

# Sweet Water on the Sea Route to China: Watering Stops and Torpedo-Jar Capacities in Long-Distance Indian Ocean Sailing\*

ELIZABETH LAMBOURN

*De Montfort University*

(elambourn@dmu.ac.uk)

## Abstract

Potable, or “sweet,” water was the foundation stone of maritime provisioning and, by implication, route planning on all but the shortest voyages in the premodern world. Without it, maritime trade and all other forms of seaborne exchange and circulation were effectively impossible. Yet water sources and technologies of transportation have been comparatively neglected in Indian Ocean history and archaeology. This paper rereads data from the ninth-century section of the *Akhbār al-Ṣīn wa-l-Hind* (*Accounts of China and India*) alongside recent evidence from two contemporary shipwrecks to examine the spacing of watering stops and the technologies of water transportation employed on long-distance sailings between the Gulf and Chinese ports. Working from the 2021 publication of the volumetric capacity of a group of so-called torpedo jars excavated in Thailand, this article proposes some preliminary quantitative estimates of the volume of freshwater, and thus the number of water jars, required on board vessels at the time. In so doing it raises important questions about the portability and handling of torpedo jars as well as the varied uses and reuses of such transport jars. Weaving passages from the *Akhbār* with information on ceramic remains from the Phanom Surin and Belitung wrecks, this article aims to start a conversation about the very real physical and physiological parameters that underlay Indian Ocean connectivity and the water transportation technologies that underpinned them.

For on the ocean the wind is not so important,  
yet it is the very availability of water which decides over life and death  
—Xu Jing, *Xuanhe fengshi Gaoli tujing* (1123)<sup>1</sup>

Water, the sweet, fresh sort of water, is probably the last thing on the minds of most scholars of the Indian Ocean, yet it was, as the above quotation reminds us, first on the

---

\* The author gratefully acknowledges Naomi Standen and John Chaffee for checking the Chinese and Japanese references.

1. Xu Jing 徐兢, *Xuanhe fengshi Gaoli tujing* 宣和奉使高麗圖經 (Illustrated record of an embassy to Korea in the Xuanhe reign-period), 1123, cited in M. Torck, *Avoiding the Dire Straits: An Inquiry into Food Provisions and Scurvy in the Maritime and Military History of China and Wider East Asia* (Wiesbaden: Harrassowitz, 2009), 216, translated by Torck.

© 2022 Elizabeth Lambourn. This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives License, which allows users to copy and distribute the material in any medium or format in unadapted form only, for noncommercial purposes only, and only so long as attribution is given to the original authors and source.

minds of many travelers and crews. Starting from a short and previously neglected ninth-century passage about water provisioning along the route between the head of the Gulf and eastern China, this article returns to a topic that has preoccupied me for several years now: that of potable water and the mass of problems related to human and animal hydration needs, technologies of water transportation, and knowledge about its location, storage, and treatment. The availability of sufficient sweet water was the foundation stone of maritime provisioning and, by implication, route planning on all but the shortest voyages; without it, maritime trade and all other forms of seaborne exchange and circulation were effectively impossible. The passage in question is included in the mid-ninth-century Arabic-language collection of mercantile know-how referred to as the *Akhbār al-Ṣīn wa-l-Hind* (Accounts of China and India),<sup>2</sup> and it provides a starting point for a reflection on the manner in which sweet water shaped not only sea routes and circulation but the composition of cargoes and the archaeological remains we recover today. This study also hopes to encourage a greater focus on travel logistics, broadly defined, in the study of the premodern Indian Ocean.

Although travel logistics has existed as a subgenre of history for some time—prominent in the history of the Roman Empire, of sporadic interest within European medieval studies and Scandinavian histories of maritime expansion, prominent again in histories of the Age of Exploration and of the two World Wars—the “how” of circulation has generally been overshadowed by the “why” and the “what.” More than how people moved, historians have been interested in why they did so and in the varied consequences of these circulations. Studies of maritime water supply are even scarcer.<sup>3</sup> The intrinsically empirical questions that underlie this branch of history—how much water did a galley slave consume in summer, what is the cargo capacity of a twenty-eight-meter sewn-plank ship—have certainly not helped it gain favor in a professional discipline increasingly focused away from narrative accounts and empirical studies. Ideas, not facts, are what makes history most exciting. Yet rather like geography, logistics provides an essential foundation to historians’ interpretations. Without it, history appears to unfold unbound by physical or indeed physiological constraints, a realm of pure ideas unconstrained by material interactions.

### Dying of Thirst

Xu Jing’s preoccupation with sweet water is understandable when we bear in mind that unforeseen delays and adverse weather conditions could exhaust a ship’s water supplies—a far more deadly threat than simply running out of food. Dehydration kills rapidly. Of the body mass of the average adult human, between 45% and 75% is water.<sup>4</sup> Beyond a 15% loss

---

2. *Akhbār al-Ṣīn wa-l-Hind*, bk. 1, Arabic ed. and English trans. T. Mackintosh-Smith as *Accounts of China and India: The First Book*, in *Two Arabic Travel Books*, ed. P. F. Kennedy and S. M. Toorawa, 22–65 (New York: New York University Press, 2014), 31–35.

3. John Pryor has dedicated substantial attention to the issue in relation to Byzantine galleys and naval warfare, and Mathieu Torck has made an important contribution with his study of East Asian maritime and military provisioning, *Avoiding the Dire Straits*, but more often the matter flows silently and undisturbed through our sources. See, in particular (and with further bibliography), J. H. Pryor and E. M. Jeffreys, *The Age of the Dromon: The Byzantine Navy ca. 500–1204* (Leiden: Brill, 2006); Torck, *Avoiding the Dire Straits*.

4. E. Jequier and F. Constant, “Water as an Essential Nutrient: The Physiological Basis of Hydration,” *European*

of body weight through dehydration, the body becomes unable to regulate temperature through perspiration, leading to overheating and death. Even in the best circumstances, humans can endure only perhaps a week to ten days without hydration, and very much less in hot and dry conditions. As Xu Jing realized, “it is the very availability of water which decides over life and death.”

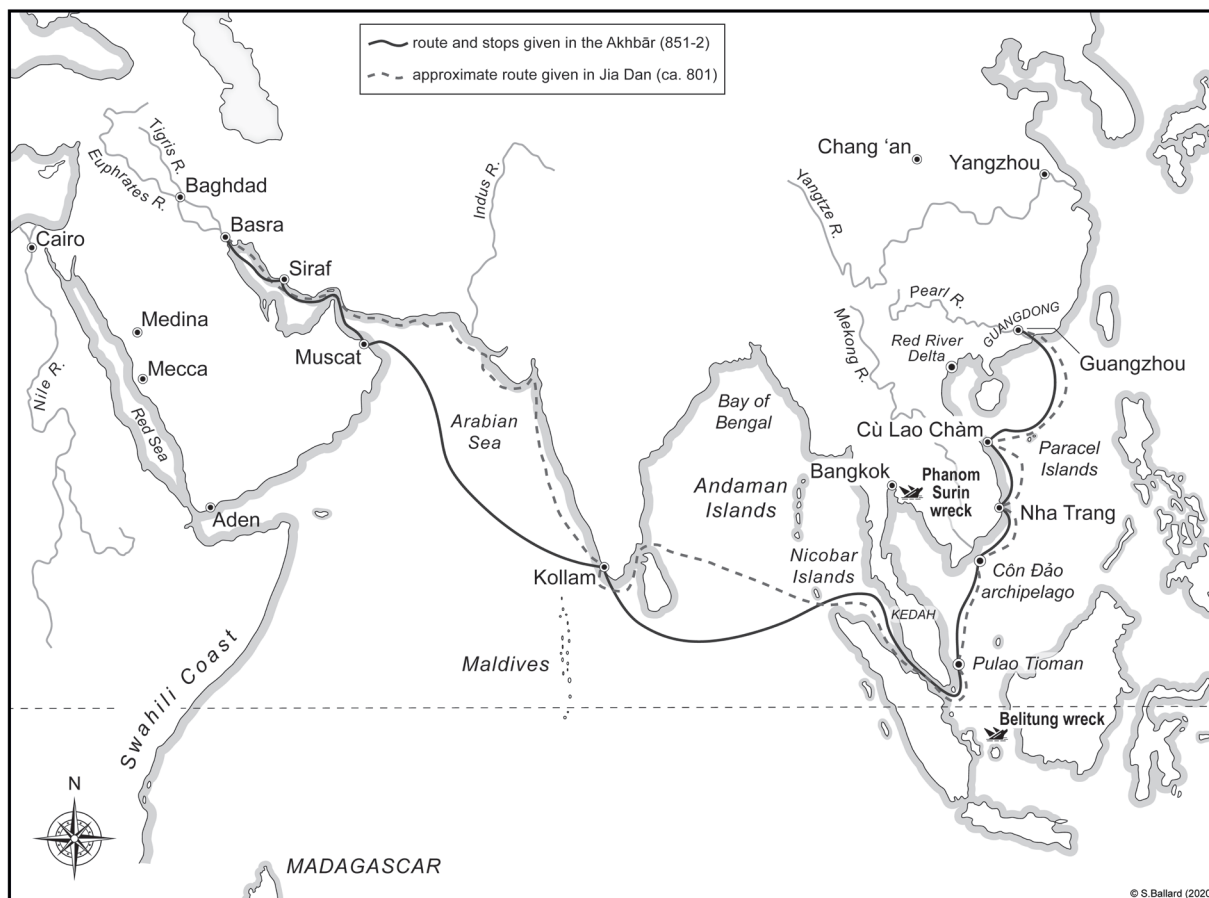
Dehydration was certainly a more present danger than were storm or shipwreck, the maritime calamities at the forefront of literary and documentary sources and therefore more often a subject of scholarly discussion. Part of the problem stems undoubtedly from the nature of the sources—provisioning as a whole is rarely discussed or recorded in textual sources before the 1500s, and freshwater is commonly forgotten even within food history—yet logic suggests that knowledge of reliable sources of sweet water played an important part in configuring premodern sailing routes. This silence may be due in part to the fact that water knowledges were part of a larger body of seafaring know-how that existed as embodied skills, learned “on the job” by example and oral communication, rather than through formal written instruction. The one prominent exception is navigation, which, possibly because of its reliance on astronomical and mathematical knowledge, was eventually recorded as a written genre. Whatever the explanation, navigational knowledge was written down in a way that the knowledges I am interested in here were generally not. Yet this key, life-saving know-how was ever present, and occasionally, very occasionally, if we take the time to listen, we can retrieve something of it from the surviving texts. As I hope to show, we can also recover evidence for it in the archaeological record itself if we are prepared to be more water-minded.

### **Water in the Ninth-Century Section of the *Akhbār al-Šīn wa-l-Hind***

The *Akhbār al-Šīn wa-l-Hind*, an Arabic-language merchant manual penned in the mid-ninth century by an anonymous author and subsequently updated in the first half of the tenth century by the merchant Abū Zayd al-Sīrāfi, has often been characterized as a medieval *Periplus*, a reference to the earlier, first-century CE Greek-language merchant manual, the *Periplus Maris Erythrae* (*Periplus of the Erythrean Sea*). Although both texts share a merchant’s interest in trade goods, local demand, and trade practices, the first part of the *Akhbār* distinguishes itself by its systematic inclusion of seafaring knowledge, including water provisioning. These interests also contrast markedly with those of two near-contemporary accounts of the route between China and the Middle East, one a set of itineraries recorded in 801 by the Chinese courtier Jia Dan (d. 805) and known as the *Guangzhou tong hai yi dao* 廣州通海夷道 (*Route to Foreign Countries across the Sea from Guangzhou*), the other the famous snapshot of routes given by the Abbasid government official Ibn Khurradādhbih in his *Kitāb al-Masālik wa-l-mamālik*, or *Book of Roads and Kingdoms*, whose final revision was completed in 885. Much effort has focused on identifying

---

*Journal of Clinical Nutrition* 64, no. 2 (2010): 115–23; C. A. Piantadosi, *The Biology of Human Survival: Life and Death in Extreme Environments* (Oxford: Oxford University Press, 2003), 42.



**Figure 1: The sea route between the Gulf and China in the ninth century as set out in the *Akhbār al-Šīn wa-l-Hind* (ca. 851–52) and in Jia Dan’s *Guangzhou tong hai yi dao* (*Route to Foreign Countries across the Sea from Guangzhou*, ca. 801). (Map by Sebastian Ballard, copyright of the author)**

the various Indian Ocean locations mentioned in each text, but in the present context the most important point is that neither author includes water sources as part of their itinerary. Jia Dan’s itinerary shows the strongest evidence of interaction with seafaring knowledges and focuses very specifically on navigational information such as direction, distance, and key maritime wayfinding points, but it does not note freshwater sources.<sup>5</sup> As one might expect of a land-bound tax official, Ibn Khurradādhbih’s itineraries for the Indian Ocean

5. An English translation is given in the introduction to Hirth and Rockhill’s translation of the *Zhufan zhi* (*Chu-fan-chih*); see Jia Dan 賈耽, *Guangzhou tong hai yi dao* 廣州通海夷道 (*Route to Foreign Countries across the Sea from Guangzhou*), English translation in F. Hirth and W. W. Rockhill (ed. and trans.), *Chau Ju-Kua: His Work on the Chinese and Arab Trade in the Twelfth and Thirteenth Centuries, Entitled Chu-fan-chi* (New York: Paragon, 1966), 9–14. A more recent translation is available in Hsieh Ming-liang, “The Navigational Route of the Belitung Wreck and the Late Tang Ceramic Trade,” in *Shipwrecked: Tang Treasures and Monsoon Winds*, ed. R. Krahl et al., 137–43 (Washington, DC: Arthur M. Sackler Gallery and Singapore: National Heritage Board of Singapore and Singapore Tourism Board, 2010), 137–38.

region generally include distances but focus overwhelmingly on regional customs and trade commodities with little to no navigational information and certainly no observations about provisioning stops or water sources.<sup>6</sup>

The importance of sweet water in route planning is made abundantly clear in a passage from the first section of the *Akhbār*. Although both sections of the manual reflect mercantile perspectives with observations and advice about local trade practices and customs along the route, readers cannot fail to notice that the first part of the text includes considerably more material on maritime phenomena and wayfinding at sea, as well as a substantial passage devoted to the provisioning points along the route between the head of the Gulf and eastern China. The merchant author reports in detail about the water supplies at particular points along the route (see Fig. 1) and the number of days of sailing between locations.<sup>7</sup> Table 1 summarizes the relevant information on water provisioning in this passage by location.

**Table 1. Watering stops between Siraf and Guangzhou as given in *Akhbār al-Ṣīn wa-l-Hind (Accounts of China and India)* before 851–52 CE**

Location (Arabic)	Modern identification	Information	Sailing distance/time to next stop	Observations
Sīrāf	Siraf, Iran	“They take water on board there ( <i>ist‘adhubū minhā al-mā’</i> ), <sup>8</sup> then they set sail”	To Masqaṭ: 200 <i>farsakhs</i>	
Masqaṭ	Muscat, Oman	“Then we take water on board at Muscat, from a well ( <i>biʿr</i> ) that is there”	To Kūlam Malī: “a month if the wind is constant”/ “about a month”	The estimate of a month is decidedly optimistic, requiring a very constant wind. As discussed below, most times given in the <i>Akhbār</i> should be understood as “best times.”
Kūlam Malī	Kollam, India	“There is also water to be had from wells”; “in Kūlam Malī they take on water”	To Kalāh Bār: “one month”	

6. Abū al-Qāsim Ibn Khurradādhbih, *Kitāb al-Masālik wa-l-mamālik*, Arabic ed. and French trans. C. Barbier de Meynard as “*Le livre des routes et des provinces* par Ibn-Khordadbeh,” *Journal Asiatique*, 6th ser., 5 (1865): 5–296.

7. *Akhbār*, bk. 1, ed. Mackintosh-Smith, 31–35.

8. The author uses the tenth form of the trilateral root *‘adhuba*, meaning “to be sweet, pleasant, agreeable.” In its tenth form the root has the meaning of someone seeking something; *ist‘adhuba mā’* thus implies “to seek out sweet water.”

Kalāh Bār	Isthmus of Kra or Kedah area <sup>9</sup>	“The crews take on water there from sweet wells ( <i>abār</i> ‘ <i>adhba</i> ), and they prefer the water from wells to water from springs and rain”	To Tiyyūma: 10 days	Described as both a country and a coast.
Tiyyūma	Pulao Tioman <sup>10</sup>	“There is sweet water ( <i>mā</i> ’ ‘ <i>adhb</i> ) for anyone wanting it”	To Kandūranj: 10 days	Island off Malaysia’s eastern coast but interestingly not described as an island in the text.
Kandūranj <sup>11</sup>	Côn Sơn island, Côn Đảo archipelago	“There is sweet water ( <i>mā</i> ’ ‘ <i>adhb</i> ) to be had by anyone wanting it” . . . “and this is the case for all the islands of the Indies—whenever wells are dug, sweet water is found in them.”	To Şanf: 10 days	The <i>Akhbār</i> adds that “at Kanduranj is a mountain overlooking the sea, where fugitive slaves and thieves are often to be found.” <sup>12</sup>
Şanf (literally Champa) <sup>13</sup>	Nha Trang? <sup>14</sup>	“There is sweet water there” ( <i>bihā mā</i> ’ ‘ <i>adhb</i> ) “When they have taken on sweet water, they set sail . . .”	To Şanf Fūlāw: 10 days	The <i>Akhbār</i> adds that “it has a king, and the inhabitants are brown-skinned people, each of whom wears two waist wrappers.”
Şanf Fūlāw (Island of the Cham) <sup>15</sup>	Cù Lao Chàm island, opposite Hoi An, Vietnam <sup>16</sup>	“And there is sweet water there”	To Khānfū: “one month” To Abwāb al-Şīn: <sup>17</sup> 7 days	It is “an island out to sea.”
Khānfū	Guangzhou	“Once the ships have [. . .] entered the river, they proceed to take on sweet water at the place in the land of China where they anchor, called Khānfū, which is a city”	Terminus	The author continues: “everywhere in China there is sweet water, from freshwater, rivers, and valleys.”

9. The latest English translation by Tim Mackintosh-Smith skirts a great deal of geographical detail and identification, and I therefore rely on the commentary in Jean Sauvaget’s Arabic edition with French translation of the first part. Sauvaget discusses the difficulty of identifying this locale but argues that it must relate to a site somewhere along the western coast of present-day Malaysia (*Akhbār al-Şīn wa-l-Hind*, Arabic ed. and French trans. J. Sauvaget as *Relation de la Chine et de l’Inde* (Paris: Les Belles Lettres, 1948), 43, n. 15.1). For a determined attempt to solve the problem see S. Q. Fatimi, “In Quest of Kalah,” *Journal of Southeast Asian History* 1, no. 2 (1960): 62-101.

10. Sauvaget discusses various later sources noting Pulao Tioman’s excellent anchorages and sources of water and the visibility of its 1050-meter-high peak (*Akhbār*, ed. Sauvaget, 44, n. 15.5).



11. The identification of this stopping point has been much debated. Sauvaget suggested that Kandūranj is a corruption of Panduranga (*Akhbār*, ed. Sauvaget, 44, n. 15.6), in the ninth century a relatively new independent coastal state; see W. A. Southworth, “The Coastal States of Champa,” in *Southeast Asia: From Prehistory to History*, ed. I. Glover and P. S. Bellwood, 209–33 (London: RoutledgeCurzon, 2004), 226–27. However, the first two syllables, Kan-dūr, suggest that this is in fact Pulo Condor (modern Côn Sơn island), one of the twelve islands that form the Côn Đảo archipelago in the southern China Sea. The archipelago was famous in European wayfinding as “a potential place to refit or even careen, take on water and firewood, or to hire a pilot to navigate to the Mekong River and Cape St-James”; C. M. H. Pham, “A Maritime Cultural Landscape of Cochinchina: The South China Sea, Maritime Routes, Navigation, and Boats in Pre-colonial Central Vietnam” (PhD diss., Murdoch University, 2016), 176. Pham notes that the name derived from the gourds, kundur in Malay, that grew on the island and that the islands offered safe anchorage during both monsoons. As she summarizes, “Pulo Condor was a very conspicuous way point on all the routes from Melaka or the Sunda Straits to China, Manila and Cochinchina, and had to be found before approaching the coast. It was a safe point of arrival and departure for any vessels moving between the south western and northern parts of the South China Sea” (182). Corrupted renderings of this toponym as baḥr Kardanj are used accurately to designate the sea between Kalah and Champa in Aḥmad al-Ya‘qūbī (d. 897), *Ta’rīkh*, English trans. M. S. Gordon et al. as *The History: Adam to Pre-Islamic Arabia in The Works of Ibn Wāḍiḥ al-Ya‘qūbī: An English Translation* (Leiden: Brill, 2018), 2:485, and later in ‘Alī b. al-Ḥusayn al-Mas‘ūdī (d. 956), *Murūj al-dhahab*, Arabic ed. and French trans. C. Barbier de Meynard and A. Pavet De Courteille as *Les prairies d’or* (Paris: Société Asiatique, 1962–79), 1:330. As Sauvaget notes, Paul Pelliot had made the identification with Pulo Condor in his earlier “Deux itinéraires de Chine en Inde à la fin du VIII<sup>e</sup> s.,” *Bulletin de l’École française d’Extrême Orient* 4 (1904) : 131–413, at 216–17. It now seems possible to discount entirely Sauvaget’s suggestion of a corrupt rendering of Panduranga.

12. *Akhbār*, bk.1, ed. Mackintosh-Smith, 33. The account matches later descriptions and drawings of Pulo Condor’s main island, Pulo (also Grande) Condor, whose peak is 549 meters above sea level and thus constituted an important wayfinding marker.

13. Many toponyms around the Indian Ocean found in Islamic sources require a clear understanding of the conventions then existing for the transliteration of local place-names into Arabic. Arabic has no letter “ch,” and sometimes the letter *jīm* was used, but a frequent substitution was the Arabic letter *ṣād*, which was commonly pronounced as a “ch” as in Barūṣ (i.e. Barūch); see R. C. Steiner, *The Affricated Sade in Semitic Languages* (New York: American Academy for Jewish Research, 1982), particularly 75–81 for an exhaustive list of examples in Arabic. Arabic also has no “p” and instead used the letter *fā’*; Ṣanf, therefore, yields Champ.

14. The *Akhbār*’s description of a king and his kingdom indicate that “Ṣanf” must have been a major polity, although William Southworth notes that “a late 8th century stele from Phan Rang uses Campa in a general sense with the name probably denoting the entire coastline of central Vietnam” (Southworth, personal communication, August 7, 2020). Southworth’s history of the coastal states of Champa suggests that in the first half of the ninth century the Red River Delta took on a particular economic importance and “encouraged an entirely different network of supply ports, in particular the port of Nha Trang [to its south], which provided a natural harbour and fresh water for ships sailing from India, Malaya and Java to northern Vietnam” (Southworth, “Coastal States of Champa,” 226). This is the basis of my identification of Ṣanf with Nha Trang. The other possibility is to identify Sanf with the Panduranga heartland of Phan Rang to its south. Sauvaget (*Akhbār*, ed. Sauvaget, 44–45, n. 16.1) does not identify a specific port, whereas Mackintosh-Smith’s map shows the site of Qui Nhon but does not justify the identification (*Akhbār*, bk. 1, ed. Mackintosh-Smith, 20–21).

15. Pūlāw is an Arabic transliteration of the Malay *pulao* or “island”; Ṣanf Fūlāw gives Champ Pulao, literally Island of the Cham. Sauvaget rightly observes that this can only be a reference to the island of that name also known from Chinese sources (*Akhbār*, ed. Sauvaget, 45, n. 16.4). Mackintosh-Smith retains the reading Sandar Fūlāt (*Akhbār*, bk. 1, ed. Mackintosh-Smith, 34, 35) found in the Paris manuscript but does not identify the site. Southworth’s history of the coastal states suggests that the Quang Nam area rose to importance only after the mid-ninth century under a new dynasty (Southworth, “Coastal States of Champa,” 228), which may explain why the *Akhbār* makes no mention of local rulers.

Another passage fills out part of the route between Kollam and the Isthmus of Kra, across the southern end of the Bay of Bengal, noting that if water supplies were running low, ships might stop at the Andaman islands. The author notes: “It sometimes happens that ships make a slow passage and are delayed in their voyage because of unfavourable winds. As a result, the ship’s water runs out, and their crews make for these people’s islands to get water. When this happens, the islanders often catch some of the crew, although most of them get away.”<sup>18</sup>

Thus, the first part of the *Akhbār* gives a rare insight into the wealth of water knowledge active in Indian Ocean voyaging in the ninth century at the peak of direct long-distance sailing between Iraq and China. As al-Sīrāfī comments at the beginning of his update of this part: “I found the date in the book to be the year two hundred and thirty-seven [851–52 CE]—a time when maritime business still ran on an even keel, on account of all the toing and froing overseas by merchants from Iraq.”<sup>19</sup> Ninth-century merchants on the route to China learned from their own voyages not only *where* water was commonly provisioned but also *which* types of freshwater—wells, springs, rainwater tanks, or indeed underwater springs—were best in locations with multiple options. The *Akhbār*’s rather oblique final observation that at Khānfū, “once the ships have [. . .] entered the river, they proceed to take on sweet water at the place in the land of China where they anchor” is elucidated by a twelfth-century Chinese source, Zhu Yu’s 1119 *Pingzhou ketan* 萍州可談 (*Pingzhou Table Talk*), which gives very precise instructions for locating underwater springs in the estuary of the Zhujiang or Pearl River:

The pavillion of the Inspector of Foreign Trade (*shibo*) of Guangzhou is close to the waterside facing the Five Islands. Below this, the river is called the “Little Sea.” In midstream for some ten feet or so the merchant-ships take on water for use on

---

16. Southworth notes that “large sherds of Islamic pottery from the ninth and tenth centuries have recently been found at Bai Lan on the Cu Lao Cham islands near the Thu Bon River estuary” (“Coastal States of Champa,” 228).

17. Literally “the Gates of China.” Sauvaget identifies these as the Paracel Islands and the Macclesfield Bank (*Akhbār*, ed. Sauvaget, 46, n. 16.6.). However, this identification has major implications for our understanding of ninth-century navigation and seamanship. The Paracels are a large area of very low shoals and reefs, barely visible above the sea and exceptionally dangerous to navigate, particularly at night. Most known routes avoid this area, hugging the coast of modern-day Vietnam and grazing the southern tip of Hainan Island to reach the main eastern Chinese ports. European ships began to use the Paracel Islands route only in the nineteenth century. For a detailed discussion and bibliography, see C. M. H. Pham, “European Navigation, Nautical Instructions and Charts of the Cochinchinese Coast (16th–19th Centuries),” *Moussons* 27 (2016): 101–29. There is no place here to discuss this identification further, but were the use of the Paracel Islands route confirmed for the ninth century, it would illustrate both the navigational acuity and the speed-focused nature of Arab sailing in this area. On the other hand, the term *bāb* suggests a passage between two fixed points or obstacles, and one might surmise that the term described a passage between the Paracels and Hainan Island.

18. *Akhbār*, bk. 1, ed. Mackintosh-Smith, 27.

19. *Akhbār al-Šin wa-l-Hind*, bk. 2, Arabic ed. and English trans. T. Mackintosh-Smith as *Accounts of China and India: The Second Book*, in *Two Arabic Travel Books*, ed. P. F. Kennedy and S. M. Toorawa, 67–133 (New York: New York University Press, 2014), 67.



their voyages; this water does not spoil, but water from outside this limit, and all ordinary well-water, cannot be stored [on board ship], for after a time it breeds worms. What the principle is underlying this I do not know.<sup>20</sup>

Zhu Yu's father had been a high-ranking official at Guangzhou, and Zhu Yu's text includes substantial material evidently transmitted from him. The underwater springs in the Pearl River at Guangzhou thus represent the final stage of the *Akḥbār's* sweet water-focused itinerary.

The *Akḥbār's* itinerary combines major trade hubs with stopping places where provisioning alone justified the stop. Places such as Guangzhou, one of Tang China's principal ports, and Kollam, the major Cera port in what is now Kerala, were both major trade hubs and provisioning stops. By contrast, Pulao Tioman, Pulo Condor, and the "Island of the Cham" seem to have been above all provisioning stops, valuable for their freshwater, timber, and other natural resources.

Prominent in the *Akḥbār* is the author's careful attention to journey times, given for the most part not in terms of distance but as days at sea. The time at sea mattered not only for timing one's arrival in China or other ports but above all for provisioning daily rations appropriately. The author's observation that the journey from Muscat to Kollam took a month "with a constant wind" is significant, a reminder to crews and travelers that they might wish to factor in delays and detours since winds were not always constant. A comparison with crossing times between Oman and southern Kerala known from other accounts and recent experimental archaeology in fact indicates far longer journey times in practice. In the fourteenth century, the Moroccan traveler Ibn Baṭṭūṭa described a crossing from Calicut to Dhofar as having taken twenty-eight days, apparently confirming the *Akḥbār's* information.<sup>21</sup> However, maritime archaeologist Eric Staples, who in 2010 sailed on the dhow replica *Jewel of Muscat* to southern Kerala, points out that this time was probably noted because of its exceptional speed; five to six weeks was probably more realistic, and crossings could take significantly longer than that.<sup>22</sup> We should thus read this journey time, and the others given in the *Akḥbār*, as a "best time" only, a baseline for the calculation of provisions.

---

20. Torck, *Avoiding the Dire Straits*, 215, nn. 769, 770; English translation after Joseph Needham, *Science and Civilization in China* (Cambridge: Cambridge University Press, 1971), 4(3):462. For the Chinese original, Torck cites Zhu Yu 朱彧, *Pingzhou ketan* 萍州可談 (*Pingzhou Table Talk*), in *Shoushan'ge congshu* 守山閣叢書 (*Collections of the Shoushan Pagoda*) (Taipei: Yiwen, 1968), 147(II):1b, 9–7. Variant translation also in Hirth and Rockhill's introduction to *Chau Ju-Kua*, 29–30. Whereas Torck (*Avoiding the Dire Straits*, 215) speculates, after Needham, that a certain brackishness helped preserve water from insect larvae, the more likely explanation is that this practice exploited known undersea springs producing exceptionally clean water. Other locations of undersea fresh springs are known in China (see Hirth and Rockhill, *Chau Ju-Kua*, 30, n. 1), in Sumatra, and of course in Bahrain in the Gulf.

21. Abū 'Abd Allāh Muḥammad Ibn Baṭṭūṭa, *Rihla*, Arabic ed. and French trans. C. Defrémery and B. R. Sanguinetti as *Voyages d'Ibn Battûta* (Paris: Anthropos, 1969), 2:196.

22. Eric Staples, personal communication, May 29, 2017.

The *Akḥbār*'s routing gives every impression of a ship and passengers in a hurry to reach China. There is a marked contrast between the *Akḥbār*'s route, with its altogether limited stops, and that recorded by Jia Dan, which includes much more coastal sailing and stops, not only along the western Indian seaboard but also throughout the South East Asian and Gulf of Tonking sections of the route (Fig. 1).<sup>23</sup> By following the Chinese coast down past Hainan Island and by coasting along the western Indian seaboard to the mouth of the Gulf, Jia Dan's route eliminates two of the three monthlong legs proposed by the *Akḥbār*. The passage between the Andamans and Sri Lanka is the longest open-ocean section of Jia Dan's route, but even it, too, is considerably shorter than the corresponding segment in the *Akḥbār* because it goes north around Sri Lanka rather than rounding the island to the south and heading directly for Kollam.

George Hourani has hypothesized that the entire journey from the head of the Gulf to eastern China, with stops, took six months or perhaps slightly more, an exceptionally fast journey compared to the overland options.<sup>24</sup> Although the *Akḥbār* gives no sailing dates, Hourani suggests that ships would have traversed the Gulf in September or October to pick up the Northeast monsoon winds between Muscat and Kollam in November–December. However, as the experimental voyage of the *Jewel of Muscat* indicates, a ship might leave Muscat as late as February and still reach the southern parts of the Straits of Malacca by June. There, ships heading for China would take advantage of the Southwest monsoon, which begins in May–June. As Pham discusses in her study of sailing along the Cochinchina coast, “ships on longer trips, sailing to China or Japan would attempt to sail beyond Cochinchina as early in the SW monsoon as possible, in order to take full advantage of the winds and currents until they reached their farther destination.”<sup>25</sup> As to why the *Akḥbār* includes so many ten-day legs between Tioman Island and its ultimate destination of Guangzhou, one answer may be the need for local pilots. As Pham observes,

the particularity of navigation in Vietnam is that it was also subject to local conditions, to a combination of tides, local winds and currents. In some places, the local sea and land breezes could overpower the prevailing monsoon winds along the coast, with sufficient force to sometimes reverse the general monsoon trend [. . .]. They occur with more strength during the SW monsoon and the transitional months.<sup>26</sup>

At least in the early modern period, Pulo Condor was a known stop at which to take on local pilots for the difficult onward journey around the Vietnamese coast.<sup>27</sup> More frequent

---

23. See fig. 1 in Hsieh Ming-liang, “The Navigational Route of the Belitung Wreck and Late Tang Ceramic Trade,” in *The Belitung Wreck: Sunken Treasures from Tang China*, 76–91 (n.p.: Seabed Explorations Ltd. New Zealand, 2004), 78, available at [https://www.iseas.edu.sg/wp-content/uploads/2016/05/04\\_hsieh1\\_074to091.pdf](https://www.iseas.edu.sg/wp-content/uploads/2016/05/04_hsieh1_074to091.pdf).

24. G. F. Hourani, *Arab Seafaring in the Indian Ocean in Ancient and Early Medieval Times*, 2nd ed., ed. J. Carswell (Princeton, NJ: Princeton University Press, 1995), 74–75.

25. Pham, “Maritime Cultural Landscape of Cochinchina,” 138.

26. *Ibid.*, 140.

27. See note 11 above.

stops may have allowed ships to take on the best pilots for each stretch of coast; in addition, lighter vessels—lighter because they carried less water between stops—may have been more maneuverable in what could rapidly become challenging sailing conditions.

### Control of Water: Authorship and Sources of the First Part of the *Akhbār*

The first section of the *Akhbār* stands out as a rare surviving written depository of travel knowledge more usually passed orally between seafarers, merchants, and travelers along the long and challenging route to China. This unique feature raises the question who authored the first section of the *Akhbār*, or at least what the author's background was. Was the anonymous author simply a merchant anxious about his water supplies? Or was he perhaps both merchant and captain (it was not uncommon for captains and crew to trade in their own right) or a merchant shipowner who was thus more acutely aware than most of the importance of water provisioning at sea? Certainly by the twelfth century the distribution of water on board vessels sailing out of the Arabian Peninsula appears to have been formally regulated. The *Muṣannaf* is a legal compendium written by the Omani Ibādī jurist Abū Bakr Aḥmad b. ʿAbd Allāh al-Kindī in the twelfth century, and it gives very detailed rulings about all manner of issues related to life at sea, such as the rights to flying fish (a valuable additional protein source) when such fish fell on deck, the need to obtain the captain's permission to hang up one's washing, or the permissibility of using seawater for ablutions. In the present context it is interesting to note al-Kindī's statement that the shipboard supply of freshwater belongs collectively to all travelers, and its distribution is managed by an appointed *ṣāhib al-māʾ*, broadly translatable as "master" or "controller" of the water.<sup>28</sup> Whether the *ṣāhib al-māʾ* was the captain, a crew member, or one of the travelers is not made clear. However, this reference does indicate a centralized system of freshwater rationing. The earlier history of the system is not known, although it seems clear that some form of regulation of the water supply would have been essential on any voyage of more than a day. The system is, however, well attested in later sources. The late sixteenth-century Mughal administrative manual *Āʾīn-i Akbarī* (*Administration of Akbar*) lists among the titles and duties of crew on a large ocean-going ship the *karrānī*, or clerk who kept the accounts and served out water to passengers.<sup>29</sup> In the later, seventeenth-century *Anīs al-ḥujjāj* (*A Pilgrim's Companion*), which belonged to a new genre of pilgrimage accounts, the author, the Indian mullah Ṣafī al-Dīn, alludes in passing to the fact that on the passage between Surat and Jedda drinking water from the ship's tank was rationed out to passengers, though we are not told by whom.<sup>30</sup> Although we

28. Abū Bakr Aḥmad b. ʿAbd Allāh b. Mūsā al-Kindī, *al-Muṣannaf* (Muscat: Wizārat al-Turāth al-Qawmī wa-l-Thaqāfa, 1403/1983), 18:57, 58.

29. Abū al-Faḍl ʿAllāmī, *Āʾīn-i Akbarī*, English trans. H. Blochmann, ed. D. C. Phillott as *The Āʾīn-i Akbarī: A Gazetteer and Administrative Manual of Akbar's Empire and Past History of India* (Kolkata: Asiatic Society, 2010), 1:290.

30. Cited in J. A. Qaisar, "From Port to Port: Life on Indian Ships in the Sixteenth and Seventeenth Centuries," in *India and the Indian Ocean 1500–1800*, ed. A. Das Gupta and M. N. Pearson, 331–49 (Oxford: Oxford University Press, 1987), 336. The *Anīs al-ḥujjāj* still awaits a definitive translation.

cannot assert that the author of the earliest part of the *Akhbār* had himself served as *ṣāhib al-māʾ*, he or one of his informants certainly possessed detailed knowledge of water sources and the sailing times between provisioning stops and was concerned with transmitting this information. However the information was obtained, whether through personal experience or through conversations with other merchants or captains, the author of the first section of the *Akhbār* has left us a precious snapshot of watering points along the route from the Gulf to China in the first half of the ninth century, and above all an important reminder of the critical importance of water as observed by Xu Jing.

### Quantifying Water Consumption

The passage from the *Akhbār* outlined in Table 1 begs the question how much water passengers and crew consumed daily and what proportion of a ship's lading capacity was ultimately taken up with freshwater.

It is notoriously difficult to give averages for human water consumption since it depends so heavily on body size, levels of activity, and environment. The United States' Institute of Medicine estimates a healthy modern average at 3.7 liters of water daily for men and 2.7 liters for women.<sup>31</sup> The physiologist Claude Piantadosi suggests that just over a liter per day might represent the absolute minimum, although he notes that "this value is not particularly realistic, because it means one cannot sweat a drop, exercise a whit, or have a loose bowel movement without risking dehydration."<sup>32</sup> Precise water rations are rarely mentioned in medieval sources. However, John Pryor and Elizabeth Jeffreys cite the 1318 *Informationes pro Passagio Trasmarino* of Marseilles, which allocates each passenger the equivalent of 4 liters of water per day,<sup>33</sup> very close in fact to the 3.7 liters for men estimated by the Institute of Medicine.<sup>34</sup> Consumption could, however, be considerably higher in high temperatures and especially when carrying out demanding physical activity such as raising and lowering sails. In the absence of data specific to tropical maritime conditions, some useful estimates are available for desert conditions. Work on Roman settlements in Egypt's Eastern Desert suggests that adults living there would have consumed between 4 and 6 liters per day in the summer,<sup>35</sup> with surviving documentary data for a quarry site indicating wintertime daily water rations ranging between 2 and 6.5 liters.<sup>36</sup> Whether one,

31. Institute of Medicine of the National Academies, *Water, Dietary Reference Intakes for Water, Sodium, Chloride, Potassium and Sulfate* (Washington, DC: National Academy Press, 2005), 73–185; recommendation repeated in M. Sawka, S. Chevront, and R. Carter III, "Human Water Needs," *Nutrition Reviews* 63, no. 6 (2005): 30–39.

32. See Piantadosi, *Biology of Human Survival*, 45.

33. Pryor and Jeffreys, *Age of the Dromon*, 356–71.

34. For Roman data, see D. Engels, *Alexander the Great and the Logistics of the Macedonian Army* (Berkeley: University of California Press, 1978); M. Junkelmann, *Panis Militaris* (Mainz am Rhein: Philipp von Zabern, 1997); and J. Roth, *The Logistics of the Roman Army at War* (Leiden: Brill, 1999).

35. S. Sidebotham, *Berenike and the Ancient Maritime Spice Route* (Berkeley: University of California Press, 2011), 12; R. Zitterkopf and S. Sidebotham. "Stations and Towers on the Quseir-Nile Road," *Journal of Egyptian Archaeology* 75 (1989): 155–89, at 164.

36. H. Cuvigny, "L'organigramme du personnel d'une carrière impériale d'après un ostracon du Mons

four, or six liters, it should be evident that ships on longer journeys would have had to carry substantial volumes of water.

Recent maritime archaeology and experimental reconstructions of historic vessels from shipwreck remains allow us to produce some tighter figures for the period in which the *Akḥbār* was authored. The last two or three decades have seen an explosion of maritime archaeology in East Asian waters. The so-called Belitung wreck is the remains of a sewn-plank vessel from the first quarter of the ninth century recovered in the Java Sea off the island of Belitung.<sup>37</sup> The sewn-plank technique is characteristic of ships built in the Arabian Peninsula and the western Indian Ocean and marks them as quite distinct, technologically, from the products of the lash-lugged technique used in Southeast Asia. Not only did the discovery of the Belitung wreck and its cargo bring new evidence to the discussion of direct sailings between the western and eastern sectors of the Indian Ocean as mentioned in the *Akḥbār* and other sources; it also provided some of the first historical data on ship dimensions. The Belitung ship is estimated to have been between eighteen and twenty-two meters long.<sup>38</sup> It carried a cargo of Chinese ceramics weighing around twenty-five tons, meaning that its total capacity must have been greater than this in order to allow for passengers, luggage, and provisions.<sup>39</sup>

In 2013 another sewn-plank vessel was identified in what is now a shrimp farm in Samut Sakhon province, located some eight kilometers inland from the modern-day coast of the Gulf of Thailand. The so-called Phanom Surin wreck is different from the Belitung in many regards. For example, preliminary analysis of its timbers suggests that it may have been constructed in maritime Southeast Asia. Its location at the head of the Gulf of Thailand is well off the main long-distance routes discussed in the *Akḥbār*, and its cargo also suggests that it was involved in regional rather than transregional trade circuits. Nevertheless, this sewn-plank vessel in the western Indian Ocean tradition confirms the general dimensions of the Belitung ship, and it also carried some West Asian ceramics. The wreck has benefited from excellent anaerobic preservation as well as professional academic excavation.

---

Claudianus,” *Chiron* 35 (2005): 309–53, at 348–50.

37. The most comprehensive and accessible studies of the wreck are the 2010 exhibition catalog and the earlier 2004 private report compiled by Seabed Explorations Ltd., the New Zealand-based company that salvaged the wreck. See R. Krahl et al., *Shipwrecked: Tang Treasures and Monsoon Winds* (Washington, DC: Arthur M. Sackler Gallery and Singapore: National Heritage Board of Singapore and Singapore Tourism Board, 2010), available at <https://asia.si.edu/research/exhibition-catalogues/shipwrecked-catalog/>; and *The Belitung Wreck: Sunken Treasures from Tang China* (n.p.: Seabed Explorations Ltd. New Zealand, 2004), available at <https://www.iseas.edu.sg/centres/nalanda-sriwijaya-centre/research-tools/compilations/the-belitung-wreck-sunken-treasures-from-tang-china/>. Research continues on the wreck at both macro and micro levels; see G. Heng, “An Ordinary Ship and Its Stories of Early Globalism: World Travel, Mass Production, and Art in the Global Middle Ages,” *Journal of Medieval Worlds* 1, no. 1 (2019): 11–54. The interpretation of the vessel remains controversial; see S. G. Haw, “The Genus *Afzelia* and the Belitung Ship,” *Journal of the Royal Asiatic Society* 29, no. 3 (2019): 505–18. Haw proposes that the ship’s wadding displays greater affinity with ship construction techniques in Sri Lanka and the Bay of Bengal area.

38. Given in M. Flecker, “A Ninth-Century Arab or Indian Shipwreck in Indonesia,” in *Belitung Wreck*, 4–39, at 18, available at [https://www.iseas.edu.sg/wp-content/uploads/2016/05/01\\_flecker\\_002t0039.pdf](https://www.iseas.edu.sg/wp-content/uploads/2016/05/01_flecker_002t0039.pdf).

39. *Ibid.*, 22.



Traces of rattan matting as well as cordage have allowed it to be dated to between 720 and 775 CE, with a most likely date in the third quarter of the eighth century.<sup>40</sup> The Phanom Surin wreck is still being studied and its route is being analyzed. However, the measurements of this superbly preserved ship are clear: it was around twenty-eight meters long with two seventeen-meter masts and an estimated cargo capacity around twenty-five metric tons.<sup>41</sup>

Experimental archaeology has been extremely important in allowing us to understand the handling of these vessels and their crewing needs. In 2009 a scale reconstruction of the Belitung ship was built in Oman as an exercise in experimental archaeology. Named the *Jewel of Muscat*, the ship was eighteen rather than twenty-two meters long, but it still took eight crew members just to manage the main sail, and a total of seventeen, including the captain, to sail the ship. The Belitung/*Jewel of Muscat* experiment gives us one figure for the possible crew numbers on board such vessels in the eighth and ninth centuries, and thus their water needs. Seventeen crew members on a fast, monthlong crossing between Muscat and Kollam, drinking only four liters of water a day each, would have needed to load some 1,900 liters or close to two metric tons of water for their journey. Adjusting for a more realistic crossing time of six weeks brings that figure close to three metric tons for crew alone, over 10% of the ship's cargo capacity, and that is before taking into account food provisions or the water and food required for passengers. It is no surprise that islands such as the Nicobars and Pulau Tioman in the eastern sector of the Indian Ocean or the Maldives, the Laccadives, and Socotra in the western sector took on such important roles as watering stops. The shorter the distance between supplies of freshwater, and indeed food provisions, the less cargo space was "wasted" in carrying them.

### Technologies of Water Containment

The Belitung and Phanom Surin wrecks also supply important material evidence of water storage technologies on board the sewn-plank vessels of the period. My research has previously highlighted the importance of onboard water tanks, often known in Arabic as *finṭās*, in western Indian Ocean ships. Figure 2 shows an example preserved in the United Arab Emirates; though dating from the nineteenth century, it represents the endpoint of a long evolutionary history in the western Indian Ocean going back to at least the eleventh century CE.<sup>42</sup> Inbuilt water tanks appear to have been a widely used technology of containment, probably because they offered a weight-to-capacity ratio—that is, the ratio between the weight of the empty container (in this case the tank) and its capacity—that was far more efficient than that of the possible alternatives such as amphorae, jars or

---

40. Dates obtained through AMS (Accelerator Mass Spectrometry) and given in J. Connan et al., "Geochemical Analysis of Bitumen from West Asian Torpedo Jars from the c. 8th Century Phanom-Surin Shipwreck in Thailand," *Journal of Archaeological Science* 117 (2020): 1–18, at 1, n. 1. However, many publications continue to date this wreck to the ninth century.

41. P. Jumprom, "The Phanom-Surin Shipwreck: New Discovery of an Arab-Style Shipwreck in Central Thailand," *Southeast Asian Ceramics Museum Newsletter* 8, no. 1 (2014): 1–4.

42. See the discussion in E. Lambourn, *Abraham's Luggage: A Social Life of Things in the Medieval Indian Ocean World* (Cambridge: Cambridge University Press, 2018), 170–71. The term occurs in a twelfth-century *fiqh* collection from Oman; see al-Kindī, *al-Muṣannaf*, 18:57.

waterskins. As the French merchant Pyrard de Laval noted in the early seventeenth century in a comparison of inbuilt water tanks with European barrels, tanks were “able to hold much more water than our barrels (*pipes*), and do not take up as much space.”<sup>43</sup> Tanks have been attested in the Mediterranean from Roman times and continued to be used in Byzantine ships.<sup>44</sup> However, storage of large quantities of water in a single tank left the whole supply vulnerable; the water might become contaminated, a leak might develop, or the ship might be damaged and the entire supply become compromised. By contrast, single containers provided better odds that in the case of a disaster some containers would remain intact.



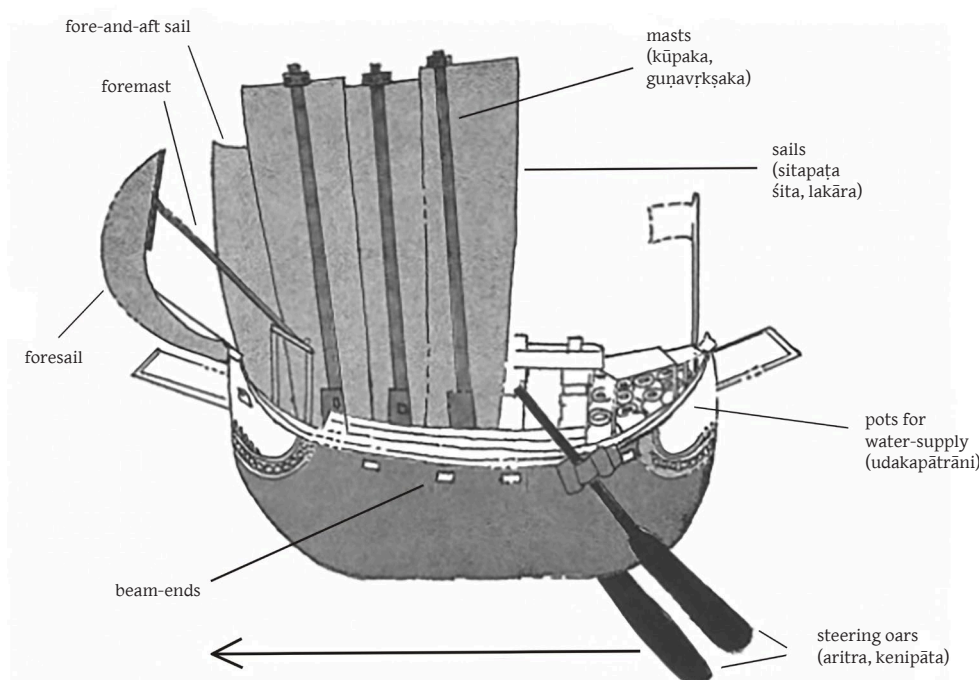
**Figure 2: A traditional Arabian ship’s tank (*fintās*), wood and iron, capacity unknown. Probably nineteenth century, Dubai Museum (Al Fahidi Fort), United Arab Emirates. (Photograph by Bjoertvedt, CC BY-SA)**

Another disadvantage of inbuilt tanks was that they required at least partial decking in order to be integrated into ships’ hulls. We know that many vessels built in the western Indian Ocean, even those used for open-ocean crossings over long distances, were undecked and continued to be constructed this way into the fifteenth century. There was little

43. My translation of F. Pyrard de Laval, *Voyage*, ed. and comm. Xavier de Castro as *Voyage de Pyrard de Laval aux Indes Orientales (1601–1611)* (Paris: Chandeigne, 1998), 1:244.

44. See Pryor and Jeffreys, *Age of the Dromon*, 363–68.

surprise, then, when the remains of neither the Belitung nor the Phanom Surin ship showed any evidence of decking. In undecked ships such as these, cargo and provisions would have been loaded directly into their holds, covered with leather or vegetal fiber matting, and passengers would have traveled on top of their goods. Aboard such undecked vessels water supplies can only have been carried in waterskins or in large storage jars, the larger of which appear to have been loaded at the stern. A number of such jars are depicted in the stern of a ship represented in a fifth-century mural painting from the site of Ajanta in Maharashtra, India (Fig. 3),<sup>45</sup> and they continue to feature prominently in depictions of ocean-going vessels into the Mughal period.



**Figure 3: Schlingloff's interpretation of the Ajanta ship image with storage vessels identified as water jars. (From Schlingloff, "Kalyānakārin's Adventures"; reproduced with permission)**

Both the Belitung and Phanom Surin wrecks yielded numerous large storage jars, which present important new material and ideas for the study of water storage technologies. Study of the Belitung material is complicated by the fact that its principal cargo consisted of Chinese ceramics—more than 50,000 items in all—and among them were large Chinese storage jars that had been used as transport containers for cargo, including smaller, more valuable ceramic pieces, star anise, and lead ingots, and were probably also trade

45. D. Schlingloff, "Kalyānakārin's Adventures: The Identification of an Ajanta Painting," *Artibus Asiae* 3, no. 1 (1976): 5–28, at 22, n. 46.



commodities in their own right. Distinguishing commercial transport containers from containers for freshwater storage is often impossible, although it can be helped by analysis of the location of finds within a wreck, since large storage vessels located near the stern are more likely to have been used for provisions. However, merchants on board may well have also carried their own water jars, leaving a scatter of personal vessels across the wreck. Scrambling the evidence further is the fact that the Belitung excavations were commercially led and focused on the recovery of complete vessels for sale on the art market. Sherds were not recovered, and the excavations thus produced an entirely skewed picture of the ship's noncommercial ceramic assemblage.

The older wreck at Phanom Surin offers better data since its principal cargo was not trade ceramics. Of primary interest here are some 431 sherds of a vessel type known as a torpedo jar, which were recently the subject of detailed scientific analysis by a team led by Jacques Connan.<sup>46</sup> Reproduction of material from the Phanom Surin wreck remains tightly controlled, but Figure 4 shows a vessel of the same type and comparable dimensions excavated from the Belitung wreck. Sometimes confused in their earlier forms with Mediterranean amphorae, torpedo jars with their distinctive bulbous bodies and pointed bases are now recognized as distinct products of kilns in central Iraq and southern Iran. Their production spans the fourth to ninth centuries, in effect extending into the early Islamic period.<sup>47</sup> Torpedo jars are currently believed to have been central to the wine trade between southern Iraq and Iran and western and northern India between the first and ninth centuries CE. The pointed base of the torpedo jar, like the bases of Classical amphorae, is designed to enable the tightest possible stacking of jars within any space, notably a ship's hold.

Yet although they are relatively widely distributed around the Indian Ocean, as Connan and his team observe, “unlike Roman amphorae, we still know comparatively little about torpedo jars in terms of their chronological development, provenance and function.”<sup>48</sup> Research to date has focused overwhelmingly on vessel typology and the identification of diagnostic features to prove that these jars constitute a distinct vessel family. Scientific analysis has helped distinguish different clay bodies and thus approximate centers of manufacture, though no torpedo jar-producing kilns have yet been identified.

---

46. Connan et al., “Geochemical Analysis of Bitumen,” reassembled jar illustrated in fig. 3 (top left); see also J. Guy, “The Phanom Surin Shipwreck, a Pahlavi Inscription, and Their Significance for the History of Early Lower Central Thailand,” *Journal of the Siam Society* 105 (2017): 179–96, at 186, figs. 9 and 10.

47. R. Tomber, “Rome and Mesopotamia: Importers into India in the First Millennium AD,” *Antiquity* 81, no. 314 (2007): 972–88; Connan et al., “Geochemical Analysis of Bitumen”; and R. Tomber, M. Spataro, and S. Priestman, “Early Islamic Torpedo Jars from Siraf: Scientific Analyses of the Clay Fabric and Source of Indian Ocean Transport Containers,” *Iran* (2020): 1–24, published online: <https://doi.org/10.1080/05786967.2020.1792797>, for further bibliography. For further details of the typology, see S. M. M. Priestman, “A Quantitative Archaeological Analysis of Ceramic Exchange in the Persian Gulf and Western Indian Ocean, AD c.400–1275” (PhD thesis, University of Southampton, 2013), now published as idem, *Ceramic Exchange and the Indian Ocean Economy (AD 400–1275)*, Research Publication 223 (London: British Museum Press, 2021), available at [https://doi.org/10.48582/ceramicexchange\\_vol1](https://doi.org/10.48582/ceramicexchange_vol1) and [https://doi.org/10.48582/ceramicexchange\\_vol2](https://doi.org/10.48582/ceramicexchange_vol2).

48. Connan et al., “Geochemical Analysis of Bitumen,” 1.

Analysis of the bitumen used to render the interior of these earthenware jars impermeable has confirmed their manufacture across southern Iraq and Iran.



**Figure 4: Unglazed earthenware transport container, a so-called torpedo jar, from the Belitung wreck. Manufactured in central Iraq or southern Iran, recovered from a wreck of the first quarter of the ninth century. Height: 113 cm. (From Belitung Wreck, cat. no. 294)**



Connan and his coauthors estimate that the sherds recovered from the Phanom Surin belonged to around six torpedo jars, each around one meter tall. In a particularly exciting and innovative development for Indian Ocean ceramic studies, Connan and his team had the capacity of one torpedo jar estimated using 3D computer modeling.<sup>49</sup> The estimated 193-liter capacity represents the total capacity of the vessel, that is, its capacity when filled to the rim.<sup>50</sup> Its effective capacity—up to the level to which we understand the jar would actually have been filled—was not estimated. Nonetheless, this is, to my knowledge, the first estimate of the capacity of an early medieval torpedo jar. In contrast to the field of Mediterranean amphora studies, where calculations of total and effective capacity, tare (the weight of a container when empty), and weight-to-capacity ratios are commonplace, studies of containers from the Gulf area have not adopted these criteria. Although it is only a single measurement and poses more questions than answers, as discussed below, Connan's estimate is extremely important. In shape and size these later torpedo jars differ markedly from earlier and much smaller "ovoid" jars, which generally have a capacity of between twenty-five and thirty-five liters; this, as Caroline Durand notes, "more or less corresponds to the content of Mediterranean amphorae."<sup>51</sup> We do not know whether the dimensions estimated by Connan and his coauthors were a standard size for the period, but the torpedo jars from the Phanom Surin, at a little over one meter high, compare well with the single torpedo jar recovered from the Belitung wreck, which is 113 cm in height (Fig. 4).<sup>52</sup>

Torpedo jars are thought to have been primarily commercial transport jars, associated, in particular, with the transport of wine. Like Classical amphorae, however, they enjoyed long lives of reuse, and it seems certain that the torpedo jars recovered from the Phanom Surin and Belitung wrecks had long since been emptied of their primary cargo and repurposed. Some may have carried provisions, and Connan and his coauthors note that the interior of one torpedo jar sherd had a grain of rice embedded in it while another bore traces of a fibrous organic material.<sup>53</sup> Rice was certainly cultivated at the head of the Gulf from an early period, and the inclusion of rice in the vessels may have occurred there quite accidentally, though it may also point to a later use of the jar to transport rice.<sup>54</sup> Rice was an important staple carbohydrate and widely traded around South and South East Asia, and it had also become a shipboard staple. Analysis of the rice grain and the unidentified fibrous organic material may be able to shed further light on their origins. Meanwhile, Connan's team also suggest that the comparatively small number of torpedo jars within the wreck assemblage make it possible that at least some had been reused for onboard water storage. Some form

---

49. *Ibid.*, 3.

50. Jacques Connan, personal communication, June 1, 2020.

51. C. Durand, "From 'Ovoid Jars' to 'Torpedo Jars': Investigations into Bitumen-Lined Transport Containers in the Gulf and the Indian Ocean in Antiquity (Second Century BCE–Third Century CE)," *Arabian Archaeology and Epigraphy* 32, no. 1 (2021): 21–32, at 27.

52. *Belitung Wreck*, 646–47 (cat. no. 294).

53. *Ibid.*

54. Durand, in "From 'Ovoid Jars' to 'Torpedo Jars,'" 27, notes the use of cultivated rice chaff to temper the clay of some earlier vessel types, but this practice does not appear with later types.

of freshwater storage would undoubtedly have been needed on board the Phanom Surin ship, and in an undecked vessel without inbuilt tanks these six watertight torpedo jars make convincing candidates. Torpedo jars were ideally suited to the long-term storage of liquids, and their pointed bases were designed to fit snugly between other jars or between the bales that constituted an important form of commercial containment.<sup>55</sup> Particularly on undecked vessels with no flat decks upon which to rest flat-bottomed jars, this base form offered distinct advantages.

The estimate of the capacity of the torpedo jar from the Phanom Surin wreck and its similarity to the jar recovered from the Belitung wreck allow us to guess at the number of days of water supply that a single torpedo jar may have supplied. Assuming an effective capacity of 180 liters to allow for some headroom at the top of the container, each jar would have held forty-five four-litre rations of water. Assuming further that torpedo jars were produced to standard sizes, as was common for most commercial containers, six jars, each carrying 180 liters of water, would have provided the ship with something like 1,080 liters of sweet water, equivalent to 270 daily rations of four liters. Dividing these amounts over the journey times cited in the *Akḥbār* indicates that six torpedo jars would have carried enough freshwater to keep twenty-seven passengers and crew well hydrated on a ten-day journey, or around ten people on a twenty-eight-day journey. The latter scenario can probably be discounted as the *Jewel of Muscat* required, as we have seen, a crew of seventeen to sail her. However, the first scenario, of a fully crewed ship carrying ten passengers on a ten-day journey, each drinking four liters a day, is more realistic. As the author of the *Akḥbār* notes, sweet water was abundant in maritime Southeast Asia: “there is sweet water (*māʾ adhb*) to be had by anyone wanting it and this is the case for all the islands of the Indies—whenever wells are dug, sweet water is found in them.”<sup>56</sup>

This hypothetical model—and hypothetical it remains until more torpedo jar capacities are measured—is helpful in making the point that a ship on one of the monthlong crossings discussed in the *Akḥbār* would have needed to provision with substantially more water than this. The seventeen crew members needed to sail the *Jewel of Muscat* reconstruction of the Belitung ship, each drinking only four liters a day, would have needed to load some 1,900 liters of freshwater, or almost exactly ten torpedo jars, for one of these crossings. Since a ship sailing with only seventeen crew members and no passengers represents an unlikely scenario, a more realistic but still conservative model would be a ship carrying a total of thirty crew members and passengers. Even if we still estimate per person water consumption at four liters per person per day, such a ship would have had to transport around 3,360 liters of water for a monthlong crossing, requiring nineteen large torpedo jars.

---

55. On this neglected form of containment, see E. A. Lambourn, “Trade and Containerization: Perspectives from the Medieval Indian Ocean World,” in *Merchants, Measures and Money: Understanding Technologies of Early Trade in a Comparative Perspective*, ed. L. Rahmstorf and G. Barjamovic, 2:99–126 (Neumünster: Wachholtz, 2021).

56. *Akḥbār*, bk. 1, ed. Mackintosh-Smith, 33.

**Table 2. Volume of potable water required for varying traveler numbers and distances between stops**

No. of crew	No. of passengers	Total no. of people	Per diem water consumption	Total consumption: 10 days between stops	Total consumption: 28 days between stops
17	13	30	4 liters/person	1,200 liters	3,360 liters
17	23	40	4 liters/person	1,600 liters	4,480 liters
17	33	50	4 liters/person	2,000 liters	5,600 liters
17	43	60	4 liters/person	2,400 liters	6,720 liters
17	53	70	4 liters/person	2,800 liters	7,840 liters

By contrast, given the reportedly easy availability of sweet water across coastal Southeast Asia, one might suggest that ships in this sector carried less water and stopped more regularly. The jars thus freed up might have carried commercial cargo or perhaps food provisions. Rice was one of the most important staples in Indian Ocean provisioning;<sup>57</sup> other common provisions included preserved (brined or vinegared) fruits and vegetables such as ginger, pepper, lemons, and mangoes. One wonders whether the fibrous traces found on one sherd from the Phanom Surin wreck came from such a pickle.

However these torpedo jars were filled, whether with water or with foodstuffs, if we are prepared to accept that they are more likely to have served as shipboard storage than as commercial containers, we can make some further calculations about the proportion of cargo capacity that provisions represented, at least in this one instance. Assuming a tare of 30 kilograms for each jar,<sup>58</sup> a single one of the Phanom Surin ship's six torpedo jars, when filled with water (which weighs one kilogram per liter), would have weighed in the region of 210 kilograms; one full torpedo jar of dry rice (at around 782 grams/liter) would have weighed around 170 kilograms. In these six jars alone, then, the Phanom Surin ship was equipped to transport between 1,020 and 1,260 kilograms of food and/or water depending on the foodstuffs and proportions between them. These provisions would have sufficed

57. See the discussion in Lambourn, *Abraham's Luggage*, 165–88.

58. Although Connan gives no estimate of the weight of the jar itself—technically its tare—large earthenware vessels of comparable dimensions, although with thicker walls, from eighth to tenth-century southern Iraq can weigh around 34 kilograms. A number of early Islamic storage jars were excavated in the 1920s and '30s during the Germano-American excavations at Ctesiphon, the former Sasanian capital in southern Iraq, under the joint sponsorship of the Museum für islamische Kunst (E. Kühnel), the German Oriental Society (1928–29, E. Reuther), and the Metropolitan Museum of Art, New York (1931–32). Some of the objects in the Metropolitan Museum are now accessible online, including a jar preserved under accession number 32.150.51, with a height of 32 1/4 in. (81.9 cm), a diameter of 19 1/2 in. (49.5 cm), and a weight of 77 lbs. (34.9 kg).

for several days' coastal sailing. In terms of proportion of cargo capacity, they would have accounted for less than 5% of the ship's estimated total capacity of twenty-five metric tons.

If 5% represents an altogether negligible portion of overall cargo capacity, it is on the longer, monthlong crossings that provisions begin to take up an ever greater proportion of the lading. As we have seen, a ship provisioning for the speediest of such long crossings, with an onboard population of thirty crew members and passengers drinking only four liters per person per day, would have had to transport 3,360 liters of freshwater—just under nineteen torpedo jars if these were the vessels being used—along with significant food provisions. With a large torpedo jar of water weighing around 210 kilograms (including the weight of the jar), the freshwater transport alone would have accounted for around 3,990 kilograms in total, or just under 15% of cargo capacity. Adding in food provisions on top of this, one can imagine provisioning on these longer crossings taking up 20% or even 25% of a ship's total cargo capacity. Some of the advantages of the later water-tank system become evident when considering the complexity of installing multiple torpedo jars within the ship's hold and ensuring that they were easily accessible on an already crowded ship. Yet jars always had advantages. They could carry anything, liquid or dry goods, in a way that purpose-built water tanks could not, and such adaptability would have been especially useful on shorter sailings in areas with plentiful freshwater. Jars also preserved water much better than tanks did. Although the effect of bitumen on the taste of the water has not been studied, we do know from later sources that water stored in wooden tanks was often contaminated.

### **Domestic Storage Jars and Stationary Reservoirs**

It is risky to extrapolate further from an estimate based on a single, fragmentary vessel; nevertheless, if confirmed by measurements of intact torpedo jars and sherds from other sites, the estimated 193-liter total capacity of the torpedo jar from the Phanom Surin wreck raises serious questions about the portability of these and other large jars, and ultimately about their original function.<sup>59</sup> With its 193-liter total capacity (and perhaps 180-liter effective capacity) this torpedo jar is much larger than the majority of Roman amphorae, the principal category of commercial storage jar for which we have capacity measures.<sup>60</sup> The size of Roman amphorae is believed to have been determined by manual handling constraints—in effect, the maximum weight that two men could lift to load and unload filled amphorae on a regular, long-term basis. Of course, humans can perform exceptional one-off lifting feats, but dock work relies on repeated lifting, and the weights handled are correspondingly lower than the theoretical maximum. The likely weight of filled torpedo jars—between 170 kilograms (for rice) and 220 kilograms (for water)—makes it highly unlikely that they were regularly lifted manually even by two men, particularly since they had no handles. One possibility is the use of a long pole, carried on the shoulders of two men, on which heavy objects, animals, or people might be suspended. The practice is seen in a late sixteenth-century view of the marketplace at Goa, in which a large storage vessel,

---

59. Unfortunately, the calculations and methods employed for this estimate are not published in the article.

60. See the table of average calculations in J. Molina Vidal and D. M. Corredor, "The Roman Amphorae Average Capacity (AC)," *Oxford Journal of Archaeology* 37, no. 3 (2018): 299–311.



probably a *martaban* jar, is encased in a basketry cover, which is then suspended from a bamboo pole (Fig. 5). As the sedan chair shown on the right of the market scene reminds us, this type of carrying method was common also for human transportation. The use of a pole has also been documented ethnographically in Burma in the manufacture of large *martaban* jars.<sup>61</sup> Using this technology, workers at ports and emporia would have been able to transport and load filled torpedo jars with minimal infrastructure. However, torpedo jars remain noticeably larger than Classical amphorae and thus more complex to handle and move when filled. Their size begs the question how effective the largest jars were in commercial contexts and whether their size responded to other functions—namely, the transport and storage of provisions, including water.



**Figure 5: View of the marketplace at Goa from Jan Huygen van Linschoten, *Itinerario* (1605), showing, on the far left, a large East Asian storage jar transported on a pole. (Image CC-PD-Mark)**

Work on storage jars in the central Islamic lands suggests that the very largest jars, approximating the capacity of the Phanom Surin torpedo jar, were only ever “stationary reservoirs,” a neat phrase coined by Brigitte Borell in her work on the later production of supersized *martaban* jars of the type seen in Figure 5.<sup>62</sup> Although we have almost no archaeological data on the volumetric capacity of transport and storage vessels during the ninth century, an important study by Ibrahim Shaddoud, based on textual sources, suggests that earthenware jars destined for the transportation of liquids such as wine, water, or oil may have had a maximum capacity of around thirty-two liters, well within the average range of the better-studied Roman amphorae and the twenty-five- to thirty-five-liter capacity of the earlier ovoid torpedo jars mentioned by Durand.<sup>63</sup> By contrast, in the domestic context,

61. B. Borell, “A True *Martaban* Jar: A Burmese Ceramic Jar in the Ethnological Museum in Heidelberg, Germany,” *Artibus Asiae* 74, no. 2 (2014): 257–97, at fig. 15: “Pottery in Nwe Nyein, Shwebo district, Upper Myanmar. Two men with a dry pot lashed into a bamboo cradle carry it to the kiln.”

62. *Ibid.*, 288–89.

63. At least as described in Abbasid-period sources; see I. Shaddoud, “Jarres dans le monde arabe (VIII<sup>e</sup>–XV<sup>e</sup>”



large, immovable storage jars were preferred and sometimes even permanently set into the ground or within the structure of the building they served. Shaddoud cites some of the vessel capacities described in the sources. In terms of large vessels, he mentions a type of oil-storage jar from the Arabian Peninsula known as a *qulla*; some Yemeni examples had a capacity equivalent to between 95 and 119 liters, while *qullas* made at Hajjar during the lifetime of the Prophet were reportedly able to store the equivalent of 206 to 238 liters of oil.<sup>64</sup> The very largest domestic storage jars found in the central Islamic lands, according to Shaddoud, were called *dinn*. He notes that this type was especially associated with wine maturation and storage and that coating its interior with bitumen was recommended in order to preserve the wine longer.<sup>65</sup> Unfortunately, it is largely impossible at present to match these specific terms to archeologically known vessels, particularly as these coarse utilitarian vessels are often not published or much studied.

The important point is that these were domestic storage vessels, not commercial jars. These examples make the point that although the 193-liter total capacity of the Phanom Surin torpedo jars is not necessarily unusual within the context of the medieval central Islamic lands, it is a size more usually associated with immovable, domestic storage jars than with commercial transport jars. Furthermore, the bitumen-coated interiors of these jars need not be seen as a technology unique to commercial vessels since it was also employed for domestic wine storage, as Shaddoud indicates. Borell's work on early modern *martaban* jars shows that whereas smaller jars were manufactured as commercial containers for export foodstuffs, "the predominant use of the large *martaban* jars, as emphasized in the sources, was for water storage," both domestically and on board ships.<sup>66</sup> Were torpedo jars so different?

We must perhaps ask whether torpedo jars of the dimensions recovered from the Phanom Surin wreck ever functioned as commercial transport containers or whether they might in fact have been designed as immovable storage vessels for onboard water transportation and provisioning. Although it is possible to imagine ways to lift and transport large filled torpedo jars, such jars were surely most efficient when used as permanently installed containers, as they were in the domestic setting on land. Large jars filled with freshwater or foodstuffs could then be decanted by each traveler into smaller, more easily handled jugs, bottles, waterskins, or jars.<sup>67</sup> Ibn Baṭṭūṭa's *Rihla* (*Travelogue*) includes a description of the

---

siècles) d'après les sources écrites, les miniatures et l'archéologie," in *Jarres et grands contenants entre Moyen Âge et époque moderne/Jars and Large Containers between the Middle Ages and the Modern Era: Conference Proceedings, First International Topical Congress of the AIECM3, Montpellier-Lattes (France), November 19–21–2014*, ed. H. Amouric, V. François, and L. Vallauri, 207–16 (Nîmes: Lucie, 2016), 208. On the average capacities of Roman amphorae derived from the examination of physical examples rather than textual sources, see Molina Vidal and Corredor, "Roman Amphorae Average Capacity."

64. Shaddoud, "Jarres dans le monde arabe," 212–23.

65. *Ibid.*, 211.

66. Borell, "True *Martaban* Jar," 292.

67. The luggage packed by the North African Jewish trader Abraham Ben Yijū for his journey back to Yemen from southern India in the mid-twelfth century included a wide range of container types (see Lambourn, *Abraham's Luggage*, 252–67). A late seventeenth-century account of the sea journey from Surat to Jedda in

provisioning of a China-bound ship at a port somewhere in maritime Southeast Asia that hints at the variety of vessels used to transport provisions, including “two elephant loads of rice [probably in sacks], two female buffaloes, ten sheep, four pint jars of fruit syrup (*jullāb*), and four *martabans* [*sic*] filled with ginger, pepper, lemons, and mangoes, all of them salted, these being among the things prepared for the sea.”<sup>68</sup> Although we may be circumspect about the extent of Ibn Baṭṭūṭa’s travels east of India, there is no doubt that he took care to collect and verify information about the East, and I see no reason to doubt the gist of this description. Meat, milk, rice, syrup, and pickles constitute a good snapshot of elite provisioning; the less well-off ate rice and pickles, sometimes with a little preserved fish. All of these required some form of containment.

The Phanom Surin wreck’s rich assemblage of smaller ceramic vessels illuminates both commercial and domestic uses. It includes Mon cooking pots and small storage jars from Central Thailand and an Iraqi or Iranian double-handled turquoise glazed jar—all obviously domestic ceramics—as well as multiple small to medium-sized Guangdong storage jars.<sup>69</sup> These smaller Chinese storage jars might have transported cargo, as evidenced by the Belitung finds of star anise and lead bars in some of them, but they were also commonly used as domestic storage vessels. In the Belitung case, the emphasis of the commercial excavations and later publications on the recovery of the ship’s main ceramic cargo has relegated the domestic ceramics recovered to the “Other finds” section of most publications. The lone torpedo jar from the Belitung wreck together with the two turquoise glazed jugs also recovered may be the sole survivors of a larger assemblage of shipboard water vessels that was overlooked in the search for intact vessels but that might have included large, 180-liter torpedo jars for storage, as seen on board the Phanom Surin, and smaller jugs into which daily or weekly rations could be decanted. It is noticeable in the Phanom Surin wreck that whereas many Chinese stonewares and other South East Asian jars survived the wreck intact, none of the six torpedo jars did. If this pattern is representative of other wrecks, it might explain why only one intact torpedo jar was recovered from the Belitung wreck. By contrast, in the Phanom Surin case, where much of the cargo appears to have biodegraded, the domestic assemblage belonging to the crew and travelers is more visible.

Furthermore, we should not rule out completely the possibility that some of the Belitung ship’s green-glazed Guangdong storage jars were also used for water storage during

---

the *Anīs al-ḥujjāj* notes that water from the tank (*finṭās*) is often distasteful and recommends that passengers carry personal supplies (Qaisar, “Port to Port,” 337). In the case of modern-day Arabian dhows, Dionysius Agius remarked that although ships carried a *finṭās*, the quality of this water was poor because the tanks were rarely cleaned out and the stored water was contaminated with wood and nails, so that “merchants and skippers had their own clean water stored in earthenware jars”; D. A. Agius, *Seafaring in the Arabian Gulf and Oman: The People of the Dhow* (London: Kegan Paul, 2005), 142.

68. Ibn Baṭṭūṭa, *Riḥla*, 4:252–53.

69. See an overview of the ceramics in Guy, “Phanom Surin Shipwreck” and now the much more detailed study of the Chinese wares in P. Sankhaprasit, “Chinese Ceramics from the Phanom-Surin Shipwreck, Thailand: Evidence for Maritime Trade between China and the Indian Ocean Region before the 10th Century AD” (MA diss., Flinders University, 2021).

the voyage. Such dual usage is certainly attested in later productions, as Borell noted in her study of large Burmese jars.<sup>70</sup> Of particular importance within the Belitung assemblage are several supersized Guangdong storage jars with a height of ninety-eight centimeters and a diameter of seventy-seven centimeters (Fig. 6).<sup>71</sup> Unfortunately their capacity is not known, but their dimensions suggest that it will be well over 150 liters once measured. One jar, eighty-eight centimeters high, displays clear formal and iconographic pointers to its intended function (Fig. 7). As noted by Regina Krahl, it is distinctive for having no lugs (essentially small handles) and a spout lower on its body, ideal for dispensing liquids; the shoulder carries an incised decoration of dragons, guardian figures in Chinese iconography.<sup>72</sup> Although Krahl suggests that this vessel was intended for shipboard use, one would need to consider how such a flat-bottomed vessel could have been installed on an undecked ship and whether it might in fact have been a commission for a patron in West Asia.

The torpedo jars from the Phanom Surin wreck may provide further evidence of the use of torpedo jars as domestic containers. Connan and his team noted that most torpedo rim sherds from the Phanom Surin site showed traces of pairs of holes drilled into the already fired clay and positioned on opposite sides of the rim; one sherd even still had “a piece of twisted rope tied in the holes.”<sup>73</sup> This observation is not entirely surprising in view of Durand’s observation that “on the complete bitumen-lined jars that have been published, from the Sasanian/early Islamic torpedo jars to the Hellenistic ovoid jars, a detail can often be observed: a small secondary hole, less than 1 cm diameter, that has been drilled, usually in the upper part of the jar” and after firing.<sup>74</sup> In some cases several holes can be seen around one vessel. Durand argues that the consistency with which this drilling is seen must relate to the content of the vessels, perhaps to allow some form of venting required during wine transport or tasting of the contents without damaging their bitumen-sealed clay stoppers.<sup>75</sup> Connan’s find of rope still tied in the holes of one sherd from Phanom Surin opens other possibilities: in this instance, the holes were positioned in such a way that he could suggest their use as “a cover fastening.”<sup>76</sup> In the absence of lugs on the shoulder of the torpedo jars, one might conjecture that the holes could have been drilled to accommodate a rope or cord in order to tension a hard stopper.

---

70. Borell, “True *Martaban* Jar,” 292.

71. Krahl et al., *Shipwrecked*, 235, no. 42. There were also large jars ranging from 78 to 75 cm in height and 50 to 45 cm in diameter (nos. 43–45), a wide range of medium-sized jars measuring between 35 and 46 cm in height and between 32 and 50 cm in diameter (nos. 46–49), and finally the smallest jars, 23 or 24 cm high and 22 to 30 cm in diameter (nos. 50–54).

72. *Ibid.*, 229, no. 3. This is cataloged as no. 160 in *Belitung Wreck* and published on pp. 446–47.

73. Connan et al., “Geochemical Analysis of Bitumen,” 7.

74. Durand, “From ‘Ovoid Jars’ to ‘Torpedo Jars,’” 28.

75. *Ibid.*, 28–29.

76. Connan et al., “Geochemical Analysis of Bitumen,” 7.



Figure 6: Guangdong greenware storage vessels of various sizes recovered from the Belitung wreck, Asian Civilizations Museum, Singapore. (Photograph courtesy of Choo Yut Shing, CC BY-NC-SA 2.0)



Figure 7: Vat or liquid dispenser, Guangdong greenware, from the Belitung wreck. Height: 90 cm; maximum diameter: 62 cm. Museum of Asian Civilizations, Singapore, 2005.100906. (Photograph by Jacklee 2011, CC BY-SA 3.0)



A similar system of threading rope through the lugs on the shoulder of vessels is seen widely in South East and East Asia, and such is the exceptional preservation of the Phanom Surin vessel that one medium-sized Chinese storage jar was even excavated with ropes still tied to its lugs.<sup>77</sup> Better mapping of the position of drill holes on other ovoid and torpedo jars might help determine whether they, too, were purposely made to tension a form of cover, or whether these holes in fact fulfilled a range of functions. It is certainly difficult to believe that the single drilled hole that is most commonly seen, according to Durand, could have served as a form of fastening.

### Conclusions

This discussion raises more questions than it answers. There are immediate practical questions to answer about the handling of large torpedo jars, whether in commercial or domestic contexts; questions, too, about the relationship between large jars of all types and the other unquestionably portable containers functionally associated with them. Most importantly, however, the preliminary data on the Phanom Surin torpedo jars underline the paucity of comparable data—capacity measures and weights—on storage containers across Afro-Eurasia. Classical archeology provides a wealth of techniques and models ripe for translation to the Indian Ocean context, and it has also demonstrated the importance of such data for quantifying trade and understanding the administration of trade. If we want to determine the range of capacities to which torpedo jars were manufactured and their variation over time, to do so effectively we will also need to know much more accurately the capacities and tares of contemporary large jars of other types from across maritime Afrasia. Durand is clear that the earlier ovoid jars from the Gulf area were many times smaller than the later torpedo jars. Why? How had trade or seafaring changed to stimulate this evolution? Or were other, as yet unimagined and unhypothesized, factors at play?

If the quantification of premodern Indian Ocean trade remains an elusive goal at present, as Seth Priestman's research has underlined,<sup>78</sup> for now we may ponder more generally the extent to which these large storage vessels responded to the very particular sailing conditions of the eighth and ninth centuries, which saw, as Abū Zayd al-Sīrāfī noted, a regular “toing and froing” between Iraq, China, and India. The phenomenon is well documented in other geographical and ethnographic texts as well as in the material culture of the period. At the time the first part of the *Akhbār* was written in the mid-ninth century, the *sufun al-ṣīniyya*, or “China-bound ships,” loaded their goods at Siraf on the Iranian side of the Gulf and sailed all the way to China; by the time Abū Zayd al-Sīrāfī was writing, less than a century later, various events had altered this pattern, with ships sailing only a portion of the route and exchanging goods at transshipment nodes such as Mantai in northern Sri Lanka or Kalah on the Malay Peninsula. As my earlier modeling of the water

77. The jar is pictured in Jumprom, “Phanom-Surin Shipwreck,” 3, fig. 9 and on the online conference poster of Imazu Setzuo et al. Conservation of Artifacts from Phanom-Surin Shipwreck, Thailand/今津節生、ソピット パヤカーン・サネ マハポール、伊藤幸司. 35th Japanese Society for Cultural Properties Science (JSSCP) Congress, Nara 2018, <https://doi.org/10.13140/RG.2.2.22155.18723>.

78. Priestman, *Ceramic Exchange*.

consumption of thirty people making a six-week open-ocean crossing illustrated, these runs would have required a huge volume of potable water, whereas coastal sailing did not. If the inbuilt water tank offered one solution to this problem, transferring domestic vessels into ships or indeed manufacturing purpose-made supersized storage jars for maritime use was another, far simpler solution.

A survey study of early Guangdong kilns noted the technological challenge such large jars would have represented for Chinese potters and the possibility of their development as a direct result of interactions with West Asian merchants then flocking to the Chinese coast:

Production of large jars like those salvaged from the Belitung shipwreck was relatively difficult under the technological conditions prevailing at that time. It was this special need that facilitated technological development. From this point of view, the Guangdong kilns became the most highly developed in making large objects. It is not clear at present if the production process was influenced by technologies from western Asia and the Middle East.<sup>79</sup>

The massive capacity of some Guangdong storage jars certainly appears to be more characteristic of domestic storage vessels from the central Islamic lands than it is of East Asian practices; the production of some large vessels without lugs is likewise closer to West Asian than to Chinese ceramic models (see Figs. 6 and 7). Interestingly, Qin Dashu and colleagues note that the very largest jars of the type recovered from the Belitung wreck appear to have been manufactured for only a short period. They may thus evidence very particular demands and sailing practices along this route. As the author of the *Akḥbār* underlines, this was a moment of uniquely close long-distance exchanges between China and Iraq. The fact that no supersized Guangdong vessels were recovered from the Phanom Surin wreck fits with that ship's likely involvement in regional Southeast Asian trade rather than long-distance voyaging. Better study of Guangdong sherds from around the Indian Ocean rim, looking beyond their body and glaze to vessel dimensions, weight, and volumetric capacities, may help clarify the life cycles of the very largest jars around this area. Concurrently, we must pay attention to the complex world of storage and transport vessels in the central Islamic lands that emerges from Shaddoud's work on Arabic-language textual sources.

Beyond specific questions about ninth-century ceramic storage jars, we need to listen for the water in our sources, because it is there, however faintly, like a damp stain on a page. Few authors show the same interest in sweet-water provisions or the places where they are found as does the author of the *Akḥbār*. One might cite Nāṣir-i Khusraw's description of rainwater collection and its trade at Aydhāb in the mid-eleventh century, but his omission of any mention of water provisioning on board the ship that carried him to Jedda is notable.<sup>80</sup>

---

79. Qin Dashu, Chang Jung, and Shan Yu, "Early Results of an Investigation into Ancient Kiln Sites Producing Ceramic Storage Jars and Some Related Issues," *Bulletin de l'École française d'Extrême-Orient* 103 (2017): 359–84, at 376.

80. Nāṣir-i Khusraw, *Safarnāma*, Persian ed. and English trans. W. M. Thackston as *Nasir-i Khusraw's Book of Travels* (Costa Mesa, CA: Mazda, 2001), 86.

Documentary references are few and far between, although in a letter possibly written in the 1120s, the Jewish trader Allān b. Hassūn mentions in passing that his ship was provisioned with water and firewood (*zawwadūnā bi-l-māʾ wa-l-ḥaṭab*) at Kollam in south India before setting out for the return to Aden.<sup>81</sup> To this one might add a few anecdotes in South Asian literary texts describing the loading of water before a ship's departure. An eighth-century Jain romance, the *Kuvalayamālā*, lists "filling the containers (*patrā*) with fresh sweet water" among the final steps before a ship's departure.<sup>82</sup> However, as the text's editor and translator notes, this had become something of a literary trope already in this period. Chinese sources provide details intermittently—Zhu Yu's description of water provisioning in the Pearl River estuary has already been mentioned, and Xu Jing's observation about the importance of freshwater at sea opened this chapter—but they do so with enough regularity to have allowed Mathieu Torck to devote a chapter to water provisioning in China.<sup>83</sup> These generally sparse written sources make the study of the surviving material evidence all the more important. The short passage in the *Akhbār*, explored in parallel with the ceramic remains from contemporary shipwrecks, begins to reveal the very real physical and physiological parameters that underlay Indian Ocean connectivity.

---

81. S. D. Goitein, "Portrait of a Medieval India Trader: Three Letters from the Cairo Geniza," *Bulletin of the School of Oriental and African Studies* 50, no. 3 (1987): 449–64, at 455 and 460–61.

82. Uddyotanasuri, *Kuvalayamālā*, French trans. C. Chojnacki as *Kuvalayamālā: Roman Jaina de 779, composé par Uddyotanasūri* (Marburg: Indica et Tibetica, 2008), 2:119.

83. Torck, *Avoiding the Dire Straits*, 211–27.

### Bibliography

- Agius, D. A. *Seafaring in the Arabian Gulf and Oman: The People of the Dhow*. London: Kegan Paul, 2005.
- Akhbār al-Ṣīn wa-l-Hind*. Arabic edition and English translation by T. Mackintosh-Smith as *Accounts of China and India: The First Book*. In *Two Arabic Travel Books*, edited by P. F. Kennedy and S. M. Toorawa, 22–65. New York: New York University Press, 2014.
- Akhbār al-Ṣīn wa-l-Hind*. Arabic edition and English translation by T. Mackintosh-Smith as *Accounts of China and India: The Second Book*. In *Two Arabic Travel Books*, edited by P. F. Kennedy and S. M. Toorawa, 67–133. New York: New York University Press, 2014.
- Akhbār al-Ṣīn wa-l-Hind*. Arabic edition with French translation by J. Sauvaget as *Relation de la Chine et de l'Inde*. Paris: Les Belles Lettres, 1948.
- ‘Allāmī, Abū al-Faḍl. *Āʾīn-i Akbarī*. English translation by H. Blochmann, edited by D. C. Phillott as *The Aʾin-i Akbari: A Gazetteer and Administrative Manual of Akbar's Empire and Past History of India*. Kolkata: Asiatic Society, 2010.
- The Belitung Wreck: Sunken Treasures from Tang China*. N.p.: Seabed Explorations Ltd. New Zealand, 2004. Available at <https://www.iseas.edu.sg/centres/nalanda-sriwijaya-centre/research-tools/compilations/the-belitung-wreck-sunken-treasures-from-tang-china/>.
- Borell, B. “A True *Martaban* Jar: A Burmese Ceramic Jar in the Ethnological Museum in Heidelberg, Germany.” *Artibus Asiae* 74, no. 2 (2014): 257–97.
- Connan, J., S. Priestman, T. Vosmer, A. Komoot, H. Tofighian, B. Ghorbani, M. H. Engel, A. Zumberge, and T. van de Velde. “Geochemical Analysis of Bitumen from West Asian Torpedo Jars from the c. 8th Century Phanom-Surin Shipwreck in Thailand.” *Journal of Archaeological Science* 117 (2020): 1–18.
- Cuvigny, H. “L’organigramme du personnel d’une carrière impériale d’après un ostracon du Mons Claudianus.” *Chiron* 35 (2005): 309–53.
- de Laval, F. Pyrard. *Voyage*. French edition and commentary by Xavier de Castro as *Voyage de Pyrard de Laval aux Indes Orientales (1601–1611)*. 2 vols. Paris: Chandeigne, 1998.
- Durrand, C. “From ‘Ovoid Jars’ to ‘Torpedo Jars’: Investigations into Bitumen-Lined Transport Containers in the Gulf and the Indian Ocean in Antiquity (Second Century BCE–Third Century CE).” *Arabian Archaeology and Epigraphy* 32, no. 1 (2021): 21–32.
- Engels, D. *Alexander the Great and the Logistics of the Macedonian Army*. Berkeley: University of California Press, 1978.
- Fatimi, S. Q. “In Quest of Kalah.” *Journal of Southeast Asian History* 1, no. 2 (1960): 62–101.



- Flecker, M. "A 9th Century Arab Shipwreck in Indonesian Waters." In *Shipwrecked: Tang Treasures and Monsoon Winds*, edited by R. Krahl, J. Guy, J. K. Wilson, and J. Raby, 101–9. Washington, DC: Arthur M. Sackler Gallery and Singapore: National Heritage Board of Singapore and Singapore Tourism Board, 2010. Available at <https://asia.si.edu/wp-content/uploads/2017/10/07Flecker.pdf>.
- . "A Ninth-Century Arab or Indian Shipwreck in Indonesia." In *The Belitung Wreck: Sunken Treasures from Tang China*, 4–39. N.p.: Seabed Explorations Ltd. New Zealand, 2004. Available at [https://www.iseas.edu.sg/wp-content/uploads/2016/05/01\\_flecker\\_002to039.pdf](https://www.iseas.edu.sg/wp-content/uploads/2016/05/01_flecker_002to039.pdf).
- Goitein, S. D. "Portrait of a Medieval India Trader: Three Letters from the Cairo Geniza." *Bulletin of the School of Oriental and African Studies* 50, no. 3 (1987): 449–64.
- Guy, J. "The Phanom Surin Shipwreck, a Pahlavi Inscription, and Their Significance for the History of Early Lower Central Thailand." *Journal of the Siam Society* 105 (2017): 179–96.
- Haw, S. G. "The Genus Afzelia and the Belitung Ship." *Journal of the Royal Asiatic Society* 29, no. 3 (2019): 505–18.
- Heng, G. "An Ordinary Ship and Its Stories of Early Globalism: World Travel, Mass Production, and Art in the Global Middle Ages." *Journal of Medieval Worlds* 1, no. 1 (2019): 11–54.
- Hirth, F., and Rockhill, W. W., ed. and trans. *Chau Ju-Kua: His Work on the Chinese and Arab Trade in the Twelfth and Thirteenth Centuries, Entitled Chu-fan-chi*. New York: Paragon, 1966.
- Hourani, G. F. *Arab Seafaring in the Indian Ocean in Ancient and Early Medieval Times*. 2nd ed. Edited by John Carswell. Princeton, NJ: Princeton University Press, 1995.
- Hsieh Ming-liang. "The Navigational Route of the Belitung Wreck and Late Tang Ceramic Trade." In *The Belitung Wreck: Sunken Treasures from Tang China*, 76–91. N.p.: Seabed Explorations Ltd. New Zealand, 2004. Available at [https://www.iseas.edu.sg/wp-content/uploads/2016/05/04\\_hsieh1\\_074to091.pdf](https://www.iseas.edu.sg/wp-content/uploads/2016/05/04_hsieh1_074to091.pdf).
- . "The Navigational Route of the Belitung Wreck and the Late Tang Ceramic Trade." In *Shipwrecked: Tang Treasures and Monsoon Winds*, edited by R. Krahl, J. Guy, J. K. Wilson, and J. Raby, 137–43. Washington, DC: Arthur M. Sackler Gallery and Singapore: National Heritage Board of Singapore and Singapore Tourism Board, 2010. Available at <https://asia.si.edu/wp-content/uploads/2017/10/09Hsieh.pdf>.
- Ibn Baṭṭūṭa, Abū ‘Abd Allāh Muḥammad. *Riḥla*. Arabic edition and French translation by C. Defrémery and B. R. Sanguinetti as *Voyages d’Ibn Battûta*. Paris: Anthropos, 1969.
- Ibn Khurradādhbih, Abū al-Qāsim. *Kitāb al-Masālik wa-l-mamālik*, Arabic edition and French translation by C. Barbier de Meynard as "Le livre des routes et des provinces par Ibn-Khordadbeh." *Journal Asiatique*, 6th ser., 5 (1865): 5–296.

- Imazu Setzuo, S. Panyakhan, S. Mahaphol and Ito Koji. (I) Conservation of Artifacts from Phanom-Surin Shipwreck, Thailand (I)/今津節生 (奈良大学)、ソピット パヤカーン・サネ マハポール、(タイ芸術局国立博物館) 伊藤幸司 (公益財団法人 大阪市博物館協会 大阪文化財研究所. 35th Japanese Society for Cultural Properties Science (JSSSCP) Congress, Nara 2018, <https://doi.org/10.13140/RG.2.2.22155.18723>).
- Institute of Medicine of the National Academies. *Water, Dietary Reference Intakes for Water, Sodium, Chloride, Potassium and Sulfate*. Washington, DC: National Academy Press, 2005.
- Jequier, E., and F. Constant. “Water as an Essential Nutrient: The Physiological Basis of Hydration.” *European Journal of Clinical Nutrition* 64, no. 2 (2010): 115–23.
- Jia Dan 賈耽. *Guangzhou tong hai yi dao* 廣州通海夷道 (Route to Foreign Countries across the Sea from Guangzhou). English translation in *Chau Ju-Kua: His Work on the Chinese and Arab Trade in the Twelfth and Thirteenth Centuries, Entitled Chu-fan-chi*, edited and translated by F. Hirth and W. W. Rockhill, 9–14. New York: Paragon, 1966.
- Jumprorn, P. “The Phanom-Surin Shipwreck: New Discovery of an Arab-Style Shipwreck in Central Thailand.” *Southeast Asian Ceramics Museum Newsletter* 8, no. 1 (2014): 1–4.
- Junkelmann, M. *Panis Militaris*. Mainz am Rhein: Philipp von Zabern, 1997.
- al-Kindī, Abū Bakr Aḥmad b. ‘Abd Allāh b. Mūsā. *al-Muṣannaf*. 42 vols. in 44. Muscat: Wizārat al-Turāth al-Qawmī wa-l-Thaqāfa, 1403/1983.
- Krahl, R., J. Guy, J. K. Wilson, and J. Raby (eds.). *Shipwrecked: Tang Treasures and Monsoon Winds*. Washington, DC: Arthur M. Sackler Gallery and Singapore: National Heritage Board of Singapore and Singapore Tourism Board, 2010. Available at <https://asia.si.edu/research/exhibition-catalogues/shipwrecked-catalog/>.
- Lambourn, E. *Abraham’s Luggage: A Social Life of Things in the Medieval Indian Ocean World*. Cambridge: Cambridge University Press, 2018.
- Lambourn, E. “Trade and Containerization: Perspectives from the Medieval Indian Ocean World.” In *Merchants, Measures and Money: Understanding Technologies of Early Trade in a Comparative Perspective*, vol. 2 of 2, edited by L. Rahmstorf and G. Barjamovic, 99–126. Neumünster: Wachholtz, 2021.
- al-Mas‘ūdī, ‘Alī b. al-Ḥusayn. *Murūj al-dhahab*. Arabic edition and French translation by C. Barbier de Meynard and A. Pavet de Courteille as *Les prairies d’or*. Paris: Société Asiatique, 1962–79.
- Molina Vidal, J., and D. M. Corredor. “The Roman Amphorae Average Capacity (AC).” *Oxford Journal of Archaeology* 37, no. 3 (2018): 299–311.

- Nāṣir-i Khusraw. *Safarnāma*. Persian edition and English translation by W. M. Thackston as *Nasir-i Khusraw's Book of Travels*. Costa Mesa, CA: Mazda, 2001.
- Pelliot, P. "Deux itinéraires de Chine en Inde à la fin du VIII<sup>e</sup> s." *Bulletin de l'École française d'Extrême Orient* 4 (1904): 131–413.
- Pham, C. M. H. "European Navigation, Nautical Instructions and Charts of the Cochinchinese Coast (16th–19th Centuries)." *Moussons* 27 (2016): 101–29.
- . "A Maritime Cultural Landscape of Cochinchina: The South China Sea, Maritime Routes, Navigation, and Boats in Pre-colonial Central Vietnam." PhD diss., Murdoch University, 2016.
- Piantadosi, C. A. *The Biology of Human Survival: Life and Death in Extreme Environments*. Oxford: Oxford University Press, 2003.
- Priestman, S. M. M. *Ceramic Exchange and the Indian Ocean Economy (AD 400–1275)*. Research Publication 223. London: British Museum Press, 2021.
- Priestman, S. M. M. "A Quantitative Archaeological Analysis of Ceramic Exchange in the Persian Gulf and Western Indian Ocean, AD c.400–1275." PhD thesis, University of Southampton, 2013.
- Pryor, J. H., and E.M. Jeffreys. *The Age of the Dromon: The Byzantine Navy ca. 500–1204*. Leiden: Brill, 2006.
- Qaisar, J. A. "From Port to Port: Life on Indian Ships in the Sixteenth and Seventeenth Centuries." In *India and the Indian Ocean 1500–1800*, edited by A. Das Gupta and M. N. Pearson, 331–49. Oxford: Oxford University Press, 1987.
- Qin Dashu, Chang Jung, and Shan Yu. "Early Results of an Investigation into Ancient Kiln Sites Producing Ceramic Storage Jars and Some Related Issues." *Bulletin de l'École française d'Extrême-Orient* 103 (2017): 359–84.
- Roth, J. *The Logistics of the Roman Army at War*. Leiden: Brill, 1999.
- Sankhaprasit, P. "Chinese Ceramics from the Phanom-Surin Shipwreck, Thailand: Evidence for Maritime Trade between China and the Indian Ocean Region before the 10th Century AD." MA diss., Flinders University, 2021.
- Sawka, M., S. Cheuvront, and R. Carter III. "Human Water Needs." *Nutrition Reviews* 63, no. 6 (2005): 30–39.
- Schlingloff, D. "Kalyānakārin's Adventures: The Identification of an Ajanta Painting." *Artibus Asiae* 3, no. 1 (1976): 5–28.
- Shaddoud, I. "Jarres dans le monde arabe (VIII<sup>e</sup>–XV<sup>e</sup> siècles) d'après les sources écrites, les miniatures et l'archéologie." In *Jarres et grands contenants entre Moyen Âge et*

*époque moderne/Jars and Large Containers between the Middle Ages and the Modern Era: Conference Proceedings, First International Topical Congress of the AIECM3, Montpellier-Lattes (France), November 19–21–2014*, edited by H. Amouric, V. François, and L. Vallauri, 207–16. Nîmes: Lucie, 2016.

Sidebotham, S. *Berenike and the Ancient Maritime Spice Route*. Berkeley: University of California Press, 2011.

Southworth, W. A. “The Coastal States of Champa.” In *Southeast Asia: From Prehistory to History*, edited by I. Glover and P. S. Bellwood, 209–33. London: RoutledgeCurzon, 2004.

Steiner, R. C. *The Affricated Sade in Semitic Languages*. New York: American Academy for Jewish Research, 1982.

Tomber, R. “Rome and Mesopotamia: Importers into India in the First Millennium AD.” *Antiquity* 81, no. 314 (2007): 972–88.

Tomber, R., M. Spataro, and S. Priestman. “Early Islamic Torpedo Jars from Siraf: Scientific Analyses of the Clay Fabric and Source of Indian Ocean Transport Containers.” *Iran* (2020): 1–24. Published online: <https://doi.org/10.1080/05786967.2020.1792797>.

Torck, M. *Avoiding the Dire Straits: An Inquiry into Food Provisions and Scurvy in the Maritime and Military History of China and Wider East Asia*. Wiesbaden: Harrassowitz, 2009.

Uddyotanasuri. *Kuvalayamālā*. French translation by C. Chojnacki as *Kuvalayamālā: Roman Jaina de 779, composé par Uddyotanasūri*. 2 vols. Marburg: Indica et Tibetica, 2008.

al-Ya‘qūbī, Aḥmad. *Ta’rīkh*. English translation by M. S. Gordon, C. F. Robinson, E. K. Rowson, and M. Fishbein as *The History: Adam to Pre-Islamic Arabia in The Works of Ibn Wāḍiḥ al-Ya‘qūbī: An English Translation*. Leiden: Brill, 2018.

Zitterkopf, R., and S. Sidebotham. “Stations and Towers on the Quseir-Nile Road.” *Journal of Egyptian Archaeology* 75 (1989): 155–89.