Additional Sail Area

An additional piece of sail was added below the original but it needed extensive adjustment before it could become a suitable sail part.

Steering

Steering was carried out by two steering oars of 59.5 and 61.5 kg The upper point was lashed forward of the upper beam and the lower point on the afterside of the lower beam (ΜΠΡΑΓΑΤΣΑ) (fig. 4).

We found that the turning maneuver was very slow. The extension of the after lower beam, to meet a position where it brings the two steering oars parallel to the center line of the vessel, is expected to improve the turning and general steering performance.

An alteration to the after edge of the blades definitely will improve steering further.

Steering oars broke in heavy seas and swell on a close-hauled tack at a high speed, when the hydrodynamic forces were increased. The breaking point was always at the uppermost end of the blade where it joins with the loom of the steering oar. The addition of steel collars, on the island of Syros, reinforced the oars and improved the situation.

The steering oars were usually lashed together by their tillers and very little adjustment was necessary during the voyage. Pulling up one steering oar improved speed when on a reach, broad reach, or when running. However, it was not advisable to lift a steering oar when close-hauled, as this increased leeway and the burden on the single oar that was being used. It was difficult to determine which steering oar should best be drawn up and which to leave down.

When sailing with little wave action, it was better to lower the leeward steering oar, but with moderate swell it was better to use the windward steering oar, as there was less possibility for it to break. Changing a steering oar took approximately 30 minutes in Force 6 and relashing approximately 15 minutes. In addition, we decided to rig a seat for the helmsman during his long standing hours.

Cargo

Thirty-five amphoras were loaded on board, together with all the other paraphernalia. The loading of each amphora took approximately 35 seconds, and unloading took approximately the same length of time, using two crew members on the mole and two on board. Each empty amphora weighed 10.1 kg (They were exact replicas). Full of wine the same amphora would have weighed approximately 43.5 kg.

When observing the loading space necessary for the 35 amphoras it was very difficult to imagine the cargo of 404 amphoras that were found upon the ancient Kyrenia ship, which was a comparatively small vessel. By looking at pictures of the loaded vessel, even if we assume that the 35 amphoras covered 1/5th of the available cargo area, then 5 times 35 equals 175 amphoras *only* as cargo. The first layer would take approximately 175 amphoras and the second presumably the same number, which would bring a total of 350 amphoras. We therefore believe that there must have been a third layer of 54 amphoras standing high above the level of the gunwale. With an approximate total empty weight equal to 10.1 kg × 404 equals 4,080.4 kg or a full weight of 43.5 kg × 404 or 17,574 kg.

In spite of all the storms encountered during the voyage, no movement of the cargo was observed.

LIFE ON BOARD

A list of provisions was prepared with the advice of Michael and Susan Katzev on the basis of what had been found on board the ancient Kyrenia ship, and what was known to have existed in the fourth century B.C.E. From these foodstuffs we prepared the following meals:

Breakfast. The mornings usually started with dried bread, *paximadi,* Cyprus *halloumi* cheese, honey and olives, chased down with wine and plenty of almonds.

Lunch. At noon fish, literally swimming in olive oil, was served with an ocean of lentils or beans called *mouchendra,* with onions and garlic, together with lots of wine and *paximadi.*

Dinner. At night, *halloumi* and dried salted meat, mainly pork, was eaten with *paximadi,* together with a deadly liquid known as *zivania,* which is made out of grape pips. It may not have existed at all in antiquity, but it is a very well known and highly respected strong drink in present day Cyprus.

We allowed ourselves the luxury of sleeping bags, as the expense of being dressed or equipped with ancient wintertime attire and sleeping facilities was not within our financial capabilities. We slept mainly inside the after or forward quarters, having covered both decks with low cost canvas and the forward quarter with a curtain also made of canvas.

"Caulking the steering beam" was the expression encrypted by our crew of "ancients" for visiting the "toilet" ("ΚΑΛΑΦΑΤΙΣΜΑ ΜΠΡΑΓΑΤΣΑΣ!"). This task was easily performed while under sail from the lower after-beam or the forebeam, depending on the urgency of the situation, irrespective of wind direction or strength or conditions of humidity.

Health and Morale

Sailing a replica of a 2,500 year old sailing vessel is a hard exercise even for a well-trained modern day sailor/racer. We believe that this exercise kept us healthy and far from the usual wintertime flu or other similar ailments, in spite of being wet, cold, without sleep and completely exposed to the elements on an almost continuous basis.

The spirit of the crew was excellent at all times, and of course we look forward to doing such a trip again, one day, even with a force 17; that is if we are sailing back home to Kyrenia!

CONCLUSIONS AND AFTERTHOUGHTS

It is highly probable that vessels sailed from west to east from the Aegean into the eastern Mediterranean basin, i.e. to Asia Minor, Cyprus, Syria, Israel, Palestine and even as far as Egypt, during the months of June to February. But it is highly unlikely that these vessels were able to return to the Aegean, sailing from east to west, during the same period.

Vessels sailed from the eastern Mediterranean into the Aegean, i.e. from east to west, only in the period of March, April and May during the Easterlies, if the Atlas Depressions existed at that time. However, the probability of sailing across to Egypt in order to return into the Aegean in the summertime must be investigated. The trip would take much longer.

When determining the placement of towns with ports/harbors great consideration was taken—apart from other parameters—of the prevailing wind, as communication and trade links depended a lot on sailing ships.

The requirements of harbor design in antiquity were seriously different from those of today. The positioning of the port entrance was of prime importance. It was probably sited in such a way as to allow an ancient vessel to sail in from the direction of the prevailing wind either on a broad-reach or running.

The ancient sailors were well-aware of the average wave length in the Aegean and they most probably took this into consideration when designing the Length on the Waterline

(L.W.L.) of their vessels. Due to their limited close-hauled sailing performance, vessels had to have a very high stern and a lower stem, contrary to contemporary naval architecture. This was because they would probably change to a "running" tack whenever they were fighting a storm. Sailing with the wind behind or after a storm with just a small storm jib or even no sails at all and a drogue towed at the end of a 300–400 m rope tied to the stern is nowadays still the best way to escape a force 10!

Most probably it was due to their understanding of storms and bad weather strategy, i.e always fighting the storm with the high stern against the breaking waves, that the anchor was dropped astern rather than from the bow.

The seemingly "wrong" relationship between the Center of Lateral Resistance (C.L.R.) and the Center of Effort (C.E.), which had a tendency to sail off the wind, was probably done on purpose in order to prevent broaching in a heavy storm. The vessel always presented a high sea-worthy stern to the heavy breakers of any storm even with the steering oars safely withdrawn. (In a storm even with no steering oars, the vessel will safely sail "after the storm" on a running tack with the wind and waves behind her high stern.)

Sailing vessels, of the same age as the Kyrenia ship, must have had a much better steering system than the one we used on the KYRENIA II. The steering system used on ancient merchant ships remains a research challenge! Commercial sailing vessels of antiquity were probably towed, rowed and/or assisted by smaller rowing vessels or "tenders" in and out of a harbor. We feel that it would have been prudent and seaman-like to carry on board, or tow behind us, such a rowing boat or tender.

REFERENCES

Katzev, M. L.
1990 An Analysis of the Experimental Voyages of KYRENIA II. Pp. 245–56 in Proceedings of the 2nd International Symposium on Ship Construction in Antiquity. *Tropis II*. ed. H.E. Tzalas, Athens: Hellenic Institute for the Preservation of Nautical Tradition.

Meteorological Service
1986 *A Study of the Surface Winds in Cyprus*. Meteorological Paper Series No. 8, Fourth Edition. Nicosia: Ministry of Agriculture, Natural Resources and the Environment. Meteorological Service.

Murray, W. M.
1995 Ancient Sailing Winds in the Eastern Mediterranean. Pp. 33–45 in *Proceedings of the International Symposium, Cyprus and the Sea*, eds. V. Karageorghis and D. Michaelides, Nicosia: University of Cyprus.

Steffy, R. J.
1985 The Kyrenia Ship: An Interim Report on its Hull Construction. *American Journal of Archaeology* 89: 71–101.
1994 *Wooden Ship Building and the Interpretation of Shipwrecks*. College Station: Texas A&M University.

Tsalas, H.
1987 *Kyrenia Ship Exhibition: A Voyage into Time and Legend aboard the Kyrenia Ship*. Athens National Archaeological Museum. Athens: Hellenic Institute for the Preservation of Nautical Tradition.