

## Role of teak and other hardwoods in shipbuilding as evidenced from literature and shipwrecks

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*One of the greatest achievements of man is the invention of watercraft which has been used from the prehistoric period onwards. Over the centuries, varieties of watercraft were designed and developed. Timber was the main component required for construction of boats and ships since ancient times until it was replaced by iron or steel. Once the size and carrying capacity of vessels was enhanced and overseas trade became more frequent, superior quality of timber was used for building boats and ships which were seaworthy. Probably, the Ashtadhyayi of Panini (5th century BC) is the oldest Indian literary work mentioning the use of a variety of timbers. Timber species such as teak (*Tectona grandis*), sal (*Shorea robusta*), sissoo (*Dalbergia sissoo*), benteak (*Lagestroemia microcarpa*), etc. were used in shipbuilding. Among these, teakwood has been termed as most valued on account of its noble qualities, specifically, long-term durability, higher strength and stiffness and absence of development of cracks and splits in the products. Most of the Indian literature as well as travellers have mentioned about the worthiness of teak, but there are no studies to corroborate the accounts. In a later period, the Europeans understood the superiority of teakwood which resulted in slow replacement of traditionally used oak and pine by teak in shipbuilding. The European rulers imposed several restrictions and permissions were not granted for the use of teak by the natives; while on the contrary, the Europeans mostly built their ships from teakwood. This has been confirmed from shipwrecks found around the world. Abundant references are found in literature on the use of teakwood in shipbuilding. There are not many studies related to use of teak in shipbuilding to confirm the statements made in literature, nor timber samples collected from many shipwrecks and archaeological sites analysed. Most of the references to teakwood available in literature as well as wrecks of teakwood-built ships explored so far are referred to in this note.*

India has contributed to world culture in numerous ways, namely in the field of philosophy, arts, architecture and material sciences. Indian literature and archaeological findings also shed light on this contribution. One of the greatest achievements worth mentioning is the invention of watercraft which is evident from rock art<sup>1</sup> and archaeological excavations<sup>2</sup>. However, no comprehensive information is available about the type of timber used in construction of floats and rafts. Later on, varieties of traditional watercrafts were built using locally available timbers. Subsequently, wood became the most widely accepted material for hull construction and remained the best material for ship and boat builders until the last century when timber was partly replaced by iron/steel or other manmade fibre/composite materials.

In the Indian subcontinent, the earliest evidences of boatbuilding come from the Indus Valley culture where representations of boats were found on seals, sealings, clay models and pottery<sup>2</sup>. A few timbers such as teak, sal and deodar were used for construction of boats, carts, houses, etc.<sup>3</sup> have been recorded from

the Harappan sites. During the Harappan period, teak was exported to the Persian Gulf countries and the Mesopotamian texts set a high value for teak<sup>4</sup>. A Harappan period shipwreck has been excavated at Ra's Al Jinns, 200 km southeast of Muscat and it shows that among other timbers, teakwood was used in the construction of the ship<sup>5</sup>. Information on the construction pattern of boats and ships, their sizes and designs is provided in literature and found in archaeological contexts<sup>6-9</sup>. Timbers such as teak, *sissoo*, *anjili* (*aini*), *sal*, etc., used in construction of boats and ships, have been validated from the remains found during inshore or offshore explorations<sup>10-13</sup>. Till date, a larger number of wrecks of Indian-built ships have been explored in foreign waters than in Indian waters. Analysis of timbers of some of the shipwrecks showed that the ships were built of teak, whereas *sal* and *sissoo* were used for frames, etc.<sup>13</sup>. Over the centuries, literary sources and traveller and shipwright accounts have suggested that teakwood is highly preferred for shipbuilding because of its noble qualities, but no endeavour was made to study the timber in ship-

wrecks to confirm whether this information about teakwood is true.

Hence, literary sources referring to teak and other timber used in shipbuilding, wrecks of Indian-built teakwood ships excavated both in Indian and foreign waters and microstructural study of teakwood found in shipwrecks have been detailed and discussed in this note.

### Literary sources on teak and other timbers in shipbuilding

Sanskrit, Pali, Prakrit and other vernacular literature provide details of varieties of boats and ships used for river and sea voyages, military expeditions, racing, trade and commerce, piracy and fishing. The earliest evidence on the use of timber in the shipbuilding industry comes from the writings of Panini (5th century BC), Patanjali (2nd century BC), Pliny, Strabo (60 BC–19 AD), the *Periplus Maris Erythraei* (60–100 AD) and Arrian (200 AD)<sup>6,14-17</sup>. In the *Ashtadhyayi*, Panini<sup>14</sup> has described a large variety of timber species, namely *amra/mango* (*Mangifera indica*), *khadirakhair* (*Acacia*

*catechu*), *simsapa*/blackwood (*Dalbergia sissoo*) and *salmali*/silk cotton (*Bombax malabaricum*) used for various purposes including ship construction. In the *Arthashastra*, Kautilya (350–275 BC) has assigned the powers of forest and forest products to the Superintendent of Forest Produce who was responsible for safeguarding forests and stated several types of timbers, including teak, which were strong and also mentioned their usefulness<sup>18</sup>. Similarly, Patanjali (2nd century BC) mentioned varieties of timber used for shipbuilding, among them *Devadaru* (deodar) used for construction of different parts of the vessel<sup>19</sup>. The *Periplus of the Erythraean Sea* (*Periplus Maris Erythraei*) (60–100 AD) described that teakwood, sandal wood, *sissoo*, black wood, copper and ebony were exported in ships from Barygaza to Apologos and Ommana on the Persian Gulf coast<sup>16,20</sup>. Teakwood and cedar was also exported to Mesopotamia for shipbuilding, construction of the Palace of Nebuchadnezzar (604–562 BC) and temple of Moon God rebuilt by Nebuchadnezzar and Nabonidus (555–538 BC)<sup>6,21</sup>. Hourani (1995) stated that Indian teakwood is most valuable because of its durability, elasticity, strength and the fact that it does not crack, split or shrink<sup>22</sup>. Later on, Al-Masudi (871–957 AD) mentioned ships of the Indian Ocean were built of teakwood, whereas Ibn Jubayr (1145–1217 AD) states that Indian timber was exported to Aydhab for shipbuilding<sup>22</sup>.

The *Yuktikalpataru*<sup>6</sup> (the wishing tree of artifice), otherwise known as *Vrksayurveda* (the science of plant life), the early medieval period text of the 11th century AD compiled by the King Bhoja of Dhar, Central India (now in Madhya Pradesh), describes a variety of wood species used for the construction of ships. He also classified various timbers; *Brahmana jati* is light and soft and can be easily joined; *Ksatriya jati* wood is light and hard and can be joined; soft and heavy variety is *Vaisya jati* and hard and heavy is *Sudra jati*. According to the *Yuktikalpataru*, if the ship is constructed of *Ksatriya* class of wood, it brings wealth and happiness and is capable of passing through troubled waters. However, ships made of different wood, can bring all kinds of difficulties and discomfort<sup>23</sup>, also they do not last for long and rot, split and sink in the water<sup>24</sup>. Hence, the text emphasizes that good quality

timber should be used for construction of seagoing ships, which could stand firm against the action of waves, currents, marine bio-fouling and would bring joy and wealth to the community<sup>6</sup>. Evidences also show that Ala-ud Din Khalji (1296–1316 AD) sent teakwood, diamond, ebony and sandalwood as a gift to the King of Persia<sup>25</sup>. During the rule of Akbar (1542–1605 AD), shipbuilding flourished especially at Surat, Broach, Diu, Nosari, Khambayat and Ganadevi for which teakwood was brought from forests of Gujarat. Similarly, Marco Polo (1254–1324 AD), Durate Barbosa (148–1521 AD), Ludovico di Varthema (1470–1517 AD) and Tom Pires (1465?–1524 or 1540 AD) have referred to the shipbuilding centres on the west coast of India and export of Indian teak to Ormuz and Arab countries<sup>26</sup>. In 1621 AD, the shipbuilding industry became more prominent along the west coast of India; as a result, the Dutch purchased local teakwood ships for their use<sup>27</sup>. During the 16–17th centuries, Oman used to import teakwood from India for building ships. Ovington (1929) commented that Indian-built ships, which were suitable for fighting against men of war, never split by the force of bullet or bore of the shot<sup>28</sup>. Boxer<sup>29</sup> also elaborated on the superiority of Indian teak over pine and oak and its durability; therefore he emphasized the need for building carracks in teakwood for the *carreira* in India but not Europe. With the increase of trade and commerce, in 1772, the East India Company did not permit building of bigger ships using oak in England; on the other hand, the company allowed the European powers to build vessels of teakwood either in India or in their colonies. This resulted in the protection of oak forests in England<sup>30</sup>. During the 17th century, Narsapur in Andhra Pradesh became the main shipbuilding centre where largest ships were constructed for the British and Dutch. Narsapur provided easy access to teak, and raw material such as iron, required for construction of ships, which were brought from the interior regions<sup>31</sup>.

It is to be mentioned that teak forests are endemic to India, Thailand, Myanmar and Laos. Ecological studies on teak in India show that teak is found in forests throughout India, but mostly common in the peninsula. Teak is the Indian deciduous species which grows mostly in moist deciduous forests and it also grows in the

moister region of dry deciduous forests<sup>32–34</sup>. Teak also grows in the Gir forests and southern region of Gujarat. The other timbers namely benteak, sal, etc., were also used for boat/shipbuilding but generally sal (*Shorea* spp) is found in eastern and northern India and this implies that wood from different ecological zones was used for shipbuilding.

### Remains of teakwood recovered from shipwrecks in Indian waters

Since the commencement of maritime archaeological studies on Indian waters, five shipwrecks (Sunchi Reef, St George's Reef, Ameer Shoals, Sail Rock and Grande Island) off Goa<sup>35</sup>, four (Minicoy Island<sup>36</sup>, Suheli Par and Bangaram Island)<sup>37</sup> off Lakshadweep Islands and one each off Poompuhar<sup>38</sup> in Tamil Nadu and Konark coast, Odisha have been explored (Figure 1). Among them, Sunchi Reef, St George's Reef and Poompuhar shipwrecks are wooden hulled, but no timber remains were found in Sunchi Reef and the timber of the Poompuhar shipwreck has not yet been analysed, whereas the timber of St George's Reef shipwreck was collected and the analysis confirmed that the timber belongs to the *Lagerstromia microcarpa* syn *Lagerstromia lanceolata* species (Figure 2), whose trade name is 'benteak'<sup>35</sup>. This species grows in Western Ghats of India and is known for its use in boatbuilding. During exploration of steam engine shipwrecks in Minicoy waters, a porthole, Jbolt with wing nut of porthole, square and round flanges, hinges were found and timber remains were noticed on the doorframe hinge and door latch (Figure 3). The anatomical analysis confirmed that both samples were made of teakwood<sup>39</sup>. An admiralty type of iron anchor with wooden stock belonging to the Portuguese period was found off Aguada, Goa. In order to understand the species of timber, anatomical analysis was performed and the result indicated that the wooden stock (Figure 4) was of teakwood<sup>10</sup>. Apart from the above archaeological studies along the River Jog basin of Maharashtra, west coast of India has brought to light teak rafters. The radiocarbon dating of the sample shows that the timber is datable to 960 ± 63 AD (ref. 40) and this emphasizes that teakwood was also used for rafters.

**Exploration of Indian built shipwrecks in foreign waters**

In the Indian context, so far no early historical period shipwrecks have been documented. However, an early medieval period shipwreck has been excavated in Belitung waters, Indonesia, datable to the 9th century AD. The recent archaeological excavations at Berenike, the early historical port on the Red Sea coast (1st century BC to 6th century AD), has yielded evidence of Indian contacts with the Roman Empire. The excavation finds include Indian pottery, pepper, Indian-Sri Lankan beads and Tamil-Brahmi graffiti on amphorae, coconuts and sail of Indian origin<sup>41</sup>. Apart from these findings, huge

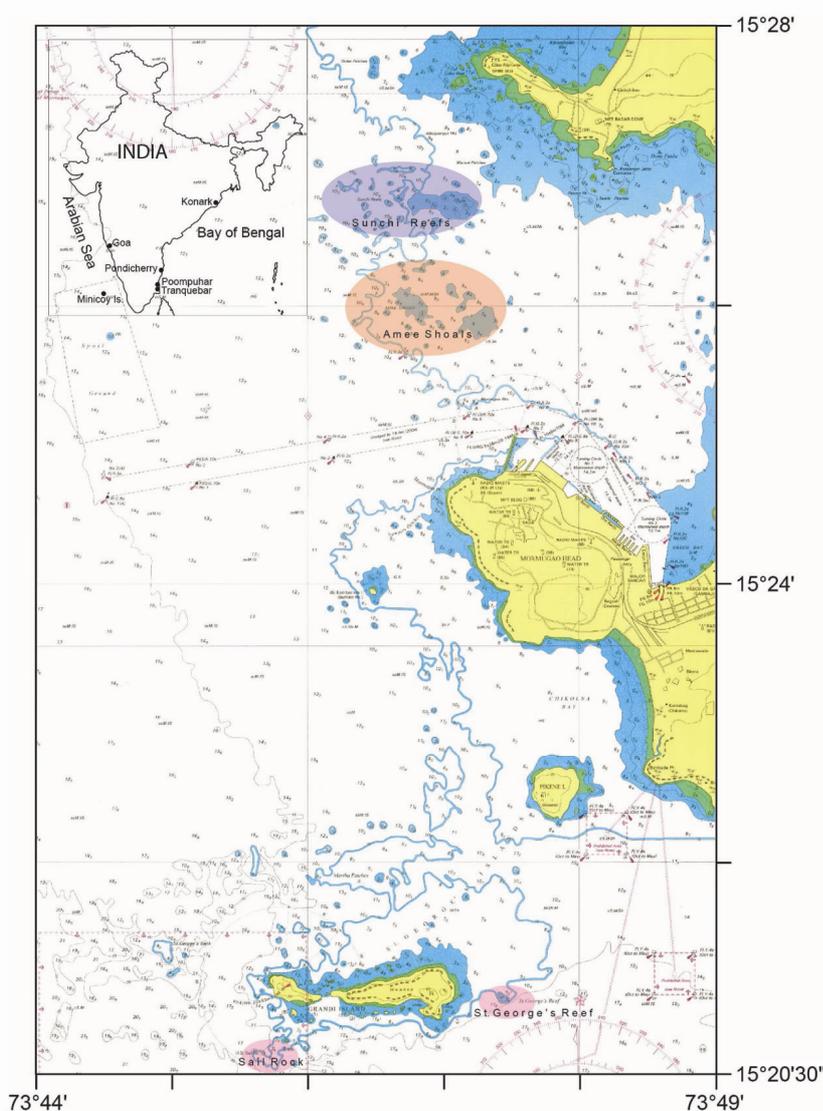
quantity of teakwood, teakwood artefacts, planks of dismantled boats, building and waste material suggest that teakwood was worked upon the site. Further, teakwood findings suggest that teakwood might have been brought from India for the purpose or could be the timber of the dismantled Indian-built ships or driftwood<sup>42</sup>. Besides Berenike, teakwood has also been reported from nearby sites of wadi Kalalat and Shenshef along the Red Sea, Egypt. More teakwood has been reported from watering station of wadi Kalalat, whereas the presence of teakwood at Shenshef is also notable<sup>42</sup>.

Several Indian-built ships have been wrecked in foreign waters, but very few

have been explored and identified. The exploration of the 9th century AD shipwreck in Belitung waters, Sumatra, Indonesia provides direct evidence of overseas trade between China and India/Arabia. The detailed study of timber shows that teakwood (Figure 5 a and b) was mostly used for beams and other timbers were used for the construction of different parts of the ship<sup>43</sup>. Further, it was suggested that the ship was either built in India or Indian timber was exported to the Middle East for its construction<sup>13</sup>.

More than 45 Asian-built wooden hulled vessels have been wrecked in Australian waters<sup>11</sup>. Among them, some of the shipwrecks have been explored and studied. The ship *Sydney Cove* built at Calcutta (Kolkata) was loaded with rice and sugar, tobacco, salted meat, Chinese tea, porcelain, leatherwear, Indian textiles and livestock<sup>44</sup> sailed on 10 November 1796 southwards until 13 December 1796. A gale force winds opened up a leak on the starboard bow which was repaired, although water was leaking in the hull. The ship encountered two rough weathers between 25 January and 8 February, Captain Hamilton attempted to save the vessel but on 9 February it was run aground between two small, low-lying islands off the Tasmania coast. The timber of the *Sydney Cove* has been identified as teak (Figure 5 c), sissoo and Indian rosewood (*Dalbergia latifolia*), all obtainable from the vicinity of the Bay of Bengal<sup>45</sup>. An iron anchor with wooden stock made of teak was recovered from the Sydney Cove (Figure 5 d). The stock was made of a single piece of solid timber, approximately 4 m in length and secured by four iron reinforcing bands<sup>12</sup>.

The 181-ton ship, *Regia*, was built of teak with iron fastenings and copper



**Figure 1.** Map showing the location of shipwrecks explored in Indian waters (Figure: Sila Tripati).



**Figure 2.** Timber remains of St George's Reef shipwreck off Goa (Photo source: Sila Tripati).

alloy sheathing at Cochin in 1835 and wrecked at Portland Bay, Victoria in 1836 (ref. 46). The keel and frame timbers as well as the construction patterns are very similar to those of the *Sydney Cove*<sup>47</sup>. The 58-ton brigantine carvel built *Thistle* was constructed at Bengal in 1825 (ref. 48) and it traded in southern Australian waters from 1831 onwards. *Thistle* was caught by a gale, anchors were lost and cables were parted. Desperate attempts were made to save the vessel but it moved towards the broadside onto the beach and *Thistle* was wrecked<sup>49</sup> on the coast of Victoria in 1837. The timber remains were analysed and showed that mainly sal (*Shorea robusta*), belian (*Eusideroxylon zwageri*) and sissoo were used in the construction of the *Thistle*<sup>50</sup>.

The 317-ton *Valetta*, built at Calcutta (Kolkata) in 1821, was beached for repairs and finally abandoned in 1825 at the Whitsunday Group, Queensland. The site was excavated in 1983, and keel and remnant planks were recovered. The *Valetta* was also made of teakwood. The report states that teak and other Indian timbers were used in the construction and fastened with iron<sup>51,52</sup>. The *Governor Phillip* was a wooden-hulled two-mast teak-built brig. It was en route from Norfolk Island to Hobart and wrecked off a reef near Gull Island northeast of Tasmania on 27 October 1848. The ship *Cumberland*<sup>53</sup> was built at Cochin and made of teak, fastened with iron knees and sheathed with copper. The *Cumberland* was wrecked one nautical mile off Deepdene Beach and about 7 miles northwest of Cape Leeuwin. Scott Sledge of the Western Australian Museum undertook explorations of the *Cumberland* in 1983–1984 and during exploration pottery, glassware, teak timber, rudder gudgeons, a sounding lead marked XXXI (being 14.1 kg lead), and many grindstones and stone blocks were recovered.

The *Santo Antonio de Tanná*, a 17th century Portuguese frigate was built in 1680 AD at Bassein, about 50 km from Mumbai. The ship was entirely constructed of teak (Figure 5 e) secured with iron fasteners. *Santo Antonio de Tanná* successfully completed a voyage between Goa and Lisbon. On 28 August 1697, the Omani forces attacked the Fort São Jesus, the main Portuguese fortress in Mombasa. *Santo Antonio de Tanná*, was called to help relieve the siege by the Omani forces. Intense fighting continued, the frigate suffered badly from

enemy action. With the next tide, the vessel was towed closer to the fort and at this time the Portuguese decided to strip and scuttle the ship believing the damage to be severe. After its mooring cables broke, it lost its rudder and ran aground before sinking on 20 October 1697. The remains of the *Santo Antonio de Tanná* were excavated almost after three hundred years<sup>54,55</sup>. In order to correlate the findings of *Santo António de Tanna* with the archaeological and historical context, a systematic study was carried out at Goa State Archives<sup>56</sup>.

In 1698, the *Cara Merchant* or *Quedagh Merchant*, a Surat-built teakwood (Figure 5 f–g) vessel, was captured off the coast of India by Captain William Kidd, the pirate. He sailed the ship to different places, and at last abandoned the vessel at Catalina Island off the south eastern coast of Hispaniola en route to New England in 1699. The Dominican Republic Government and the Indiana University, USA jointly carried out explorations and excavated the *Cara Merchant*. The excavation find includes 26

cannons, a number of anchors and several tons of scrap iron<sup>57,58</sup>. In 2008, during excavations, one cannon and wooden remains were recovered. Subsequently, SEM micrographs of a cross-section of teakwood were analysed identifying it as teakwood (Figure 6). The SEM micrographs of *Cara Merchants* resemble the SEM micrographs of teakwood from Surat<sup>59</sup>. According to Kidd, the *Quedagh Merchant* was ‘built at Surrat’ (Surat), a city on the west coast of India<sup>60</sup>.

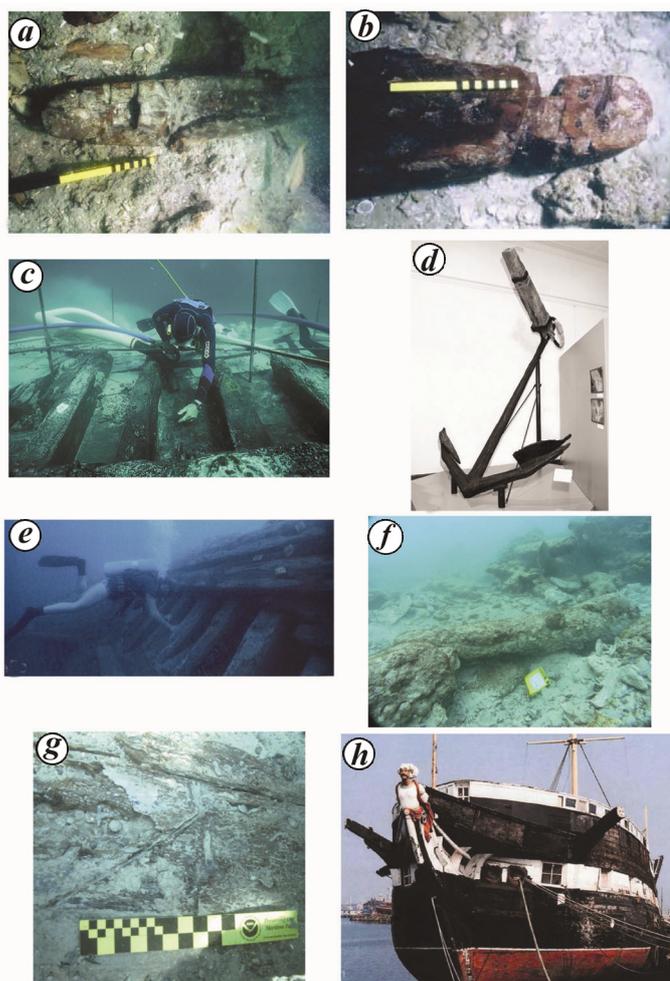
*HMS Trincomalee Frigate* of 1065 tons with 46 guns was built of high quality Malabar teak (Figure 5 h) in Bombay<sup>61</sup> (Mumbai) for the Admiralty in 1817. *Trincomalee* sailed to different countries, put in services for various purposes and served in the Royal Navy of the East India Company till 1897. At a later date, *Trincomalee* was sold to George Wheatley Cobb and she was restored and renamed *Foudroyant* in honour of HMS *Foudroyant*, whose earlier ship had been wrecked in 1897. After the death of Cobb, *Foudroyant* was brought to Portsmouth where it was reconstructed



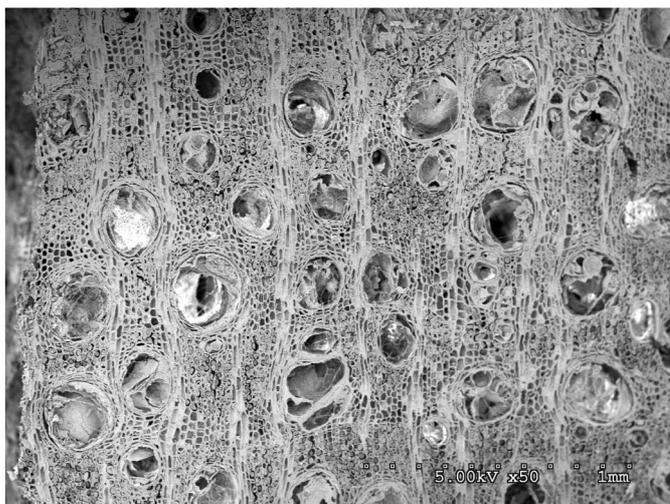
**Figure 3.** Presence of timber on doorframe hinge and door latch collected from steam engine shipwreck off Minicoy Island, Lakshadweep (Photo source: Sila Tripati).



**Figure 4.** Iron anchor with teakwood stock from Aguada Bar off Goa. (Scale: 50 cm with 5 cm division) (Photo source: Sila Tripati).



**Figure 5.** a, b, Teakwood timber from Belitung shipwreck (Photo source: Michael Flecker). c, d, Sydney Cove ship structure and iron anchor with teakwood stock (Photo source: Tasmanian Parks and Wildlife Service). e, Hull remains of *Santo Antonio de Tanna* shipwreck (Photo source: Robin Piercy). f, g, Timber remains of Surat-built *Cara Merchant* or *Quedagh Merchant*, shipwreck (Photo source: Charles Beeker). h, Malabar teak-built *HMS Trincomalee Frigate* (Photo source: Valerie Fenwick).



**Figure 6.** SEM micrographs of cross-section of teakwood of *Cara Merchant* or *Quedagh Merchant* shipwreck (Photo source: Charles Beeker).

and during the World War II, she was used for accommodation and stores<sup>62</sup>. Subsequently, she was restored again and renamed *Trincomalee* in 1992. Now, *Trincomalee* is the oldest floating British frigate and the second oldest floating ship in the world.

### Discussion and conclusions

The question comes up as to why teak was one of the best preferred timbers for shipbuilding over oak and other timber species both by the Europeans and Indians. Teakwood is a very resilient species, quite hard and scented due to presence of higher amount of natural extractives and oily substances which prevents attack by the biodeteriorating agents and preserves the wood for longer duration. Teak has greater durability and also resist adverse conditions; therefore, it is mainly used for shipbuilding, building constructions, railway carriages, etc.<sup>32</sup>. Regarding the noble qualities of teak, its usefulness in shipbuilding and ready availability, several observations are made by shipwrights, merchants, travellers and others. Among them, in 1802, Anthony Lambert, a merchant in Calcutta, has mentioned the durability of teak and its proximity to Surat: ‘The excellence of teak for the purpose of shipbuilding and its durability are too well known to require any description; although it must be observed that Pegue teak is not reckoned equal to what grows on the Malabar Coast, and near Surat...’<sup>6</sup>. Similarly, Sir Robert Seppings<sup>63</sup> also noted the quality of teak and reported, ‘Teak is the most durable, but differs very much in quality,’ he continued to ‘designate Malabar Northern Teak as the most valuable timber in the world for shipbuilding’. In the 18th and 19th centuries, many treatises were published on oak and teak citing details of their qualities, durability, etc. One among them was entitled ‘*Observations on the Expediency of Shipbuilding at Bombay*’, published by W. T. Money in 1811. Money has described that oak contains lignic acid, and when it comes in contact with iron; the rate of corrosion and decay of iron occurs faster and reduces the endurance of the ship. Iron was used extensively in construction of vessels because of cost effectiveness and easy availability. In case of teak, it abounds in oleaginous particles, which protect iron from corrosion by the action

of the acid. It is to be noted that Malabar teak is about one quarter less in weight than oak, neither splits, nor is dangerous like oak or with iron. Moreover, teak-built ships generally last for more than 50 to 60 years. Additionally, teak does not splinter to the extent that oak does and teak is a more durable timber than oak<sup>61</sup>, therefore; preferred in shipbuilding. Further, Vaidya<sup>64</sup> states that teakwood was used as well as traded for shipbuilding in the Indian Ocean countries for centuries and ships built of teakwood can be used for up to 50 to 65 years and sometimes last up to 80 years.

During the European period, there were many shipbuilding centres along the east and west coasts of India, among which the Wadia Master Builders of the Bombay Dockyard had built several ships. Records pertaining to the Bombay Dockyard show that between 1736 and 1884, the Wadias built a total of 334 vessels both for Indian and European rulers, merchants and others. Archival information shows that more than 215 shipwrecks, both Indian and foreign built, have been wrecked in Indian waters. Attempts have been made from 1988 onwards to explore the shipwrecks. Among these, the St George's Reef shipwreck appears to be made of teakwood<sup>10</sup>. Numerous wrecks of teakwood-built ships might have been in Indian as well as foreign waters, but the sea conditions and lack of information on the exact location of shipwrecks hinders locating them. It is believed that wrecks of teakwood-built ships might be in the waters of Great Britain, France, The Netherlands, Denmark and Portugal because they had their colonies and shipbuilding yards in India. Wrecks of Indian-built ships have been explored in African and Australian waters. These studies suggest the development of shipbuilding and construction of ships and shed light on historical connections. An analysis of the timber helps to indicate its origin and recognizing the species is the keystone to the identification of the shipwreck. Shipwreck finds and references<sup>65</sup> suggest that the Brazilian species, 'Tapinhoan', was also considered as one of the best timber for shipbuilding. An Admiralty Long Shank iron anchor with a wooden stock has been retrieved off Goa waters. Anatomical analysis of timber confirmed that the wooden stock was made of *Terminalia* spp. and *Phoebe* spp<sup>66</sup>. These timbers are generally found in Indo-

Malayan region, Pacific Islands, Tropical America and the West Indies. It is to be noted that *Terminalia* and preservative treated *Phoebe* woods were used in shipbuilding, oars, shafts, masts and hatch covers.

The analysis of timbers and shipwreck finds suggests that in addition to teak, other timbers were also used in shipbuilding but teak was preferred because of its noble and inherent qualities. Though many teakwood-built ships might have wrecked in different parts of the world, some have been excavated and details of the ship and timber have been identified on the basis of available literature. The wood anatomy of many of the shipwrecks needs to be carried out to know details of the timber. Wood anatomy of the *Cara Merchant* shipwreck has been studied<sup>58</sup>. According to Kidd, the *Cara Merchant* was 'built at Surat' and teak from Dang forest was used for its construction. In order to compare the microstructure of the wood, teak sample of Dang forest was collected from Wadia family, Surat, and analysed and compared with *Cara Merchant*. The study confirmed the statements made on teakwood and its use in shipbuilding. Timber analysis suggests the species, but it is difficult to identify the exact provenance of teak because the microstructure analyses do not show any variation in terms of their geographical location. However, more studies are required for further authentication of wood species used in shipbuilding.

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