39. Reconstruction and Sailing Performance of an Ancient Egyptian Ship

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Introduction

Recent discoveries at the pharaonic harbour of Mersa/Wadi Gawasis on the Red Sea provide direct and dramatic evidence of ancient Egyptian seafaring. At Gawasis, recycled cedar hull planks tunneled by marine borers and related artifacts testify to characteristics of seagoing ships. The range of ship components excavated there permitted our team to test whether the independently invented Egyptian approach to ship construction worked as well at sea as it did on the Nile.

Thousands of boat and ship representations and hull models complement 24 excavated watercraft dating from the First Dynasty to the Persian period (c 3050-450 BC). Although we are now familiar with the construction of these river craft, much less is known about seagoing vessels. Discoveries at Gawasis (Ward & Zazzaro 2010; Ward 2007, 2009; Zazzaro 2007a, 2009) and Ayn Sukhna (Pomey in this volume) provide the first physical evidence of such ships.

While these finds illustrate adjustments made to Nile construction practices to permit long-distance sailing, few inferences about operation, maneuverability, seaworthiness and other characteristics may be drawn. Building a full-scale reconstruction with ancient shipbuilding techniques confirmed that the indigenous Egyptian traditions of thick and irregularly shaped planks fastened by deep unlocked mortise-and-tenon joints work as well as the methods used by Mediterranean shipwrights (Fig. 1).

Our reconstruction is theoretical, a floating hypothesis like the trireme *Olympias*, as there is no extant ship to replicate (Table 1). The full-scale ship draws on all available scientific evidence about long-distance seagoing ships, including physical remains and representations, especially the Punt relief from Hatshepsut's funerary temple at Deir el Bahri (Ward, Couser & Vosmer 2007; Couser, Ward & Vosmer 2009). The ship's design approximates construction technology of the first quarter of the second millennium BC.

Fig. 39.1. Min of the Desert *at sea, December 2008 (Photo: S. Begoin).*

Length-over-all	20.3 m
Length of main hull	18.3 m
Beam on sheer	4.9 m
Depth in hull below beams	1.7 m
Height at top of rail	2.3 m
Displacement	30 T

Table 39.1. Dimensions for Min of the Desert *as calculated by naval architect P. Couser.*

Between April and November 2008, Ebad El-Rahman Shipyard in Rashid (Rosetta) built *Min of the Desert*, named for the deity repeatedly invoked in inscriptions at Gawasis. With the exception of *Acacia nilotica* tenons and mulberry (*Morus* sp.) rudder posts and crutches, all parts are made of Douglas fir

(*Pseudosuga douglasii*) because of its similar density and bending strength to *Cedrus libani*, the Lebanon cedar used by the ancient Egyptians.

Measurements of excavated timbers and dimensions scaled from the relief repeatedly demonstrated parallels between the Punt reliefs and Gawasis finds. While these correlations may be coincidental, Ward decided to rely on the Punt ships for rigging and overall hull specifications. Couser used the relief as a basis and placed the DWL at about 36% of the overall depth of the hull. The construction of the hull drew more directly on the cedar planks from Gawasis and finds of Middle Kingdom boats from Dashur and disassembled planks at Lisht (Ward 2000).

Rigging

Standing and running rigging details (Fig. 1), as well as specifications for oars, rudder support, sails, and mastcap, were extrapolated from the Punt reliefs, Gawasis finds, ship models and representations (Reisner 1913). The single mast is stepped into a solitary floor timber modeled on an excavated example from Lisht (Ward 2000: 106-128). The mast heel, shaped like that in a New Kingdom illustration, fit into a mortise cut in the top of the floor timber. The mast is forward of the midships beam between two carlings and abuts it. A fixed 'mast yoke' fashioned from 2.2-cm-diameter line provided fore-and-aft resistance close to the deck; it encircled the mast and passed around the second beam aft of it.

The mast is short, only 8.3 m above the deck and about half the length of the lower yard. It is crowned by a metal assembly of three graduated rings spaced about 10 cm apart and two strips of 8 fairleads embedded on each side of the tapering mast. Modern safety standards for wood mast diameters (45 cm) and yards (28 cm) substantially exceed measurements taken from the Punt relief (28 cm and 14 cm), but we followed published guidelines for the mast. The yards were so heavy at 28 cm that we could not raise them without pulleys, and they were reduced to 17 cm at the centre and 5 cm at their tips, still about 15-20 % larger than those shown on the reliefs. Yards overlap at the mast, creating a 1.7-m-long fish secured by internal tenons and external binding.

The Egyptians fixed the lower yard to the mast with a rope parrel. Stays are secured to the masthead and block. An aft stay and an inner forestay run from there to rope girdles wrapped around the hull near the junction of keel timbers and the hull planking fore and aft. An outer forestay passes between the walls of the forward platform and is tied far forward around the sleeve that carries the bow finial. There are no shrouds.

Four wood crutches along the centerline support a 15-cm-diameter cable laid of three 3-strand ropes. Crutch design reflects T44 from Gawasis and dimensions from the Punt relief. Forward of the mast, crutches were notched slightly on the aft face to provide a solid connection to the beams they leaned against, a pattern reversed for the two crutches aft of the mast. The cable end is spliced around the forward girdle and tied to the aft girdle behind the rudder posts. When the cable was tightened at the beginning of the day, less water accumulated in the bilge, but we did not have the ability to isolate conditions to determine whether a taut truss was the dominant factor in the observed difference (about 20 %).

Sixteen lifts passed through fairleads (manufactured from steel rather than bronze) and were taut once the upper yard was hauled into place by brute force. Inner and outer topping lifts stabilized the upper yard. Excessive side-to-side movement of the yard prompted us to add a preventer that immediately solved the problem.

Sail Design and Specifications

The oldest sail remains known originate in Egypt, but date only to the 3rd century BC and about 100 BC. There are both cotton canvas and linen sail fragments from this later period (Whiteright 2007). Worn sail fragments were reused to wrap a mummy now in Lyon; the linen cloth weave measures 22 x 12 threads/cm (Wild & Wild 2001). During the Middle and New Kingdoms, c 2050-1350 BC, all studied sail fragments from boat models with masts are made of linen (Reisner 1913). In tomb reliefs and models of artisan workshops, people weave long strips of linen in a range of widths. Narrow strips probably were sewn together along their long edges to create sails, though few details are certain.

Excavations at Gawasis in 2005/6 produced a 65 cm long fragment of linen with tabling doubled-over and stitched down, wedged against the long edge of a plank fragment re-used in the walkway of Gallery 2. The heavy fibers in a coarse weave, combined with the reinforced hem, are consistent with sail design, though it is impossible to make a definitive identification (Zazzaro 2007b). Abundant linen

Fig. 39.2. Sail details (Photos: C. Ward).

scraps and linen bast fibers at Gawasis attest to the availability of the material, an Egyptian resource for at least 8000 years.

Extensive review of relevant images and models of sailing ships revealed some common features. Sail breadth is slightly greater at the foot than the head. Some sails also appear to have a greater depth in the center than on the leeches, but our experience with optical illusions while sailing Min suggests that this may be a visual effect rather than an appreciable physical difference.

A few boat models from tombs have original sail fragments remaining, and details of those fragments are enlightening but not sufficient to provide all the specifications for a working sail reconstruction. For example, some model sails have leech ropes sewn along all edges, and some have cringles (holes) along the head and foot. There is an additional line threaded through these cringles to which lace-lines for fastening to the spars are attached. Details of seams, hems, attachment points, and line and sailcloth dimensions are usually lacking. Our decisions about these features reflected archaeological data as much as possible, but also relied on ethnographic data shared with Ward and el-Maguid by sailors from Lake Borolos (Fig. 2).

Due to limits of time and budget, white cotton sailcloth of 800 g/m was used to construct a primary sail and a storm sail of trapezoidal planform, respectively 5.40 x 14.25/14.45 m and 3 x 6.8/7 m. Sailmakers originally from Upper Egypt but now working in the Lake Borolos area of Egypt's Delta built the larger sail of 32 strips of fabric approximately 45 cm wide. Seams were handsewn, with a single round seam.

Tabling was folded over and then doubled over an internal boltrope of 13-16 mm and stitched down on the leeches. Large hemispherical holes along the edge are reinforced by stitching, and at least for the eight attachment points for ribbands on the lower edge, by a 6mm rope. Holes over the internal boltrope left the tabling along the sail edge intact. Sailmakers attached an external boltrope to the sail at the smaller holes by threading it through the hole and knotting it over the inner boltrope rather than sewing the boltrope it. Holes and knots were spaced 22.5 cm apart on the head and 45 cm apart on the foot in accordance with sails on the Punt relief.

Oars

Oar dimensions and blade shapes were drawn primarily from oars on boat models from ancient Egypt, especially 18-19 cm long examples from Meir c 2000 BC. Ward relied on these because only the oar looms are visible on the Punt ship reliefs; those examples measure 18.5-21 cm long and 5-6 mm wide depending on where they are in the ship. Gawasis finds include 10 probable loom fragments with a slightly flattened oval section of about 5-5.5 cm. Lengths and diameters of the looms on the relief, combined with the archaeologically attested diameter and Min's calculated height above the water resulted in proportions for Min's oars that compared well to the Punt relief examples and produced easily workable oars.

Two lengths of oars accommodate the greater height at the ends of the hull. The loom extends into the separate blade and, on the models, had a triple binding, or single binding over leather, at the loom/blade interface. The end of the loom is locked to the scoop-shaped blade by a ligature. The design was extremely successful in practice. Each rower braced her outboard foot against the bulwark and faced the stern to row. Rowing upwind, steady speeds of 2.5 knots were achieved over short distances by a crew of only 14 rowers. In practice, most rowing was done by the six-member Ladies Rowing Team, responsible for keeping the bow pointed downwind while the rest of the crew raised the sail. Two men could turn the hull in less than a minute under duress.

Observations

The hull shape of *Min of the Desert* - a shallow long dish with midships keel protrusion of only 2 cm in the central third of the ship meant that converting sideways sail force into forward motion was somewhat inefficient, and that the boat tended to slide downwind. The way the vessel moved through the swells confirmed our expectation that we were under-ballasted. The ship was expected to displace 30 tons., with a calculated dry weight of about 14 tons., but had only 9 tons of sand and gravel in sacks. Sailing performance may have been enhanced by another few tons of ballast.

Additional ballast would also have improved rudder performance. After a stern curvature adjustment, the rudder loom did not receive a necessary length increase of 45 cm. The additional length would certainly have helped handle the swells we encountered, as the rudders lifted out of the water as waves greater than 2 m passed under the hull.

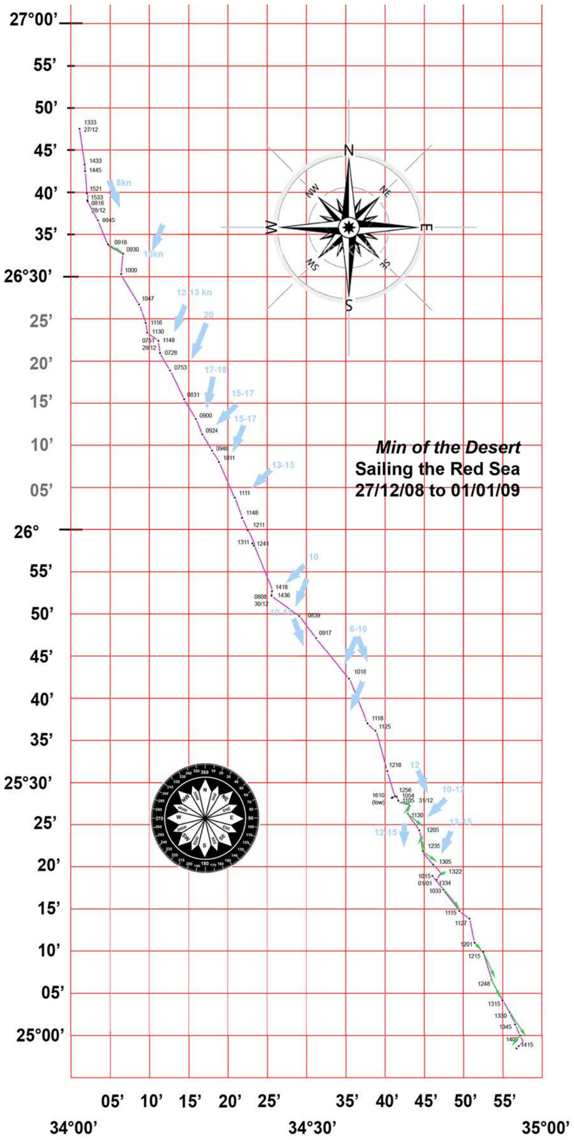

Fig. 39.3. Preliminary calculations of positions, wind direction, wind speed, boat heading and course made good are illustrated in light blue arrows, the boat heading indicated by green arrows, and the course made good in purple (T. Vosmer).

Overall, the ship performed well, but we were unable to sufficiently experiment with the ship in the time available to us. Certainly downwind Min flew along smartly, especially on a broad reach as one would expect, but we had few opportunities to push the limits and lacked extensive instrument notation or calculation. Due to unanticipated difficulties, we had only handheld GPS units and an anemometer to record data (Fig. 3).

Min's performance (speed and course made good) dropped off as the boat came onto a true beam reach, but off the wind up to about 100 degrees apparent wind, it was more than adequate. It could not effectively sail a reach, but demonstrated impressive apparent efficiency and lack of significant expected leeway on point of sail between a broad reach and a beam reach. In many cases with the wind at, for

Mast tip above deck	8.3 m
Mast diameter at deck	45 cm
Yard diameter at ends	17 cm/8 cm
Lower yard above deck	2.0 m
Upper yard above deck	7.7 m
Length of sail along lower yard	14.5 m
Length of sail along upper yard	14.3 m
Length of lower yard	16.7 m
Length of upper yard	15.7 m
Sail area	80.9 m^2
Storm sail area	23.8 m^2

Table 39.2. Principal dimensions of rigging elements.

example, 110 degrees according to plotted course and headings, the leeway was only about 15 degrees, half what Vosmer expected in a boat with this hull shape. While this does not confirm that *Min* could make a direct passage up the Red Sea against a wind, nor claw its way off a lee shore, it does indicate a relatively high degree of manoeuvrability and a good margin of safety, even under difficult conditions.

Vann notes, "We discovered that it was better to not raise the upper yard all the way but to lower it just a bit and let the sail billow, like in the reliefs…We could sail anywhere from straight downwind to 90 degrees off either side, and there was no risk at all. We didn' t have to fear small wind shifts. Everything was smooth, and we had all the time in the world to make any changes. Those thick lower sheets began to make tremendous sense. We changed our tack simply by letting one out a bit and pulling the other one in. We led the upwind sheet across the deck for better leverage when we were higher on the wind. And we were sailing at 7 knots, about as fast as a modern cruising sailboat with the same waterline and conditions."

"We tried initially to use the braces to help adjust the sail, and we put too much pressure on one and snapped the upper yard. We had tried to lead the braces forward, a departure from the reliefs, a practice you'd use on a modern boat. But after the accident, we went back to the reliefs, led those lines aft and kept them fairly loose. We used them only to shape the sail. One brilliant aspect of the ship's rigging design is that all of the heavy loads are taken by the mast rather than the braces and sheets. On Min, the lower yard is bound to the mast, so the sheets handle only the side to side adjustments, not the primary driving load. I was able to adjust the sail myself, with no one else's help, if I first loosened one line and then tightened the other, though usually we had two people on each line…I could do it alone up until about 12-15 knots of wind, when a second person was required."

Conclusions

Min of the Desert proved conclusively that the ancient Egyptians were fully capable of long-distance sea voyages in ships relying on technology developed beside the Nile. It is the only reconstruction of an Egyptian vessel to rely on archaeological data for its design and internal structure. The combination of thick planks shaped to interlock with one another along their edges and fastened by deep, unpegged mortise-and-tenon joints remained structurally sound.

Min can sail across the wind up to an angle of about 100 degrees off the wind, and as few as two rowers could manoeuvre the ship. The ship outperformed expectations in terms of sailing and sea keeping, actively demonstrating that a rig copied directly from the Hatshepsut Punt reliefs was efficient and effective. *Min of the Desert* is now permanently anchored at the visual prow of a new Supreme Council of Antiquities museum dedicated to the sea beside the Suez Canal.

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