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REFLECTIONS OF A TIMBER ECONOMY: THE INTERPRETATION OF MIDDLE KINGDOM SHIP AND BOAT TIMBERS

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Timbers of boats and ships are rarely perceived and studied as a collection of individual objects rather than as a single comprehensive unit. This has been true, as elsewhere, in Egypt, where the remains of twenty-five to thirty-five functional watercraft from the pharaonic period have been excavated thus far,[1] ranging from fragments discernible as boat components only from context to complete (or nearly so) vessels interred in association with royal burials.[2] When a watercraft *is* analyzed as a collection of individual artifacts (comparable to the analysis of, for example, faunal or human remains), the resulting data can extend far beyond the scope of its construction and technology (the usual foci of nautical studies), back to events in the shipyard where it was built, up the supply-chain, and into the forests from which the timbers were harvested. Each of these stages resulted in modification(s) to the raw material. When timbers are examined with such processes and the larger cultural and environmental contexts in mind, it is possible to gain insight into human-environment interactions, including: forestry practices, responses to environmental change and variation, timber selection, stockpiling, deadwood use, timber conversion (economy of wood use), and timber supply and trade.[3] Through their origin, shape, size, general quality, and other features, ship and boat timbers will reflect methods of managing and acquiring wood, a "timber economy."

The archaeological study of wood-use behaviors and extrapolation of other such cultural knowledge from wood is a relatively recent development in the field of tree-ring analysis, one usually credited to Jeffrey S. Dean in 1996.[4] Although Dean addressed the interface of human behavior and the environment as evidenced from structures other than ships, the usefulness of the application of such an approach toward boat timbers is obvious. To maintain the spirit but adapt the topic of an observation by Dean: the more we understand the behavior involved in wood procurement, use, discard, and consumption, the better we will be able to understand human/environment interactions, especially in societies—such as that of ancient Egypt—that made intensive use of wood.[5] To this end, six categories of behavioral information have been identified and are discussed below.[6] Dendrochronological evaluation, which would expand the possibilities to absolute dating and analysis of environmental conditions, would be ideal but has yet to become commonplace in Egypt or for ancient Egyptian materials.[7] For that reason environmental and chronological topics are largely absent from the following discussion.

THE MATERIAL EXAMINED

Chronologically, most pharaonic ship and boat timbers cluster in the Middle Kingdom, and these will be the focus of the following examination. Particularly considering its antiquity, this corpus is comparatively rich for nautical remains and includes: disarticulated Nilotic work boat timbers from Lisht (Twelfth Dynasty),[8] four near-complete small Nilotic funerary boats from Dahshur (Twelfth Dynasty),[9] and recent finds from the Red Sea sites of Ayn Soukhna (Eleventh/Twelfth Dynasty)[10] and Mersa/Wadi Gawasis (Twelfth Dynasty).[11] At the time of writing, the finds from Ayn Soukhna (and an earlier possibly related site Wadi El-Jarf, dating to the Fourth Dynasty)[12] have undergone only preliminary analysis but are expected to yield much information in the near future. The timbers from Wadi Gawasis are fragmentary and likely came from several vessels but remain useful for the present analysis. Other watercraft timbers have been found, such as at Lahun (Twelfth Dynasty) in the early twentieth century CE, but excavators only noted their existence without preservation or study.[13]

TOOL MARKS

Tool marks on Middle Kingdom timbers permit a confident reconstruction of the tool kit used in their creation and subsequent vessel construction (Fig. 1).[14] This evidence is further substantiated by numerous finds of contemporary tools, some iconographic evidence (Fig. 2), and even model of carpentery shops demonstrating tools in use (Fig. 3).[15] Various sizes of copper-alloy axes, adzes (which, when inverted, double as planes[16]), chisels, drills, and pull saws employed in ship construction have left their evidence directly on timbers (Fig. 4).[17] Wooden mallets would have struck chisels and driven tenons into mortises, and polishing stones were likely used on the surface of the wood.[18] Whetstones kept the implement edges sharp. All of the extant ship and boat timbers demonstrate the use of some or all of these tools, with those of the Dahshur boats being the most revealing, due to their good preservation.[19]

ASSEMBLY AND CONSTRUCTION MARKS

Middle Kingdom timbers preserve little evidence of assembly and construction marks, but what can be identified is consistent with the deliberate nature of Egyptian construction practices. Incised marks found on disarticulated (hull?) planks and a single standard hieroglyph chiseled into a deck plank found at the port/way station at Wadi Gawasis *may* relate to construction methods.[20] Despite the lack of larger context in this case, the presence of assembly marks on the timbers of the Khufu I (Old Kingdom, Fourth Dynasty) vessel strengthens the argument. In this case, 1,131 marks (650 different hieratic signs) were used to indicate the correct placement of individual timbers.[21] It should, however, be duly noted that the Wadi Gawasis timbers are largely refuse and have no published or apparent adjoining pairs to confirm assembly correlations.

Black painted lines indicated the planned loci for mortises on some of the hull planks of the Pittsburgh Dahshur boat (CMNH 1842-1).[22] These were almost certainly cutting guides laid by a master and left for an apprentice or laborer to chisel away. Such organization should not be unexpected in ancient Egyptian shipbuilding and perhaps mirrors a philosophy of preparation such as that employed in architectural construction and decoration.[23] Construction of a vessel would have been the responsibility of a single person no more than would a tomb

FIGURE 1. A tool kit from Thebes. Perhaps the most complete woodworking set from ancient Egypt; although these examples date from the New Kingdom, each of the tools is evidenced in the Middle Kingdom as well (see Gale et al. 2000, 355-6; Killen 1994). (British Museum, London. EA 6046, 6040–43; © Trustees of the British Museum.)

FIGURE 2. Little shipbuilding iconography is known from the Middle Kingdom, this being the most active scene. The tomb of Khnumhotep III at Beni Hasan (from Newberry et al. 1893, pl. XXIX).

FIGURE 3. Meketre's (TT 280) model carpentry shop, Eleventh Dynasty (JE 46722; courtesy the Egyptian Museum, Cairo).

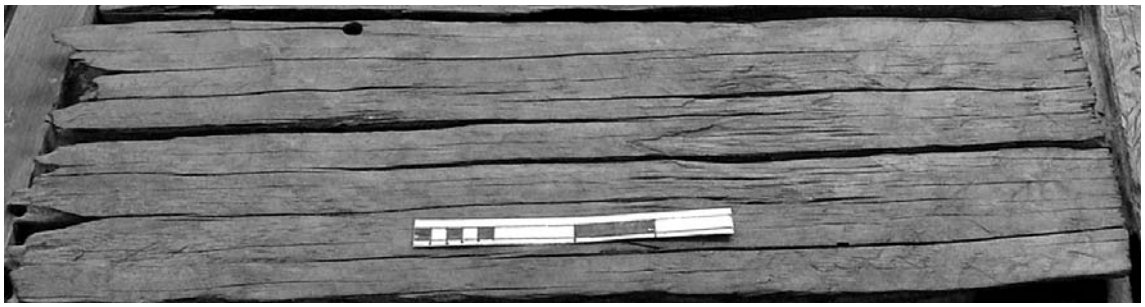

FIGURE 4. Adze marks on a deck plank from a Twelfth Dynasty boat from Dahshur (CG 4926; courtesy the Egyptian Museum, Cairo).

or temple.[24] This, therefore, calls for methods of work division and delegation. Marking timbers with paint for certain cuts and sending them through an assembly-line-like process could have been efficient and would have taken advantage of a large pool of workmen available to a king. Such laborers could have been trained in different woodworking skills, which would be generally consistent with the highly centralized nature of pharaonic society.

Construction guides were not confined to surface marks. Half-mortise-and-tenon joints were found at butt joints of hull planks in the Dahshur boats. These non-structural components were used not as joinery per se but rather as guides to place a timber or timbers during the construction process. If necessary, the timbers could be removed, adjusted, and replaced as many times as needed until the correct hull shape was achieved, at which time standard mortise-and-tenons would be employed to fasten them.[25] This fitting technique also reflects a concern for efficiency and accuracy.[26]

SPECIES IDENTIFICATION AND USE

Written records from the whole of the pharaonic period indicate the employment of no fewer than sixteen different woods in ancient Egyptian wooden ship and boat construction.[27] Far fewer species have been archaeologically attested to in nautical construction. Most ship and boat components for Middle Kingdom timbers have been subjected to species identification, sometimes only recently (Table 1). For example, the wood of the Cairo Dahshur boats, on display since 1896, did not undergo even basic scientific identification for a hundred years, when a small selection of hull planks from both vessels was identified as *Cedrus libani*, as had long been suspected.[28] For new discoveries, such as those at Wadi Gawasis and Ayn Soukhna, species identification seems to be standard procedure.

TABLE 1. Timber species and uses.

SITE/OBJECT	HULL	DECK	FRAMES	TENONS	OTHER
Ayn Soukhna	*Cedrus* sp. *Quercus* sp.	?	?	*Acacia* sp	?
Mersa/Wadi Gawasis	*Cedrus libani*	*Cedrus libani*, *Ficus sycomorus*, *Acacia nilotica*	*Cedrus libani*	*Acacia nilotica*	*Faidherbia albida*, *Avicennia marina*, *Pinus* sp, *Quercus* sp.
Lisht	*Tamarix* sp. *Acacia* sp.		*Tamarix* sp. *Acacia* sp.	*Tamarix* sp. *Acacia* sp.	
Lahun	?	?	?	?	?
Dahshur: Pittsburgh CMNH 1842-1	*Cedrus libani*	*Cedrus libani*	n/a	*Tamarix* sp.	
Dahshur: Chicago FMNH 1842	*Cedrus libani*	*Cedrus libani*	n/a	Likely *Tamarix* sp.	
Dahshur: Cairo CG 4925	*Cedrus libani*	Likely *Cedrus* sp.	n/a	Likely *Tamarix* sp.	
Dahshur: Cairo CG 4926	*Cedrus libani*	Likely *Cedrus* sp.	n/a	Likely *Tamarix* sp.	

Cedar is the predominant species in Middle Kingdom boats, including most of the wood from the four extant Dahshur boats,[29] ship parts at Wadi Gawasis,[30] and two hulls at Ayn Soukhna.[31] The merits of cedar as a shipbuilding material have been clearly stated elsewhere and need not be reiterated here.[32] This wood, a nonnative species imported from the Levant since the Predynastic Period,[33] would have fit the required level of prestige for ceremonial river craft, while its resins make it preferable for working seagoing vessels. Joinery components, however, especially tenons, tend to be constructed from a denser and sturdier local wood, typically acacia (*Acacia nilotica*), sycomore (*Ficus sycomorus*), or tamarisk (*Tamarix* sp.). This correspondence suggests that the Egyptians were aware that that cedar, while ideal for hull planks, was too soft to stiffen the vessels and serve "in the manner of little internal frames," as J. R. Steffy phrased it.[34] Acacia, sycomore, and tamarisk—all better suited to the task—grew abundantly in Egypt until the medieval period.[35]

The identification of the Lisht timbers as tamarisk and acacia[36] provide a contrast to the cedar-built ships. These are the disarticulated remains of what was probably an Eleventh Dynasty work boat,[37] to judge by the robust nature of the timbers and their eventual re-use in a construction ramp at a site that would have received supplies of building stone by boat. The Lahun timbers were likely similar.

With regard to species identification and vessel purpose, Cheryl Ward posited two categories of wooden watercraft: 1) ceremonial and seafaring vessels built of imported cedar and 2) more economically significant freighters and other working boats created from the abundant local supplies of tamarisk and acacia.[38] This dichotomy stems from both function of construction style and intended use. Work boats for the Nile could make use of smaller planks of lower quality, as the Nile is relatively calm and has predictable waters.[39] Additionally, because the Nile lacks the wood-boring shipworm (*Teredo navalis*), a resinous wood, which would deter this bivalve mollusk pest, is not necessary. The presence of shipworms may have necessitated the use of cedar at sea.[40] As for the use of cedar in ceremonial watercraft, such vessels were demonstrations of power and wealth; building them from valuable imported wood would have been a conspicuous display.[41]

Some diversity from the core resources of cedar, acacia, and tamarisk can be found in boat construction. At Wadi Gawasis, ship timbers include previously unknown Egyptian uses of apple-ring acacia (*Faidherbia albida*) and mangrove (*Avicennia marina*),[42] although in apparently small quantities, perhaps indicating repairs en route to or from Punt.[43] At Ayn Soukhna, the stores of timbers for two seafaring ships included a very few oak (*Quercus* sp.) planks, but the bulk of the specimens are cedar.[44]

TIMBER SIZE AND SHAPE

The circumstances of Egyptian timber resources, including the limitations (e.g., of available size) of local species and the expense of importing better wood, encouraged compensating technological advances in wooden ship construction. It is generally assumed that timber that was either large enough or of sufficiently good quality for use in ships, especially imported species, was at a premium for most of Egyptian history.[45]

The Dahshur boats, each approximately 10 m in length, lack the panache associated with most royal ceremonial endeavors, especially the funerary rituals to which they are attributed.[46] Compared to the Old Kingdom funerary vessel of Khufu (43.5 m in length),[47] the small Dahshur boats raise a number of questions. Could Senwosret III, perhaps the most

powerful ruler of the Middle Kingdom, acquire for his funerary boats only small timbers,[48] many of which had been used at least twice before? Given that local species were available in lengths of up to 8 m at least into the New Kingdom,[49] it raises critical questions as to their availability in earlier periods: first, how much *quality* timber could be provided locally in a given period, and, second, could such provisions keep pace with demand?[50]

Senwosret III ruled during a period of widespread and robust international commerce, so it is not likely that Egypt experienced an interruption in its foreign timber supply.[51] One viable explanation for the thrift of the Dahshur boats might be that the rulers of the Middle Kingdom did not indulge in some of the excesses of their Old and New Kingdom counterparts. This idea is reinforced by the use of mud-brick cores, rather than stone, in pyramids of mid-Twelfth Dynasty date and later, and similar adjustments.[52] The modest size of these boats is less likely to reflect limited materials than it is broader philosophical changes toward more responsible stewardship, or at least less irresponsible stewardship, of materials.[53] Other potential reasons include, as suggested to me by Noreen Doyle, an attempt to associate the new object—and thus the owner—with some prestigious watercraft or event from the past by reusing timbers, and in fact the boats do have very high levels of reuse (noted below).[54]

The use of joggling (notches; Lisht timbers[55]) and top-and-butt joinery (joinery along long edges and ends; Dahshur boats) in hull planking[56] might suggest that Egyptian boatbuilders were more interested in structural concerns (i.e., redistributing stresses) than in timber conservation; in fact, the timbers of the Dahshur boats were shaped in a manner that appears to have wasted a significant amount of wood.[57] Nonetheless, it is possible, and perhaps even likely given the extensive signs of reuse evidence on some of the Cairo Dahshur boats (CG 4925 and CG 4926),[58] that the timbers were themselves shaped from serially reused wood (see section on "Reuse," below, for more detail). Repetitive reuse may create comparatively little waste for any single iteration, but the end result could appear to a later investigator to be a single event with excessive waste.

REUSE

Wood, especially the imported material, was sufficiently valuable to prompt, when possible, its reuse.[59] Recent finds and analyses are developing a more complete understanding of the apparently common practice of timber reuse in watercraft, including for royal ships made of imported timbers. The practice appears early, perhaps during the First Dynasty[60] and likely even on the grand Khufu I vessel;[61] in the Middle Kingdom, most timbers bear evidence of reuse, attesting that it was, by then, standard practice, more common even than the employment of new timbers, insofar as current archaeological remains inform us.

Reuse can take many forms and not need be limited to multiple applications of the timber in watercraft. The Lisht and Lahun timbers provide excellent examples of non-nautical reuse of ship timbers. Boats, perhaps Nilotic barges,[62] were disassembled and used to reinforce at least six separate quarry- and construction-related slipways near Middle Kingdom pyramids.[63] Ward attributes multiple stacked mortises on these timbers to "miscalculation" in construction,[64] but this is more likely evidence of prior use(s).[65] These timbers also offer evidence of repair: a trapezoidal plug was used to tighten a joint that had come loose over time.[66]

Another kind of reuse appears at Ayn Soukhna. Here ship timbers were found arranged in bound groups that were stored raised above the ground in artificial caves along the coast.[67] Pomey has convincingly suggested that this sort of arrangement was for storage between

expeditions and that the fire to which the timbers were subjected was deliberate, likely so that they could not be used again.[68]

Wadi Gawasis provided evidence of yet another method by which the Egyptians put timbers to new purposes. At this site, red paint on wood debitage highlights damaged portions of planks for removal,[69] indicating that the timbers were intended to be used again.[70] Many of the mortises found in planks on the site also indicate reuse of the wood. A brief personal inspection of several dozen of the Wadi Gawasis timbers in December 2006[71] provided this author with an opportunity to compare this evidence with that presented by the Cairo Dahshur boats (described below). It is this author's opinion that many of the timbers then available had been reused at least once (some likely more often), but in what context is not known.

Repurposed timber comprises at least 60 percent (and probably more) of the material in the Cairo Dahshur boats, Egyptian Museum Catalog (CG) 4925 and 4926.[72] Surplus mortises, that is, without mates, indicate reuse.[73] In the extreme, exemplified by timbers of CG 4926, some hull planks (which can be only 7.5 cm wide; 1 palm) have stacks of up to five unmated mortises (each c. 1.7 cm wide; approximately 1 digit). Evidence suggests that these planks were reused no fewer than three times.[74] Furthermore, on CG 4926, two structural beams near midships have peg holes, but there are not enough deck planks of sufficient size with peg holes to match: this too is likely evidence of reuse. For what purpose the timbers were previously crafted cannot be determined at present. Such profuse evidence of emendation suggests that the trees providing the timber that eventually went into these boats were felled considerably earlier than the end of Senwosret III's reign.

Critically, repurposing and reuse are almost certain to create misleading radiocarbon dates for these hull timbers.[75] Not surprisingly, radiocarbon dates from the Chicago (FMNH 1842) and Pittsburgh (CMNH 1842-1) Dahshur boats yielded a wide range of dates clustered around the twentieth and nineteenth centuries BCE.[76] The author is not aware of any radiocarbon dating of the Cairo boats.

Peter Ian Kuniholm's laboratory group (formerly of Cornell University, now at the University of Arizona) has made significant progress determining that dendrochronology for the Eastern Mediterranean, including Egypt, would be a reasonable pursuit despite inherently limiting factors for the period and species.[77] He sampled ("cored") the Pittsburgh Dahshur boat in the early 1990s, but it was not until 2000 that he was able to collect sufficient related material to fully understand the implications of the boat's tree-ring data. He derived two long ring series: 336 years from the hull planks and 400 years from the deck planks, for a combined overlapping length of 523 calendar years.[78] These aforementioned results went overlooked, largely as they are "floating" chronologies; that is, they not are yet anchored to a precise calendar year owing to gaps in the Near Eastern cedar chronology. Recognition of the appearance that "the wastage of trimmed-away wood on the [deck planks] in [the Pittsburgh Dahshur boat] is extraordinary" and that the hull planks too were "very heavily trimmed"[79] resolved the concern about *how* the timbers fit the growing chronology. As previously noted, this observation is very likely the result of serial reuse, not a single event that produced much waste. The boat timber chronologies were found to overlap with several other contemporary artifacts from Egypt, including a coffin and a wooden sarcophagus.[80] It is significant to note that these matches both dated to the earlier Eleventh Dynasty.

TIMBER CONVERSION STUDIES

From the Middle Kingdom, the vessels that at the moment provide the most reliable studies of timber conversion (i.e., the creation useable timber from raw timber) are the Dahshur boats, as they are nearly complete and the most thoroughly studied.[81] Because only fractions of hulls can be reconstructed from Lisht and Wadi Gawasis, timbers from these two sites would provide more complications than benefits in such analysis. More material is needed, and generally timbers must be placed into the context of a hull so that the proportions of the vessel can be calculated and timber estimates subsequently extrapolated. In the case of the Dahshur boats, boatbuilders used an estimated minimum of eighteen mature cedar trees for each hull, including its beams, decking, and planking.[82] This estimate was achieved through dendrochronological comparison of timber grains, by which portions of a single tree can be identified. If this figure holds true for four other[83] Dahshur boats, it would indicate the importation of approximately one hundred trees, a kingly haul regardless of their conditions.

Dendrochronological analysis can be extremely informative regarding timber conversion and the amount of waste-wood produced in the obtaining of construction materials. Kuniholm's analysis of the Pittsburgh Dahshur boat suggested not only that a great percentage of wood was wasted in the boat's construction but also that much of the wood employed was reused. These two practices would seem contrary, but, viewed in appropriate context, this may be further evidence of the trend toward better stewardship of the resources available to Senwosret III. It is possible, even likely, that these timbers were imported significantly before Senwosret III's reign and, as discussed above, harvested from other vessels or structures. Their initial application(s) and the associated repetitive trimming would be the cause of what *appeared* to Kuniholm as one event of "extraordinary" waste, with each subsequent reuse explicable as the product of an intention to conserve materials.

Dendrochronological analyses have also demonstrated that opposing port and starboard planks were cut from the same tree, probably to encourage symmetry in hull shape.[84] It is not surprising that the shipbuilders employed this practice, and, except where reuse prevented it, it is probably common throughout the five hulls; however, only the Pittsburgh hull has been sampled as to enable this kind of analysis. Matching distinct knot and grain patterns in the remainder of the hull suggests that symmetry was practiced elsewhere on the Pittsburgh boat.[85] The rate of reuse in the Cairo Dahshur boats obscured such initial analysis, but these timbers should still be reexamined specifically for this trend confirmed by the knots. The Chicago boat, being the least studied and best preserved of the Dahshur group, would be an ideal candidate for such analyses.

Timber conversion studies can also reveal the methods used to shape the timber and the quality of cuts.[86] Ceremonial vessels appear to have higher quality cuts that consumed a greater quantity of material. For example, many timbers in the Cairo Dahshur boats were hewn from or near the center of a large tree, potentially producing much waste wood. Kuniholm encountered likewise with the Pittsburgh boat, as noted previously. On the other hand, the Lisht timbers, from a work boat, were cut so that an "economy of wood use is evident."[87] The carpenters cut the timbers strategically to avoid major knots and compression wood[88] and to take advantage of the natural grains and curvatures, presumably to maximize strength and minimize weaknesses.

CONCLUSIONS

While there are still several avenues for research available to be applied to the corpus of Middle Kingdom timbers that might reveal much more behavioral information—especially the dendrochronological evaluation of relative timber ages, age clusters, and wood anatomical studies via the analyses performed above[89]— it appears that some awareness of the finite nature of shipbuilding wood was acknowledged during the Middle Kingdom and concerted measures were taken to address this constraint. Reuse, in some form, occurs among all known ship remains from the period. Locally grown timbers were cut with greater attention toward timber conservation and less regular evidence of reuse (for the greatest, or necessary, balance of quality and quantity), probably reflecting the importance of the vessels in the economy (and also practicality), whereas imported timbers were cut to maximize quality with apparently less regard to cost; this is probably reflected by their infrequent use and already disproportionate expense.[90]

When interpreting timber from other periods of Egyptian history, the above should be kept in mind, especially for the Old Kingdom, for which the ceremonial Khufu vessels provide the primary ship timber evidence.[91] It should also be noted that timbers from ceremonial boats have survived out of proportion with their working counterparts, which skews the data. Cultural trends evidenced in ceremonial contexts or imported timbers in any context may not be representative of the practices for other kinds of ships and boats; the evidence above suggests that they are significantly different from those employed for utilitarian vessels constructed from local woods.

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ENDNOTES

1 This figure includes the fourteen Early Dynastic boats buried at Abydos, though these may not have been functional (Mark 2012, 107–126), but does not include recent finds of up to thirty-five Late Period and more recent vessels at Thonis-Herakleion (Fabre and Goddio 2013; School of Archaeology, University of Oxford n.d.).

2 E.g., Haldane 1988, 1992; Lipke 1984; Mark 2009; Ward 2000, 2004.

3 Creasman 2010a, 40–77.

4 Nash 2002, 254. The concept was, however, proposed much earlier by William J. Robinson in his 1967 doctoral dissertation, *Tree-ring Materials as a Basis for Cultural Interpretations*, University of Arizona.

5 Dean 1996, 466, the original quote being: “The more we understand the behavior involved in wood procurement, use, discard and consumption, the better we will be able to assign unambiguous dates to human events.”

[6] The methods presented are only "illustrative of the possibilities of extracting certain non-chronological information" (Robinson 1967, 7).

[7] See Creasman in press.

[8] Ward 2000, 107–128; Haldane 1992; Haldane 1988, 141–152.

[9] Creasman 2010b, 2005; Creasman et al. 2010, 2009; Ward 2000, 83-102; Patch and Haldane 1990; De Morgan 1895, 82–85.

[10] Abd el-Raziq 2008; Pomey 2012; Tallet 2012; Pomey 2011; Pomey 2009.

[11] Ward and Zazzaro 2012, 2010a, 2010b, 2007; Bard and Fattovich 2007, 2010.

[12] Tallet 2013, 2012; Tallet and Marouard 2012.

[13] Petrie et al. 1923, 12, pl. 15.

[14] Ward (2000, 25–30) offers a summary of these tools. Despite the discovery of additional ship timbers since her work was published, no new tools have come to light; see also Goodman 1976, 17–18.

[15] See, e.g., Winlock (1955, 33–38, pls. 28–29) for further information on the Meketre models.

[16] Lucas and Harris 1999, 449; Killen 2010. The plane has not been evidenced archaeologically, iconographically, or textually during any phase of the pharaonic period. This is an important distinction that cannot likely be made by investigating the tool marks on the timbers out of context.

[17] See Creasman 2010a, 2005; Ward and Zazzaro 2010a, 38; Ward 2004, 2000.

[18] Ward and Zazzaro 2010a, 38.

[19] See Creasman 2010b, 2005, 65–66, 106–107; Ward 2000, 83–102.

[20] Ward and Zazzaro 2010a, 38.

[21] Ward and Zazzaro 2010a, 38; Lipke, 1984, 82, 86 figs, 54–55; Mark 2009, 146.

[22] Ward 2000, 92–93, fig. 41.

[23] For example, see Eyre (1987, 167–221) for a study in organization of labor during the New Kingdom.

[24] Robins 1994, 30.

[25] Frederick Hocker is credited with advancing the "temporary fastening" concept. See Ward 2000, 85–89, fig. 38.

[26] For a discussion of half-mortises, see Creasman 2005, 39–53, 86–127, fig. 16.

[27] Gale et al. 2000, 335–352.

[28] See Creasman 2010b.

[29] Creasman 2010b; Ward 2000, 92. Although it is sometimes suggested that they functioned as large models (Patch and Haldane 1990, 41), the Dahshur boats are generally believed to have been used in some aspect of Senwosret III's funerary procession, and thus, as sacred objects, should have been built of valuable timber.

[30] Gerisch et al. 2007, 185–188.

[31] Pomey 2012.

[32] Pulak 2001, 24–36; Ward 2000, 20–22; Gale et al. 2000, 349–350, 367–368.

[33] Gale et al. 2000, 349.

[34] Steffy 1994, 33.

[35] Gale et al. 2000, 367.

[36] Ward 2000, 110.
[37] Haldane 1988, 1992; Ward 2000 107–128.
[38] Ward 2004, 14.
[39] See the Lisht timbers in Ward 2000, 125 fig. 70, 127 fig. 71, and Haldane 1992, 102–108, 115–133).
[40] Most of the damage resulted from shipworm, which clearly presented a problem for seafaring vessels, as demonstrated by the approximately 47 liters of debitage and gribble from Wadi Gawasis (Ward and Zazzaro 2010b, 32).
[41] Ward 2004, 14.
[42] Gerisch et al. 2007, 185–188.
[43] Ward and Zazzaro 2010a, 31.
[44] Pomey 2011, 9.
[45] Brand 2010, 2; Deglin 2011, 85; Gale et al. 2000, 334; Mark, 2012. Ward (2000, 15) disagrees. This assumption is largely untested.
[46] Creasman 2010b.
[47] See Mark 2009 for a recent synthesis and reanalysis of the Khufu I vessel.
[48] For example, of the approximately ninety-nine structural timbers used in the construction of the Cairo Dahshur boats, only one exceeds 4 m in length. The majority, fifty-one, are less than 2 m, thirty-nine timbers are between 2 and 3 m, and eight are between 3 and 4 m (Creasman and Doyle 2010, 24). The Khufu I vessel has timbers that exceed 20 m in length (Lipke 1984).
[49] Janssen 1975, 373–375; Gale et al. 2000, 367.
[50] The author is not aware of any ancient text or other reference that provides such information or analysis.
[51] Callendar 2000, 137–171.
[52] Creasman 2005, 4–7; Arnold 1991, 164.
[53] Samuel Mark (personal communication, 15 July 2010) proposes that this situation might be more complex, and that several other possibilities exist.
[54] Noreen Doyle (personal communication, 8 January 2013) has suggested this parallel to the reuse of stone building materials discussed, e.g., in Brand 2010, 3. Yet another, not necessarily incompatible, possibility is that boat burials may have had less significance in the Middle Kingdom than the Old Kingdom, resulting in smaller vessels: see Creasman (2005, 5–6) for a discussion of the miniaturization of watercraft in ancient Egyptian tombs through time. Further work on this subject is in preparation.
[55] See Ward 2000, 127 fig. 71.
[56] See Steffy (1994, 291) for clarification of the terms.
[57] Most were hewn from the core of trees; Ward 2004, 14.
[58] Creasman 2010b.
[59] For more detail on this subject, see Creasman 2013.
[60] P. P. Creasman, personal investigation of the boat found at Abu Roash, courtesy of the Grand Egyptian Museum Conservation Center.
[61] Mark 2009, 149–150.
[62] Haldane 1992, 102–112; Ward 2000, 107–108.

[63] Lahun: Petrie et al. 1923, 2, 12, 34, pl. XIII and XV); Lisht: Arnold 1991, 86–92; 1992, 92–95, 102–112, especially supplementary map VI.

[64] Ward 2000, 112.

[65] For the reuse of mortises, see Creasman 2013: 160–163, figs. 3–4.

[66] Ward 2000, 112.

[67] Pomey 2009, 2; 2011, 9; Creasman and Doyle 2010, 16; Tallet 2012, 150–151, 160 fig. 10; Yoshimura and Kurokochi 2013.

[68] Pomey 2009, 2.

[69] Ward and Zazzaro 2010a, 38.

[70] Ward and Zazzaro 2010a, 41.

[71] By the kind invitation of Kathryn Bard (co-principal investigator, with Rodolfo Fattovich) and with the assistance of Chiara Zazzaro, for which I am most grateful.

[72] Creasman 2010b, 2013:160. Not all of the timbers of the boats are present, and some of the existing timbers are not in a state of preservation allowing for proper analysis.

[73] Steffy 1994, 33.

[74] Not five iterations as the author previously thought (Creasman 2010b, 113, fig. 10); see Creasman 2013, 161 n. 55.

[75] For a non-nautical example of old, reused wood causing an object to date older than expected, see Weinstein 1984.

[76] Ward 2000, 83; according to Ward these boats appear not to exhibit as high a rate of reused timber as those in Cairo.

[77] Kuniholm 2001, 79–81.

[78] Kuniholm 1992, 31 January.

[79] Kuniholm 2001, 81.

[80] Kuniholm 2001, 80–81.

[81] Once excavated and reconstructed, the Ayn Soukhna ships should also be useful in this respect.

[82] M. Newton's estimate for the Pittsburgh boat (Ward 2000, 96).

[83] Although only four boats from Dahshur are known in museum collections, at least one more boat was found during excavations (Creasman et al. 2009, 2010).

[84] Ward 2000, 96.

[85] Ward 2000, 96; this method is incredibly underused in the analysis of ship timbers. Many investigations of timber do not record knots and grain patterns in their one-to-one timber drawings, even when such drawings exist. This utility makes a good case for the practice.

[86] See Gale et al. (2000, 354–370) and Killen (1994, 12–18) for the most thorough analyses of ancient Egyptian timber preparation methods.

[87] Ward 2000, 110.

[88] Compression wood can cause significant structural problems (e.g., cracks) if not prepared appropriately. Compression wood is prevalent in cedars especially (Pulak 2001, 24–25) and if *not* present likely indicates one or more of the following: a thorough timber selection process; some form of tree management, such as removal of limbs during growth; or extreme timber waste to reach the core of a large tree where compression wood is less significant.

[89] The absence of an absolute chronology has led to significant dispute about the order and timing of many events, epitomized by conflicts noted in Kitchen (1991, among many others) and Wiener (2006).

[90] Ward 2004, 14–16.

[91] Tallet 2013.